23 & 24
February, 2019
Karachi, Pakistan

Proceedings

10th International
Civil Engineering Conference

Technological Transformation of Civil Engineering

Editors
Dr. Shamsoon Fareed
Dr. Abdul Jabbar Sangi
Dr. Sarosh Hashmat Lodi

Jointly Organized by

BUILD BETTER WORLD PAKISTAN 1948
The Institution of Engineers Pakistan Karachi Centre

NED University of Engineering & Technology

In Collaboration with

For a Better Quality of Life
The Asian Civil Engineering Coordinating Council

Federation of Engineering Institutions of Islamic Countries (FEIIC)

Federation of Engineering Institutions of South & Central Asia (FEISCA)

Association of Consulting Engineers (Pakistan)

Balochistan University of Information Technology Engineering & Management Sciences (BUITEMS), Quetta

Balochistan University of Engineering & Technology, Khuzdar

Sir Syed University of Engineering & Technology

DHA Suffa University, Karachi

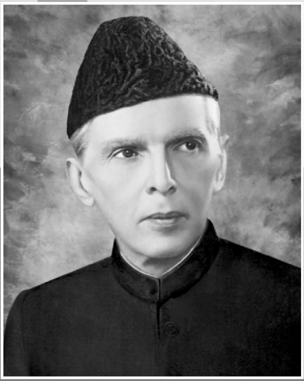
and

International Workshop on
Role of Youth & Young Professional in
Science, Engineering, Technology & Innovation for Disaster Risk Reduction (DRR)

Supported by
United Nations
Educational Scientific and Cultural Organization
24th February, 2019 at IEP, Karachi Centre

MESSAGE FROM THE

FATHER OF NATION



NATIONAL MOTO OF
PAKISTAN

FAITH
UNITY
DISCIPLINE

ایمان
اتحاد
تنظیم

UPON THE INDEPENDENCE OF PAKISTAN, THE ABOVE NATIONAL MOTO WAS INTRODUCED AND ADOPTED BY THE COUNTRY'S FOUNDER MUHAMMAD ALI JINNAH

Muhammad Ali Jinnah

"If Pakistan is to take its proper place among the progressive nations of the world, it will have to take up a good deal of leeway in the realm of scientific and technical education which is so necessary for the proper development of the country and the utilization of its resources. The establishment of institution like the Institute of Engineers will greatly stimulate technical research and help in disseminating available information.

The Institute of Engineers will not only benefit the engineers themselves by improving their technical knowledge but also bring lasting benefits to public services which they are called upon to perform. I wish the Institute every success"

QUAID-E-AZAM'S message to the first inaugural meeting of the Institute of Engineers Pakistan on 20th June 1948.

MESSAGE FROM THE

CHIEF MINISTER SINDH

Engr. Syed Murad Ali Shah
Chief Minister Sindh

I feel honored to know that the Institution of Engineers Pakistan and NED University of Engineering & Technology are holding the 10th International Civil Engineering Conference on 23 & 24 February 2019 in collaboration with The Asian Civil Engineering Coordinating Council, Federation of Engineering Institutions of Islamic Counties and Federation of Engineering Institutions of South & Central Asia. Karachi Centre of the Institution of Engineers Pakistan has organized nine such conferences in the past and this is the tenth in the series. I wish all those attending the conference a happy and comfortable stay of two days during the conference.

Engineers have played significant role in the overall development of the Country. The Institution of Engineers Pakistan has helped the engineers in widening their engineering knowledge and techniques by holding various technical activities. Its services to the nation are exemplary. The Institution of Engineers Pakistan has also played vital role by deliberating over the pertinent issues and making appropriate recommendations to the government. The 10th ICEC-2019 is one of the feature events of these continuing development efforts of the Institution of Engineers Pakistan (IEP) and NED University of Engineering & Technology (NED)

I am sure the 10th International Civil Engineering Conference being attended by engineers from all over Pakistan and from around the world will provide an excellent opportunity to the participants to benefit from the experiences of one another and to find solutions to our current problems. The knowledge transferred by this Conference will be helpful for the participants, in increasing their professional ability and find ways and means to tackle the national and International problems.

The role played by the Institution of Engineers Pakistan is commendable and I wish every success for the Institution.

MESSAGE FROM THE

PRESIDENT

Federation of Engineering Institutions of Islamic Countries (FEIIC)

Engr. Syed Murad Ali Shah
Chief Minister Sindh

The Federation of Engineering Institutions of Islamic Countries (FEIIC) is an international non-profit professional organization, established in 1989, with the aim of fostering cooperation in engineering education, research and professional practice in the Islamic Countries. It comprises of 22 member countries and a number of corporate and institutional members from amongst academic and research institutions, consultants, contractors and national organizations.

FEIIC, in cooperation with its members, has organized many scientific and research conferences, seminars, and workshops in its member countries on various aspects of engineering and related issues, such as engineering education, accreditation of engineering qualifications, and affordable housing etc. We are committed to share and exchange the experiences and expertise of the member countries with each other in addressing the crucial challenges in engineering and technological fields and in adopting the emerging trends and new concepts in engineering education, research and development and their implementation.

This 10th International Civil Engineering Conference (ICEC-2019) on "Technological Transformation of Civil Engineering)" is one of such efforts by the Institution of Engineers Pakistan, an active member of FEIIC, which we hope will bring the researchers and practicing engineers together on a shared platform to share and exchange their expertise and experiences.

Finally, I would like to congratulate and commend the partners and Organizing Committee of the Conference for all their efforts and wish all the participants a very successful and enriching experience at the Conference.

MESSAGE FROM THE

PRESIDENT

The Federation of Engineering Institutions of South & Central Asia (FEISCA)

Eng. Jayavilal Meegoda
President – FEISCA
Immediate Past President - IESL

It is with pleasure that I send this message on the occasion of the 10th International Civil Engineering Conference (ICEC-2019) on "Technological Transformation of Civil Engineering)"

Papers presented being of good level in International authorship and topics range, the Conference will be a forum that will enrich the regions knowledge and expertise potentials and be a platform for sharing innovations and advances in Civil Engineering and related disciplines among countries in the region.

The Federation of Engineering Institutions of South & Central Asia (FEISCA) as a collaborating partner to the event looks forward to the improved professional collaboration that would result among engineering institutions of the region.

The FEISCA hopes that the confluence of technology and expertise would ultimately flow to the engineering community at large contributing to the sustainable socio-economic development in the region.

While congratulating the IEP, Karachi Centre and NEDUET, Karachi for successfully organizing the ICEC-2019, I also convey my well wishes to all the fellow collaborating partners of this event.

I wish all the participants a very successful and enriching experience at the Conference.

MESSAGE FROM THE

CHAIRMAN

The Institution of Engineers Pakistan, Karachi Centre
Members Executive Committee – FEIIC, FEISCA & ACECC

Engr. Sohail Bashir, FIE (Pak)
Chairman IEP, Karachi Centre
& Chief Organizer, 4th IEEC-2019

The Institution of Engineers Pakistan (IEP) is playing a vital role in the development of Pakistan since its inception within the frame work of its aims & objectives which revolves around the promotion of technology, advancement of the engineering practice, application of principles of science in engineering and dissemination of technical knowledge. Upholding its tradition continuously for the last ten years, this year also the 10th International Civil Engineering Conference is being hosted by the IEP Karachi Centre with more zeal and enthusiasm. The theme for this year conference is " Technological Transformation of Civil Engineering".

The conference shall dwell on the latest technological development in the field of Civil Engineering and allied engineering disciplines which would not only broaden the vision of participants but shall led them to the frontiers of the existing knowledge and the way forward. Indeed to hold such International gathering, in the present security scenario was not only a challenge but was also an uphill task for which IEP Karachi Centre, NEDUET and all collaborating Institutions deserves all commendation. The collaborative role of Department of Civil Engineering NEDUET, BUITEMS, BUET-Khuzdar, DHA Suffa University and Sir Syed University of Engineering & Technology deserves special commendation.

On behalf of The Institution of Engineers Pakistan, Karachi Centre and the Organizing Committee of ICEC-2019, I would like to express my sincere appreciation for active participation, both from academia and industry. Indeed, all the members of Advisory Board, Management Committee, Coordination Committee and Technical Review Committee worked extremely hard to make this event happen. I have no doubt whatsoever that without their cooperation, support and active participatory role, this event would not have been possible for which I record my appreciation for all of them. Special thanks to the Conference Key Note Speaker of Inaugural session, Dr. Naveed Anwar, Vice-President, Knowledge Transfer, Asian Institute of Technology, Bangkok, Thailand and Key Note Speaker of closing session, Mr. Randolph Langenbach, Conservationtech Consulting, Oakland, California, USA. Thanks to Prof. Saeed Kenai from Algeria, invited speakers from industry, authors and sponsors for strongly supporting the conference. I also take this opportunity to pay my sincere gratitude to the Chief Guest and Guest of Honor of Inaugural & Closing sessions for sparing their valuable time for this event. My sincere gratitude are to Engr. Prof. Dr. Sarosh Hashmat Lodi, Vice Chancellor, NEDUET, Engr. Prof. Dr. S.F.A. Rafeeqi, Immediate Past Chairman, IEP, Karachi Centre for their guidance & help in organizing ICEC-2019.

One of the salient features of this years ICEC-2019 is that in parallel to this conference an International Workshop on the Role of Youth & Young Professionals in Science, Engineering, Technology & Innovation for Disaster Risk Reduction (DRR) is being organized by IEP & NEDUET with the suppot of UNESCO for developing Young Trainers in this Area. Irina Rafliana and Hilman Arioaji, Master Trainers of UNESCO from Indonesia will conduct this Worksop.

I would like to take this opportunity to place on record my sincere application to Engr. Prof. Dr. Abdul Jabbar Sangi, Engr. Shoaib Ahmed, Engr. Prof. Dr. Mir Shabbar Ali, Engr. Al-Kazim Mansoor, Engr. Farooq Razzak Fazal, Engr. Bushra Nadeem Mufti, Engr. Dr. Shamoon Fareed, Engr. Faiza Saeed, Engr. Dr. Syed Fazal Abbas Baqueri and Dr. Azmatullah for their hard work for ICEC-2019.

Finally, I would like to welcome each one of the participant and hope that they will find ICEC-2019 not only useful in enhancing their technical knowledge but also to be forum to meet many highly respected engineers under one roof for effective interaction in future.

MESSAGE FROM THE

SECRETARY

The Institution of Engineers Pakistan
Karachi Centre

Engr. M. Farooq Arbi, FIE(Pak)
Secretary,
The Institution of Engineers Pakistan
Karachi Centre

The Institution of Engineers Pakistan is playing a vital role in the Development of the Nation since its inception within the periphery of its approved aims and objectives, mostly revolving around the promotion and advancement of the practice and application of principles of Engineering, through its nine Centers spread across Pakistan and four overseas Centers. Upholding its traditions, the 10th International Civil Engineering Conference is being hosted by IEP-Karachi Centre this year. The Conference shall explore the latest technological development in the field of Civil Engineering and would broaden the vision of the participants.

On behalf of the Institution of Engineers Pakistan, Karachi Centre and the Organizing Committee, I would like to express my sincere appreciation for all participants, both from academia and industry, who played their role through contributions to the Conference and through their participation. In fact, all the members of the Technical Program Committee worked extremely hard to make this event happen. I have no doubt whatsoever that without their cooperation and their significant role and support, this event would not have been possible. Special thanks also goes to the keynote speakers, invited speakers, and authors, for strongly supporting the Conference, while there are no words to thank the Chief Guest/Guest of Honor who have spared their valuable time for this important event.

Finally, I welcome each participant and hope that they will find the 10th International Civil Engineering Conference not only useful in many respects but also to be a good opportunity to meet people and connect positively through networking in available time slots.

MESSAGE FROM THE

VICE-CHANCELLOR

Balochistan University of IT, Engineering and Management Sciences (BUITEMS)

Engr. Ahmed Farooq Bazai (S.I)
Vice Chancellor
Balochistan University of IT, Engineering
and Management Sciences (BUITEMS)

It is a matter of honor for me to be a part of the tenth International Civil Engineering Conference (ICEC-2019). The conference series has provided an ideal platform for a fruitful exchange of information, fostering key dialogue and research collaborations among stakeholders including academia, industry and the government. This year's conference theme "Technological Transformation of Civil Engineering" is highly relevant to modern day technological problems, and advancements within the domains of engineering, promoting inter-disciplinary cross-cutting technological breakthroughs in Civil Engineering is being organized to share progress and varied futuristic technological advancements in the vital arena of engineering.

I sincerely appreciate the efforts of the entire organizing team in making this conference possible, and acknowledge the efforts of The Asian Civil Engineering Coordinating Council, Federation of Engineering Institutions of Islamic Countries, Federation of Engineering Institutions of South & Central Asia, Association of Consulting Engineers (Pakistan), Balochistan University of Engineering & Technology, Khuzdar, DHA Suffa University, Sir Syed University of Engineering & Technology, and BUITEMS, Quetta in jointly making this conference a success.

On behalf of BUITEMS, I would like to extend my warm wishes to all the delegates and participants.

MESSAGE FROM THE

VICE CHANCELLOR

Balochistan UET Khuzdar

Engr. Prof. Dr. Ehsanullah Khan
Vice Chancellor
Balochistan UET Khuzdar

I am delighted to have the opportunity to share a few thoughts at the time of 10th InternationalCivil Engineering Conference (ICEC-2019). It is a great initiative taken by Institute of Engineers Pakistan (IEP) and NED University of Engineering and Technology Karachi along with other reputed partners including Balochistan University of Engineering and Technology Khuzdar.The 10th edition of the conference itself is an indicator of the quality and credibility of the Conference Internationally. The theme of the Conference "Technical Transformation of Civil Engineering "is most relevant as technological advancements have made a huge impact on Civil Engineering internationally. The areas of research included in the conference are not only relevant to the field of Civil Engineering globally but also significant in terms of importance of application in Pakistan.

I firmly believe that this conference will open a new era of research with a focus on technological transformation in the field of Civil Engineering and will help researchers in addressing the challenges faced in Civil Engineering in an efficient and effective manner.

I warmly congratulate the organizers of the conference for holding such a high quality International Conference and assure them that Balochistan UET Khuzdar will continue to collaborate in such future endeavours as well.

MESSAGE FROM THE

CO-CONVENER

ICEC-2019

Engr. Dr. Abdul Jabbar Sangi
Co-Convener, ICEC-2019
NED University of Engineering and Technology,
Karachi

It is my pleasure to be the Co-Convener of the 10th International Civil Engineering Conference (ICEC-2019) jointly organized by The Institution of Engineers Pakistan Karachi Centre and NED University of Engineering & Technology in collaboration with The Asian Civil Engineering Coordinating Council, Federation of Engineering Institutions of Islamic Countries and Federation of Engineering Institutions of South & Central Asia on Saturday 23rd & Sunday 24th February, 2019 in Karachi. The event is organized in partnership with regional universities including Balochistan University of Engineering & Technology Khuzdar, Balochistan University of Information Technology, Engineering & Management Sciences (BUITEMS) Quetta, Sir Syed University of Engineering & Technology, Karachi and DHA Suffa University Karachi.

This year, the 10th International Civil Engineering Conference (ICEC 2019) is being held under the theme "Technological Transformation of Civil Engineering". The idea is to bring together latest civil engineering knowledge, research and development efforts from scientific community, engineers and practitioners focusing on recent innovations and impact of technology on Civil Engineering that can help in contributing towards establishing a better built environment. The multiple challenges faced by developing countries related to built environment can only be solved by adopting innovative technological approach towards the development process.

I would like to thank IEP and NED committee members, partner universities, volunteers, authors and the invited speakers from the industry for their valuable contribution towards the event. I hope that this conference would strengthen further the meaningful interactions between industry, academia and scientific community, which will enable further research and development.

MESSAGE FROM THE

VICE-CHANCELLOR

NEDUET
& Convener ICEC-2019

Engr. Prof. Dr. Sarosh H. Lodi
Vice Chancellor,
NED University of Engineering and Technology,
Karachi

It gives me an immense pleasure to welcome you to the 10th International Civil Engineering Conference (ICEC 2019) which is jointly organized by The Institution of Engineers Pakistan, Karachi Centre and NED University of Engineering & Technology in collaboration with International organizations and regional universities. This conference provides the platform to researchers, academics, engineers and experts, not only from Pakistan but also from different countries around the world to share their research in the field of Civil Engineering and explore possibilities for collaboration in various fields.

The theme of the Conference i.e. "Technological Transformation of Civil Engineering" is of great significance. The theme is aligned with the fact that Civil Engineering profession has integrated technology from many other disciplines for enhancing its efficiency and productivity. Moreover, the technology specifically that of construction technology has also gone through prosperous evolution. Use of artificial intelligence (AI), virtual reality (VR), 3D printing and other technological advancements in Civil Engineering profession are transforming traditional civil engineering. Future of Civil Engineering profession lies in technology. Therefore, it is important to discuss and deliberate such transformation to keep up with the developed world.

I am sure that 10th International Civil Engineering Conference (ICEC 2019) will provide an excellent opportunity to the participants to benefit from the experiences of one another.

I wish all participants a successful conference in the beautiful city of Karachi. The Institution of Engineers Pakistan, Karachi Centre and NED University of Engineering & Technology would feel immense pleasure to welcome you in future conferences as well.

ORGANIZING TEAMS

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Convener ICEC-2019

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Co-Convener
ICEC-2019

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PROGRAMME

Day 1 - Saturday 23rd February, 2019

INAUGURAL SESSION

Day-1: Saturday, 23rd February, 2019

09:30 - 10:00 am	**Registration and Seating**
10:00 - 10:05 am	**Recitation from the Holy Quran**
10:05 - 10:10 am	**National Anthem**
10:10 - 10:15 am	**Conference briefing by** Engr. Prof. Dr. Asad-ur-Rehman Khan Chairman Department of Civil Engineering, NEDUET
10:15 - 10:20 am	**Welcome Address by** Engr. Sohail Bashir Chairman IEP Karachi Centre
10:20 - 11:00 am	**Key Note Address by** Dr. Naveed Anwar Vice-President, Knowledge Transfer Asian Institute of Technology Bangkok, Thailand
11:00 - 11:05 am	**Address by** Engr. Prof. Dr. Sarosh H. Lodi, Vice-Chancellor, NED University of Engineering & Technology & Convener ICEC-2019
11:05 - 11:10 am	**Address by Guest of Honor**
11:10 - 11:20 am	**Address by Chief Guest**
11:20 - 11:25 am	**Presentation of Conference Memento**
11:25 - 11:30 am	**Vote of Thanks by** Engr. Prof. Dr. Abdul Jabbar Sangi, Co-Convener, ICEC-2019
11:30 - 11:45 am	Tea / Networking

How Latest Technological Advancements are Transforming the Civil and Structural Engineering Profession?
By Dr. Naveed Anwar

The engineering profession is currently passing through an era of tremendous developments in the fields of information technology, computing and visualization technologies, smart sensors and artificial intelligence. Often, these developments are done independently with a particular research focus in related fields. However, some of these innovations have the potential to open new paradigms and research areas which may significantly alter the course of a particular engineering profession. This paper presents a brief review of some recent technological advancements which can potentially transform the profession of civil and structural engineering in near future. These may include a wide range of new technologies ranging from the development of advanced software-based learning environments on one side to the applications of artificial intelligence in structural design on the other side. An overview of some particular technologies with their innovative applications in structural engineering education and research, structural modeling, analysis and design, construction management and monitoring, and other related areas is also presented.

Technical Sessions

Day-1: Saturday, 23rd February, 2019

11:45 - 01:15 pm	**Technical Session 1** Structural Engineering (Convention Center)
11:45 - 01:15 pm	**Technical Session 2** Construction Engineering & Management (Engr. Asfia Aleem Hall)
11:45 - 01:15 pm	**Technical Session 3** Transportation Engineering (Dr. S.A. Hassan Hall)
01:15 - 02:00 pm	Lunch and Prayer Break
02:00 - 03:30 pm	**Technical Session 4** Structural Engineering (Dr.S.A.Hasan Hall)
02:00 - 03:30 pm	**Technical Session 5** Construction Engineering & Management (Convention Center)
03:30 - 03:45 pm	Tea Break
03:45 - 05:00 pm	**Technical Session 6** Geotechnical Engineering (Dr. S.A. Hassan Hall)
03:45 - 05:00 pm	**Technical Session 7** Water Resource Engineering (Convention Center)
05:00 pm	Asr Prayer

Day 2: Sunday, 24th February 2019

10:00 - 11:30 am	**Technical Session 8** Structural Engineering (Convention Center)
10:00 - 11:30 am	**Technical Session 9** Construction Engineering & Management (Dr. S.A. Hassan Hall)
11:45 - 01:15 pm	Closing Session
01:15 - 01:30 pm	Zohar Prayer
01:30 - 02:00 pm	Lunch

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PROGRAMME

Day 2 - Sunday 24th February, 2019

CLOSING SESSION

10:00 - 11:30 am	**Technical Session 8** Structural Engineering (Convention Center)
10:00 - 11:30 am	**Technical Session 9** Construction Engineering & Management (Dr. S.A. Hassan Hall)
	CLOSING SESSION
11:30 - 11:45 am	**Networking**
11:45 - 11:50 am	**Recitation from the Holy Quran**
11:50 - 11:55 am	**Conference Highlights by** Dr. Shamsoon Fareed, Program Secretary, 10th ICEC 2019
11:55 - 12:00 noon	**Address by** Engr. Sohail Bashir, Chairman, IEP, Karachi Centre & Chief Organizer, 10th ICEC -2019
12:00 - 12:35 pm	**Key Note Address by** Mr. Randolph Langenbach, Conservationtech Consulting, Oakland, California, USA
12:35 - 12:40 pm	**Address by** Engr. Prof. Dr. Sarosh H. Lodi Vice-Chancellor, NED University of Engg. & Technology & Convener ICEC-2019
12:40 - 12:45 pm	**Address by Guest of Honor**
12:45 -12:50 pm	**Address by Chief Guest**
12:50 - 12:55 pm	**Presentation of Chairman Medal for "Best Paper"**
12:55 - 01:00 pm	**Concluding Remarks by** Engr. Dr. Abdul Jabbar Sangi, Co-Convener, ICEC-2019
01:00 - 01:10 pm	**Presentation of Conference Memento**
01:10 - 01:15 pm	**Vote of Thanks by** Engr. M.Farooq Arbi, Secretary & Vice-Chairman (Civil) IEP, Karachi Centre
01:15 - 01:30 pm	Zohar Prayer
01:30 - 02:00 pm	Lunch

Recovering the Lost 'Moment': How Timber-Laced Masonry May Hold the Secret to Stopping Pancake Collapse of Concrete Moment Frames (PART 2)
By Randolph Langenbach

Traditional masonry construction has proven to be remarkably resilient in a number of recent earthquakes. This resilience has been a result of the use of timber as reinforcement in the masonry walls – in Pakistan, both as frames, as in dhajji-dewari, or as horizontal ring beams, as in bhatar. In this talk the focus will be on the beginning of the modern era in the field of structural engineering of multi-story buildings. From 1880s & 1890s, when the first of what came to be called "skyscrapers" were constructed in Chicago, and then also in New York City and San Francisco. These were the first of what were tall buildings of full skeleton frame construction. By 1906, when the Great San Francisco Earthquake and Fire occurred, there were approximately 27 steel frame mid-to-highrise buildings of 5 to 19 stories in that city. Significantly, none of these buildings collapsed as a result of the earthquake.

If one looks at the earthquake performance alone, the positive performance of these buildings is worth studying because the steel (and sometimes concrete) framework of every single one of them was infilled and clad with multiple wythes (leafs) of brick masonry, with outer surfaces of stone or terra cotta. The framework itself was often lightweight and lacked wind braces. The paper will explain this development, with references to the common practices of that day and age, making note of the fact that the transition from masonry bearing walls to the predominant use of frames occurred when engineering shifted more and more into reliance on calculations. The paper will document how in the first decades of the 20th century saw the adoption of the moment frame, and the development and broad acceptance of the contraflexure methodology of moment frame analysis further refined the design of these frames. Masonry infill and cladding conflicted with this analysis method of the engineering design of multistory buildings, because there was no way to include it in the calculations except as dead weight.

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PROGRAMME

Day 1- Saturday, February 23, 2019 — ICEC 2019 Parallel Technical Sessions

Technical Session 1 Structural Engineering 11:45 am to 1:15 pm **IEP Convention Centre** **Session Chairs** Engr. Khalil Ahmed Engr. Prof. Dr. Asad-ur-Rehman Khan	**Technical Session 2** Construction Engineering & Management 11:45 am to 1:15 pm **Engr. Asfia Aleem Hall** **Session Chairs** Engr. Bushra Nadeem Mufti Engr. Sohail Ehtesham Engr. Umaid Hasan Akhtar	**Technical Session 3** Transportation Engineering 11:45 am to 1:15 pm **Dr. S.A. Hassan Hall** **Session Chairs** Khalid Zaheer Mirza Engr. Mukesk Kumar Engr. Prof. Dr. Adnan Qadir
Keynote **Mechanical performance and durability of recycled aggregates in ordinary and self-compacting concrete** *Prof. Said Kenai*	**Invited Talk by** **Engr. Ghulam Mujtaba Shaikh, Halcrow on** **5D BIM and its Industry Applications**	**Invited Talk by** **Engr. Ashar Lodi, Exponent Engineers on Transport Scenario and Mass Transit Implementation in Karachi**
Effect of methylcellulose on different properties of fresh and hardened concrete *ZeeshanUllah, Husnain Tariq But, Muhammad Saad, Muhammad Salman, Mustansar Hussain*	**Comparison of physical attributes of real time project using BIM - A case study** *Abdul Hannan Qureshi, Syed Wajhi U. H. Naqvi, Abdul Qadeer, Muhammad Kamran, Talha Bin Tahir*	**Multi-criteria Decision Making in Urban System Traffic Evaluation** *Malik Kamran Shakir, Dr Muhammad Bilal, DrNadeem Anwar Qureshi, Dr Arshad Hussain, Muhammad Adeel*
	Hazard identification in construction safety: A visualization-based approach *Ramsha Akram, JamaluddinThaheem, Shamraiza Khan*	**Application of Artificial in Intelligence in Traffic Congestion Modeling** *Prof. Dr. Mir Shabbar Ali, Karam un Nisa Dr. Sana Muqeem, Zohaib Hassan*
Investigation on selected properties of concrete blended with maize COB ash *Zubair Hussain Shaikh, Aneel Kumar, Manthar Ali Kerio, NaraindasBheel, Ali AizazDayo, Abdul WahabAbro*	**Challenges in wide-spread adoption & implementation of infrastructure building information modelling (BIM) during infrastructure asset(s) lifecycle management** *Syed Wajhi U. H. Naqvi, Abdul HannanQureshi, Muhammad Kamran, Abdul Qadeer, Talha Bin Tahir*	**Potential of integrated bus rapid transit (BRT) System in motorcycle dominant cities** *Syed Fazal Abbas Baqueri, Muhammad Adnan, Mir Shabbar*
Shear Behavior of Recycled Aggregate Concrete Beams *Muhammad Saad Khan*	**Quantifying the factors for quality of pavement rehabilitation** *Umair Imran, Muhammad Bilal Khurshid, Muhammad Jawed Iqbal*	**International Drivers' Comprehension of Traffic Control Devices A Case Study for Foreign Drivers Living in South Korea** *Sarang Jokhio, Jin-Tae Kim*

Day 1- Saturday, February 23, 2019 — ICEC 2019 Parallel Technical Sessions

Technical Session 4 Structural Engineering 2:00 pm to 3:30 pm **Engr. Dr. S.A. Hasan Hall** Session Chairs Engr. ArifKasam Engr. Dr. TehminaAyub	**Technical Session 5** Construction Engineering & Management 2:00 pm to 3:30 pm **IEP Convention Centre** Session Chairs Engr. S. Asim Ali Tirmizi Engr. Ashkar Dawar
Invited talk by **Engr. Dr. Abul KhairMasroor – EA Consulting** **on Earthquake Engineering Design Practice in Pakistan**	**Invited Paper by Engr. Rehan ul Ambia Riaz** **Reasons and Remedies For Time and Cost Overruns On Construction Projects - A Live Case Study**
Codes comparison for the seismic response of SMRF A case study of Quetta Balochistan *Naik Muhammad, Muddassir Ahmed Khan, Nisar Ahmed, Muhammad Idress, Shafiullah, Aimal khan, Danish Haider, Muhammad Habib, Zafar Baloch, Saeed Ullah Jan Mandokhail*	**A study on the impact of leadership styles on employee motivation in construction projects of Lahore** *Muhammad Saad, ZeeshanUllah, Shahid Iqbal, Mustansar Hussain, Muhammad Salman*
Seismic performance analysis of an irregular existing building using the future seismic code RPA 2018 and nonlinear dynamic analysis *YoucefMehani, AbderrahmaneKibboua, BenazouzChikh, Mustapha Remki*	**Impact of China Pakistan Economic Corridor (CPEC) on supply and demand of construction materials** *ZeeshanUllah, Muhammad Salman, Husnain Tariq But, Muhammad Saad, Mustansar Hussain*
Dynamic response analysis of submerged floating tunnel under waves and earthquakes *Naik Muhammad, Zafar Baloch, Muhammad Habib, Saeed Ullah Jan, Azamatulla Khan*	**Analysis of key factors affecting labor productivity in general construction projects in Pakistan** *Muhammad Taha Jawed, Syed Rafay Ali Bukhari*

The Institution of Engineers Pakistan

Karachi Centre

in collaboration with

NED University of Engineering & Technology

PROGRAMME

Day 1- Saturday, February 23, 2019	ICEC 2019 Parallel Technical Sessions
Technical Session 6 Geotechnical Engineering 3:45 pm to 5:00 pm **Dr. S.A. Hassan Hall** Session Chairs Engr. Farooq Fazal Dr. Saeedullah Jan Mandokhail	**Technical Session 7** Water Resource Engineering 3:45 pm to 5:00 pm **IEP Convention Center** Session Chairs Engr. Nooruddin Ahmed Engr. Asfia Aleem Prof. Dr. Syed Imran Ahmed
Invited talk by **Engr. Al-KazimMansoor, SOILMAT** **on The State of the Art of Geotechnical Engineering Practice in Pakistan**	**Invited talk by** **Engr. Dr. Bashir Lakhani, Techno Consultants** **on Water Issues of Karachi**
	River flow forecasting using artificial neural network and distributed hydrological modelling *RayyanArif Ahmed, MoidZaffar*
The effect of soil reinforcement with crumb tyre rubber on the strength of Silty Sand *Khawar Khalid, Zaheer Ahmed Almani, Aneel Kumar, Sarfraz Ali Abro*	**Comparison of narrow bed and wide bed irrigation systems in perspective of water saving and crop yield for cotton crop** *Muhammad Saleem Raza, Danish Kumar, ShafqatMajeed, Munsif-ul-Haq, AdeelMurtaza*
	Satellite based rainfall aplication in hydrological modelling *Haris Akram Bhatti*
Effect of lime and wheat straw on the shear strength characteristics of calayey soils *Amanullah Marri, Mirwais, Sadia Moin, Gul Muhammad*	**Evaluating Water Quality fo Malir River for Detrimental Effects on Vegetables & Ground Water.** *Dr. Imran Ahmed, Sania Siddiqui, Sana Wajid, Komal Abdullah, Roha Tariq, Nageen Yosuf, Shanza Sattaaar*

Day 2- Sunday, February 24, 2019	ICEC 2019 Parallel Technical Sessions
Technical Session 8 Structural Engineering 10:00 am to 11:30 am **Engr. Dr. S.A. Hasan Hall** Session Chairs Engr. Sartaj Ahmed Khan Engr. Jawed Ali Rizvi Engr. Prof. Dr. Shoaib Haroon Ahmad	**Technical Session 9** Construction Engineering & Management 10:00 am to 11:30 am **IEP Convention Centre** Session Chairs Engr. Payam ul Haq Siddiqi Engr. Farhat Adil Engr. Dr. Mansoor Imran
Invited talk by Mir Salman Ahmad - BASF **On** **Use of Chemicals / Admixtures in Construction**	**Invited Talk by Engr. Arif Sattar from NED Alumni Network, USA** **Invited Talk by Engr. Ariful Islam, AA Associates**
Artificial lightweight aggregate production through cold bonded pelletization using industrial by-products *MunibUlRehman, Khuram Rashid*	**Potential drivers for adoption of green procurement in construction industry** *Ali Arsal, Aftab Hameed Memon, Nafees Ahmed Memon, Muhammad Akram Akhund, Ali Raza Khoso*
Seismic characterization of Peshawar region using Ambient Noise *Syed WaqarYounas, ShahidUllah, TawqeerAlam*	**Factors affecting selection of procurement method in public sector construction projects** *Izhar Hussain Bhutto, Nafees Ahmed Memon, Ali Raza Khoso, Muhammad AslamLeghari, Shabir Hussain Khahro*
Compressive membrane action (CMA) and its application to structures *Nabeel Anis Khan*	**Adoptation and perception of unmanned aerial vehicle in the construction industry** *Syed Abdullah Shah Hashmi, Shakeel Ahmed, Ehsanullah Kakar, Salah Uddin, Abdul Majeed*
Analysis of settlement-induced building damage using damage surveys: A case study in Islamabad, Pakistan *Muhammad Abdus Salaam, Shaukat Ali Khan, Adhban Omar Ahmed Farea*	

FULL LENGTH PAPERS

How Latest Technological Advancements are Transforming the Structural Engineering Profession?

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Abstract
The engineering profession is currently passing through an era of tremendous developments in the fields of information technology, computing and visualization technologies, smart sensors and artificial intelligence. Often, these developments are done independently with a particular research focus in related fields. However, some of these innovations have the potential to open new paradigms and research areas which may significantly alter the course of a particular engineering profession. This paper presents a brief review of some recent technological advancements which can potentially transform the profession of civil and structural engineering in near future. These may include a wide range of new technologies ranging from the development of advanced software-based learning environments on one side to the applications of artificial intelligence in structural design on the other side. An overview of some particular technologies with their innovative applications in structural engineering education and research, structural modeling, analysis and design, construction management and monitoring, and other related areas is also presented.

Keywords
Information technology, engineering profession, artificial intelligence, computing, visualization, smart sensors.

1. Introduction

Since last few years, the innovative developments in information technology, computing and visualization, communications and artificial intelligence have happened almost in an exponential manner, especially when considered along with their cost reduction per feature and widespread availability. The corresponding developments in other disciplines and areas (with probably the exception of medicine, genetics and a few others) are showing much less innovative growth. Many practical fields have taken significant advantage of the recent advancements in computing technology to adapt, apply and enhance the way they work and address the real-world issues. In structural engineering, there has not been a major breakthrough in the basic practice, perhaps since the introduction of the finite element analysis-based computing around 50 years ago. However, recent trending technologies and innovations in information technology and inter-disciplinary research areas are likely to end this so-called stagnancy in near future.

Take, for example, the case of computer modeling of structures for the purpose of analysis and design. The routine design office practice requires one or more dedicated structural engineers who are expected to develop a detailed comprehension of architectural plans in order to be able to create an accurate geometry in a finite element-based analysis software. This process of structural modeling may take up to several days or even weeks depending upon the complexity of structure and modeling or discretization scheme adopted for a particular design project. Now let's compare this case with advanced automated modeling being utilized in the field of medical sciences. For example, the routine techniques for treatment of rotten or eroded teeth may involve the laser scanning of teeth to develop a detailed computer model of geometry and 3D printing of required filling part to treat and "retrofit" the affected area. These marvelous developments are the result of advanced image-processing-based photogrammetric techniques and machine learning-based algorithms. Another recent example of technological advancements in these areas is the advent of self-driving cars. Artificial intelligence is now able to successfully replace even the highly skilled tasks. Imagine if all of these technologies are made available for structural engineers in near future. They can significantly change not only the required skills from future engineers but can also potentially transform the whole profession altogether.

In this paper, a brief overview of all such recent technologies is presented with their potential applications in structural engineering. It discusses how these ideas may be used to improve the way the structural engineers solve the problems and develop more innovative, effective, sustainable and safer solutions for the built environment.

2. Structural Engineering Education – The New Learning Paradigms

The vision 2025 of American Society of Civil Engineers (ASCE) (2007) have defined future civil engineers as master planners, designers, constructors, operators of society's economic and social engine, innovators and integrators of ideas and technology across the public, private, and academic sectors. They are described as managers of risk and uncertainty caused by natural events, accidents, and other threats; and leaders in discussions and decisions shaping public environmental and infrastructure policy. All of these attributes raise some key questions. What is it that the future civil and structural engineers should learn? And, how they can learn, and continue to learn effectively? The answers to these questions simply demand an inter-disciplinary approach which can provide an opportunity for students to investigate, visualize and discuss their own ideas and explanations of various engineering principles being taught as curriculum. The development of intelligent tutoring systems provides a new way to harness and exploit the educational potentialities of computers keeping in mind the social dimensions of learning process. The goal of an intelligent tutoring system can be expressed as its ability to customize or rather individualize the learning process.

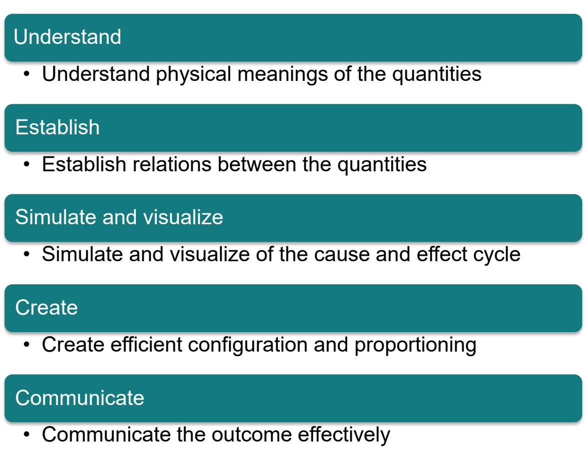


Figure 1: The key skills required for engineers to meet the future demands

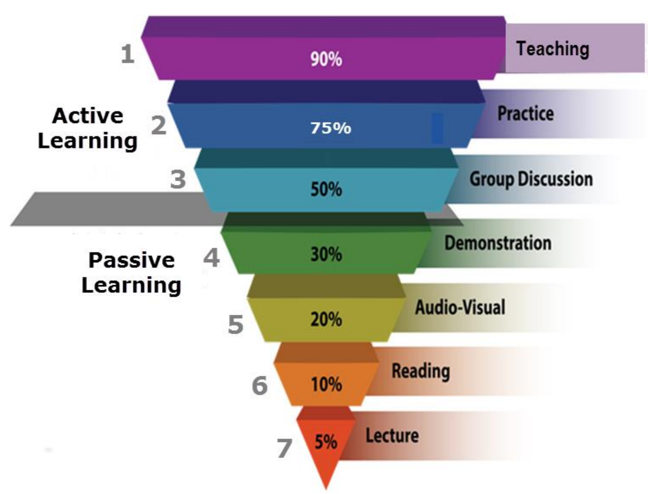


Figure 2: The percentage of knowledge retention for different modes of learning environments.

The key skills required for engineers to meet these future demands are summarized in Figures 1 and 3. They show that the expectations from future engineers are far beyond basic understanding. They are expected also to be able to create new engineering designs, to be able to test the unknowns and to be able to communicate effectively the solutions they develop. Now the basic question is how can these skills be developed? Figure 2 shows the average percentage of knowledge retention after the students are exposed to different conventional or unconventional modes of learning environments. It is evident that the interactive modes of learning results in most retention rates while one-way, instructive and conventional teaching modes result in significantly reduced retention rates. This clearly shows the direction required to be adopted for equipping next generation civil and structural engineers.

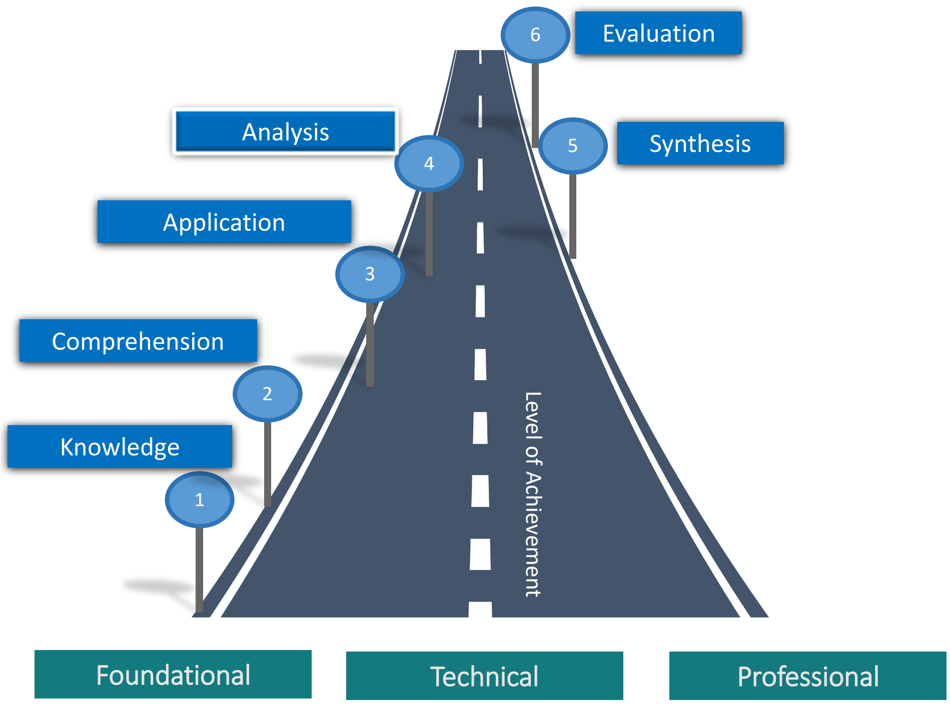


Figure 3: Preparing the civil engineers for the future

The impact of knowledge explosion in almost all areas of engineering demands a rationalization of curriculum which requires a fundamental change in current teaching and learning methods. In this regard, the conventional instructional simplicity in conjunction with collaborative interactive software-based learning can successfully facilitate the knowledge transfer as well as understanding of engineering concepts. In recent years, many innovative instructional methods have been developed for both technical and nontechnical courses and emphasize free discussion and expressions of student opinions, with minimal teacher-centered presentation of information since the involvement of students is critical for effective classroom learning (Richard 2000).

The World Wide Web offers educators a new medium to deliver teaching and learning material – one which bring new and exciting ways of learning, and an alternative to traditional teaching techniques" (Allen 1998). The instructional approaches based entirely on self-paced computer-assistance are extremely effective. As an example of interactive learning environments required for developing above mentioned skills in engineers, a recently developed knowledge platform called "AIT Share" is introduced here. This online learning environment provides an access to the knowledge generated at the Asian Institute of Technology (AIT) in Thailand through online lecture videos and related courses. One worth mentioning initiative taken through this platform is the Professional Masters Degree in Structural Design of Tall Buildings (PM-TB). It is an online degree offered by AIT through its Civil and Infrastructure Engineering Department under School of Engineering and Technology (SET). Currently, it is providing state-of-the-art knowledge in structural engineering to a lot of professionals around the world.

Figure 4: AIT Share platform and Professional Masters Degree in Structural Design of Tall Buildings (PM-TB).

In subsequent sections, various applications of some technologies as shown in Figure 5 will be discussed.

Figure 5: Some advanced technologies discussed in subsequent sections

3. Advanced Computing Technologies

Structural engineering is the backbone of physical infrastructure development. The practicing civil and structural engineers are involved in a broad spectrum of activities and tasks, such as conception, selection and development of structural systems suitable for a particular application, preliminary sizing and design of structural components, coordination and collaboration with several other disciplines to consider their requirements such as with architects, mechanical and services engineers, electrical engineers, geotechnical engineers, etc. The structures may have a variety of intended functions including buildings, bridges, tunnels, dams, transmission and communication towers, power plants, expressways and industrial plants. All these multi-dimensional and complex tasks require extensive, rigorous and efficient computing technologies.

At present, automated computing is the main means for the application of engineering knowledge. The growth and development in the application of computing tools and technologies, and the development of new paradigms has been incremental and linear. These include the development of new Human Computer Interfaces (HCI), new display technologies and devices, the Brain Computer Interfaces (BCI), and Robotics etc. Figure 6 illustrates an overview of new paradigms in which automated computing is finding its novel applications.

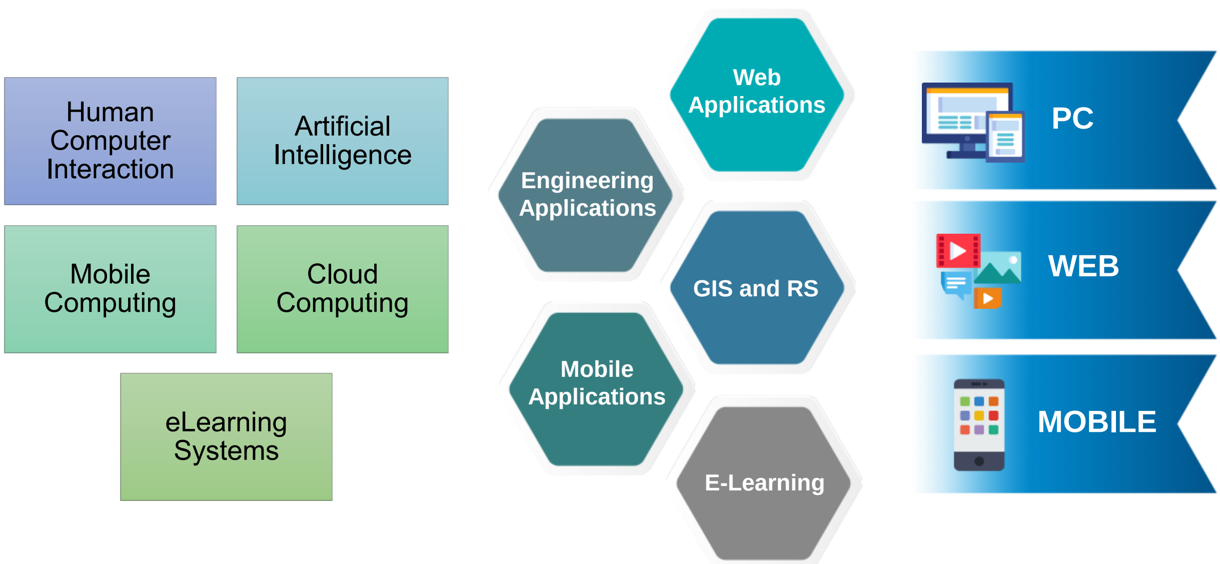


Figure 6: Some of the areas in which automated computing is finding its novel applications

Because of the emergence of modern mobility, connectivity and access technologies over the last few decades, information and data sharing, access and transfer has gone through a revolutionary change. Whole world is now considered as global village because of these fast track technologies. Internet, intranet, remote desktop, VPN, WLAN, wireless technology, 3G, 4G, GPS, GPRS, Cable TV, WiMax, Mobile Broadband and many other innovative techniques has made it possible to access any sort of knowledge within such a limited time which was not even imaginable in the past.

Typically, in client-server computing, a network-friendly client version of the application was required on client computers which utilized the client system's memory and CPU for processing. Cloud computing differs from the classic client-server model by providing applications from a server that are executed and managed by a client's web browser, with no installed client version of an application required. Centralization gives cloud service providers complete control over the versions of the browser-based applications provided to clients, which removes the need for version upgrades or license management on individual client computing devices. Desktop applications that connect to internet-host email providers may be considered cloud applications, including web-based email services. As compared to the traditional techniques, cloud computing is more flexible, mobile, highly automotive and cost effective technique.

An initiative in structural engineering applications of cloud computing is taken by Computers and Structures Inc. (Figure 7) by developing cloud-based tools and platform for automated structural analysis programs. The goal is to help produce next generation of engineers that have greater understanding, skills and tools to design and construct safer build environments. CSi has also launched mobile applications for convenient visualization of structural analysis results.

Figure 7: CSi mobile applications and CSi cloud

Most of practical structural engineering problems, in their nature, can be conceptually boiled down to "relating the effects with their causes". The causes can be the natural or man-made hazards which might change with time. These hazards pose actions to structures in the forms of forces or displacements. The effects are the structural deformations and internal stresses. The overall problem might be simplified into whether the effects are acceptable or not. The difficulties in this process might lie in defining the causes, determining the actions, establishing the acceptability of effects and making sure whether the effects are acceptable.

The attempts to explicitly relate the effects with their causes to reach an acceptable design decision have led the structural engineering professions to the development of various design philosophies. A relatively recent paradigm shift in current approach towards analysis and design of building structures is termed as "Performance-based Design (PBD)". It refers to the methodology in which structural design criteria are expressed in terms of achieving a set of performance objectives or levels. It ensures that the structure as a whole reaches a specified demand level including both service and strength design levels. It is the practice of thinking and working in terms of ends rather than means.

Currently, the PBD methodology has been extensively applied to the seismic loads and seismic design of structures. However, attempts are being made to extend this methodology for wind loading as well. In this regard, research and development is being carried out at several international universities and research organizations. One such example is the Asian Institute of Technology (AIT) in Thailand. The research initiatives are mostly focused on seismic hazards, seismic response, wind engineering and the development of automated computational tools. The development of computing applications in structural engineering at AIT initiated in 1985 with the conception of MicroACE Club. This club was started as a group of engineers and computer enthusiasts and was later expanded to Asian Center for Engineering Computation and Software (ACECOMS). Several new software and tools were developed through

ACECOMS and its partners including XETABS, GEAR, GRASP and BATS. These tools were mainly based on finite element modeling, static/dynamic, linear and nonlinear analysis, optimization, performance-based evaluation and graphical visualization. Currently, AIT is a regional hub of latest advancements in computational technologies and their applications in structural engineering. An AIT's constitutive organization, AIT Solutions, also have applied the PBD approach to more than 100 high-rise buildings around the world. This have resulted in a huge amount of research and innovative solutions in the areas of structural modeling, computing methodologies, analysis procedures and structural design.

Figure 8: AIT's experience in structural engineering with performance-based review of more than 100 high-rise buildings

4. BIM and Visualization Technologies

The applications of virtual reality (VR), augmented reality (AR) and mixed reality (MR) in the field of structural engineering can be a ground-breaking step in understanding the fundamental nature of problems related to structures. They have the potential to transform the very nature of how we interact with structural models and their response. For example, the VR can help to stimulate environments that can stimulate physical presence of structures. Using VR, structure's stimulation can be observed either on computer screen or through special stereoscopic display which may enhance the understanding of the structural engineers towards solving the problems related to the modeling and designing of structures. Additionally, just like in case of medical and gaming applications, introduction of haptic systems or interfaces for structural simulation may prove useful for training and understanding the nature of issues related to structures (Anwar and Nawaz, 2011).

In order to understand and visualize the structures in a more realistic way, it is highly desirable for a structural engineer to generate a Building Information Model or BIM (Figure 9). BIM is the process of developing building model which is used in presenting and visualizing building components, construction sequences, resource allocation and other disciplines of construction process in a virtual environment. BIM process generates 3D Model encompassing geometric and geographic information of the building and properties of its components. Using BIM, structural detailing drawings can be produced more quickly. Through the process of BIM and integrated project delivery, structural designers can keep away from costly clashes by examining beams, pipes, HVAC and electrical systems before the commencement of the construction. BIM may not only help to optimize parameters of the structural model at par with the design rules but also more purified engineering design can be made on sound theory minimizing rough calculations. Integrated modeling, analysis and design can be achieved without splitting up the tasks. Another important advantage of BIM is that more attention can be given to cost factors by studying alternative solutions on one model and hence better and optimized construction can be obtained solutions.

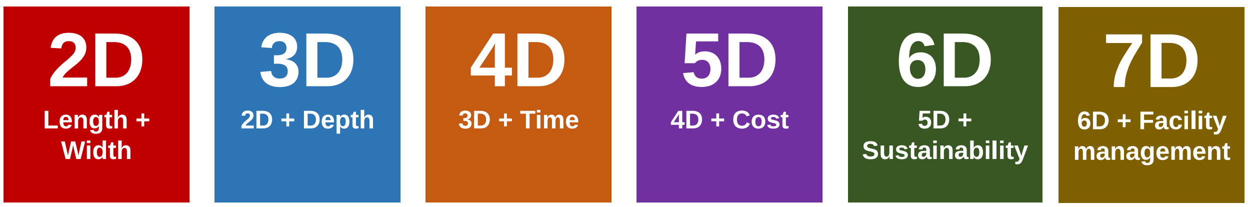


Figure 9: BIM development and applications

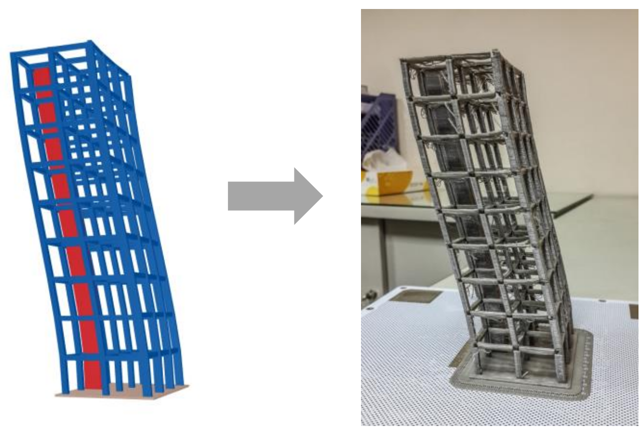
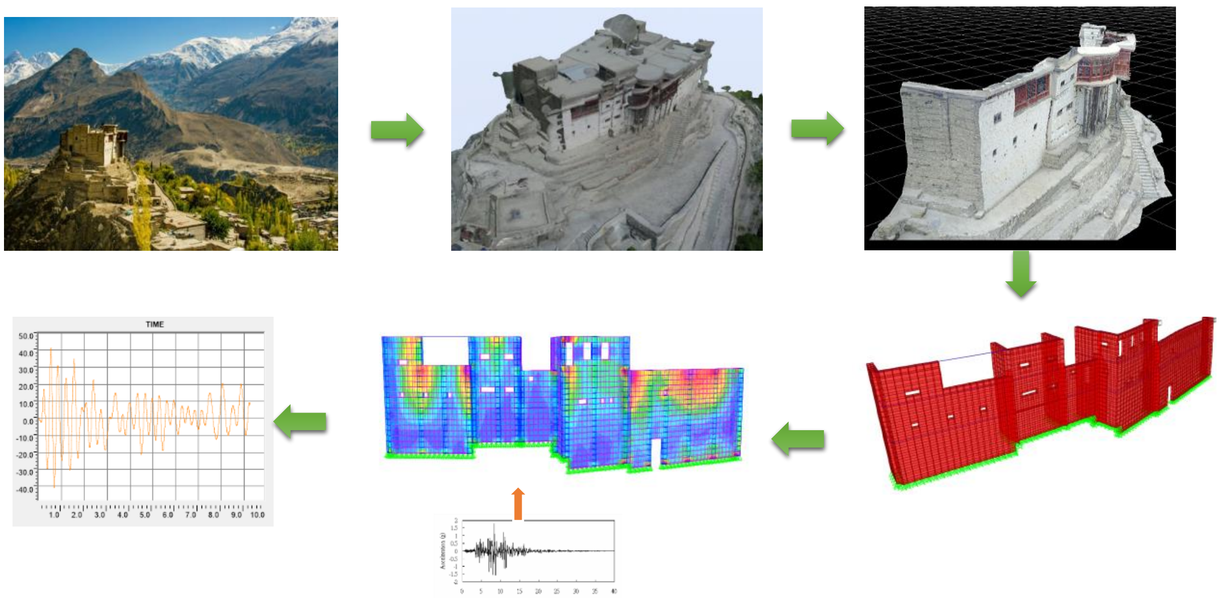


Figure 10: 3D printing for physical visualization of analysis results (e.g. the first vibration mode shape of a building structure)

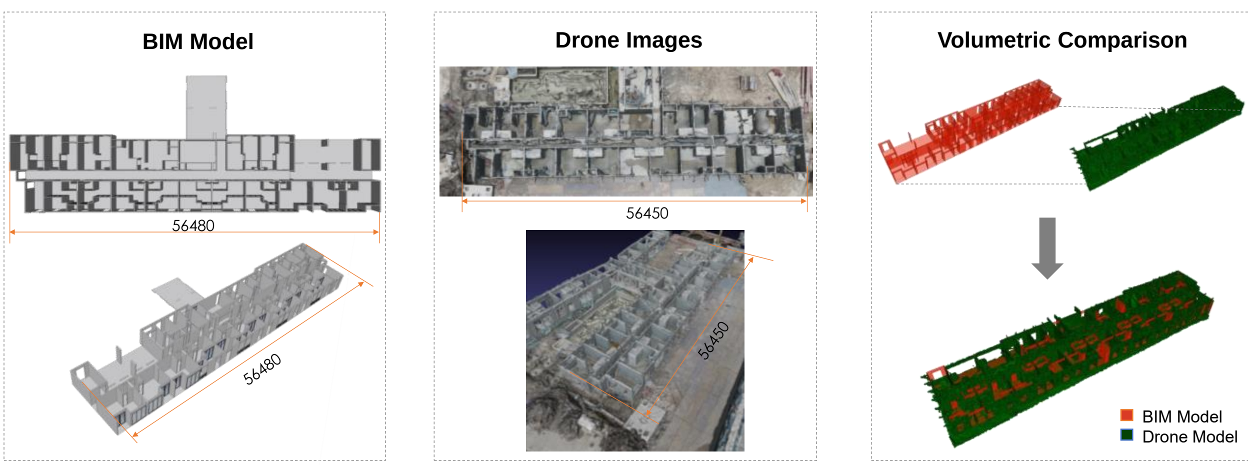
One of the difficulties for structural engineers is to visualize the results or output of the analysis carried out on structures. Sometimes even after a successful analysis, it is difficult to present the output in an understanding way. For this purpose visualization is a technique that be applied to communicate a message by creating images, diagrams or animations. Visualization today has ever-expanding applications in science, education, engineering (e.g. product visualization), interactive multimedia, medicine, etc. In conjunction with 3D printing, the engineering visualization has endless applications from results of structural analysis on one hand to the manufacturing of reduced-scale structural samples for shake-table testing or wind-tunnel testing on the other hand.

5. Applications of Drones and Unmanned Aerial Vehicles (UAVs)

The use of drones and unmanned aerial vehicles (UAVs) is continuously increasing in various fields. Many industries are embracing the rapidly improving scientific tools and introducing smart solutions to solve real-world problems (Zucchi, 2015). The planning and monitoring of construction activities is one of the key areas where the drones and UAVs can significantly improve the performance and speed. In fact, the construction industry can take the advantage of such technologies in almost the whole range of practical aspects. For example, the drones and UAVs can be potentially used at several stages in a construction project including pre-planning, detailed survey and mapping of job site, construction process monitoring, post-build checks, and sales and marketing (Liu et al., 2014). Similarly, the drones can serve as a real time tool for the planners to monitor if their construction projects on the ground are conforming to their vision or not. The data acquired from drones can also help developers and construction firms to keep a track of their inventory and plan out the entire construction site.



(a) Automated computer modeling and structural analysis of structures using drones images



(b) Smart monitoring of progress in construction projects using drones

Figure 11: Applications of drone and image processing-based technologies in structural engineering

More recently, the progress in the design and navigation of low-weight and autonomous drones and UAVs have resulted in their more practical and cost-effective operation in the fields of architectural engineering and construction management and monitoring. A recent research at AIT have resulted in the development of a fully automated smart construction monitoring and reporting system based on real-time data obtained from drones and UAVs. The data in terms of drone images from multiple locations and point clouds (from 3D scanning of construction site) can be used to construct a 3D model using the photogrammetry techniques. This so-called "drone model" can be converted to FEM model and analyzed under any specified loading (Figure 11 a). This drone model can also be directly compared to BIM model at various construction stages to monitor the construction progress (Figure 11 b). Beside construction scheduling and costing, this comparison can be expanded to include real-time recording, reporting, billing, verification and planning. This fully automated system can significantly reduce the effort required in traditional construction monitoring and reporting procedures. The system not only provides convenient and smart ways of site supervision and management but also results in better operations, planning and effective on-site adjustments. Figure 12 shows an integrated application of drones and 3D printing technologies in modeling, analysis and design of a dome structure.

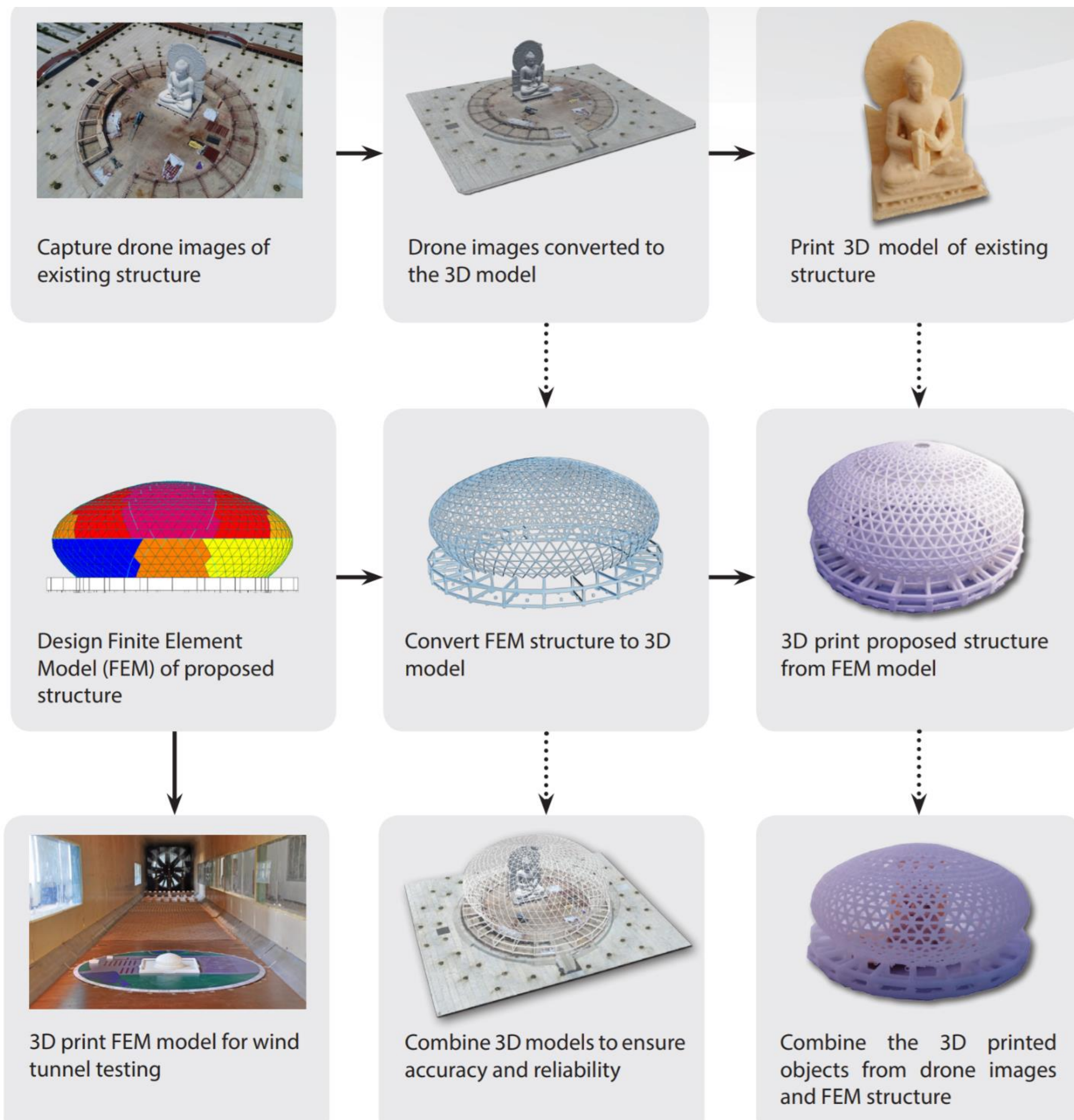


Figure 12: An integrated application of technologies in structural design

6. Applications of Sensor Technology

The development of integrated sensors, RFID, GPS, wireless and other technologies can be, and are being used for real-time monitoring of the structural response, both for ambient conditions and during events such as string winds, earthquakes, moving loads, temperature and moisture changes etc. These sensors can also be employed to track and monitor the time dependent phenomena such as shrinkage, creep, concrete aging, degradation, ionization, chlorine attack etc., and link these inputs to the structural models to produce meaningful response that can be communicated to the owners, public, and the researches in real time.

An example application of sensor technology for networked structural health assessment and post-earthquake response of tall buildings is presented in Figure 13. After every earthquake event, the sensor system sends data to the Post-earthquake Assessment (PEA) system and alerts the relevant parties involved in the process. The PEA system can be accessible from anywhere and provide real-time information of the recorded data. Upon initial evaluation of every structure, the PEA system provides the building owners, building management teams, structural engineers and government authorities with the structural assessment results and an overall picture of the seismic risk posed by the recent earthquake event.

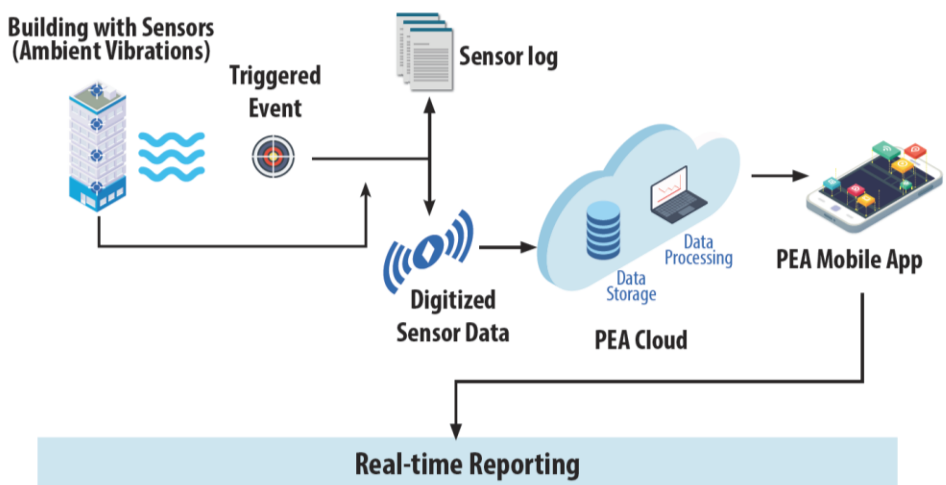


Figure 13: Post-earthquake assessment of building structures using smart sensing technologies

7. Artificial Intelligence (AI) and Machine Learning (ML)

In the computing field, artificial neural networks, fuzzy logic, genetic algorithms, deep thinking, big data and data mining, optimization etc. are some important and powerful tools applied to solve difficult problems with a different and appealing approach. With increasing complexities in new structural forms systems, analysis procedures and modelling complexities, the need of a quick and prior knowledge about proportioning the initial geometry and configuration of structural members is also increasing. A relatively faster and reliable estimation of approximate sizes of members and key response parameters can greatly facilitate the preliminary design and feasibility of a project. Artificial intelligence and machine-learning can greatly help in developing innovative solutions.

Figure 14 shows a machine learning-based approach to directly determine various key design parameters based on experience gained from previously designed buildings. The objective of this system is to provide means of assisting the design team and clients to make key design decisions based on cumulative experience rather than relying on judgment of individual designers. This system is based on a heuristic tool using Artificial Neural Networks (ANN) that can provide fast and reliable results based on two algorithms (Multi-layer Perceptron with Back Propagation, and PCA-Sparse- Extreme Learning Machine with online Sequential learning). The system is also capable of incremental learning with the availability of more data in future.

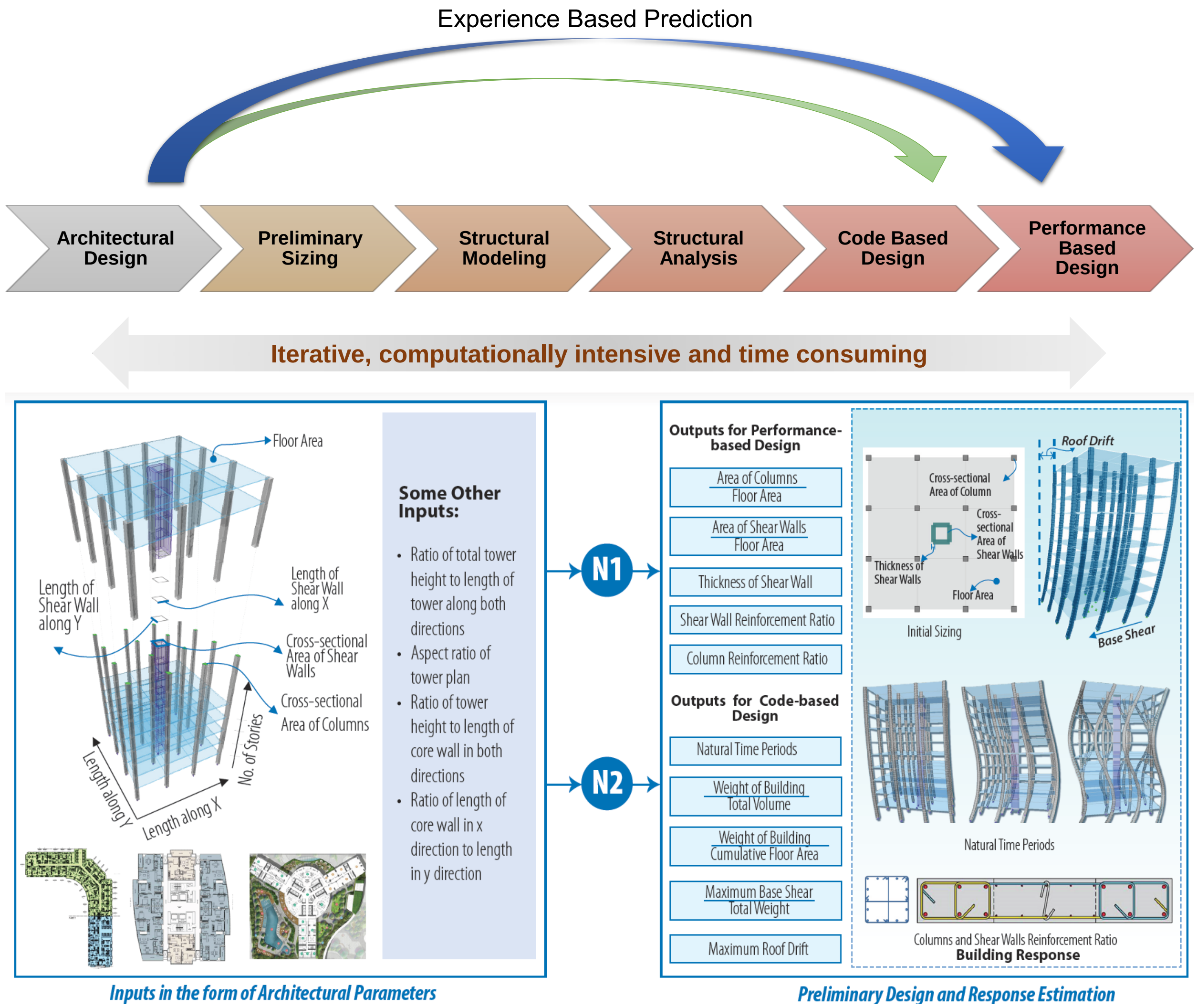


Figure 14: The use of artificial neural networks in pleniminary design of buildings

8. Concluding Remarks

During the last few decades, revolutionary advancements are going on in various fields and professions. Remarkable efforts are being done in various walks of life to absorb this innovatory change and to make best use of the modern computing technologies and devices. The effect of this progression is very obvious and evident in our lives and we can observe these modern techniques and devices everywhere around us like internet, intranet, smart phones, tablets, GPS, GPRS, new operating systems, social and professional networks, cloud computing, VR, AI and many more. The development of intelligent tutoring systems provides a new way to harness and exploit the educational potentialities of computers keeping in mind the social dimensions of learning process. Apart from the fact that structural engineers were in fact one of the pioneers and originators of application of computing systems and methods (e.g. finite element method), it seems that the modernization of computing techniques and devices have not kept pace in structural engineering. Introduction of modern computation methods and smart systems in structural engineering can be very handy and useful resulting in construction of smart cities for future (Figure 15). This is possible only with inter-disciplinary approach containing the elements of planning, engineering, technology and management. It is need of the hour to for structural engineers to embrace modernized computing techniques and devices, not only to provide answers to ever increasing number and nature of problems but also to match up with the pace of the development booming around us.

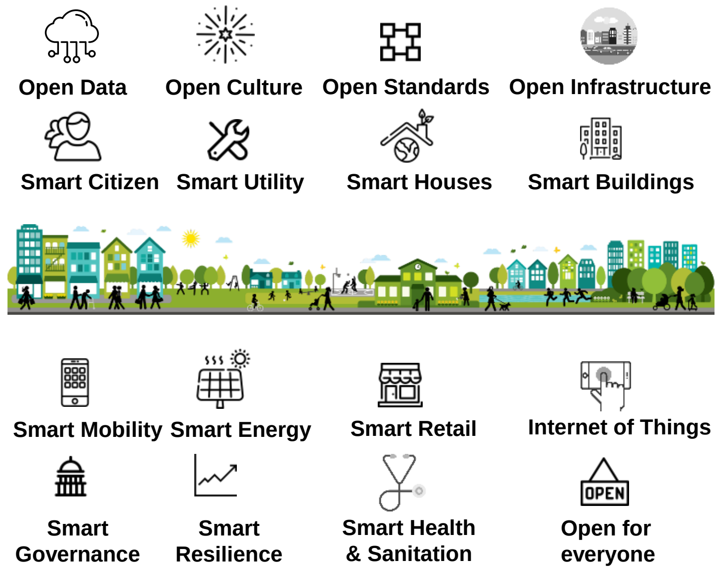


Figure 15: Key elements of smart cities: The convergence of planning, engineering, technology and management

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Effect of Methylcellulose on Different Properties of Fresh and Hardened Concrete

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Abstract

Construction industry is considered as one of the biggest industries in the world. It mainly covers construction of roads, dams, highways, bridges, residential, commercial and high-rise buildings. Some useful construction materials are used for the construction of all the structures including steel, concrete and wood. Concrete is widely used construction material all over the world for the construction of various structures. Concrete usually contains cement, sand, crush and water which collectively regulate its strength and other properties. It is essential to understand the properties and behavior of the material under different types of loadings. It will lead to the safe and economical design and also improve the service life of structures. Contrary to these qualities, concrete structures have some problems including cracking, weathering, weak in tensile and thermal cracking. A wide range of admixtures are available in order to overcome these defects. In this research methylcellulose used as an admixture to improve the properties of concrete. A standard concrete mix was used to pore the beams, cylinders and cubes with 0.60 constant water to cement ratio and methylcellulose was added in it at different percentage by weight of concrete from 0% to 1%. The properties of concrete were changed in fresh as well as in hardened form but the slump value of concrete reduced by increasing the percentage of methylcellulose which will lead to reduction in bleeding and segregation. By increasing the percentage of

methylcellulose tensile strength of concrete was increased. However, compressive strength and flexural strength were reduced a little which can be controlled by the use of any other admixture.

Keywords
Normal Strength Concrete, Methylcellulose, Admixture, Slump Improvement and Strength Gain.

1 Introduction

Construction industry mainly relies on concrete. Besides the economy of concrete structures, these also have different other properties under different loading including compressive strength and durability. But on the other hand, concrete structures are very poor in tension loading along with some other problems like thermal and shrinkage cracks, porosity and corrosion of steel bars inside concrete. In order to reduce these effects, admixtures are used in the concrete by a fraction of the weight of cement. For instant, tensile strength of concrete can be improved by using methylcellulose in concrete between 0.2% to 0.8% but it will reduce the slump value and compressive strength as well. This addition of methylcellulose also increased the mechanical and thermal properties of concrete (Doğangün, 2004).
The relatively low conductivity of silica fume, latex and methylcellulose will also decrease the thermal conductivity of concrete up to 46% if 15%-30% silica fume and 0.4% to 0.6% of methylcellulose were added in the concrete by the weight of cement. This mixture will also improve the density of concrete (Ghobarah, 2001). The simple addition of carbon fibers will not be effective in increasing the thermal conductivity of concrete because of air voids but the addition of methylcellulose along with the carbon fiber will increase the thermal conductivity of concrete up to nine percent (Kwok & Samali, 1995).
The surface treatment of steel bars and the use of different admixtures will helpful in controlling the corrosion of steel bars inside the concrete body. The use of methylcellulose between 0.3% to 0.7% will control the corrosion up to 32% (Sezen, Whittaker, Elwood, & Mosalam, 2003). Bond strength is the fundamental properties of reinforced concrete and it provides good strength to carry the load. The bond strength and corrosion resistance of concrete can be improved by using methylcellulose along with the ozone treatment of steel bar (Damcı, Temur, Bekdaş, & Sayin, 2015).
In under water structures, methylcellulose can be used as an anti-wash admixture. In order to add the anti-wash out admixture in the concrete, slump value is of high importance and must be controlled in construction of underwater structure (Nehdi, Duquette, & El Damatty, 2003). The mechanism of adsorption of methylcellulose is totally different from water reducing agents and this difference provides the compatibility of Portland cement and methylcellulose(Topçu & Ateşin, 2016).
But it is mandatory to ensure that methylcellulose will not make the bond with C3A element of cement because this bond will reduce the workability of concrete (Givi, Rashid, Aziz, & Salleh, 2010). Methylcellulose is hydrophilic white powder and can be dissolved in a cold-water and derived from cellulose. Like other cellulose material, methylcellulose is non digestible and non allergen in nature (Salas, Delvasto, de Gutierrez, & Lange, 2009).
In order to get the better result from concrete in which methylcellulose has been used as an admixture, the curing process must be started right after the final setting time. This will provide the better and smooth surface of concrete and reduce the cost of finishing work (Cordeiro, Toledo Filho, Tavares, & Fairbairn, 2009). In the areas where weather condition is hot and dry

which causes rapid evaporation and leads to freeze and thaw problem, the use of methylcellulose will be helpful in controlling the cracks produced under these conditions (Fairbairn et al., 2010). The rapid drying shrinkage will affect the floor performance. The addition of methylcellulose by the weight of cement and early curing will reduce this problem and improve the concrete floor performance (Modani & Vyawahare, 2013). Under the different conditions, it was observed that addition of methylcellulose slightly reduce the compressive strength of concrete due to reduction in slump value. Therefore in order to achieve the better result form this concrete mixture, early curing process must be carried out (Dahake & Ghugal, 2013).
Durability of concrete structures highly depends upon the use and method of mixing of admixtures in concrete. The addition of methylcellulose by weight of cement improve the mechanical and other properties of concrete up to considerable level (Jumadurdiyev, Hulusi Ozkul, Saglam, & Parlak, 2005).

2 Research methodology

The research is based on the experimental study. In the initial stage different preliminary tests were performed like dry density test, bulk density test, surface saturated dry density test, water absorption test, crushing value test, initial and final setting time tests of cement, sieve analysis tests of cement, fine and course aggregates and consistency test of cement. In order to achieve required compressive and tensile strength of concrete, trial mixtures were prepared and samples of cylinder and cube were tested. The methylcellulose was used in percentage by the weight of cement in different percentage between 0% to 1%. The concrete mix ratio of 1:2:4 with 0.60 water to cement ratio was kept constant for all the samples. Each sample was given a specific identity like BS1 to BS6 that indicates percentage of methylcellulose from 0% to 1%. The pond curing was carried out for all the samples.

3 Results and Discussion

In the first steps the effect of methylcellulose on slump value was evaluated. It is clear from the table 1 that as the percentage of methylcellulose increases the slump value decreases. At 0% methylcellulose, the slump value was 95mm and it is going to decrease with constant increment in the value of methylcellulose in concrete. This decrease in slump value will also affect the compressive strength of concrete.

Table 1: Slump Values

Sr. No.	Beam ID	Slump (mm)	Methylcellulose Quantity (% by weight of Cement)
1	BS1	95	0%
2	BS2	82	0.2%
3	BS3	75	0.4%
4	BS4	65	0.6%
5	BS5	58	0.8%
6	BS6	47	1%

After the slump test, compressive strength of concrete was evaluated and results are shown in the table 2 below.

Table 2: Rate of Gain of Compressive Strength

Sr. No.	Cube ID	Methylcellulose Quantity (% by weight of Cement)	3-Days Compressive strength (MPa)	7-Days Compressive strength (MPa)	28-Days Compressive strength (MPa)
1	BS1	0%	9.043	14.638	21.098
2	BS2	0.2%	6.781	12.166	16.793
3	BS3	0.4%	6.354	11.482	15.610
4	BS4	0.6%	5.382	11.304	14.748
5	BS5	0.8%	5.061	10.766	13.349
6	BS6	1%	4.523	7.212	12.489

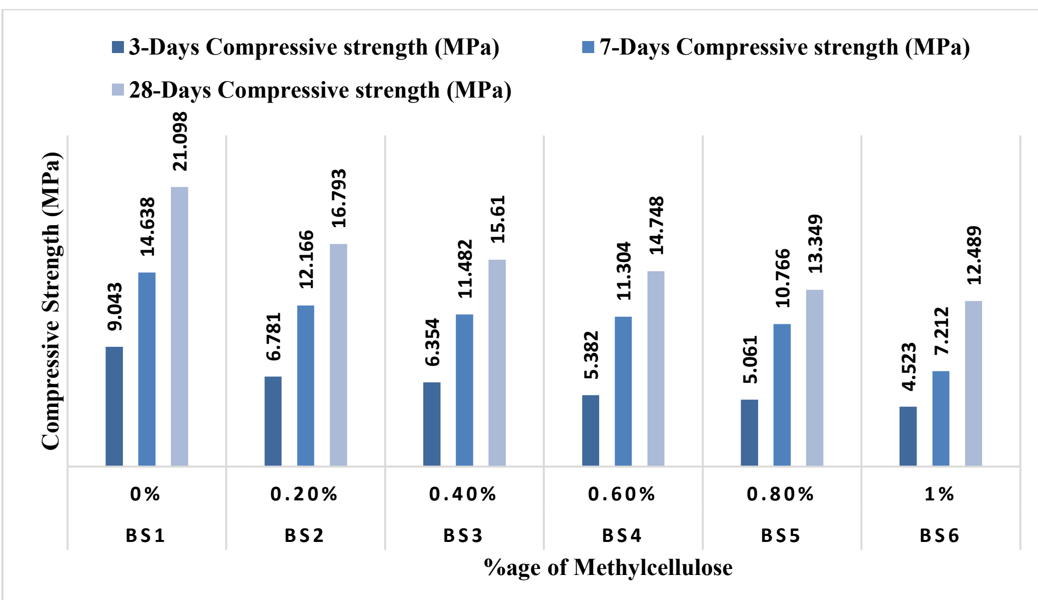

Figure 1: Rate of Gain of Compressive Strength

Concrete cubes of size 70mm x70mm x 70mm were tested at different ages to find out the effect of Methylcellulose on rate of gain of compressive strength of concrete. It is clear from the Table 2 and Figure 1 that as the percentage of Methylcellulose increases the rate of gain of compressive strength as well as the compressive strength goes on decreasing. At 0% of Methylcellulose the compressive strength is maximum while at 1% of Methylcellulose the compressive strength is minimum.

Table 3: Comparison of Compressive and Tensile Strength

Sr. No	Cube ID	Methylcellulose Quantity (% by weight of Cement)	28-Days Compressive strength (MPa)	28-Days Tensile strength
1	BS1	0%	21.098	1.268
2	BS2	0.20%	16.793	1.474
3	BS3	0.40%	15.61	1.611
4	BS4	0.60%	14.748	1.884
5	BS5	0.80%	13.349	2.023
6	BS6	1%	12.489	2.194

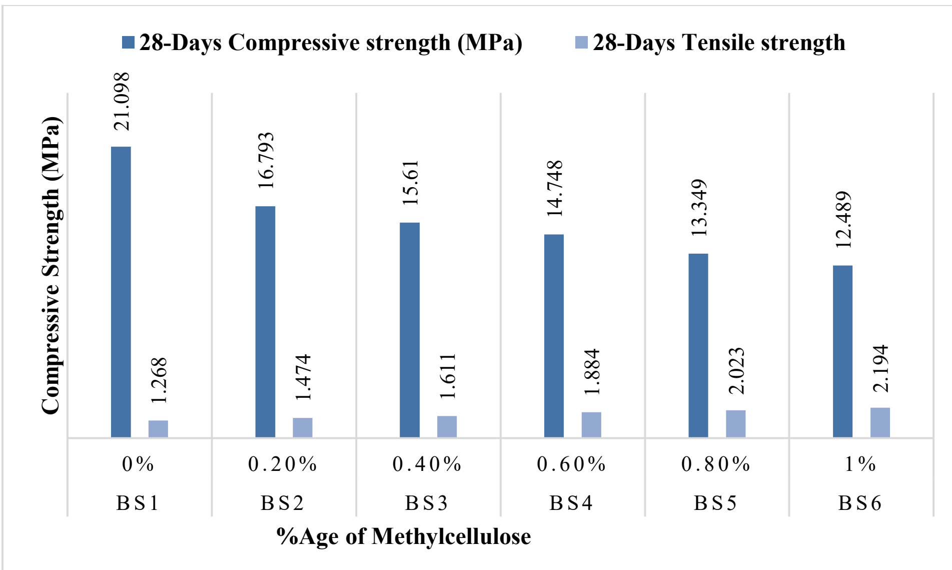

Figure 2: Comparison of Compressive and Tensile Strength

The Table 3 and Figure 2 indicates that on average the tensile strength of concrete is nearly 11.5% of compressive strength of concrete which seems to be good. As the percentage of methylcellulose increases the tensile strength is also increasing at a rapid rate.

4 Conclusions

Based on results, it is concluded that with addition of methylcellulose, tensile strength of concrete was increased. With the increase in percentage of methylcellulose, workability of concrete decreased that also affect the slump value but these properties can be improved by controlling percentage of methylcellulose in concrete mixture. But on the other hand, this reduction in slump value will also reduce the chances of segregation and bleeding. Compressive strength of concrete was reduced and flexural strength was also reduced a little bit by using methylcellulose. Consistency, measured in percentage, was increased with increasing percentage of methylcellulose in cement paste. Both initial and final setting times were decreased with increasing percentage of methylcellulose in cement paste. It indicates that methylcellulose can be used as an accelerator to some extent.

5 Recommendations

From the results and conclusions, it is recommended that by controlling percentage of methylcellulose addition in concrete, slump value can be controlled and it may lead to the strength improvement of concrete. As concrete is weak in tension therefore, use of methylcellulose can solve this problem up to some extent. The rate of gain of strength of concrete with methylcellulose as an admixture has been improved and hence curing process can be started at early stage that can also play a vital role in improving the strength. Further research can be carried out to find out the causes of reduction of compressive strength of concrete with different percentage of methylcellulose. Other concrete properties such as permeability, weather resistance and bond strength with steel can be investigated in further research.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Investigation on Selected Properties of Concrete Blended with Maize Cob Ash

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Abstract

In this experimental study priceless product maize cob ash as a binding material has been used which possess pozzolanic properties. The cement is partially replaced as 0%, 5%, 10%, 15% and 20% with maize cob ash as a cement replacement material. In this study, 25 cylinders were prepared to analyze the split tensile strength, and 25 cubes were prepared for compression strength test with water/cement ratio 0.5. These specimens were tested at the curing age of 28 days in 1:2:4 of concrete mix. Slump test were conducted to check the workability of each mixture. On the bases of results, it can be concluded that 5% replacement of cement with maize cob ash is optimum.

Keywords
Maize cob ash, Split tensile strength, Compressive strength, Workability.

1. Introduction

Concrete is an extremely universal and heterogeneous (fine aggregate, course aggregate and cement) civil-engineering material and plays a vital role in the development of every society of the nation for infra-structures. Practice of Civil engineering works as well as construction works worldwide depend on massive usage of concrete. It is a man-made civil engineering material that is made with mixing (fine aggregates, coarse aggregates, cement and water) in a proper ratios. All these decorations contribute in the strengthening of concrete (Augustine and Michael, 2016). The development of replacement cementious materials (RCMs) has been become significant in the advancement of low cost building materials for the production of self-sufficient shelter especially in the progressing nations. For overcoming the prices of the cement worldwide every sector of the society, specially in under-developing countries, it was thought that it should be an alternate option and locally available material which can balance the affordable prices for construction (Elinwa and Mahmood, 2002). The current rate of production of cement is approximately 1 to 1.3 billion ton per year. Its increment is predicted to be about 3.4 to 3.6 billion ton per year, up to the year of 2015 (Coutino, 2003). The production of every ton of cement ; in the atmosphere green house is liberated by the one tone of carbon dioxide (CO2). So, it caused discharge of carbon dioxide (CO2) gas about 290 to 310 million automobile calculating almost 6% to 8% of the total world manufacturer of carbon dioxide (CO2) gas (Meyer, 2002). Peeping into this research, utilization of agricultural waste-material is binding material and environmental friendly. And the utilization of agricultural wastes products are found with huge quantity that is filled in three phases {water, land and air).This agricultural waste products possess pozzolanic properties which were studied further for knowing the characterizes of blended cement in the concrete, Corn cob ash (CCA) (Adesanya 1996, Adesanya, 2000, Adesanya, 2001), waste burnt clay (Syagga et al., 2009; Lu and Sabuni, 2002) Rice husk ash (RHA) (Kma, 2003; Sabuni et al., 2002; Nehdi et al., 2003; Bui et al. 2005) and saw dust ash (SDA) (Udoeya, 2002). In this research corn/maize cob ash is an agricultural waste material by production and has the great importance in sub-Saharan Africa crop of cereal. In the year 2000 all over the world according to the report data base of food and agricultural organization (FAO) about 580 to 590 million tons of corn were manufactured (FAO, 2002).The United states werebthe highest corn producer about 42% to 44% and Africa manufactured 6% to 8% (Maize, 2002).

Now-a-days the world is facing two major issues i.e. global warming and energy crisis. Approximately 0.8 tons of CO_2 is being emitted into atmosphere due to manufacturing of one ton cement which accounts for 5 to 8 percent of worldwide CO_2 emission. The cement is being made and used widely in our country and huge energy (900 to 1600) is required in manufacturing of cement. On the contrary, Pakistan is confronting an acute energy crisis. The cement cost is escalating day-by-day; it is resulting significant increase in the overall construction cost.

In order to lessen the manufacturing of cement, obtain reduction in both CO_2 emission and energy consumption and ultimately decrease in construction cost, an environmentally friendly pozzolanic material is definitely required. In this regard, an investigation has been carried out with the inclusion of maize cob ash as a partial replacement of cement in the concrete.

2. Material and Method

2.1 Material

Cement, Maize cob ash (MZA), course aggregate, fine aggregate and water were utilized.

In this research ordinary Portland cement (OPC) market name Lucky cement brand was used as a binding material. Hill sand was used which was passed from sieve size 4.75mm and course aggregate was brought from the market, It was strewed in the cemented clean ground after that was washed after drying in open air atmosphere passed from sieve size of 20mm**.** Replacing cemented material Maize cob was collected from the Larkana city and dried for 3 to 4 days then burnt on un-control temperature after cooling of Maize cob ash it was grinded and pass from sieve No. #200µm and replaced with cement 0%, 5%, 10%, 15% and 20%.

2.2 Mix proportion

Mix proportion of Maize cob ash concrete is shown in Table 2.

Table 1: Mix Proportion

Mix ID	Cement (%)	MCA (%)	F.A (%)	Coarse aggregate (%)	W/C Ratio
MCA 0%	100	0	100	100	0.5
MCA 5%	95	5	100	100	0.5
MCA 10%	90	10	100	100	0.5

MCA 15%	85	15	100	100	0.5
MCA 20%	80	20	100	100	0.5

2.3 Method

In this study physical tests were tested which were workability, compressive strength and split tensile strength. Slump test was immediately conducted for each batch as per code specification of (BS-1881-102-1983). For compressive strength test 5 cubes were prepared for each batch and test at the age of 28 days wet curing. The size of cube was 100mmx100mmx100mm as per code specification of (BS 12390-3-2009). For split tensile test 5 cylinders were prepared for each batch and test at the age of 28 days wet curing. The size of cube was 200mmx100mm as per code specification of (BS 12390-6-2009).

3. Results and Discussion

3.1 Workability of Maze cob concrete

Slump value of Maize cob ash concrete is shown in Table 2.

Table 2: Slump Test

Type of concrete	Mix Proportion	W/C ratio	Slump (mm)
MCA 0% Concrete	1:2:4	0.5	44
MCA 5% Concrete	1:2:4	0.5	40
MCA 10% Concrete	1:2:4	0.5	35
MCA 15% Concrete	1:2:4	0.5	28
MCA 20% Concrete	1:2:4	0.5	22

The results of slump test shown in Table.2 illustrate that the slump workability with the inclusion of Maize cob ash is decreased the slump about 50% compared with the control mix.

3.2 Compressive Strength of Maize cob concrete

Compressive strength of Maize cob ash concrete is shown in Figure 1.

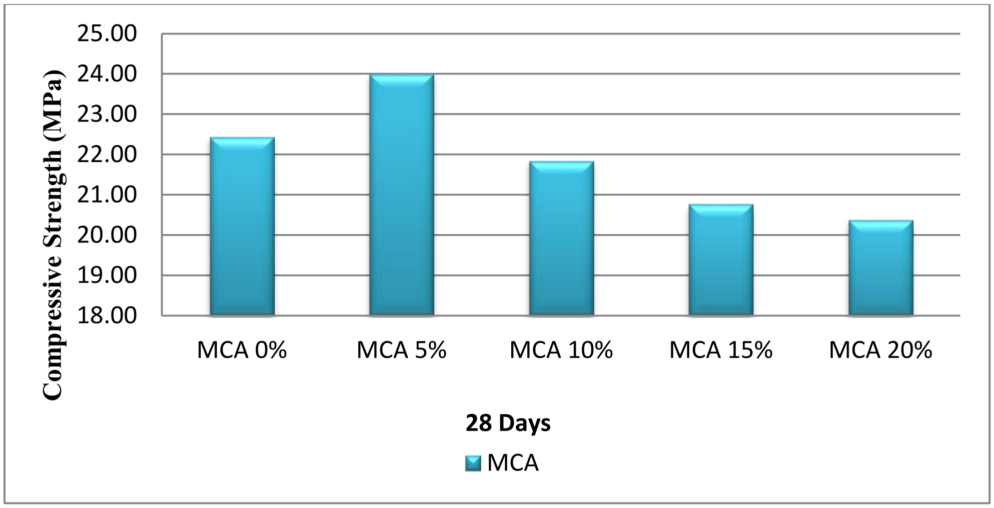

Figure.1 Compressive strength of Maize cob ash

As a result of compressive strength shown in the Figure.1 illustrate the compressive strength maize cob ash is increased with inclusion of maize cob ash up to 5% than that of control concrete mix. The further replacement of cement with maize cob ash from 5%, the compressive strength is decreased as compared to control mix. The maximum compressive strength 24MPa is achieved at 5% replacement of cement with maize cob ash which is 7% more than that of control mix.

Figure.2

Figure.3

Compressive strength test of Maize cob ash concrete after and before breaking

3.3 Split Tensile Strength of Maze cob concrete

Split tensile strength of Maize cob ash concrete is shown in Figure 2.

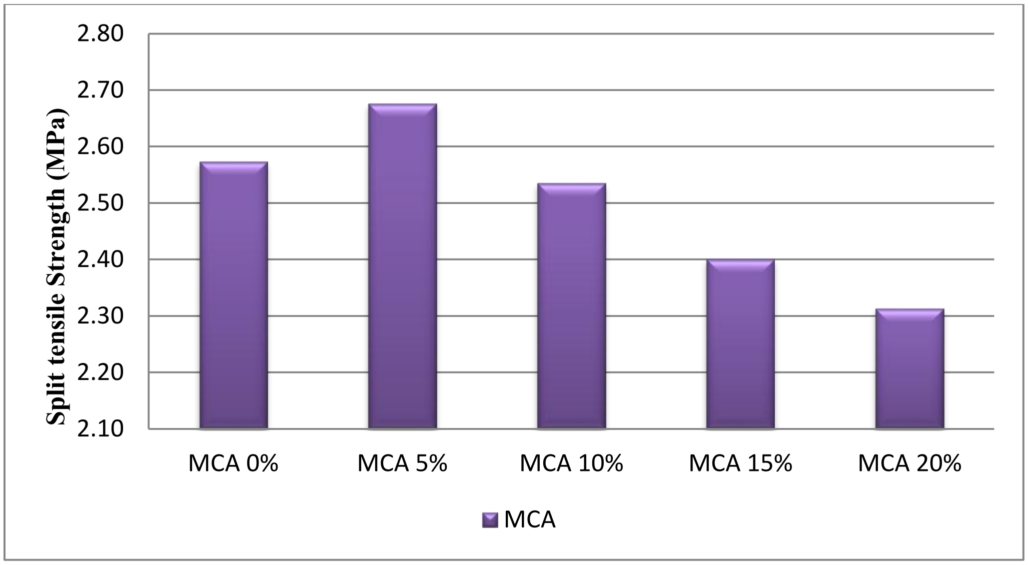

Figure.4 Split tensile strength of Maize cob ash

As a result of split tensile strength shown in the Figure.4 illustrate the split tensile strength maize cob ash is increased with inclusion of maize cob ash up to 5% than that of control mixing. The further substitution of cement with maize cob ash from 5% tensile strength is decreased as compared to control mix. The maximum tensile strength 2.68MPa is achieved at 5% replacement of cement with maize cob ash which is 1.52% is more than that of control mix.

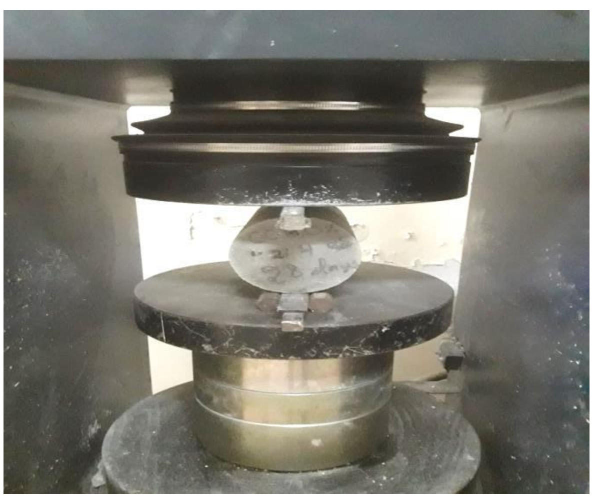

Figure.5

Figure.6

Split tensile test of Maize cob ash concrete after and before breaking of cylinder.

4. Conclusion

Based on the conducted research it can be concluded that:

1. The slump test indicates that with the inclusion of Maize cob ash workability is decreased as compared with the control mix.

2. The compressive strength maize cob ash is increased with inclusion of maize cob ash up to 5% than that of control concrete mix. The further replacement of cement with maize cob ash from 5%, the compressive strength is decreased as compared to control mix. The maximum compressive strength 24MPa is achieved at 5% replacement of cement with maize cob ash which is 7% more than that of control mixing.
3. Split tensile strength maize cob ash is increased with inclusion of maize cob ash 5% than that of control concrete. The further replacement of cement with maize cob ash from 10% tensile strength is decreased as compared to normal mix. The maximum compressive strength 2.68MPa is achieved at 5% replacement of cement with maize cob ash 1.52% is more than that of control mix.

On the bases of conducted research, it can be concluded that 5% replacement of cement with maize cob ash is optimum.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Shear Behavior of Recycled Aggregate Concrete Beams

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Abstract

This paper presents an experimental study done on the structural behaviour of longitudinally reinforced Recycled Aggregate Concrete (RAC) beam specimens. RAC beam specimens, designed to fail in shear, at two replacement levels of recycled aggregates (0% and 30%) were tested under two-point bending. Furthermore, existing code formulations for NAC were used to predict load carrying capacity of all beam specimens. Compressive, splitting tensile and flexural tensile strengths for RAC mixes were found to be lower than NAC. Shear strength variation was found to be less prominent. Ultimate deflections were higher and initial stiffness of RAC beam specimens were lower than NAC beam specimens. Strength predicting formulations for NAC are found to be adequate for shear critical beams without transverse reinforcement made up of RAC.

Keywords
Recycled Aggregate Concrete, Natural Aggregate Concrete.

1. Introduction

Rapid urbanization has resulted in large scale new construction to cater the need of the population influx. These constructions ranging from residential units to infrastructure projects require substantial consumption of natural and financial resources. Concrete being one of the main material used in these endeavors, becomes important from the point of view of manufacturing. According to (PK, 2001), globally, construction industry ends up using approximately 1.6 billion tons of cement, and approximately 10 billion tons fine and coarse aggregates every year. This results in large scale deforestation and top-soil loss.

Although, to cater the need for new construction projects, material consumption as mentioned above is a big issue related to environment as it puts pressure on natural resources. However, another problem related to this is the dismantling of existing structures. This dismantling can be the result of end of service life of existing structures or to make provision for new construction (Bilal S.Hamad & Ali H.Dawi, 2017). For both of these reasons, this dismantling results in substantial amounts of waste. This waste commonly termed as 'construction and demolition waste' (CDW) is another global issue. In European community, CDW is the largest contributor to waste in terms of amount generated. Construction sector is alone generated 871 million tons of waste 2014, which constitutes 33.5% of the total waste generation (Anon., 2017). In Canada, the construction sector is contributor of approximately 11 million tons of waste every year and roughly only 42% of this is reused or recycled, concrete alone constitutes 52% of this waste (Venta GJ & Nisbet M, 2001). In USA this CDW was estimated to be 170 million tons in 2010 (S. Arora & S. Singh, 2016). In China, this CDW alone constitutes 30%-40% of the total solid waste generated in cities (J. Z. Xiao, et al., 2012). So, the rapid pace of construction puts pressure on the natural resources for the material extraction and the dismantling results in considerable amounts of waste, both of these phenomenon results in negative impact on the environment. An effective way to address these issues is the recycling of the waste generated and utilizing it in the new construction processes, this will alleviate pressure on the natural resources and also the landfills. This recycling also has financial benefits, as the cost of extracting new material is higher and the cost of dumping waste will increase as these sites become distant due to exhaustion of capacity of nearby dumping sites.

One effective way of recycling this CDW is by using it as aggregates in the new concrete. These aggregates are produced by crushing the rubble, and are termed as 'recycled aggregates' (RA). The concrete produced from these recycled aggregates is called 'recycled aggregate concrete' (RAC). To utilize the benefits of this RAC, which can result in effective waste management and preservation of quarrying sites, its properties and behavior has to be evaluated on material and structural levels.

Recycled aggregate concretes have been studied extensively worldwide. In (Wentao & Jason, 2010), effect of source strength on the final properties of RAC was studied. Slabs were casted from NAC having different strengths (20 MPa, 40 MPa and 60 MPa) and then these slabs were crushed to produce RCA, this methodology was adopted so that the source strength of RCA is known and the lithology of aggregate part remains same. Then RAC were made from these RCA with a strength target similar to that of source of RCA. Compressive strength gain, slump loss and flexural strength was measured of the resulting RAC mixes. It was concluded that to make RAC of a given strength, strength of concrete from which RCA are to be obtained should be at least similar to target strength or more than that.

Nine simply supported beams under two-point bending were tested by (S.Ignjatović, et al., 2017), with three replacement ratios (0%, 50% and 100%) and three shear reinforcement ratios (0%, 0.14% and 0.19%) with a shear span to depth ratio of 4.2. The beams without shear reinforcement made up of NAC and RACs behaved differently, a pure diagonal crack was formed in the NAC beam whereas an 'S' shaped crack was formed in the RAC beam. This 'S' shaped crack had an angle of 45^{o} while the diagonal crack of NAC beam had an angle of 30^{o}. Service load deflections for all replacement levels (0%, 50% and 100%) did not differ by more than 10% for same amount of reinforcement. Similarly no significant difference in normalized shear strength was observed for all beams with shear reinforcement. For beams without shear reinforcement, 100% and 0% replacement specimens were almost equal but the specimen with 50% replacement exhibited 15% lower strength.

Shear and flexure critical specimens were also assessed by (Knaack & Kurama, 2015). Natural coarse aggregates were crushed limestone while recycled aggregates were obtained from demolition waste from a foundation made in 1920. It was concluded that the changes in ultimate load capacity for both shear and flexure critical specimens were small, however initial stiffness was affected by recycled aggregate inclusion, similarly ultimate deflections for flexure critical specimens were found to be higher too.

Similar to above mentioned studies done on recycled aggregate concrete there are numerous other examples too, however such studies in Pakistan are not many if not completely absent hence this paper is a step in this direction.

2. Experimental Program

2.1 Material Properties

Ordinary portland cement from was used for concrete mixes. Two fractions of coarse aggregates were used, out of which 60% by weight had size 5mm-15mm and 40% by weight had size 15mm-25mm. 5mm passing river sand was used as fine aggregate for all mixes. Reinforcement was provided by 10mm and 12mm bars. Recycled aggregates were obtained from crushing tested beam specimens. Primary crushing was done by handheld jackhammers and secondary crushing was done by crushing plant installed in Department of Civil Engineering, NEDUET. Same size fractions (5mm-15mm and 15mm-25mm) were obtained for recycled aggregates too. Recycled aggregates were soaked for 24 hours to account for their higher absorption. Superplasticizer named 'Rheobuild 834' was used to achieve target workability.

Natural aggregate concrete mix having 28-day compressive strength of *30MPa* is selected as the reference mix. Yield strength of reinforcing bars was found to be *510MPa*.

2.2 Specimen Details

Compressive strength, splitting tensile strength and flexural tensile strength were evaluated for investigation of mechanical properties. *100mm* diameter and *200mm* length cylinders were tested to evaluate compressive and splitting tensile strengths according to ASTM C39 & ASTM. Flexural tensile strength was evaluated by testing *100mm* wide, *100mm* deep and *500mm* long prisms according to ASTM C78. Samples can be seen in Figure 1.

Figure 1: Specimens for splitting tensile (left), flexural tensile (middle) and compressive (right) strengths

Test beams selected for present study are *2133mm* in length, *150mm* wide and *200mm* deep with effective depth of *165mm*. Only tension reinforcement was done by providing two *12mm* bars. Test specimen details can be seen in Figure 2. Shear span to depth *'a/d'* for the specimens was 3. Region beyond supports is provided with closed stirrups in both types of specimens. The only change in the specimens was the type of concrete used which differed by recycled aggregate replacement percentage. Two beam specimens were tested, one for each concrete type.

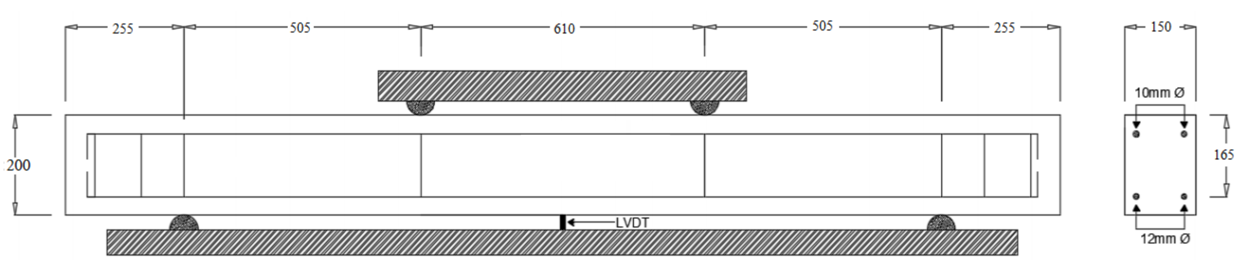

Figure 2: Test Beam Specimen (all dimensions are in mm)

2.3 Testing Protocol

Specimens were tested at deformation controlled rate of *2mm/minute* in the Material Testing Laboratory in Department of Civil Engineering, NEDUET. Midspan deflections were measured by LVDT (linear variable differential transformer). The constant moment region of beam specimens was marked with grid points spaced at *25mm* x*25mm*. Photographs were then taken by a tripod mounted camera focused on the mid-span and load values were recorded at the instance of taking photographs. Photographs could then be observed against load levels for crack propagation.

3. Results and Discussion

3.1 Mechanical Properties

Cylindrical specimens (for compressive & tensile strength) and prismatic specimens (for flexural tensile strength) were tested after 28-day wet curing. Results are shown in Table 1, which are average of 3 specimens. A decline in all the strengths can be seen in the recycled aggregate concrete specimens. All type of strengths for RAC were inferior to NAC, however the extent of loss was almost equal for all type of strengths.

Table 1: Mechanical Properties

	Strength (MPa)		
	Compressive	Splitting Tensile	Flexural Tensile
RAC00	30.22	5.65	6.55
RAC30	27.14	5.08	5.9

3.2 Structural Behaviour of Beams

Recycled aggregate concrete beam specimen exhibited hairline cracks at load level of 25kN and 35kN respectively at midspan. Shear crack appeared in the web on the right shear span of beam. This crack propagated towards the load point on the top and support on the bottom. Bottom propagation was diagonal in nature till reaching reinforcement level, after which it propagated horizontally towards the support. Top propagation of crack occurred with straight and inclined crack connecting the loading point and initial crack. Upon penetration of crack till the top fibre, specimen failed with concrete crushing on the top at 69kN. Some hairline flexural cracks were also visible. The crack seems to be taking form of letter ‘Z’. Crack angle at mid-depth is 49^{o} and it reduced to 20^{o} in the below part and reduced to 20^{o} in the upper part too.

While testing natural concrete beam specimen, failure occurred with a diagonal crack having shallower inclination than the ‘S’ shaped crack observed in other recycled aggregate concrete specimen. The specimen failed at load level of 67kN. Crack angle measure 29^{o}. Failure exhibited well-known brittleness that is associated with shear failures.

Variation observed in the ultimate load carrying capacity is not significant. However, initial stiffness of recycled aggregate concrete specimen was found to be lower than the stiffness of natural aggregate concrete specimen, such findings are also reported by (Knaack & Kurama, 2015) & (Arezoumandi, et al., 2015) and they attributed the lower stiffness of RAC specimens to the reduced elastic modulus. Failure mode of both the specimens and the load deflection curves can be seen in Figure 3 and Figure 4 respectively.

Figure 3: Failure patterns of (left) RAC and (right) NAC beam specimen

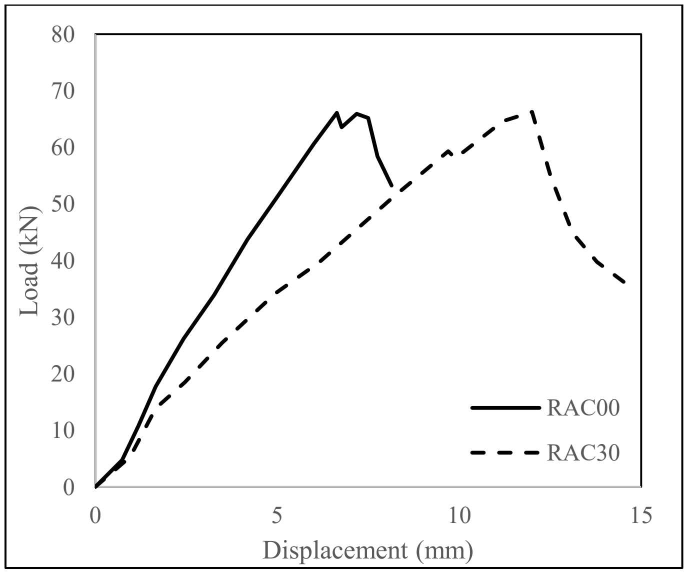

Figure 4: Load-Deflection Curves of Tested Beam Specimens

3.3 Strength Prediction

In contrast to flexural behaviour of reinforced concrete specimens where predicting models are based on single fundamental theory, shear predicting models differ each other due to lack of rational theory. Shear strength predicting models, mostly are based on empirical equations that are formed from experimental results and hence differ from each other (Ofonime & Ijiok, 2016). In this section, Eurocode 2 (CEN Eurocode 2, 2004), ACI-318 (ACI Commiittee 318, 2008), BS-8110 (BS 8110-1, 1997) and MC-2010 (Model Code, 2010) will be deployed for prediction of experimental results. Formulations are enlisted in Table 2.

BS-8110 and EC-2 take into account longitudinal reinforcement ratio, compressive strength of concrete and depth of specimen to estimate shear strength. MC-2010 has different level of approximations with increasing accuracy, first two will be used in this study, model code in addition to above parameters, also include shear at mid-depth of web to predict shear strength, in the first level of approximation the strain is calculated with the assumption that strain in longitudinal reinforcement remains linear at time of failure while the second level approximation incorporates calculation of strain and also includes aggregate size into the equation. For ACI-318, the simplified equation will be used. The purpose of this is to see whether the conservative predicting models remain conservative with predicting values for recycled aggregate concrete or not.

Experimental results for shear critical beams and their predicted values are shown in Table 3. The ratio of experimental to predicted values by all predicting equations is more than 1 depicting safe estimates. However, important thing is that the ratios do not differ by much. Hence, predicting formulations for natural aggregate concrete are found to be equally applicable for recycled concrete specimen too.

Table 2: Shear Strength Predicting Formulations

Code	Formulation	Eq.
BS-8110	$V_{pred} = \begin{cases} 0.79\left(\frac{100\,A_s}{bd}\right)^{\frac{1}{3}}\left(\frac{400}{d}\right)^{\frac{1}{4}} bd, & f_c < 25\,MPa \\ 0.79\left(\frac{100\,A_s}{bd}\right)^{\frac{1}{3}}\left(\frac{400}{d}\right)^{\frac{1}{4}}\left(\frac{f_c}{25}\right)^{\frac{1}{3}} bd, & f_c \geq 25\,MPa \end{cases}$	(3)
EC-2	$V_{pred} = 0.18\,k\,\left(\frac{100\,A_s f_c}{bd}\right)^{\frac{1}{3}} bd$ $k = 1 + \sqrt{\frac{200}{d}} \leq 2$	(4)
ACI-318	$V_{pred} = 0.17\sqrt{f_c}\,bd$	(5)
MC-2010	$V_{pred} = k_v\sqrt{f_c}\,(0.9d)(b)$ *Level of Approximation I (LoA I)*: $k_v = \frac{180}{1000+1.25(0.9d)}$ *Level of Approximation II (LoA II)*: $k_v = \frac{0.4}{1+1500\varepsilon_x}\,\frac{1300}{1000+k_{dg}(0.9d)}$ $\varepsilon_x = \frac{V_{test}\left[\frac{d}{0.9d}\left(\frac{a}{d}-1\right)+1\right]}{2E_sA_s}$ & $k_{dg} = \frac{32}{16+d_g} \geq 0.75$	(6)

Table 3: Shear Strength Predictions for Beam Specimens

		Predicted Load (kN)					Pexp/Pred				
					MC-2010					MC-2010	
	Exp. (kN)	EC2	BS-8110	ACI-318	*LoA I*	*LoA II*	EC2	BS-8110	ACI-318	*LoA I*	*LoA II*
RAC00	69.6	59.5	53.5	46.4	38.7	43.8	1.2	1.3	1.5	1.8	1.6
RAC30	66.7	57.2	51.0	44.7	35.9	42.5	1.2	1.3	1.5	1.9	1.6

Further visualization of above discussion can also be seen in [Fig. 5]. All the predicted values are below the experimental values and like mentioned above, the difference between the prediction accuracy and precision is minimal when comparing different concrete types.

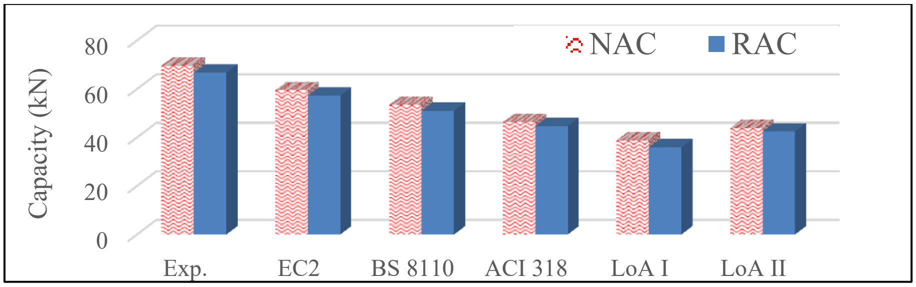

Figure 5: Shear Strength Prediction Comparison

4. Conclusions

Following conclusions can be drawn:

- Compressive, flexural and splitting tensile strengths of recycled aggregate concrete were found to be inferior to natural aggregate concrete.
- Ultimate load carrying capacity of longitudinally reinforced beams made out of recycled and natural aggregate concrete did not differ greatly. However, recycled aggregate concrete beam specimen exhibited lower stiffness and thus failed at a higher deflection. This can be due to lesser elastic modulus of recycled aggregate concrete.
- For both specimens, the prediction accuracy of all strength predicting equations is found to be approximately similar.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Comparison of Physical Attributes of Real Time Project Using BIM (Building Information Modeling): A Case Study

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Abstract

BIM follows an integrated project delivery approach and acts as project cost manager and automated quantification that incorporates 4D time as well as 5D cost modelling. BIM process improves the performance through the whole life cycle of projects. BIM visualizes projects in virtual n-dimensional models for identifying possible conflicts in design, construction and operations. Pakistan construction industry lags in such information technology applications i.e. the use of conventional 2-D CAD drawings does not support a true collaborative approach and hinders the joint involvement of the primary stakeholders during the design phase of the project. This poor integration of information results in damaged project time line and less practical estimates which overruns the planned budget. This paper summarizes the case study of implementation of BIM on residential building project and comparison of qualitative and particularly quantitative attributes and its validation from on-site available data; with the conclusion that application of BIM on residential unit projects in Pakistan can be hugely beneficial in terms of diminishing time overrun, material estimation, reduced conflicts, better variations management, cost management, decision making and quality management. Navisworks has come out as a great BIM tool for clash detection and quantity estimation with the highest accuracy.

Keywords
BIM, Estimation, Revit, CAD, Residential Unit

1. Introduction

In recent times Building Information Modeling (BIM) has become a highly debated topic since it is a valuable tool for reducing construction industry's disintegration and enhancing its efficiency. Owing to government support and standardization, BIM has become common in some parts of world (Lu et al., 2012; Tomek & Matějka, 2014). BIM follows an integrated project delivery approach and acts as project cost manager and automated quantification that incorporate 4D time as well as 5D cost modelling and updates project team with updated information and data (Smith, 2016). BIM process improve the performance through the whole life cycle of projects e.g., design and construction integration, cost and risk assessment, coordination and communication, documentation, productivity and quality, energy efficiency, and project management for horizontal projects as well as vertical projects (Lu et al., 2012; Woo et al., 2010; Azhar, 2011; Eastman et al., 2011; Barlish & Sullivan, 2012)

Building Information Modeling (BIM) visualizes projects in virtual n-dimensional models (n-D) for identifying possible conflicts in design, construction and operations. Pakistan construction industry lags in such information technology applications and follows the traditional project delivery approaches for construction projects. For instance, the use of conventional 2-D CAD drawings does not support a true collaborative approach and hinders the joint involvement of the primary stakeholders during the design phase of the project. This results in different versions of designs between architects, consultants, contractors and even owners. This poor integration of information later effects negative labor productivity which damages project time line and less practical estimates which most likely overruns the planned budget (Masood et al., 2014)

This paper summaries the case study of implementation of BIM on residential building project and comparison of attributes (qualitatively and quantitively). Major focus is given to quantitative aspect of BIM, its comparison and its validation from on-site available data (in light of practices followed in Pakistan construction industry).

2. Literature Review

BIM's concept can be traced back to 1960s. Whilst robust modelling programs started to emerge in the next two decades, ArchiCAD development in 1982 is viewed by many as the real start of BIM. Development of Revit in 2000 marked a paradigm shift towards effective BIM application (Bergin 2010). Evidently many stakeholders could benefit from effective BIM implementation (Olatunji et al.,). BIM technologies solve the key issues associated with 2D documents such as the difficulty and the amount of time it takes to access information of such a project, energy efficiency analysis, structural details, cost estimates and others (Nascimento et al., 2016). The use of BIM has led to reduced costs, better profitability, improved customer-client relationships and most of all better time management (Azhar et al., 2015). BIM used as a project management tool over the complete life cycle of the project, results in controlled cost as well as duration and provides effective workflows (Aladag et al., 2016).

Although BIMs perception has been around for over two decades but BIM application and adoption has been comparatively slow in the construction sector in comparison with other industries. However, over the past five years there has been a change of mind set as technology and application issues improve and the construction sector realizes the significant benefits to be gained from the use of this technology (RICS 2013). McGraw Hill (2014) states that adoption of BIM has been increased among contractors with time i.e. in North America it was 28% in 2007 but in 2012 the figure escalated to 71%.

Eastman et al., 2011, Sacks et al., 2010 and Sacks et al., 2018 narrates that for BIM to provide edition, compilation, evaluation and report of data regarding construction projects, the following domains must be considered: 1) 3D visualization ; 2) Rapid generation of various design substitutes; 3) Usage of model data for predictive analysis of the structure; 4) Information maintenance and model integrity; 5) Automatic generation of documents and drawings; 6) Collaboration in the design and construction; 7) Rapid assessment and generation of alternative construction plans alternatives; and 8) Electronic/ online object-based communication.

3. Research Methodology

The main purpose of this project is to determine the potential of BIM implementation in residential buildings and checking the accuracy of estimated quantities by comparing quantities generated by BIM software and the quantities which were obtained from manual calculations by traditional methods. For this purpose, a case study was conducted by selecting a residential building (Under construction). The residential building site had following dimensions:

a) G+1 Residential Unit (with semi-basement).
b) Plot Size = 50ft. x 90ft.
c) Total covered area = 5783 sq. ft.

The rationale behind selection of this project is that these kinds of residential units are a common practice in Pakistan and a comparison of physical attributes of such a project will be applicable to a wide range of residential unit projects of similar nature.

Data is to be acquired for the project's finished phases and on-going phase. Completed phases are then to be executed (separately) utilizing BIM tools and techniques while ongoing phase will be managed simultaneously for comparative analysis. Acquired and generated data sets are then to be compared towards yielding an estimate of improvement or decrement post application of BIM versus traditional methodologies. The study involves use of software tools such as;

Autodesk Revit 2017	(for generation of 5D model as shown in figure 1 & figure 2)
Navisworks Manage 2017	(for model integration, clash detection, quantity takeoff etc. as shown in figure 3)

The following work breakdown structure shall be followed;

a) 3D Architecture modelling.
b) 3D Structural rebar detailing in model.
c) Generation of schedules and estimates.
d) Finding clashes between architectural and structural aspects of project.
e) Comparison between generated quantity estimates by BIM and traditional methods.

Figure 1: Modelling in Revit 2017

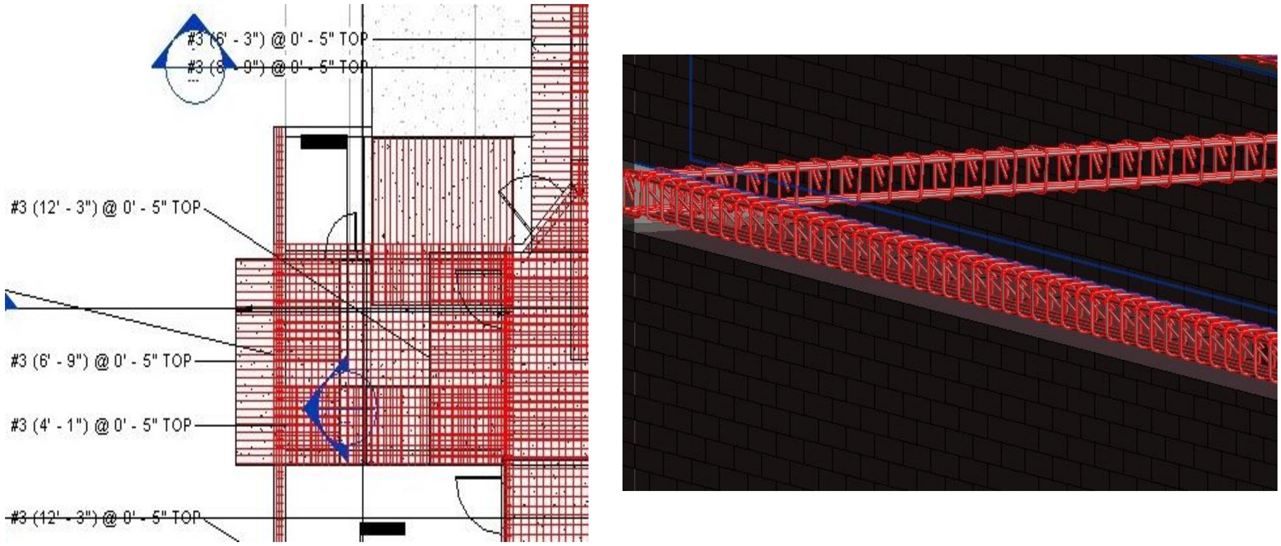

Figure 2: Reinforcement Plan in Revit 2017

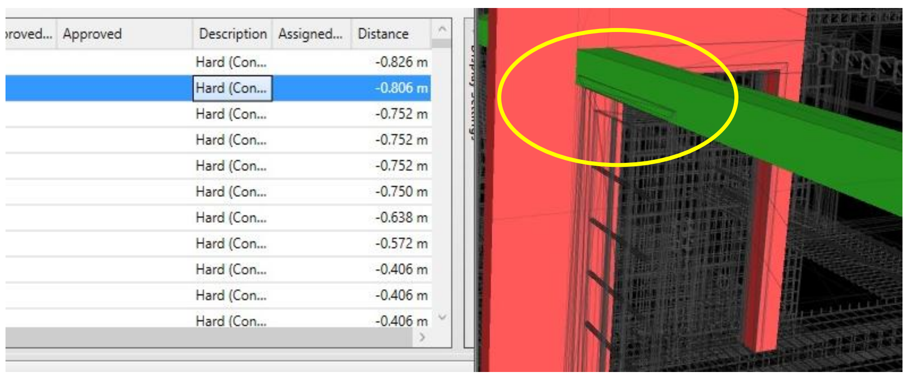

Figure 3: Clash Detection in Navisworks Manage 2017 (Architectural-Structural Clash)

4. Findings

A fully attributed, integrated 5D model of the subject project was developed on Revit, based on the CAD files acquired from the designer. Architectural model was developed initially, post completion, the structural detailing was carried out. The components were allotted realistic materials and appropriate cost based on acquired BOQ. The model was imported to Navisworks (manage) where quantity estimation and architectural vs structural clash detection was carried out.

The findings and observations have been classified in two sets, set no. 01 being qualitative in nature while Set 02 comprises of quantitative comparison and analysis. Set 01 bears the observations and findings in the model development and its implications.

Modelling of a structure in three dimensions on CAD is cumbersome and time consuming. On the contrary modelling on Revit is quite stream-lined and efficient. 3D CAD drawings are a set of deadlines, polylines and polygons that do not hold any attributes other than dimensions and colour. Models generated on BIM platform such as Revit bear components capable of attribute assignment such as material, cost, thermal and structural properties etc. These attributes grant simulation capabilities making energy performance, structural integrity, photovoltaic and lighting analysis etc. possible. The capability to have a virtual realistic design of the deliverable can help make better informed decisions and reduce change orders and client dissatisfaction. The model can be shared on a Common Data Environment or CDE, such as BIM 360 or A360 where all stakeholders can be kept dynamically up to date with revisions, changes, proposals and progress leading to reduced conflicts and an overall capacity for better strategic management.

Revit model allowed the capacity to take off quantities and estimate cost with a few clicks while conventional methods are time consumptive and prone to errors. The construction manager quoted multiple events of mal-procurement management, which could have been avoided via BIM techniques. The efficient and dynamic quantity estimates drawn from the 5D model gives a strategic overview of materials required and a timeline of procurement can be drawn much more efficiently. This can be utilized to file pre-emptive long-term supply contracts, positively effecting the overall project cost.

BoQ Items	Component	Method of Estimation				
		Revit	**Navisworks**	**Excel**	**Manual Calculations by Contractor**	**Actual Consumption on Site**
Bricks	**Basement**	12008	12124	12589	12626	12328
	Ground Floor	44044	44580	48706	49084	47850
	First Floor	36119	36110	36108	36052	36200
Concrete	**Basement**	495.1CFT	491.3CFT	492CFT	400.83CFT	503CFT
	Ground Floor	1461.76CFT	1458.6CFT	1398.4CFT	1387.85CFT	1495CFT
	First Floor	1104.25CFT	1110CFT	1181.3CFT	930.8CFT	1142CFT
Beams Material		724.79CFT	725.6CFT	721.9CFT	724CFT	735CFT
Tonnes of Steel in Footings		3.55T	3.58T	3.62T	4.021T	3.70T
Tonnes of Steel in Retaining Wall		1.644T	1.651T	1.798T	1.867T	1.70T
Tonnes of Steel in Columns		1.467T	1.478T	1.319T	1.267T	1.5T

Table 1: Comparison Between Values Obtained from Different Methods

On-site execution faced multiple events of component clash during execution, leading to improvised solutions, possibly lowering the quality of deliverable and effecting functionality. A clash detection maneuver was carried out on Navisworks Manage, which allowed us the insight into the architectural elements clashing with the structural elements in our integrated model. Employing BIM can greatly increase the quality of structure and reduce time overrun significantly as clashes are detected and resolved beforehand in the virtual environment, streamlining the execution phase.

Set 02 of the findings comprise of comparative analysis between the quantities taken off from Navisworks, quantities calculated manually by the project team (initial calculations based upon drawings) and excel based pseudo-manual calculations done for the purpose of this study. All the three set of quantities were compared with the actual site consumption (actual on site material consumption along with its wastages) used to calculate the degree of accuracy for each approach. The model developed in Revit is a live entity interacting with each interface. The quantities taken from the software thus are live quantities embedded in the virtual construction environment. A general benefit of quantity takeoff via

BIM tools can be the accommodation for changes either minor or major. The quantity table interface is a dynamically linked tabulation of the virtual entity which updates automatically with any change in the entity, sparing the project team of hectic re-calculations and assessments which are always prone to human error. All sets of quantities are depicted in Table 01.

Comparative analysis suggests that manually acquired preliminary quantities by the project stakeholders are considerably off in most cases. The values assumed by the parties surpass the actually used quantities by a hefty margin and in some instances are unrealistically low. The actual usage data has been factored in for wastage. It can be observed that the estimation values provided by Navisworks are the most relevant and might be remarkably accurate if wastage is ignored and a professional syndicate well-versed in BIM and its tools are employed for model generation. The excel based estimates prove to be more accurate than thumb-rules based estimation employed by the stakeholders.

5. Conclusion

It can be concluded that application of BIM on residential unit projects in Pakistan can be hugely beneficial in terms of diminishing time overrun, material estimation, reduced conflicts, better variations management, cost management, decision making and quality management. All in all, the virtual design and construction modules give a much needed strategic overview of the project beforehand leading to better risk management. The increase in strategic management capabilities is pivotal in reducing wastage in the construction industry. Small – Medium Scale Enterprises or SME's should be encouraging to employ BIM capabilities and experiment its utilization in the ever-growing residential unit construction sector of Pakistan. Navisworks is a great BIM tool for clash detection and quantity estimation. The quantities taken off in Navisworks are the most reliable amongst all methods employed in this study.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Hazard Identification in Construction Safety: A Visualization-based Approach

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Abstract

The construction industry significantly contributes into the socio-economic growth of country as expansion of infrastructure help in its development. But it is also the most unsafe industry and susceptible to several accidents, near misses, injuries and fatalities. Despite its low safety performance, construction industry is a source of employment for majority of workforce. It is reported that lack of education and training add into the miserable situation of the industry which needs to be eradicated as most construction workforce is illiterate. Construction safety is all about managing already identified hazards but the unidentified hazards present a major problem. To respond this gap, construction hazards are assessed and addressed using Building Information Modeling (BIM) based advanced visualization tools. The aim of study was achieved with the help of relevant literature, expert opinions, and case study investigation through BIM modeling. The results reveal the most occurring hazards are fall from height and crane boom contact on construction sites. Hazards were visualized according to proposed scenarios on jobsite to educate the workforce which consequently helped in improved safety condition. Based on this, it is recommended to perform automated rule-based checking of hazards using iBIM to remove the subjectivity of manual identification practices.

Keywords

Construction safety; Hazard identification; BIM; Visualization

1. Introduction

Construction industry is one of the most substantial industries due to its contribution to socio-economic development and job market. But it is also reflected as the most hazardous industry due to its exposed and dynamic nature. Despite all the efforts for developing regulatory, managerial and contractual systems, construction industry still lacks in safety performance with injury rate of 50% higher than all other industries (Farooqui et al., 2008). In the workplace comparison of European statistics over the years 2008 to 2016, construction industry represents the highest number of fatalities. Zahoor et al. (2017) identified many reasons for accidents in construction industry such as its distinctive environment, workers behavior and attitude, ever changing and problematic worksite conditions, and poor safety practices which ultimately result in perilous work conditions. This emphasizes a dire need for incorporating safety into each phase of construction. According to Zhang et al. (2015) pre construction and construction stages are two phases of safety management. Former includes the identification of possible safety threats while the later includes minimization of hazards by proper monitoring, investigation and record keeping (Carter et al., 2006).

Traditional safety planning and control rely on workers' capabilities to examine and remove dangerous situations within the composite and active construction atmosphere.Farooqui (2012) highlighted that 49% of construction accidents are due to poor judgment of hazards by the workers. This human error cannot be removed but it can be minimized by proper safety training and hazard recognition. Advanced technologies like radio frequency identification (RFID), sensor based technology, virtual reality, information communication technology (ICT), 3S (GPS, GIS, RS), construction automation and building information modelling (BIM) can help in this regard.

The emerging trend of relying on advanced tools and technologies helps in visualizing the situation in early stages of a project. Visualization not only digitalizes the information, but also represents the conditions of construction projects and processes systematically and precisely. It also helps the workforce to effectively understand and analyze the risks associated with construction sites (Sulankivi et al., 2012). Visualization aids in overcoming language barriers associated with workers because moving stimuli captures the human attention for significantly longer than static stimuli (Azhar, 2017). Such a promising feature must be benefitted through wide application in construction safety. But the state of practice and literature does not tell the same tale. To bridge this gap, the current study develops a strategy for construction site safety management using visualization system of BIM to comprehend worksite safety hazards. For this, hazards were identified using comprehensive literature review and rank was calculated by relative importance index and literature score. The main objective was to educate the workforce about hazarduous situations occuring on jobsite that can help in prevention from injuries and accidents. This was achieved with the help of case study and workers were encouraged to adopt this way of learning and identifying hazards.

2. Literature Review

2.1 Hazards in construction safety

Hazard can be described as a source of harm or potential damage to someone (Carter et al., 2006). The first and foremost reason behind high hazardous rate is that safety is not a primary concern for most of the stakeholders in the developing countries (Zahoor et al., 2016). Apart from reputed construction firms, majority of the small sized companies do not even have safety manual (Raheem et al., 2013). Similarly, there is no proper enforcement of safety policies on construction sites. Further, Zahoor et al. (2016) highlighted unsafe measures such as working at height without required personal protection equipment (PPE), scaffolding with no guardrails, direct contact with temporarily laid power lines and many others are result of improper planning. Carter et al. (2006) highlighted that the reason behind high fatality rate is the inability to identify and anticipate hazards.

Therefore, in an attempt to overcome these alarming situations, researchers have been struggling to identify possible techniques available for hazard identification. These techniques can be categorized into graphical and non-graphical. Non-graphical hazard identification techniques include hazard and operability study (HAZOP), job hazard analysis (JHA), what if analysis, concept hazard analysis (CHA), preliminary hazard analysis (PHA) and many others (Glossop et al., 2000). HAZOP is a systematic process and used throughout project lifecycle. While CHA and PHA are suitable for conceptual and early design phases of a project and JHA is used to identify, estimate and control risks in a systematic way. These techniques require safety professionals to recognize hazards and make decisions which can be error-prone (Zhang et al., 2015). After practicing non-graphical techniques for hazard identification, any noteworthy improvement was not observed in accident statistics (Azhar, 2017). Thus, Li et al. (2018) suggested adopting advance tools and technologies for hazard identification which ultimately leads to construction safety improvement. Owing to graphical features, these advance tools can help enhance communication at all stages of project, thus removing the coordination and language issues (Azhar, 2017).

2.2 Visualization based construction safety

The use of digital technologies is rapidly increasing in the developed part of the world while their application in developing countries has a lot of catching up to do. Visualization is one of the fundamental elements of digital technologies as it helps in understanding the needed information facilitating the workforce who lacks the ability to comprehend the product. Visualization technologies have been used by many researchers for different dimensions of construction management. Like, Heesom et al. (2004)

worked on improving the planning of construction projects with the help of four dimensional computer-aided design (4D CAD). Further, Nasir (2017) developed construction tasks videos to provide visual training to labor on worksites and presented the ways to utilize visualization for lean construction techniques.

Visualization is the most valuable tool for enhancing safety practices in the construction industry. It is reported by Guo et al. (2017) that inappropriate planning is a critical safety issue. Therefore, it is suggested that visualization technology can help in overcoming planning problems and increase the communication level. But safety information has been used customarily on jobsites which made it difficult to identify hazards and effectively communicate them to workforce. Additionally, the growing foreign employees require a clear graphical representation of safety hazards to asses jobsite circumstances (Azhar, 2017). To address these issues, Clevenger et al. (2015) proposed 3D visualizations to provide effective training to workers for safety knowledge. They tested this approach on a group of students which resulted in increased cognition level.

Based on such a motivation, the first aim of this study is to identify the most occurring hazards on construction sites for which a detailed literature review has been carried out. A total of 25 papers relevant to hazard identification on construction sites were reviewed to extract 9 categories of hazards, as shown in Table 1. To rank a factor on the selected scale, papers were carefully read and reread to clearly understand their significance as given by the authors of selected papers. Like, Jo et al. (2017) piloted a study on analysis of construction accidents for year 2011 to 2015. They found from exhaustive surveys and statistical tests that occupational injuries and fatalities were the highest for H1; therefore its significance has been noted as 'High'. Similar is the case with other hazards. Consequently, literature score has been assessed by the product of normalized scores through quantitative and qualitative analyses, and hazards are ranked accordingly.

Table 1: List of hazards identified from literature review

Code	Hazard	Frequency	Significance	Literature Score	Selected References
H1	Fall from height	15	High	0.79	(Al-Humaidi et al., 2010), (Kang et al., 2017), (López et al., 2008), (Im et al., 2009)
H2	Crane boom contact with power lines	8	High	0.42	(Castillo-Rosa et al., 2017), (Chi et al., 2009), (Cheng et al., 2010), (Im et al., 2009), (Farooqui, 2012)
H3	Struck by falling objects	6	High	0.32	(Wu et al., 2013), (Chi et al., 2009), (Jo et al., 2017), (Im et al., 2009)
H4	Contact with energized equipment	8	Medium	0.25	(Castillo-Rosa et al., 2017), (Cheng et al., 2010), (Jo et al., 2017), (Farooqui, 2012)
H5	Contact with overhead power lines	8	Medium	0.25	(Castillo-Rosa et al., 2017), (Cheng et al., 2010), (Jo et al., 2017)
H6	Struck by moving equipment	6	Medium	0.19	(Jo et al., 2017), (López et al., 2008), (Wu et al., 2013)
H7	Caught in trench cave-in	3	Medium	0.16	(Jo et al., 2017), (Farooqui, 2012), (Cheng et al., 2010)
H8	Other (fire, poisoning, explosion, etc.)	4	Medium	0.13	(Cheng et al., 2010), (Jo et al., 2017)
H9	Caught under the over turned equipment	2	Low	0.02	(López et al., 2008)

As a result of an extensive content analysis, it is found that fall from height (H1) and crane boom contact with power lines (H2) are the most occurring hazards on construction sites with greater value of literature score while the hazard of workers being caught under the overturned equipment (H9) has the least frequency (2) according to literature score.

3. Methodology

The objectives of this study have been accomplished in three major stages and explained subsequently.
The stage-1 involves the identification of hazards from peer-reviewed articles. The articles were extracted from different databases such as ScienceDirect®, Web of Science, Google Scholar and Scopus. The most occurring hazards on construction sites were extracted from the selected articles. Afterward, content analysis was performed to calculate the qualitative and quantitative score of the hazards. Afterwards on the basis of these scores, literature score was assessed and hazards were ranked as given in Table 1.
The Stage-2 of this study includes the data collection phase in which experts were approached to ask their opinion on the identified hazards. For this purpose, an online survey was conducted using a questionnaire which was distributed to over 200 construction professionals through their official email address, LinkedIn™ and ResearchGate®. The questionnaire consisted of two major sections; the first one was about demographic information of the respondent. While in second section, respondents were asked to provide opinion on the identified hazards and mark them on the scale of 1 to 5 (1=very low and 5=very high) and a short question to encourage respondents to highlight any other hazard not listed above. To check the reliability of the collected information, Cronbach's alpha test was performed. Further, to know the current trend of hazards occurrence in construction projects, relative importance index (RII) was calculated by the formula given in Equation 1 where W is weight assigned to each hazard by respondents, H is the highest impact which is 5 for current case, and n is the sample size.

$$\mathrm{RII} = \frac{\sum W}{(H * n)} \qquad (1)$$

The value of RII ranges from > 0 to 1; the greater value of RII shows the higher significance of hazard. Afterward, the total score (TS) was calculated by integrating RII with literature score (LS). However, because of the subjective approach the percentage contribution of literature score was set to 30% in TS while the industry score (RII) was given 70% weightage. The formula is shown in Equation 2.

$$\mathrm{TS} = (0.7 * \mathrm{RII}) + (0.3 * \mathrm{LS}) \qquad (2)$$

Along with the survey, interviews of local experts were conducted to discuss safety limitations. The major reported constraint of traditional safety management is lack of familiarity of workers with safety issues. For this purpose, an enabling technology is needed that helps in the investigation of safety issues and enhances the performance of construction site safety.
After assessing the hazards on construction sites, it was decided to visualize the hazards on a case study of a real construction project to investigate the efficiency of visualization in hazard identification. The selected project is of a mosque and is located in Mardan, Pakistan with an estimated cost of PKR 60 million. The estimated time for completion of the project was 1.5 years. The data was collected from the respective authorities to generate the BIM model. As the selected building is mosque, such buildings are rich in their architectural designs and need sufficient attention during construction. Likewise, Vatan et al. (2011) stated that safety evaluation of such buildings is essential based on qualitative as well as quantitative data. For doing so, the identified hazards were visualized according to different scenarios on construction site to familiarize the workers with the situation. Subsequently, experts were asked to give their opinion on the proposed approach. Afterwards, future recommendations along with limitations are discussed.

4. Analysis and Results

4.1 Survey responses

The survey was distributed all over the world and 33% response rate was received. The demographic information in Figure 1 shows that respondents belong to different countries. Most of the respondents were from the developing countries because the casualty rate is higher in these regions (Khawam, 2017). It was reported by Raheem et al. (2016) that no regulatory bodies are formulated for safety implementation in most of the developing countries. Even if a regulatory body exists, it does not enforce safety regulations which ultimately increase the fatality rate (Zahoor et al., 2017). While there were few respondents, approximately 15% from the developed part of the world, it was observed that safety condition is satisfactory in these regions because of functional and efficient regulatory authorities which take appropriate actions in case of any non-conformance (Khawam, 2017).

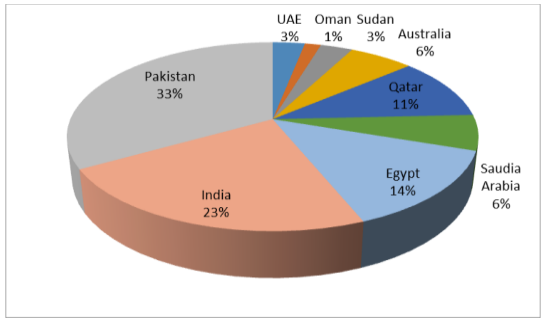

Figure 1: **Demographic information of respondents**

The professional experience of respondents was asked in years revealing that there are 20 respondents with experience ranging between 0 to 5 years while 14 respondents reported experience between 5 to 10 years. Rests of the respondents are with greater than 10 years' experience. The collected data comprised of respondents with different qualification. Synthesis of data shows that almost 47% of the respondents were BSc qualified while 53% of them have a higher qualification. The qualification of respondents does not correspond to their professional experience; most of the BSc qualified professionals have pretty good knowledge of construction site as they usually start their professional career as site engineer.

4.2 Data Analysis

Initially, Cronbach's alpha test was applied and value came out to be 0.8 making data reliable. Further, RII was calculated as shown in Figure 2, indicating that fall from height (H1) has the highest frequency of occurrence on construction jobsites. It has been reported that fall represents the highest number of fatalities almost every year. Most of the accidents occur due to fall at elevation of less than 30ft on construction building projects. Many regulatory bodies have worked on fall protection measures, but the state of construction accidents is still repenting (OSHA, 2017). Huang et al. (2003) revealed the major reason behind injuries and fatalities is misinterpretation of hazards by human and cannot be minimized by experience therefore effective safety training should be provided. Traditional safety training and education, provided to workers mostly relies on verbal and manual explanation of safety regulations, is not sufficient for detecting and eliminating fall related hazards (Azhar, 2017).

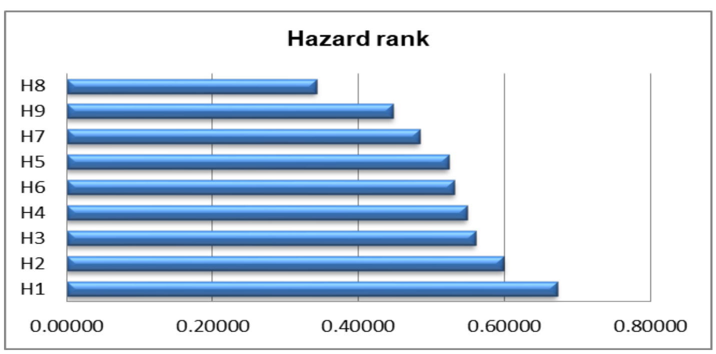

Figure 2: **Rank of hazards obtained by calculating total score**

Furthermore, Zhang et al. (2015) presented the traditional 2D fall protection plan where an elaborate color-code was used to highlight the required fall prevention systems. It was concluded that this kind of manual inefficiencies usually lead to improper hazard identification resulting in accidents on construction sites. As majority of the stakeholders use as-built drawings in execution phase for hazard identification, but the changing site conditions do not account for proper safety planning (Azhar, 2017). For this reason, it was found necessary to integrate schedule which is not possible in manual approach. Therefore, an integrated technology such as BIM is considered constructive in hazard identification to ensure construction safety (Clevenger et al., 2015, Enshassi et al., 2016).

Next significant hazard is contact with crane boom (H2). Most of the construction operations are associated with crane on jobsite which results in large fraction of fatal injuries and casualties (Beavers et al., 2006). Neitzel et al. (2001) revealed that up to one-third of accidents and fatalities in construction involve incidents related to cranes. The reasons behind these high fatalities are improper communication between operators, riggers and signal people. Therefore, researchers started moving towards digital approaches and performed crane planning with the help of visualization approach. Fang et al. (2014) tested this visual based training approach on a group of related people and found it efficient in providing safety.

Caught under the overturned equipment (H9) and hazards occurring due to fire, poisonous material and explosion (H8) came out to be the least significant because they account for less number of accidents and injuries as compared to others. According to Duan et al. (2011), several accidents and injuries occur due to presence of dangerous substance like wooden scrap, chemical and explosive material, and the resultant death rate varied from hundreds to thousands. But when these hazards were compared with fall and caught/in between incidents, accident fraction goes half. Fraction of these hazards could be lower down by proper training and awareness. Visualization method imprints on one's mind about the harms and severity of any specific hazard which ultimately helps in reduction of accidents.

It can be observed that the top-ranking hazards have been previously reported along with a series of redressal action and mechanisms. However, the industry continues to experience accidents due to these hazards and despite such elaborate counter strategies, their effectiveness remains challenged (Han et al., 2009). This generates a calling to look for out-of-the-box solutions and technology can be relied upon for this purpose. BIM has the potential to address some of these serious hazard causing factors (Enshassi et al., 2016). The current study attempts to investigate this potential through case study of a running project.

5. Case Study

To authenticate the results of content analysis and online questionnaire survey, a case study was performed on an ongoing construction project. As already explained in the methodology, the selected project type is of a mosque because of inherent complexity in its architecture design and construction.

After a series of interviews and interactive sessions with the project stakeholders, it was decided to use visualization based approach for hazard identification and its education with advanced tools and techniques. According to Enshassi et al. (2016), hazard identification and safety education are the two main applications of BIM for construction safety. For that reason, a BIM model with level of development (LOD) 300 was generated to accomplish these objectives. The model was critically examined to identify and visualize the hazards on jobsite. The main emphasis includes the visualization of identified hazards shown in Figures 3-6. The generated model is shown in Figure 3 which is a complete digital representation of construction site on the selected day. Considering and scrutinizing the site situation, many hazardous conditions were explored and presented to site staff. They were encouraged to ask questions and get clarifications by interacting with the model.

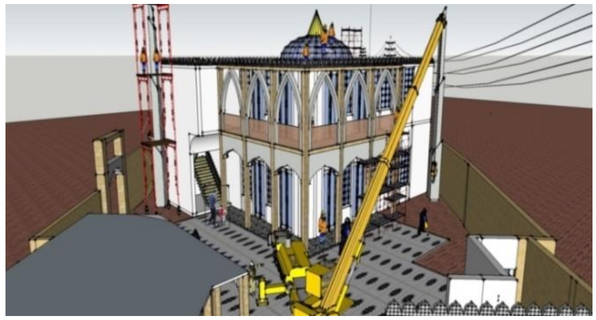

Figure 3: **A comprehensive visualization of case study site**

The workers asked to change the views, modify the magnification levels, enable/disable model layers and see various 3D walkthrough. As a result, this exercise assisted the workers in grasping the possible hazards easily. Stakeholders illustrated that most of the workforce was illiterate and cannot even properly understand languages other than their native language. Thus, this visual presentation enhanced their level of understanding and aided in overcoming language barrier. The workforce was motivated and active after this advanced way of toolbox talks. After presenting the complete picture of site, different hazards were focused and explained exclusively.

The injuries and fatalities resulting from fall are maximum both in literature and industry score. This is generally because of the negligence of workforce and disregard of safety rules and regulations It can be seen in Figure 4 that workers are operating on height without personal fall arrest systems and no guardrails are provided on sites where falls had occurred from over 6 feet.

Figure 4: **Fall from height**

Lipscomb et al. (2008) found that in fall accidents from height, scaffolding was in a deplorable condition in two-third of the observed cases and workers were not equipped with required PPE. However, it is recommended to wear fall arrest when working over 6' height (OSHA, 2017). Percentage of slip/trip with fall contributed of 58% in total accidents. It can be prevented by using fall arrest systems and providing guardrails on the desired positions. This kind of information cannot be entirely comprehended through manual instructions; thus, a visual demonstration is necessary to realize the sensitivity of situation.

Similarly, overhead power lines are already present on most of the construction sites. It is mandatory to keep in mind the safe distance from power lines otherwise hazard causation is evident. Figure 5 portrays the same kind of situation in which there is a possibility of crane-related fatality while equipment movement. Beavers et al. (2006) conducted a survey in which out of 119 fatalities, 90% of the sufferers were not crane-operators. He concluded that this is a systematic problem of construction industry; also there is no proper training mechanism of crane operators. The recommended safe working distance from overhead power lines by OSHA (2017) is not generally followed, resulting into casualties. Likewise, there are many safety devices that can help in reducing injuries due to crane such as anti-current device, operator and rigger protection, anti-collision and other. Anti-current devices help in preventing current conduction from power lines to the elements and personnel that are in contact with crane. Similarly, cab reinforcement can be used for operator protection (Neitzel et al., 2001).

Figure 5: **Crane boom contact with overhead power lines**

While planning for safety, site information such as placement of equipment, materials and personnel are usually examined manually, creating a chance for error because of the subjective approach (Azhar, 2017). There are many constraints of manual approach such as changing site conditions, different perspective of workers and subjectivity at large (Zahoor et al., 2017). These limitations can become a bottleneck for cautious decision-making on construction sites. Therefore, visualization can be beneficial in such cases. The major application area for visualization is construction site monitoring. Visualization of construction site would help in assessing the location of resources as well as machinery thereby preventing injuries which usually results from struck by falling equipment and machineries as shown in Figure 6.

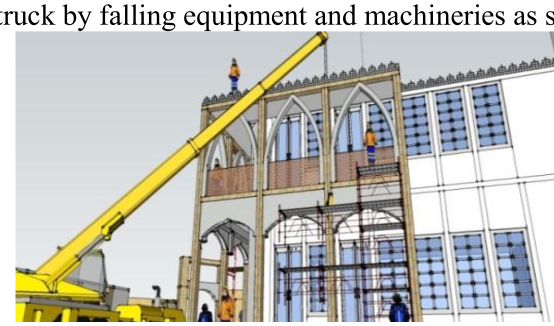

Figure 6: **Stuck by moving equipment**

This visualization based effort helped the workers in clearly understanding the safety situation resulting into prevention from hazards. The project team appreciated the use of visual based presentations for educating workers about the hazards. They added that adopting this practice in safety toolbox talks can aid in educating about the hazards and bring down the accident statistics.

6. Conclusion

Safety management is considered to be one of the critical factors of project success. Therefore, it is necessary to implement safety rules and regulations for all construction activities. For this purpose, safety planning is essential because the unidentified hazards present the most problematic conditions (Zhang et al., 2015). Advanced methods of hazard identification help in improving safety management on construction sites (Enshassi et al., 2016). But there is dire need to educate the workforce about hazards in an effective way. Observing these concerns, the current study tests an effective method of hazard identification and delivering safety knowledge to site staff. Hazards were identified from literature and their significance was determined. Afterward, they were ranked by combining the literature and industry scores. A case study was conducted to visualize the hazards on construction site. Actual site conditions were presented in the digital form which was utilized to educate the workers about risky situations. The workforce appreciated the use of visualization technology for hazard identification; thereby it helped in improvement of understanding the safety rules and regulations. The construction industry can adopt this method for delivering safety knowledge to workforce in toolbox talks. It also helps in addressing the language barrier and ultimately reduces the rate of fatalities.

Future research is proposed to perform automated rule-based checking of hazards by use of iBIM. This will remove any subjectivity in the hazard identification process which is still done through brainstorming and past experience. OSHA and other safety regulation systems can be utilized to populate the rules database for specific hazards.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Challenges in Wide-Spread Adoption & Implementation of Building Information Modelling (BIM) on Infrastructure Projects

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Abstract

Building Information Modelling (BIM) has seen extensive application in building construction industry but the infrastructure industry has been reluctant in implementing BIM on infrastructure projects. This study aims at establishing the major barriers in widespread I-BIM adoption for lifecycle management in horizontal construction sector. Quantitative research technique was adopted for identification of key factors and they were graded, as per prominence, based on percentages of collected responses given by professionals of infrastructure industry. This paper concludes that employers from infrastructure sector are not fully acknowledging the potential benefits of I-BIM, hence there is a general lack of demand. Poor Interoperability and in-efficient functionality were also concluded as major factors hindering the effective implementation of I-BIM.

Keywords
Infrastructure, BIM, Construction, Management, Engineering

1. Introduction

Construction industry is generally outpaced in innovation by the manufacturing sector though the advancements are not entirely non-existent (Eadie, 2016). Latest improvements in software and management tools have yielded an industry revolutionizing technique referred to as „Building Information Modelling" or „BIM" which integrates 3D modelling with information (Aouad, 2006)on management for optimization of cost, time and sustainability (Arayici et al, 2011, Aouad et al, 2006). Eadie (2016) elaborates BIM as a 3D model-based process that provides construction experts core insights and tools to efficiently manage all phases of a project"s lifecycle.

BIM is experiencing rapid growth in the construction industry (Dave et al, 2016, Jarvis, 2015). Researchers are suggesting BIM implementation throughout the building lifecycle, from conceptualization to decommissioning. However, there is limited acceptance and implementation of BIM in roads & highways industry (Yabuki, 2010, Shah et al, 2009). Arguments and statistics from (McGraw Hill Constructions, 2012), (Dave et al, 2016), (Autodesk, 2014), (Autodesk, 2012) and (Drogemuller, 2009) conclude that Horizontal BIM (infrastructure or civil engineering sector) has not seen the same level of adoption as „BIM for Buildings‟ (Vertical BIM).

In order to overcome the lag in I-BIM adoption, the key barriers in its effective implementation need to be resolved. This paper aims at identifying prominent hurdles in adoption and effective implementation of BIM on infrastructure projects.

2. Literature Review

Literature points towards the inherent difference in the characteristics of infrastructure projects as a major barrier that limits effective implementation. Infrastructure projects are usually linear and geospatially vast in nature, rendering traditional planning and management techniques not as applicable and effective as for vertical building projects (Dave et al, 2016). Research is lacking in establishing the exact benefits of employing virtual design and construction techniques on large infrastructure projects (Shah et al, 2009).

There are numerous challenges, particularly for large transportation engineering organisations in efficient implementation of infrastructure BIM (Fanning, 2014). One major issue is "interoperability" (development of standards that enable transfer of information between several software systems) providing data access for multiple users over extended length of time (Ted McKenna, 2015). Eadie et al. (2014) gathered information with the help of online survey from 74 main construction contractors, based in United Kingdom, for ranking of barriers linked with BIM. "Lack of supply Chain Buy-in" and "Scale of Culture Change Required/Lack of Flexibility" were ranked as two most important barriers in BIM implementation. Whereas, "Lack of management support" and "Other Competing Initiatives" were low ranked, thus, clarifying industry priorities.

A research conducted by McGraw Hill Constructions in 2012 concluded that use of BIM in infrastructure projects was considerably lesser than on building projects. I-BIM was being used by a mere 27% of infrastructure organizations. The study also determined an average lag of 3 years in different classes of BIM. Chan (2014) studied the barriers for implementation of BIM in construction industry of Hong Kong. Based on 52 collected responses via questionnaire survey, „lack of training/education‟, „lack of qualified in-house staff‟, „lack of client demand‟ and „lack of standards‟ were highlighted as major barriers against adoption of BIM. Training and Software Costs, lack of clientele and Potential Legal Issues were established by Oduyemi et al. (2017) as non-technological challenges.

3. Research Methodology

This research employs the Quantitative Method of research where similar choices of respondents are grouped and a percentage is acquired. The method was suitable for this research as data was to be collected in the form of polls. A „Structured Questionnaire‟ was designed for data acquisition, that comprised of „Closed End Questions‟. The questionnaire was inspired by the McGraw Hill, 2012‟s findings. The questionnaire was forwarded to international civil engineering and construction industry experts using Bristol Online Survey tool.

The targets were selected based upon satisfaction of the following criteria;

a) Part of an international multi-dimensional construction firm that undertakes horizontal construction projects and preferably vertical construction projects as well.

b) Must have been part of infrastructure development projects, as a Civil Engineer (or similar such as Transportation Engineer, Water Resource Engineer etc.) or Construction Manager.

Attained sample‟s composition by geography is illustrated in table 1.

Table 1: Sample Distribution by Geography

Geographic Sample Distribution		
Response Rate	60	60/100
United Kingdoms	27	45%
Middle East	9	15%
USA	8	13.3%
South Asia	16	26.7%

Table 2: Distribution of Sample by Organization Type

Organization Type	No. of Participants	Sample Percentage
Employer / Owner	15	25.0%
Consultant / Designer	24	40.0%
Contractor	21	35.0%

Table 3: Distribution of Sample by Organization Size

Organization Type	No. of Participants	Sample Percentage
Large (>250 Employees)	22	36.6%
Medium (50-250 Employees)	17	28.3%
Small (<50 Employees)	21	35%

4. Findings

Figure 1 illustrated the response percentages of professionals who are currently employing or have previously employed I-BIM on infrastructure project/s, regarding the slow rate of I-BIM adoption compared to V-BIM or „BIM for Buildings‟. 23.1% of them believe that the cost associated with I-BIM implementation (training staff, procuring software and hardware etc.) is the most prominent barrier, demoralizing potential organizations from making use of the technique. This is particularly true for small-medium scale enterprises or SMEs, as such a hefty investment in the current market scenario where employers are not well aware of potential benefits of I-BIM implementation on project lifecycle, can translate into a negative or unimpressive return on investment (ROI) 19.2% chose the general lack of I-BIM understanding in the industry as a major hurdle while 15.4% are of the view that I-BIM employment on small-medium scale construction endeavours is not efficient and does not yield the desired outcomes. It can be argued that small-medium scale projects do not involve complex information flows which may fall victim to mis-management, consequently application of BIM might streamline the flows regardless, though the ROI would be less compared to large projects.

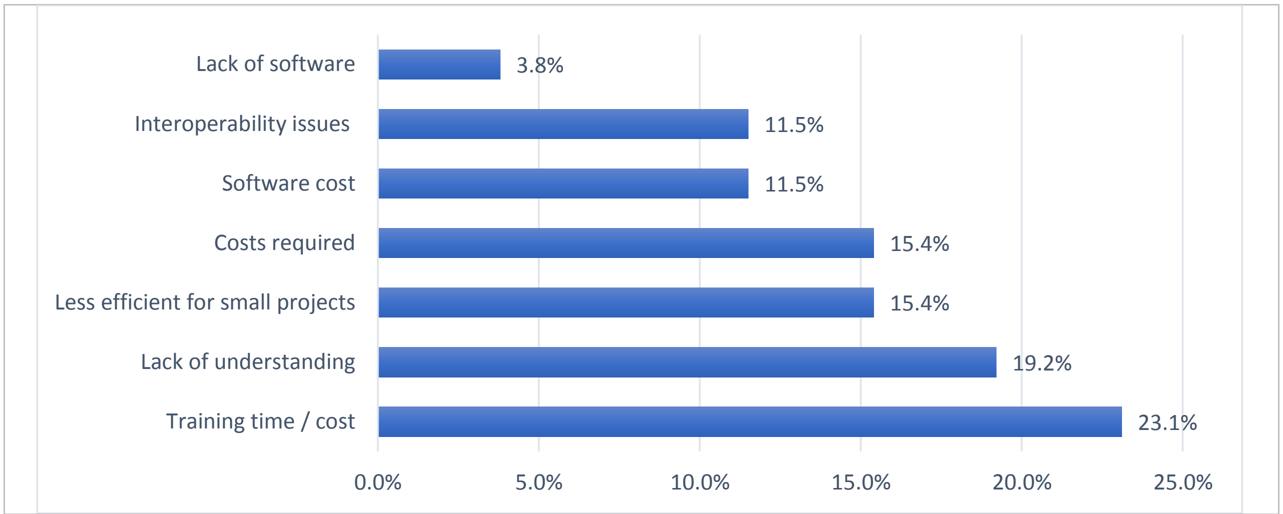

Figure 1: Users Comments on Rationale Behind Lag in I-BIM Adoption

Figure 2 depicts the I-BIM user‟s views regarding the most prominent barriers in wide spread adoption of I-BIM. 35% of the users agreed that the there is a general lack of demand in the infrastructure industry for BIM. This can be associated with the fact that potential benefits of BIM are not fully realised by the stakeholders due to lack of research and precedence. Legislation and regulation can be a major counter measure such as the UK government obligated implementation of level 2 BIM on public sector infrastructure projects which shall contribute towards an increased rate of research, adoption and implementation leading towards improvement in I-BIM tools and techniques. 30% of the users stated that essential levels of training are not available to equip the manpower with I-BIM skills required to meet the desired ROI. 20% believe that the software cost is a major hurdle which can be seen as the high initial capital required to build the necessary I-BIM functional infrastructure. 15% identified low interoperability as the most major barrier. McGraw Hill, 2012‟s figure of interoperability being chosen as the most major factor is considerably higher than the one acquired in this study, which points out to the fact that interoperability has been considerably addressed since 2012. The advent and adoption of Industry Foundation Class files is a major factor in improvement of interoperability, though a considerable percentage still feels the need for further improvement.

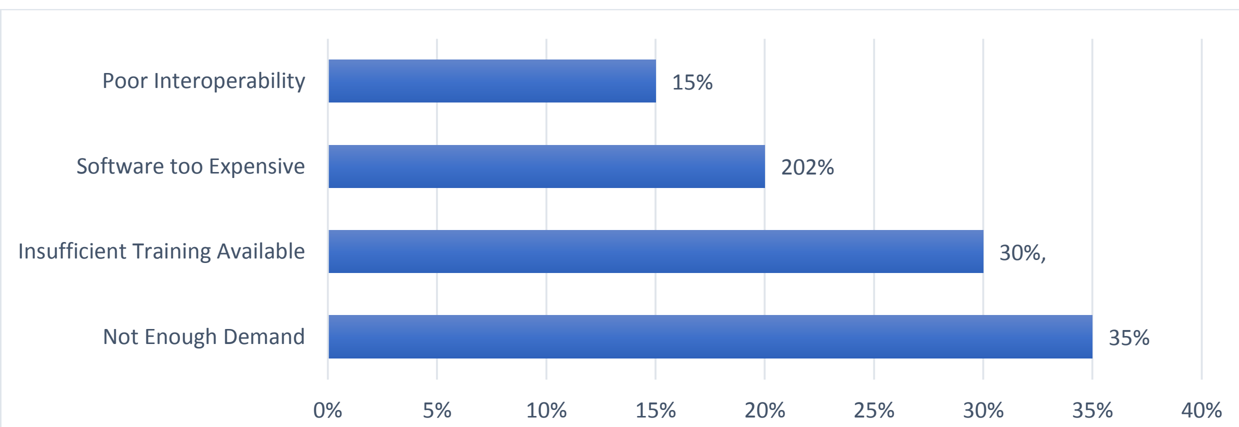

Figure 02: Users View - Most Prominent Barriers in I-BIM Adoption

Non-users when inquired about their attitude towards I-BIM yielded the results depicted in figure 03. 58.1% of the non-users hold a positive view of I-BIM and believe that I-BIM can be beneficial if implemented, while 29% claim their organization is looking into adopting BIM in next 5 years. 9.7% do not believe I-BIM to be beneficial and are pessimistic towards the ROI of such an endeavour. 3.2% claim having negative experience of I-BIM implementation, therefore have abandoned its use.

Non-User‟s views about the most prominent barriers keeping them from adopting I-BIM are summarized in fig 04. 24.4% believe that investment in building I-BIM capabilities is not yet feasible due to lack of demand in the industry. 20.5% claim lack of sufficient training required to reap maximum benefit out of I-BIM implementation is not readily available. 17.9% claim the initial finances required to build I-BIM capabilities as the most major barrier keeping them from employing subject technique.

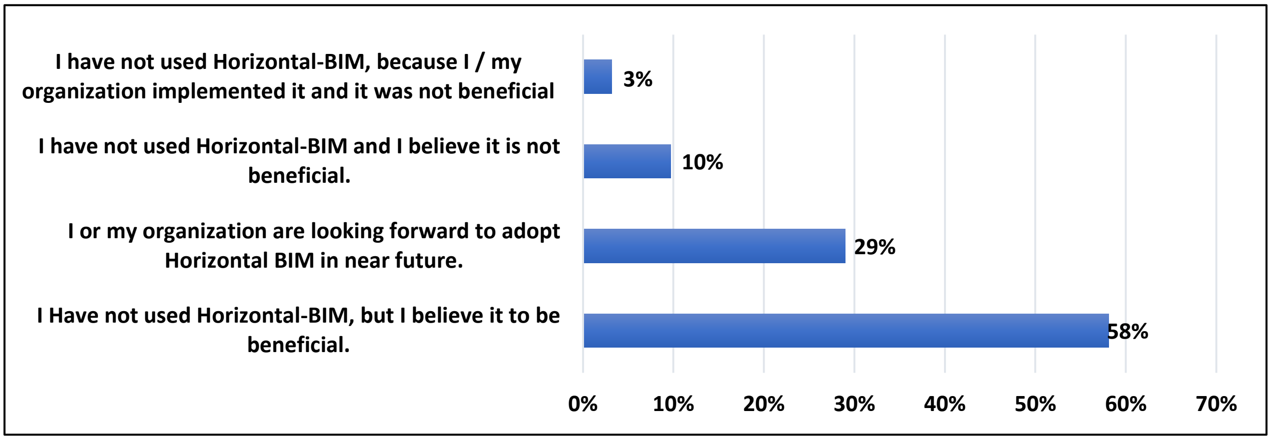

Figure 03: Non-User's Attitude Towards I-BIM

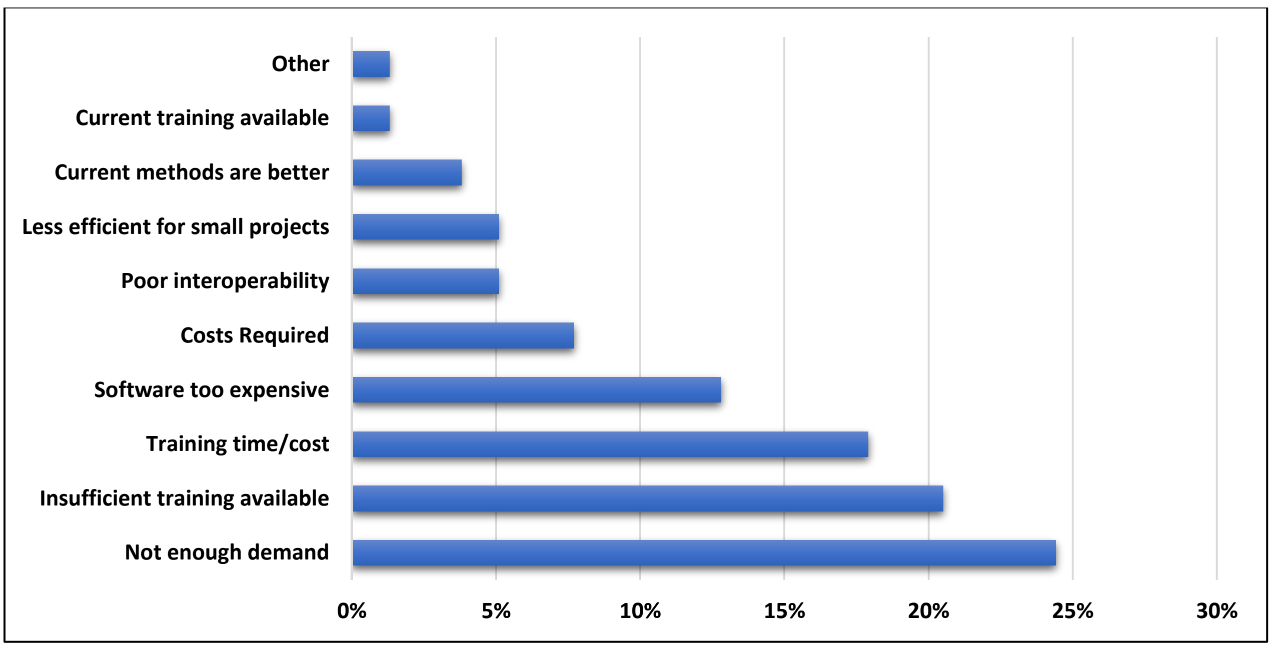

Figure 04: Factors Discouraging Non-Users from Adopting I-BIM

5. Conclusion

The primary objective of this study was to determine the barriers which hinder adoption and optimum use of I-BIM in infrastructure construction (horizontal projects). Based on acquired data the time required for training, procurement and operational costs of hardware to utilize resource heavy I-BIM software packages combined with general lack of understanding regarding I-BIM processes are identified as the significant barriers in adoption of I-BIM by the I-BIM users. Study also shows significantly positive attitude towards I-BIM by 58.1% of the non-users. Whereas, in next five years, 29% of the non-users are looking into adopting I-BIM. However, 9.7% of the non-users believe I-BIM is not a useful tool, whilst, 3.2% of the users have abandoned I-BIM post application on past projects. It was also identified by the non-users that there is a general lack of demand/clientele for I-BIM in the industry and also the cost required for development of capabilities in I-BIM are the key barriers keeping them from adopting this technique.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Quantifying the Factors for Quality of Pavement Rehabilitation

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Abstract

Synthesizing the factors that have an impact on the quality of pavement rehabilitation from managerial perspective in Pakistan and establishment of a benchmark through quantification of these factors for future improvements in quality was the basic purpose of this research. The methodology adopted for the present study included, at first, a detailed study of literature which helped to go through any similar past studies and previously identified factors. Then questionnaires were distributed among experienced individuals who were requested to rate the shortlisted factors as per their experience and knowledge. The data collected from 113 questionnaires helped to quantify the five main factors. After assignment of weights to the factors, contribution of each to the quality was clear.

Keywords
Quality Control, Quality Management, Quantification Of Factors, Pavements Rehabilitation, Quantify Quality

1. Introduction

Cost, time and quality are famously known as "The Iron Triangle" (Atkinson, 1999). This Iron triangle is the main competing objective in any project and through appropriate utilization of resources one can create a balance in it so that desired results are achieved (Heravi and Faeghi, 2012). According to a study, costs and schedules are affected mainly due to risks related to finance in Pakistan (Choudhry *et al.,* 2014). This study aims to focus at quality among the three contributors in iron triangle from the perspective of pavement rehabillitation. The attitude of the management is not flexible towards quality (Farooqui and Ahmed, 2008). Number and length of roads in Pakistan is increasing rapidly as the time progresses. The quality requirements should be kept in mind along with this evolution of roads and highways in Pakistan. The substandard work of subcontractors is the major problem here in Pakistani construction industry resulting in compromise of quality (Choudhry *et al.,* 2012). The true meaning of quality is still unknown and quality management is considered to mean that standard specifications are followed, which is surely a misconception. The reasons of this problem are availability of employees who are generally uneducated labor, which are untrained and have inadequate knowledge about quality (Asim *et al.,* 2013). Pavements are the main mode of transportation in Pakistan and provide life to several other sectors like commerce, national defense and trade. Transportation assets are among the major high valued assets of state and government of Pakistan (Saeed, 2013). There is no established methodology in order to estimate the level of quality being implimented.

This study aims to quantify and rank the factors that impact the quality of pavement rehabilitation in Pakistan from managerial perspective. The pavement rehabilitation in Pakistan has faced number of quality related issues. The system for check of quality is unsubstantial and has flaws in it. Pavements are generally not long lasting and most of them undergo premature failure. There is lack of general understanding in Pakistan about quality of pavement, especially pavement rehabilitation. Very less research work has been performed for quantifying quality related to pavement rehabilitation. There are several material, construction and management related factors that have impact on the quality of pavements and there is a dire need to identify and quantify these factors on the basis of their importance.

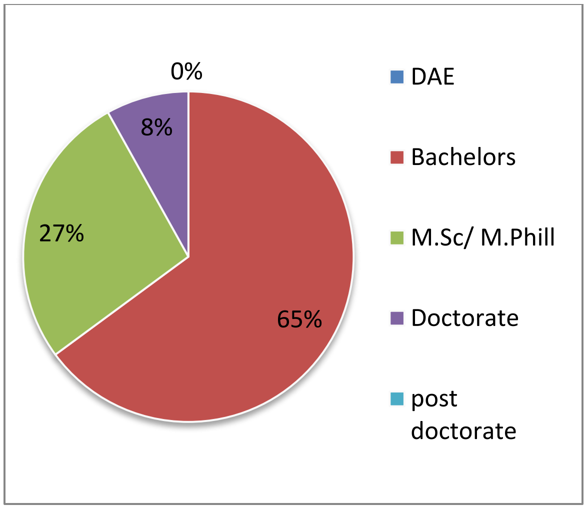
1.1 Management Related Concepts

There are number of researches that define quality in different ways. Independency from inadequacy, customer satisfaction and final product to be harmonized, combination of requirements satisfying characteristics and completion of required task with satisfaction within allowable time are several different ways through which the concept of quality is clarified (Juran and Godfrey, 1999; Bezelga and Brandon, 2006; Noble, 2006; Atkinson, 2003). There are number of aspects that contribute to management of quality for rehabilitation of pavements like quality planning, quality standards, quality control etc. Quality management plan is document that shows the quality level which is acceptable to the owner and describes the ways in which the data collection will guarantee the quality in processes and deliverables (Pierce *et al.,* 2013). Quality plan projects the requirements of customer and combines it with the actions, standards and procedures to highlight what is needed to be done, how it will be done and who will do it. Quality control is necessary if we want pavements to fall within the criteria of quality or satisfy the requirements of client. Quality control is physical inspection of whether the end product meets the certain technical requirements (Bezelga and Brandon, 2006). QC is also assessing and adjusting the activities in order to achieve the desired level of quality (Flintsch and McGhee, 2009). Contractors play a vital role in quality of rehabilitated pavements. Following the described specifications and the standardization of workmanship are the factors which determine the extent of contribution to the quality of a construction project (Alzahrani and Emsley, 2013). Quality assurance is the term used for an initiative to ensure that services to the owner are provided according to highest level of pavements related standards in industry. According to ISO 9000 "part of quality_management focused on providing confidence that quality requirements will be fulfilled" is Quality assurance (Noble, 2006). Quality control is group of specific processes involved in Quality Assurance and activities related to it. Hence there are number of concepts that contribute in final management of quality and must be kept in mind. Management of pavement rehabilitation is generally taken for granted but this must not be the scenario.

2. Research Methodology

Synthesis of management related factors for quality of pavement rehabilitation and their quantification were the two major objectives of this research. Several other studies have been conducted in this regard (Jha and Iyer, 2006; Al-Hassan, 1993; Abas *et al.,* 2015 and many others). In accordance with study conducted by Chen *et al.* in 2014 weights were assigned to each factor and sum of weights was equal to 1.

Questionnaire survey was the primary method which was adopted in order to gather the data. Questionnaires were distributed among the experienced professionals that had enough knowledge on pavements. Following figures show the qualifications and experiences of the respondents.



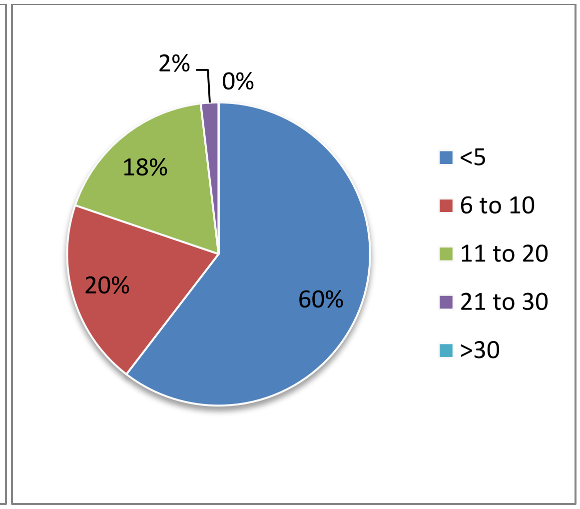


Figure 1: Experiences of Respondents **Figure 2: Highest Qualifications of Respondents**

The questionnaire was divided in two sections. First section had two parts. In first part respondents were requested to comments on the 5 factors which were listed. In second part of this section respondents were asked to suggest any other factor which cannot be subdivided under already mentioned 5 factors. The second section required the respondents to rate the factors on likert scale from 1 to 5 (1-Irrelevant, 2-Not so important, 3-Important to some extent, 4-Significant and 5-Extremely important). All five factors included in questionnaire are explained below:

2.1 Contractor's Capability

Contractor"s capabilities generally include availability of machinery, labor, other staff and past experience pertaining to pavement rehabilitation. The contractor is directly involved in construction so the importance of this factor can never be ignored.

2.2 Payment and Finances

This factor includes all the finances and expenses that occur during the lifetime of the project. The respondents were asked to rate this factor according to the importance they perceive.

2.3 Site Management

Managing the site means availability of staff, machinery, labor, technical officials and any other such requirement that contributes in smoothness of work at site. All 113 respondents were requested to rate it according to the level of importance they give it.

2.4 Owner's and Quality Consultant's Capability

This is one of the major factors as owner is the one utilizing the final product and quality consultant is the one who provides the assistance in making the implementation of quality to be easier. Individuals were requested to rate them as per the experience of both, teams they have and cyclic checks they perform to keep the quality of pavement rehabilitation within acceptable limits.

2.5 Organizational Structure

The respondents rated this factor while keeping in mind the importance of all the aspects that contributed in official procedures of the organization like communication, bidding, availability of standards and allocation of responsibilities etc.

3. Research Findings

The data was distributed in 185 professionals that had enough knowledge on pavements and categories which included all the officials from owners and managers to the workers, thus a complete effort was made for participation of everybody and to know the thinking paradigms of all the officials, from management to labor class. 113 questionnaires were received back, giving the response rate of 61% which is considered to be good enough for such research. SPSS was used in order to find the Chronbach‟s alpha coefficient and the value was 0.756 which was acceptable. This showed that data is reliable. For weights same results of questionnaires were used.

Factors were sorted as per their mean score, minimum as well as maximum assigned rating and ranking of the factors, as shown in Table 1. Formula used by (Assaf *et al.*, 1995) was the basic idea for calculation of mean score. Figure 1 gives the summary of data received from 113 respondents.

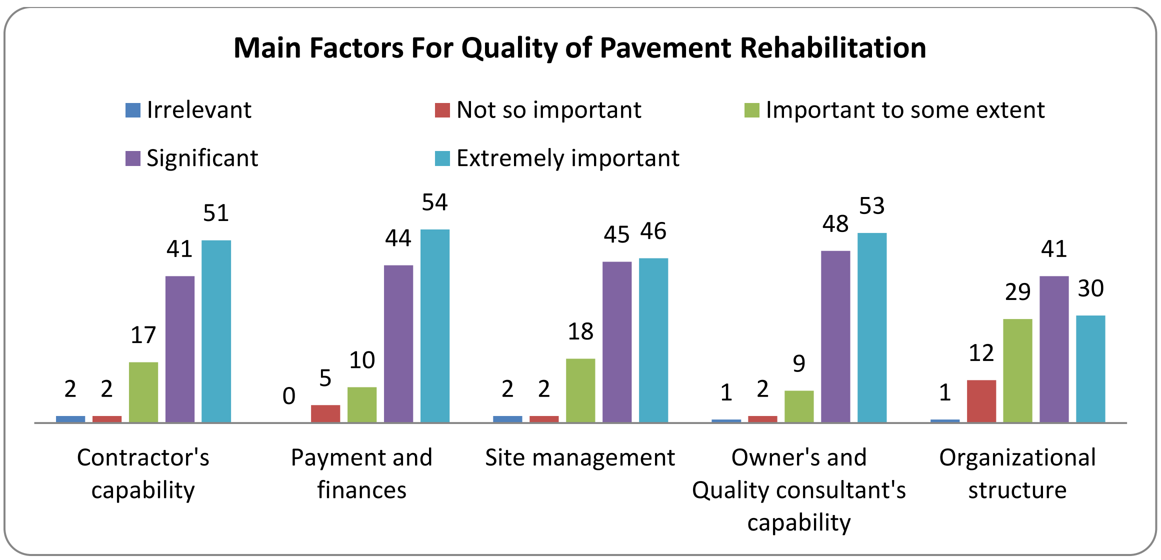


Figure 3: Respondents' Data

Table 1 shows the minimum and maximum rates that were obtained from respondents along with the mean score which was calculated using the Excel. After using percentage score method on Excel, weightings were assigned. Finally the factors were ranked according to the mean and corresponding weights.

Table 1: Ranking and Weighting of Factors

Factors	Minimum	Mean score/relative importance	Maximum	Rank	Weighting
Contractor‟s Capability	1	4.21	5	3	0.202
Payment and Finances	2	4.300	5	2	0.207
Site Management	1	4.16	5	4	0.200
Client‟s and Quality Consultant‟s Capability	1	4.32	5	1	0.208
Organizational Structure	1	3.77	5	5	0.183

Non parametric (Spearman) correlation was used to find the correlation coefficients using SPSS to assess the strength of relation among each and every factor. The results of SPSS can be seen in Table 2.

Table 2: SPSS Results For Spearman's Correlation Coefficient

Correlation Coefficient	Contractor‟s Capability	Payment and Finances	Site Management	Client‟s and Quality Consultant‟s Capability	Organizational Structure
Contractor‟s Capability	1 (Maximum)	0.264** (Low)	0.520** (Moderate)	0.244** (Low)	0.272** (Low)
Payment and Finances		1 (Maximum)	0.253** (Low)	0.191* (Low)	0.144 (Low)
Site Management			1 (Maximum)	0.378** (Moderate)	0.508** (Moderate)
Client‟s and Quality Consultant‟s Capability				1 (Maximum)	0.499** (Moderate)
Organizational Structure					1 (Maximum)

**correlation is significant at the 0.01 level(2-tailed)
*correlation is significant at the 0.05 level (2-tailed)

Ordinal linear Regression also known as proportional odds model was run in SPSS to find the odds of rating higher or lower of each factor as compared to the factor which is by default set as a redundant or reference by SPSS. It must be kept in mind that odds (not probabilities) are calculated after taking the exponential of the estimates provided by SPSS. SPSS by default sets the one which is coded high as reference (value as 0) which means that as the first alphabet „s‟ of site management comes after the „c‟ of contractor‟s capability, „p‟ of payments and finances, „c‟ of client‟s and quality consultant‟s capabilities and „o‟ of organizational procedures so site management is set as a reference/redundant. The conclusions after going through the results of SPSS are shown in Table 3.

The values below show the chances of rating the factor higher or lower as compared to site management. The result of table 3 shows that the value of odds is 1.155 for contractors‟s capabilities which means that chances or odds of rating contractor‟s capability higher as compared to site management are 1.155 times of odds of rating site management. In case of organizational structure the value of odds is below 1 so this suggests that the odds of rating organizational structure higher than site management are 0.446 times of odds of rating site management which means the chances of rating are lower as compared to site management. Similarly the odds can be deduced for the rest of factors.

Table 3: Ordinal Linear Regression

Main factors	Odds (after taking exponential)	Conclusion	Elaboration
Contractor‟s Capability	1.155	Odds of rating are 1.155 times higher than that of reference	Odds are higher as compared to reference
Payment and Finances	1.37	Odds of rating are 1.37 times higher than that of reference	Odds are higher as compared to reference
Site Management	REFERENCE (0)	-	-
Client‟s and Quality Consultant‟s Capability	1.406	Odds of rating are 1.406 times higher than that of reference	Odds are higher as compared to reference
Organizational Structure	0.446	Odds of rating are 0.446 times than that of reference	Odds are lower as compared to reference

The weights assigned in Table 1 can help to estimate the level of management that is being implemented for any project of pavement rehabilitation in Pakistan. The index formula introduced below can help the analysis of the managerial condtions of quality for pavement rehabilitation projects. The formula has been used in several other researches (Jiang *et al.,* 2011). On being assigned the rating from an experienced individual, following equation will give the value out of 1 which clearly gives the idea of the level of management for quality is being implimented.

$$Q_i = \sum_{i=1}^{N} \left(\frac{W_i x\, R_i}{5} \right) \qquad \text{(Equation 1)}$$

Where,
W_i = weightage of ith factor (one of five factors).
R_i = Rating assigned to the ith factor.
Q_i = level of management out of 1.

3.1 Example

Consider that an experienced official from a pavement rehabilitation project in Pakistan rates contractor‟s capabilities as 3, payment and finances as 4, site management as 3, client‟s and quality consultant‟s capabilities as 5 and organizational structure as 4 for that project then:

$$Q_i = \frac{(3*0.202+4*0.207+3*0.2+5*0.208+4*0.183)}{5} = 0.7612 \text{ out of 1 or } 76.12\ \%$$

This value gives us a clear idea of level of management being applied to cater for the quality. Values from 0 to 60 percent were set as low quality, from 61 to 70 percent to be of fair quality, 71 to 80 percent as of moderate quality, 81to 90 percent falls in range of good quality and 91 to 100 is range of excellent quality. As per the range, the example shows that the project falls in range of moderate quality. The ranges can be changed as per the need.

4. Conclusion

The present study highlights the importance of management for the implimentation of quality in pavement rehabilitation in Pakistan. The most important factor was considered to be client"s and quality consultant"s capabilities. This shows that as client utilizes the final product and quality consultant ensures the acceptable level of quality at site, so their importance can never be ignored. The second in priority of importance is avalability of payments and finances which clearly depicts that quality is surely affected by fluctuations in payments as it may cause delays and in extreme conditions termination of work as well. Relatively, organizational structure impacts the least to the quality of pavement rehabilitation. The major focus of project based organization is the execution of work in efficient as well as effective way. In such case knowing the level of management being implemented for quality would be a great step forward and will contribute in competency. The three major applications of this paper are highlighting the important factors that contribute to the rehabilitation of pavements, secondly the quantification of these factors which can help as a benchmark and in the end a methodology is introduced that could act as a quality management calculating tool for any pavement rehabilitation project in Pakistan. Conducting a similar study in any other field or any other area in field of construction is suggested.

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10th International International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Multi-criteria Decision Making in Urban System Traffic Evaluation

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Abstract

Safe, efficient and user-friendly transportation of people and goods have been a premier point of concern for all the developed and the developing countries around the globe. Grand trunk road is the most vital interstate connection in Pakistan. It carries about 80 % of the country freight traffic. When this heavy traffic passes through the twin cities of Rawalpindi and Islamabad, it causes congestion and environmental hazards. A bypass to Rawalpindi city is, therefore, inevitable. Other than this, the Bypass will likewise give a short access to the traffic on the Motorway (M2) bound for the western part of Rawalpindi. For the purpose of this research work Rawalpindi Bypass is taken as a hypothetical scenario and is evaluated for its benefits. Besides addition to the networks of highways across Pakistan this bypass has many other benefits which include decrease in congestion from Islamabad and Rawalpindi main arteries (ISB Highway and IJP Road) that results in travel time savings, mitigation of traffic delays, fuel usage cost savings, safety and reduced air pollution by reduction in emissions of volatile organic compounds. This study examine the basic relationship between the traffic delays, fuel usage and environmental emissions like Carbon Monoxide, oxides of sulphur and oxides of nitrogen. A comparison between the fuel usage and environmental emissions of the current scenario and future scenario was made respectively. The authors have taken the existing roadway structure with no improvements as DO-NOTHING Scenario, whereas the construction of Rawalpindi Bypass as alternative B and C. The transportation decision making process usually involves the evaluation of effectiveness and efficiency of an alternative decision with respect to a base case DO-NOTHING Scenario.

Keywords
Traffic Delays, Safety, Vehicle Operating Cost, Environmental Emissions

1. Introduction

The core of transportation decision making is the evaluation of transportation projects and programs in the context of available funding. For this reason, the principles and procedures of transportation project evaluation and programming are of interest to transportation engineers and planners, transportation agency administrators, facility managers and service providers, environmental groups and the general public. This is a critical issue for governments everywhere. Each year, several trillions of dollars are invested worldwide in transportation facilities with a view to enhancing transportation system mobility, security, and safety, and to spurring economic development while minimizing environmental and other adverse impacts. Same is the case within Pakistan. In most countries, the sheer size of existing transportation assets and investment levels, coupled with the multiplicity of transportation system impacts and stakeholders, necessitates a comprehensive, yet integrated and consistent approach to evaluating such impacts. The new millennium is characterized by continued growth in commercial and personal travel demand, and transportation agencies and providers strive to keep their assets in acceptable condition so as to offer desirable levels of service in the most cost-effective manner and within available resources. Consistent with such efforts is the need for best-practices evaluation and monitoring of the expected impacts of alternative investment decisions, policies, and other stimuli on the operations of existing or planned transportation systems and their environments. Rawalpindi is the city without a bypass and more than 15000 trucks pass through the city in 24 hours on average. This volume of truck traffic seriously affects environment of the city. A bypass to Rawalpindi city is, therefore, inevitable. Besides this, the Bypass will also provide a short access to the traffic on the Motorway (M2) destined for the western part of Rawalpindi. Absence of bypass results in mixed traffic, traffic Congestion, grid locks, environmental hazards (noise and air pollution) and traffic safety issues. During study, it was revealed that the intra city traffic is compelled to pass through the city of Islamabad and Rawalpindi and this traffic combined with the local slow-moving vehicles results in high traffic congestion and traffic management problems usually on IJP road Rawalpindi and Islamabad expressway. The provision of Rawalpindi bypass will help reduce the traffic pressure in twin cities. The Project involves Project Cost estimations of Rawalpindi Bypass, travel time savings,vehicle operating cost savings, and environmental impact or pollutant emissions reduction . Existing road way structure with no improvements taken as DO-NOTHING Scenario, whereas the construction of Rawalpindi Bypass (55 Km) with 2 lanes in each direction is taken as Alternative B and Rawalpindi Bypass (45 Km) as Alternative C. Existing scenario shows the existing traffic pattern distributed along the N5 and Islamabad highway. Heavy traffic which is coming from Punjab cities and from Peshawar uses N5, at pirwadai flyover the heavy traffic is diverted towards IJP road and from faizabad interchange the traffic it diverts onto Islamabad Highway. Figure 1 is showing existing or do-nothing scenario.

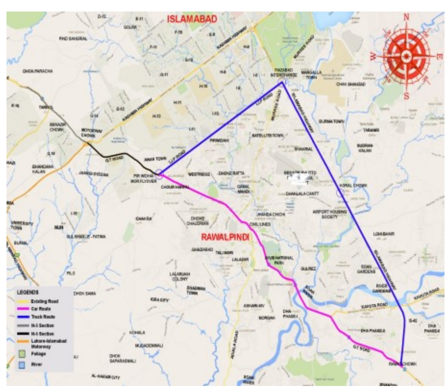

Figure 1: Existing Scenario / Do nothing scenario

For alternative 1 the start point of Rawalpindi Bypass project is 5 Km short of Rawat, which is an important junction on the N-5 and terminates at Nicolson Monument Islamabad at junction of N5. Total length of alignment is 55 Km. Figure 2 is showing alignment # 1

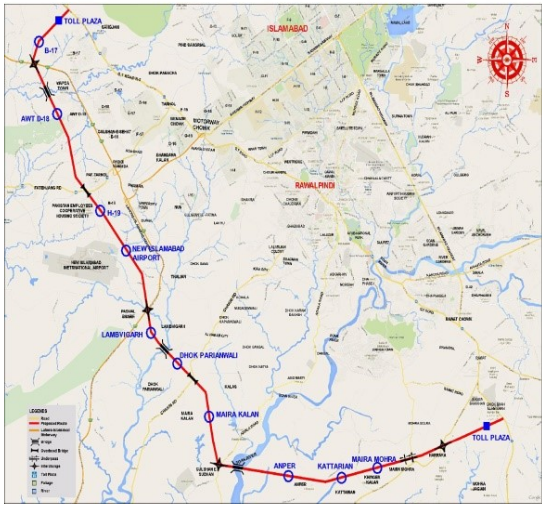

Figure 2: Alignment # 1 for the proposed Rawalpindi Bypass

For Alternative # 2 the start point of Rawalpindi Bypass project is 1 Km short of Rawat, which is an important junction on the N-5 and terminates at sector B17 Islamabad at junction of N5. Total length of alignment is 45 Km. Figure 3 showing alignment # 2.

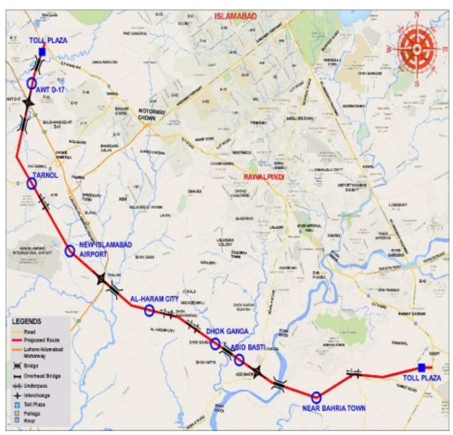

Figure 3: Alignment # 2 for the proposed Rawalpindi Bypass

2. Literature Review:

2.1 Traffic Delays:

Enhancements to a transportation system are often expected to yield increased travel speed or decreased waiting or transfer times, and consequently, reduced travel time. The savings associated with reduced travel time typically constitute the largest component of transportation user benefits. In this chapter we study issues associated with travel time as a transportation performance measure and methodologies for the assessment of travel-time amounts and unit monetary values for the purpose of evaluating the travel-time impacts of transportation projects. Given that the values of travel time vary by certain attributes of the trip and the trip-maker, it is important to establish the travel-time amount. The overall framework for assessing travel-time impacts involves the estimation of travel-time amounts, travel-time values, and overall savings in travel-time costs.

2.2 Vehicle Fuel Usage:

Vehicle fuel usage costs are direct expenses that comprise the costs of vehicle ownership (fixed) and vehicle operation (variable). The latter category, typically referred to as vehicle operating costs (VOC's), varies with vehicle use and is typically expressed in cents per mile traveled by a vehicle. For most transportation modes, VOC involves energy use, tires, maintenance, repairs, and mileage dependent depreciation (Sinha et al, 2008). Hepburn developed a VOC model in 1994 for urban roadways that considers the sum of four VOC components (tires, vehicle depreciation, maintenance, and fuel) as a function of two VOC factors: speed and vehicle class. The model is particularly useful for evaluating VOC impacts of transportation interventions that mostly yield a change in average operating speeds or policies that cause a shift in vehicle class distribution

2.5 Environemental Emissions :

Transportation or "mobile" sources of air pollution, particularly motor vehicles, are a primary source of local carbon monoxide problems and are considered the main cause of excess regional photochemical oxidant concentrations. Transportation vehicles typically emit carbon monoxide, nitrogen oxides, small particulate matter, and other toxic substances that can cause health problems when inhaled (Williams, 2007).

2.6 Multi Criterion Decision Making:

In multi criteria decision making, a key step is the explicit or implicit assignment of relative weights to each performance criterion to reflect its importance compared to other criteria; for example, to what extent is safety improvement more important than travel-time reduction, increase in facility condition, vehicle operating cost decrease, increased economic development and improved aesthetics.

3 Research Methods:

The methodology used in this research was based on highway capacity manual. Traffic data was collected using manual counts on two locations on N5, one location at Nicolson monument near Taxila and one near Rawat on GT road, thus covering both entry and exit point for new bypass. Than traffic data was converted into average annual daily traffic (AADT). Environmental Emissions and Fuel Usage was calculated using Hepburn model and highway capacity manual equations. In the last fuel used by vehicles during the intersection delays was converted into cost using Hepburn model again for both current scenario and future scenario. Based on these performance criteria different alternatives are evaluated and then a better alternative is selected through multi criteria analysis.

3.1 Cost Estimation:

The second part and the most important part of this research work is the cost estimation. The cost for alternatives is calculated using the engineer's estimate of E35 while following the NHA CSR 2011 specifications. All the costs are calculated as an average cost after considering the costs of E35 expressway. Using consumer price index provided by FBS Pakistan the cost is converted into year 2018 from year 2011. Aggregate cost of each component of pavement is than added to find the total project cost of each alternative. All costs are converted to year 2018 using CPI indices i.e. CPI_{2011}= 202.32 &CPI_{2018}=236.11. Using aggregate costs cost for each proposed alignments for Rawalpindi Bypass have being calculated. Each alignment is to be assumed as 3 lanes on each side. Alignment 1 length is 55 Km while of alignment 2 the length is 45 Km. The total cost is divided into two elements which are cost for acquiring land and construction cost. The cost of proposed alignment no 1 for year 2018 is Rs. 45 Billion while for alignment no 2 it is Rs. 35 Billion.

4. Analysis and Results Discussion:

4.1 Traffic Delays Analysis:

For traffic delay analysis a present case scenario and an alternative scenarios are taken for analysis purposes. The traffic counts are converted into AADT which includes 70% non-commercial and 30% commercial vehicles. The commercial vehicles that are mostly the trucks are diverted to IJP road which passes through Faizabad Interchange joining the Islamabad Express way and travel to Rawat. In bypass case scenario out of total AADT 17000 which includes 9000 Trucks and 8000 cars are diverted on bypass while the rest is traveling on the existing route. There will be no trucks traveling on the existing routes as all the trucks are diverted on bypass. The existing road is divided into numbers of sections. Travel time before and after intervention. HCM method is used for calculations of speed. These calculations are made after making some assumptions of free flow speed for different segments taken for analysis. The unit travel time costs are converted to year 2018 using CPI index for year 2011 & 2018. Unit travel time cost for cars is taken as 320 PKR and for trucks PKR 222. Detail results are shown in figure 4. From the analysis, it is concluded that 29.38 Mins per vehicle can be saved after constructing Rawalpindi bypass. If converted into monetary benefits using unit travel time cost the net benefit will be equivalent to PKR 960 Million per year that is a huge amount of savings for country like Pakistan where there always a budget deficit

Figure 4: Travel Time Savings

4.3 Fuel Usage or VOC:

For the calculation of vehicle operating cost Rawalpindi bypass was considered as a case study. Rawalpindi by pass is supposed to be constructed to divert the traffic on N-5 from Taxilla to Rawat directly. Before the construction of bypass the vehicles travel via two routes from Rawat to Taxila. These two routes directly pass through the city of Rawalpindi thus creating a lot of congestion on roads and increasing the vehicle operating cost. The vehicle operating cost calculation (VOC) was done by using the Hepburn model (Comsis, 1999). The model considers speed and vehicle characteristics for the calculation of VOC. The Hepburn model is used for the calculation because the routes for which VOC is to be calculated has different variation of speed sections. After applying the methodology VOC before the intervention is first calculated. Results are shown in figure 5.

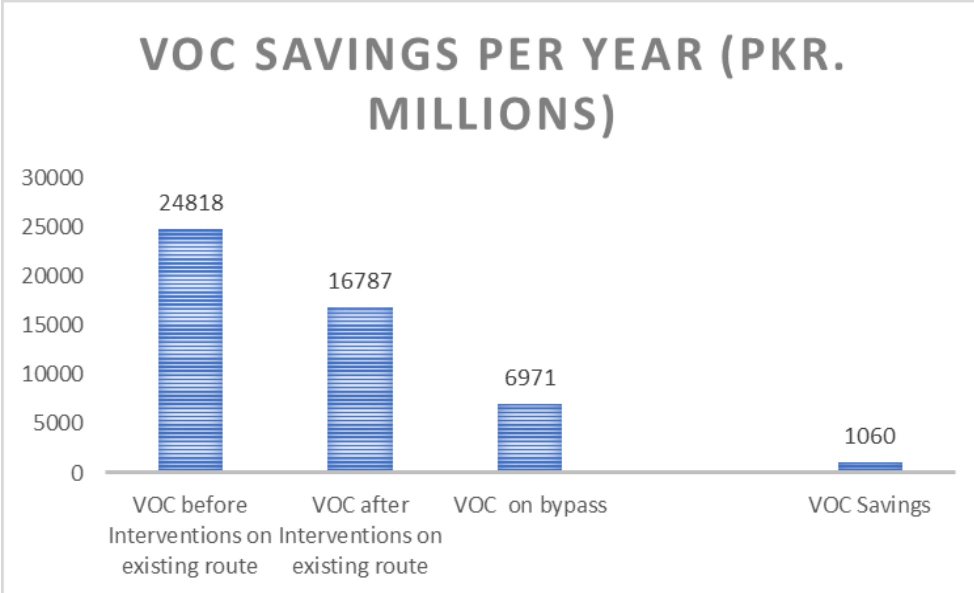

Figure 5: VOC Savings

4.4 Air Quality Impact:

In evaluating the impact of transportation improvements on air quality, the first step is to estimate the change in emissions as a result of changes in the average speed of vehicles, increases in motor vehicle trips, and increases in VMT due to these improvements (Williams, 2007). Traffic data was analyzed using Synchro software. Major inputs required for analysis were Peak hour volumes, Number and type of lanes. Different pollutant values per vehicle mile travel (VMT) taken for analysis are provided in table 1. Where, Volatile Organic Compounds = VOC, CO = Carbon Mono Oxide, Nox = Nitrogen Oxide and CO2 = Carbon dio oxide. The results are shown in figure 6 and table 2.

Table 1: Pollutant Emissions as per vehicle class (TCRP 2003)

MODE	VOC (g/VMT)	CO (g/VMT)	Nox (g/VMT)	CO2 (g/VMT)
CAR	1.88	19.36	1.41	415.49
TRUCK	2.405	18.445	6.87	1453.92

The overall emissions before and after interventions are shown in table 2

Table 2: Overall Pollutant Emissions before and after Interventions

Pollutant	Emissions (Kg/Day) Before Intervention	Emissions (Kg/Day) After Intervention	Emissions (Kg/Day) on Rawlpindi Bypass
VOC	4269.75	2754.30	1375.88
CO	39995.29	28363.4648	12032.8444
NOx	6387.34	2065.72755	2743.6725
CO2	1523530.11	608715.702	615734.411

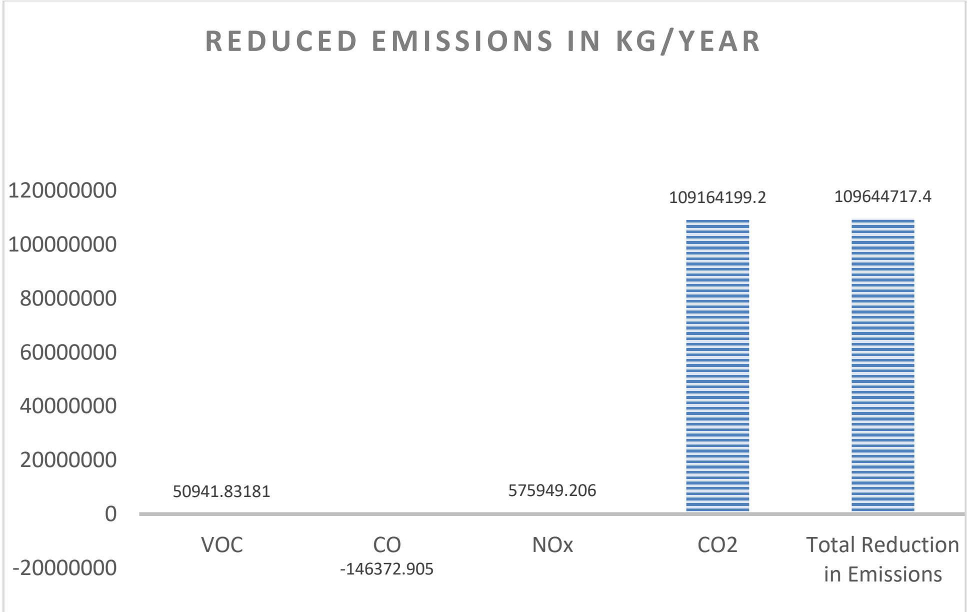

Figure 6: Reduction in Emissions after intervention

5. Discussions:

From the results shown in table 1 we can easily assess that traffic delays not only causes inconvenience to the motorists but also it is imperative that it can cause huge damage to the environment by increasing the emissions. Rawalpindi bypass is therefore a definite need for both cities of Islamabad and Rawalpindi. A brief comparison of results are shown in table 1 below.

Table 1: Results (Delays, Fuel Usage and Emissions in Current and after construction of Rawalpindi bypass)

Criteria	Without Rawalpindi Bypass	After Rawalpindi Bypass Constructions	Total Savings/Bene fits	Total Monetary Benefits
Traffic Delays / Travel Time Savings	67.3 Mins	37.92 Mins	29.38 Mins	PKR 960 Millions
Vehicle Operating Cost / Vehicle Fuel Usage	PKR 689 Million / Day	PKR 50 Millions / Day	-	PKR 2.904 Million / Day
Emissions	1523530.11 Kg / Day	608715.702 Kg /Day	-	299080.00 Kg / Day

From the above mentioned results one can easily understand the importance of constructing the Rawalpindi bypass. Traffic delays are really a big problem not in terms of social but also in terms of environmental and economics point of view. If we don't solve these issues now than we will have to face a lot of difficulties in future. For Example if Rawalpindi bypass is not constructed and existing scenario prevails than the cost of fuel wasted during idling time will increase by 293.3% and environmental emissions will increase by 305%. So for Safe environment and cost efficient traffic systems the existing transportation system of Islamabad and Rawalpindi city should be improved by constructing Rawalpindi Bypass.

6. Conclusions:

The core of transportation decision making is the evaluation of transportation projects and programs in the context of available funding. For this reason, the principles and procedures of transportation project evaluation and programming are of interest to transportation engineers and planners, transportation agency administrators, facility managers and service providers, environmental groups and the general public. This is a critical issue for governments everywhere. Each year, several trillions of dollars are invested worldwide in transportation facilities with a view to enhancing transportation system mobility, security, and safety, and to spurring economic development while minimizing environmental and other adverse impacts. Same is the case within Pakistan. This study provides indications of good practices that could be followed in the evaluation of alternatives transportation systems for the purpose of decision making, on the ground of demand estimation and Traffic on different segments, Travel Time Saving and analysis that proved to be 2.535 Million PKR per day or 960 Million PKR per year, the Vehicle Operating Saving Cost proved to be 1060 Million PKR per year. Similarly the total Emission Reduction was around 1096447 Tons/Year.

Finally the study incorporates following conclusions which are given as under.

1. Rawalpindi Bypass will surely be reducing congestion on both case scenarios under consideration (base-case scenario and alternative scenarios both).

2. Rawalpindi Bypass's saving vehicle operating cost is estimated to be 1060 Million PKR per year in accordance to 2018 constant PKR.

3. Traffic delay analysis shows that 4380 hours /year with the cost of 960 Million PKR/ year will be saved after making this asset operational.

4. The Emissions Reduction is proved around 299 Tons/day.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Application of Artificial Intelligence in Traffic Congestion Modeling

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Abstract

Traffic Congestion is a complex dilemma faced by major cities. This research is intended to fill the void in existing research based on congestion prediction, with a focus on Karachi's indigenous traffic conditions. Recently, Intelligent Transportation Systems (ITS) became an integral part of traffic research which helped in modeling and forecasting traffic conditions. In this work, the fuzzy logic model in MATLAB framework for traffic congestion prediction is generated. The method is used to define traffic congestion during morning rush hours. The evaluation is based on the data set of University road (arterial) Karachi. The data is collected from 8 am to 11 am at two locations for speed, flow rate, and density through good quality cameras. The results of actual output and predicted output were compared. Also, results for two separate locations were observed. The model generated is accurate up to 80% with a prediction error of 21% which satisfies the criteria of a true model.

Keywords
Traffic Prediction, Congestion, Artificial Intelligence, Fuzzy Logic

1. Introduction

Traffic congestion is one of the main issues especially for the metropolitan cities around the world. Karachi is a metropolitan city of Pakistan and it too has a major traffic congestion problem on its arterials. Studies showed that Karachi has a daily loss of Rs. 1 Million due to traffic congestion (Ali, Adnan et al. 2014) and it not only effects economy but it also affects environments for the citizens, it degrades air which is inhaled by the citizens, and also the noise is a big issue for people having heart problems. From the report of Asian Development Bank, 9% of motor vehicles increase annually in Karachi city which means 280 vehicles every day increases in this city, this growing situation is resulting in increased traffic congestion day by day which ultimately results in loss of economy, increases health hazards and also the loss of time. Time loss includes the delay in travel time while increasing fuel usage and vehicle maintenance costs hit citizens economically. Furthermore, air pollution and noise pollution cause health hazards.

2. Literature Review

Various researches has been done so far in order to propose the technique to measure traffic congestion and model have been developed by various researcher and their major focus was on quantitative causes of congestions. Research also proves that qualitative factors such as driver behavior, ease in buying vehicle, pavement condition, and vehicle heterogeneity and driver behavior are also triggers congestion (Ali, et al 2017).If these parameters excluded in congestion model, the applicability of the congestion model will suffer. To date, few models have attempted to undertake a parametric cause-effect type analysis of congestion prediction. Most models have used trajectory mapping and velocity data to predict the onset of congestion based on previous velocity and trajectory behaviors in congested conditions. (Li, Han et al. 2007) used macroscopic traffic models to predict highway traffic density, the results of which were combined using a learning framework. (Zheng, Li et al. 2008) used GPS to obtain vehicle velocities, and weighted the results to predict the traffic state. (Kong, Li et al. 2009) made a similar attempt, mean velocity calculation after obtaining data from numerous GPS-equipped probe vehicles to estimate the traffic state. (Yi Liu, 2014) used different variables with a Bayesian network for determining the probability of congestion occurring: proportion of severe congestion mileage of road network, urban land expansion coefficient, density of the road network, proportion of urban public transport investment to gross domestic product, growth rate of private car ownership rate, proportion of rail trips to public transport trips, ten thousand people ownership of buses and death rate of ten thousand vehicles.

Artificial intelligence has also been used for congestion prediction. (Shankar, Raju et al. 2012) used fuzzy logic to map the impact of velocity and traffic density on traffic congestion. (Dunne and Ghosh 2011) used an Artificial Neural Network to predict the traffic regime (congested or non-congested) based on multivariate adaptive learning. The project described in this study uses a fuzzy logic model that utilizes a multivariable expert system based on 9 different variables to predict traffic congestion, in order to preserve the utility of qualitative variables in congestion prediction.

This research utilizes Artificial Intelligence (AI), a branch of computing that is specially designed to mimic life and perform calculations on imprecise and non-discrete phenomena.

3. Objectives

The objective of this research is to develop a traffic congestion prediction model for an urban arterial that incorporates quantitative congestion factors through fuzzy logic.

4. Scope

Video based primary field data is collected and MATLAB fuzzy interface is used for data analysis and model development.

5. Methodology

The methodology which has been adopted to execute this research is shown below Figure 1.

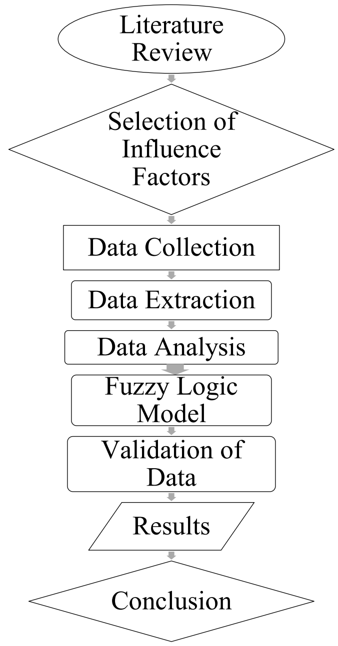

Figure 1: Research Methodology Flow Chart

5.1 Data Collection

The location has chosen for data collection is University road, based on two prime locations Babar Hospital (Jail Chowrangi to Safoora for the time of 1.5 hours) and Sir Syed Bridge (Safoora to Jail Chowrangi for the time of 2.5 hours). The time of the day had picked is from 8 am to 11 am.

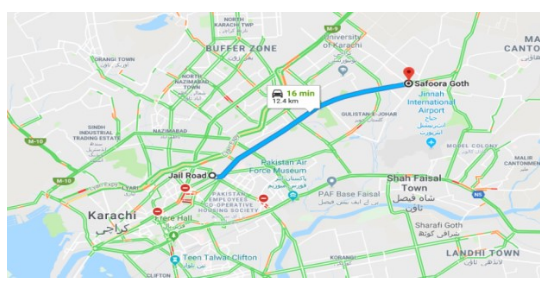

Figure 2: Google Map of the selected location

Manual traffic flow count is categorized by a visual assessment of the vehicle size. The modes of vehicle considered in this research are motorbikes, rickshaws, buses/minibuses, trucks.

5.2 Data Extraction

5.2.1. Speed

1. First, a trap is created by editing the video having a fixed length

Figure 3: Trap for Speed, Density and Flow-rate calculation

2. Sample size/min is calculated for each type of vehicle (bus, truck, cars etc.) by measuring speeds of random samples from each video and calculating the standard deviation. For example, 11 samples/min for cars at the standard deviation of 4.23.
   No of samples is calculated by the following Equation 1

$$\boldsymbol{n} = \left(\frac{\boldsymbol{\sigma . s}}{\boldsymbol{\epsilon}}\right)^{\mathbf{2}} \qquad \text{Eq. (1) (Crunkleton and Tarnoff)}$$

   Where,
   n= no of samples
   $\sigma = Mean$
   $s = Standard\ Deviation$
   $\varepsilon = Error$

3. Then speed is measured per min for each type of vehicle according to sample size
4. Speed is then averaged for each type of vehicle according to sample size

5.2.2 Density

1. Snaps are taken every 15 sec i.e. 4 snaps/min for counting of vehicles in a 100 m section.
2. Average for 1 min for each type of vehicle is calculated.
3. Density is calculated by the sum of vehicles in a 100 m section in a min, also simultaneously volume is converted to passenger car equivalent by multiplication factors as shown in Table 1.

Table 1: PCU factors used for Analysis *(Adnan 2014)*

		PCE Factors Estimation Approaches			
		Headway		Speed	Regression
S. No.	Vehicle Type	Eq. 1	Eq. 6	Eq. 8	Eq. 10
1	Small cars	1	1	1	1
2	Large Cars	1.142	1.086	1.182	1.757
3	Three wheelers	1.387	1.076	0.909	1.35
4	Motorcycles	0.595	0.603	0.453	1.068
5	Mini Buses	1.675	1.212	3.024	3.718
6	HCL	1.526	1.313	2.881	2.068
7	Pickups	1.56	0.925	1.543	1.204
8	Heavy vehicles	2.035	1.461	3.288	1.951
9	Non-motorized	2.271	2.177	3.138	2.408
Validation Consistency (RMSE)		0.063	0.021	0.031	1.568

5.2.3 Flow rate

Vehicles passing a line are counted for 15 min at the rate of 1min.The flow rate is calculated in total vehicles passing per hour.

6. Congestion and Delay Estimation

There are several ways to detect congestion on an arterial from different traffic parameters out of which flow rate and travel time index are highlighted in chapter 8 of the book "Traffic congestion - a concise guide" (Falcocchio and Levinson 2015).

For the data collected over two locations at university road: Babar hospital and Sir Syed bridge, traffic congestion is detected over each point of the interval of 1 min.

According to the Quebec Ministry of Transportation

1. Congestion thresholds are established at 60% of the posted speed limit (Falcocchio and Levinson 2015).
2. As university road has a posted speed limit of 60 kph (37mi/hr) therefore threshold is created at 0.65 of 37 equals 22 mi/hr.
3. Q_{max} is calculated over 22 mi/hr using flow speed equation. i.e.

$$\boldsymbol{Q = K_j\left(V_f - \frac{v^2}{V_f}\right)} \qquad \text{Eq. (2)}$$

Where,
Q = Qmax (Maximum density)
K_j = Jam Density
V_f = Free flow velocity of vehicles
v = Velocity at any instant

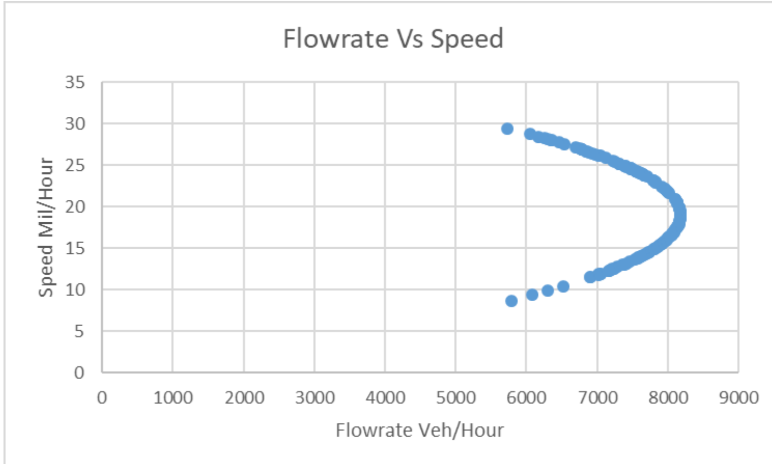

Figure 4: Graph showing speed flow model and Qmax value

The graph has been plotted as shown in figure 4 between speed and flow rate that shows speed flow model and Qmax value.

6.1 LOC – Level of Congestion

Congestion severity can be titled as LOC or Intensity of congestion. It is measured by the delay rate any section of the route is having. It relates the tolerance of the drivers under congested condition (Lomax, Turner et al. 1997) .The suggested congestion delay standards for various sizes of urbanize areas are shown in Table 2.

Table 2: Suggested Congestion Delay standards for various sizes of urbanized areas

Functional Classification	Small Urban Communities	Mid-sized Urban Areas	Large Urban Areas
Expressways – freeways	1.0-1.2min/mile (50-60mph)	1.3-1.5min/mile (40-45mph)	1.7-2.0min/mile (30-35mph)
Class – I Arterials	1.7-2.0min/mile (30-35mph)	2.4-3.0min/mile (20-25mph)	3.0-4.0min/mile (15-20mph)
Class – II/III Arterials	2.4-3.0min/mile (20-25mph)	3.0-4.0min/mile (15-20mph)	4.0-6.0min/mile (10-15mph)

Those points which are congested are categorized into two parts: congestion and severe congestion.
Delay is calculated using Equation 3

$$Congestion\ Delay\ Rate = \left(\frac{1}{Congested\ Speed\ (mph)}\right) - \left(\frac{1}{Free-Flow\ Speed}\right) \qquad \text{Eq. (3)}$$

*As in the above equation, it is clear that it only works for congested speeds.

(Falcocchio and Levinson 2015) develop the rating scale for explanation of level of congestion as shown in Figure 3 it explains that any delay that is greater than 4 min/mile is considered to have severe congestion otherwise the delay rate below it is the tolerable congested condition.
If there are congestion and delay < 4 min/mile it is congestion and when the delay having value zero it means no congestion.

$Delay = 0$	$Delay \leq 4min$	$Delay > 4min$
No Congestion	**Congestion**	**Severe Congestion**

Figure 5 : Congestion Rating

7. Data Analysis

The collected data has been analyzed using MATLAB and steps are discussed below

7.1.1 Normalization of Data in Excel

Data collected from the videos were first normalized in MS Excel in the range of 0 to 1 because Fuzzy logic in MATLAB only understands the input between the range of 0 to 1. Data were normalized by using the following Equation 4.

$$x_n = \frac{x - x_{Minimum}}{x_{Maximum} - x_{Minimum}} \qquad \text{Eq. (4)}$$

In this research, three parameters i.e. speed (mile/hour), density (vehicle/mile) and flow rate (vehicle/minute) of the traffic has been considered so the collected 4 hours data was normalized.

7.1.2 Importing Data into MATLAB

After normalizing, out of 4 hours data set 3 hours data set was imported data in MATLAB.

7.1.3 Selecting Fuzzy Logic Interface and its Parameters

In the next step, the fuzzy logic toolkit is started in MATLAB interface and when the fuzzy interface begins, “SUGENO” interface was selected for training. Figure 5 shows SUGENO interface.

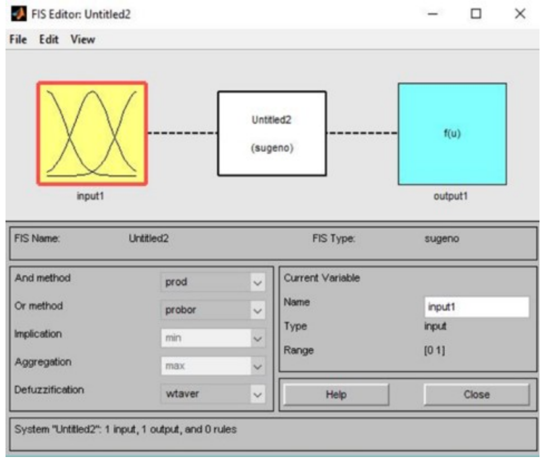

Figure 5: Fuzzy Logic Interface

7.1.3.1 Adding MFs in inputs

The next step was to add MFs (Membership functions) for each input. MFs for input depend upon the division of scale. Scales for each parameter is mentioned below

Table 3: Scale

Parameter	Unit	Scale
Speed	mi/hr	**1**=28.5-38 **2**=19-28.5 **3**=9.5-19 **4**=0-9.5
Density	veh/lane/mi	**1**=0-215 **2**=215-430 **3**=430-645 **4**=645-860

7.1.2 Adding MFs in output

Number of MFs in output depends upon the number of normalized values of output in workspace sheet. In this research, there were 180 (data for 3 hours) values of output i.e. flow rate, therefore, constant estimated value of output were assigned for each MF.

7.1.3 Making rules in a fuzzy logic

After defining the MFs of both the inputs and output, rules are added according to the actual data collected from the videos. The input data is divided into four scales i.e. "mf1", "mf2", "mf3" and "mf4" .Figure 6 shows defining of rules set at each data set.

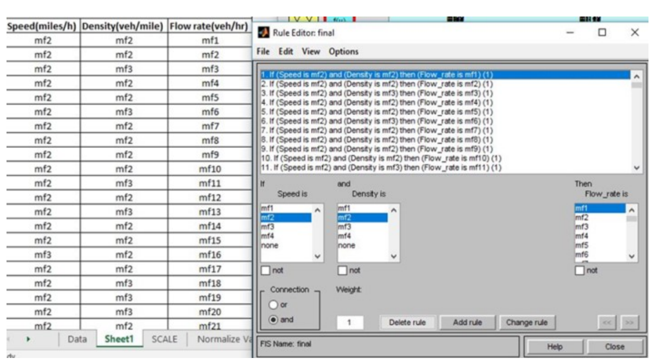

Figure 6: Defining Rules in rule editor

7.1.4 Export normalized predicted output into Excel

Predicted normalized values from workspace of MATLAB interface were exported into Excel for de-normalization for making it easier to interpret and also to compare it with the observed values.

8. Results

The fuzzy logic tool Box was used to develop the membership functions. However, the Fuzzy Logic prediction model was executed through a code in order to verify the results of the Fuzzy Logic Tool Box.
Figure 7 shows a comparison between the measured flow rate and flow rate predicted by Fuzzy Logic for 3 hours. It shows that the predicted flow rate is lower than the predicted one.

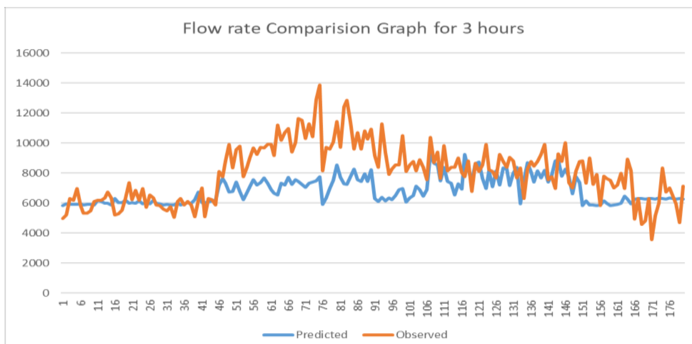

Figure 7: Flow rate Comparison graph for 3 hours' data

8.1 Congestion and Delay Limits

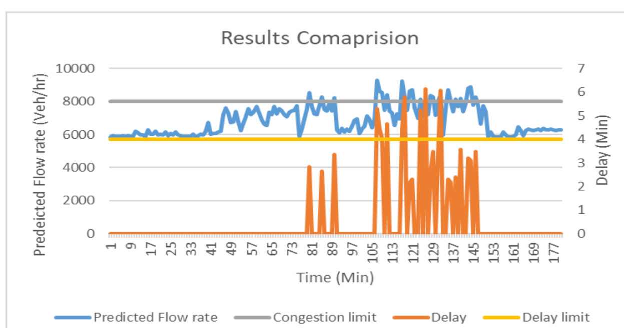

Figure 8: Congestion and Delay Limits

It can be seen from figure 8 that severe congestion occurs about 45-50min out of 3 hours having delay greater than 4min/mile.

9. Conclusion

Traffic congestion prediction model has been developed for major arterial of Karachi i.e. University Road that incorporates quantitative congestion factors that are speed, density, and flow rate through fuzzy logic. The prediction error is close to zero i.e. 0.21 from the trained model and 0.14 from tested results of one-hour data and accuracy of the model is about 81%.
It can be concluded that out of two results observed at two different locations, Sir Syed Bridge will be the red zone in morning rush hour. Traffic management is to implement the right decisions from the traffic congestion prediction results obtained and to maintain movement inland transport around the infrastructure therefore the results from this research will be used by the transportation professionals and help them to make efficient traffic policies in order to reduce the congestion problem.

10. Recommendation

The presented research work has much constraint but it can be improve by adding more things as listed below:

1. The study can be further stimulated to other urban arterials of Karachi like Shahra-e-Faisal and Rashid Minhas road etc.
2. It will be an outstanding approach if all the work is interconnected to each other through an electronic system using signals and sensors such as EETS (European Electronic Toll Service) and VCNL.
3. The scope of the work can be expanded to incur static quantitative congestion factors like no of bus stops, no of intersections etc. and qualitative congestion factors as well like, driver behavior, encroachment etc.

Maintaining flows, headways, assigning safety measures and reducing travel time are the majors which mitigate the traffic congestion . Some of the measures help in reducing the congestion are mention below

1. Regulating posted speeds by variating it on the overhead gantries.
2. Usage of the opposite lane especially as emergency exits in high volumes.
3. Giving drivers alternate route options through variable message signs.
4. Allocating right traffic police at the right location at right time.
5. Assisting infrastructure planners to construct and improve infrastructure projects by giving daily congestion trends.

11. Acknowlegments

This research is part of final year project of students Muhammad Ammar, Naqi Haider, Mohammed Hasan and Asad Ali their efforts are appreciatively acknowledged.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Potential of Integrated Bus Rapid Transit (BRT) System in Motorcycle Dominant Cities

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Abstract

Recently, many Asian cities have included BRT in their transport planning. However, due to the poor public transport system and urban sprawl majority of individuals prefer to use motorized two-wheelers. In such a case, it may take a long time before motorcyclists finally opt in favour of mass transit. This study aims to explore the potential of efficient travel options to attract motorcyclists in Karachi city. These travel options are sensibly defined such that they are already available (e.g. hiring services) or will be available in near future such as BRT along with various access/egress options such as motorcycle sharing. An extensive state-of-the-art SP survey data is collected for this study with customized choice stations and travel alternatives for each respondent. A sequential estimation of Nested Logit model is built on the data and a two level model structure is applied. The top model consists of private vehicle, E-hiring and BRT while the lower model consists of various BRT access/egress combinations. The results show that 1) motorcycle usage is strongly related to the individual and household socioeconomic characteristics and 2) accessibility to BRT network decreases the probability to use a motorcycle.

Keywords
Motorcycle, Bus Rapid Transit, Motorcycle-dependent cities, Sequential estimation, Nested Logit

1. Introduction

Bus Rapid Transit (BRT) services, mainly due to their affordability, value for money and reliability have been widely acknowledged worldwide especially in South America and Europe (Hensher, 2007; Hidalgo & Gutiérrez, 2013). BRT has also been introduced in some Asian cities in Vietnam and Thailand (Nguyen & Nguyen, 2017; Satiennam, Jaensirisak, Satiennam, & Detdamrong, 2016). However, there are several characteristics of Asian cities that are different from the South American cities where the BRT has been successfully developed such as Bogota, Columbia (Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009). For instance, extensive usage of private vehicles due to the poor public transport network, urban sprawl caused by poor city planning or its complete absence completely distinguish many Asian cities. As a result, various integrated schemes are proposed to strengthen the BRT network and trigger shift from private vehicle users to BRT. Two relevant examples of these integrated schemes are the network of feeder buses in Bangkok (Satiennam, Fukuda, & Oshima, 2006; Satinnam, Fukuda, & Oshima, 2006) and integration of Rickshaw with BRT in Dhaka (Rahman, Timms, & Montgomery, 2012).

Subjected to the urban sprawl and poor public transport system in the Asian cities, the majority of the individuals prefer to use motorized two-wheelers (afterwards referred as motorcycles) which in some cities even account to 90% of total mode share (Schipper, Huizenga, & Ng, 2005). Besides, flexibility (the opportunity to use public roads in freestyle), affordability, ability to quickly manoeuvre in a congested road environment, and less parking issues in the city centre, all, in turn, make motorcycle an attractive travel mode (Albalate & Fernández-Villadangos, 2010). Thus, people living in the Asian countries are more inclined towards the use of motorcycle and the top three largest motorcycle markets in the world are in Asia (Belgiawan et al., 2014). In case the motorcycles are already widespread before the availability of a high-quality mass transit system then the former undermines the performance of latter. In such a case, it may take a long time before motorcyclists finally opt in favour of mass transit. In the present circumstances, there is limited scientific literature available that describe policies for motorcycle dominant cities (Arasan & Perumal, 2009; Satiennam, 2011) and it remains a challenging task to encourage motorcyclists towards other transport (Satiennam et al., 2016). In line with the trend in other Asian cities, many Pakistani cities are also welcoming BRT because of the advantages that it brings. Yet motorcycle remains to be the most dominant travel mode for individuals due to its comfort and door-to-door journey. Motorcycle ownership in Karachi is increasing day by day because of its easy purchase and low operating cost; individuals having a low income can easily own a motorcycle. Furthermore, the degrading condition of public transport buses, the absence of a mass transit system and the subtraction of urban rail network which was previously functional also led to motorcycles as prime transport mode for the majority of commuters. This has not only resulted in traffic congestion and social and environmental problems in the city but has also made the traffic management a burdensome task.

Considering the problems (health, street crime, and crashes) created due to extensive use of motorcycle, the focus of this research is to determine whether and how the availability of an efficient BRT in Karachi influence motorcyclists to use these options? In this regard, a Stated Preference (SP) survey is developed specifically for motorcyclists. The survey includes all relevant services that have the potential to curtail motorcycle usage such as E-hiring services, BRT system along with various access and egress modes such as walk, feeder bus, park and ride and especially *motorcycle sharing* service. Unlike bike sharing schemes which has been widely explored, motorcycle sharing, up to the best of our knowledge, has not been discussed in the literature.

The next section of this paper summarizes the literature review. Section 3 presents the case study including the. Section 4 describes general results and Section 5 describes the model output. The last section describes discussion and conclusions.

2. Literature Review

A number of studies investigated the potential of mode shift from private vehicles towards BRT. Alvinsyah (2005) investigated user perception towards a new public transport mode and concluded that the user preference towards public transport depends on the travel time and availability of a feeder service. Easrnst (2006) studied early-shift from a private vehicle to BRT and found that only 6% of the BRT riders were motorcyclists. Levinson et al. (2003) observed that the shift varies from one setting to another. For instance, above 70% of car users shifted to BRT in Houston while this ratio was only 20% in Vancouver, Canada, 29% in France, 18% in Los Angles (Callaghan & Vincent, 2007) and only 12% in Beijing, China (Deng & Nelson, 2012). This percentage difference portrays that the difference in the BRT system, users opinion and local circumstances, all directly affects ridership.

A majority of literature on motorcyclists' behaviour is from the Asian cities. The studies explored motorcycle ownership in general and the potential shift of motorcyclists to BRT in particular. A study analyzed motorcycle ownership in Ho Chi Minh City (HCMC), Vietnam through an in-home interview survey (Nguyen & Nguyen, 2017). The study developed a Multinomial Logit (MNL) model through household characteristics (family composition, children and adults, car ownership, household income and number of vehicle licenses), motorcycle usage (purchase price and years of usage), and travel attributes (trips per day, travel distance and ridesharing with someone within the household). Most of the household variables were found to be significant. However, no relationship is found between motorcycle ownership and its usage i.e. a household owning more motorcycles will also use it more frequently. This result suggests that the policies that aim to limit motorcycle ownership may not be effective as owning less number of vehicles does not necessarily restrict the Vehicle Miles Travelled (VMT). A study examined the potential of Mass Rapid Transit (MRT) to attract motorcyclists in Hanoi, Vietnam through an SP survey (2015). The results identified travel time as the most significant attribute in mode choice. Another study examined mode shift from motorcycles to MRT through an SP questionnaire survey (Hoang & Okamura, 2015). The results showed that being female, old age, performing long-distance trip, and the proximity to MRT station significantly increase the probability of using mass transit. It has been observed in the case of Taiwan and other Asian cities that motorcycle use prevails despite an improved public transport system. Therefore, the main challenge is to shift motorcyclists to BRT and MRT system. A sensible explanation of this behaviour is that motorcycle dependence has existed for a long time which also affects public transport behaviour (Javid, Okamura, Nakamura, & Wang, 2013). In view of the above discussion, this study describes the efforts undertaken to analyze potential shift of motorcyclists to BRT in Karachi. A special emphasis is put on the combination of various access/egress modes for the BRT and particularly motorcycle sharing. Furthermore, E-hiring services are also included. The details of the study are further described.

3. Case Study

3.1 Karachi City Current Status

Karachi is the metropolitan hub, the biggest city of Pakistan and eighth populous metropolitan city in the world with an estimated population of above 24 million (Express Tribune, 2013). The Household Travel Survey of Karachi conducted by the Japan International Cooperation Agency (JICA) estimates public transport share for around 60% of all trips (Japan International Cooperation Agency, 2012). However, due to the limited infrastructure (buses and lines), there is a devastating ratio of 1:34 passenger per seat. Thus, those who can afford other means of transport avoid using public transport. Motorcycles constituted 52% of the mode share in 2011 and taking into account the increasing rate of ownership it must be around 60% now.

Commuting in Karachi city has gradually become more and more cumbersome with the passage of time. This is mainly because the metropolis still waits for its first BRT to be operational. Thus, those who do not own a vehicle ends up in spending a major share of their monthly income on transport. A new motorcycle is priced around Rs. 45,000 and has much lower fuel consumption than cars or public transport fare. Moreover, motorcycles are also available in instalments with a mere down payment of Rs. 5,000. Therefore, in the present circumstances, motorcycle ownership seems to be a very attractive alternative. Those who can afford it, purchase it to avoid the hassle of travelling via public transport. There were 450,000 registered motorcycles in 1990 (**Error! Reference source not found.**) which increased to 500,000 in 2000, in 2010 it rose to above 1 million (Hasan, 2011) and in 2012 about 1.5 million (Web Desk, 2012). At present it is estimated that 700 new motorcycles hit the road on a daily basis which was around 340 ten years ago, thus, raising the total figure to 2.7 million with an increase of 230% in last decade or so (Ayub, 2017). Earlier, it was estimated that there will be 3.64 million motorcycles in 2030 (Hasan, 2011). However, based on the exponential increase in motorcycle ownership and the absence of an efficient BRT service, this assessment can be safely termed as underestimation of motorcycles ownership.

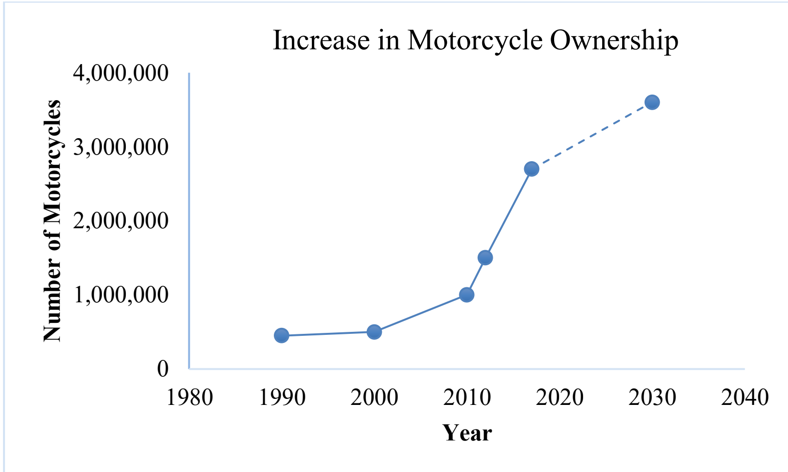

Figure 1: Motorcycle Ownership in Karachi City

3.2 Survey Design

The data for this study is obtained through a questionnaire survey that is designed using the Qualtrics platform (Qualtrics LLC., 2018b). The questionnaire comprised of three parts:

1. The first part contains questions to collect respondent's socioeconomic and household information such as age, gender, income, profession, driver license, the number of persons, the presence of children/old age persons, number of persons earning in a household and if the respondent is a household head.
2. Description of travel alternatives that are part of the SP questions. This is provided as BRT and other access/egress modes are not yet operational in the city. Therefore, for respondents to better understand the characteristics of these alternatives and make an informed decision, detailed information about the alternatives is important. This information includes the availability, pricing, frequency, and all possible access/egress combinations.
3. A series of six SP questions to determine their travel mode choice. The respondents were asked to consider their main trip of the day while making a decision. The SP survey mode alternatives are categorized into three main types:
    a. BRT along with four access/egress modes in the SP survey: walk, feeder bus service, motorcycle sharing and Park and ride (only for access). every possible combination of access and egress mode is considered as a separate alternative. This modification resulted in 12 BRT alternatives.
    b. E-hiring services. There are numerous E-hiring services (Uber, Careem, Bykea) that provide various options such as car, motorcycle and three-wheelers in Karachi.
    c. Private vehicle i.e. respondent's current travel mode. This inclusion makes the choice set more realistic as in reality, the respondent can choose to continue using their current mode. There are no attribute-levels assigned to this mode and 'your current travel time and cost' is mentioned.

Six attributes are used in the SP survey of which four represents a travel time component and one for travel cost and transfer (only applicable to BRT) each. Attribute values are assigned on the basis of proposed network and fare obtained from Karachi Strategic plan – 2020 (City District Government Karachi (CDGK), 2007) and official website of the government and Karachi Mass Transit Cell (KMTC, 2008). Full orthogonal design is generated in R software using the package *AlgDesign* (Wheeler, 2004) which resulted in 24 questions. Each respondent is provided with SP questions. Two additional variables *main time* and *total time* are also shown in the SP question. The former is the respondent's current travel time while the latter is the summation of all the time components. This was observed to make the scenario as realistic as possible. The real-time customization is supported in Qualtrics through Piped-text option (Qualtrics LLC., 2018a). Besides, the type of E-hiring service (car/ three-wheeler/ motorcycle) and private vehicle (car/ motorcycle) are also tailored for each respondent on the basis of their frequent travel mode and E-hiring service, respectively.

The survey was distributed during April – May 2018 through social media. The data was cleaned by discarding the respondents who 1) took less than 10 minutes to complete the survey since it takes more than 10 minutes to properly complete the survey (observed through pilot survey data) and 2) are females, as in Pakistan female don't usually drive motorcycles due to the culture and tradition and only use it as a pillion rider. A total of 216 respondents after are left resulting in 1296 choice observations.

3.3 Model Specification

The utility function comprises of the individual, household-related as well as travel alternatives characteristics.

$$U_{in} = \sum_{k=1}^{k} \beta_{in}^{ind} xkn + \sum_{l=1}^{L} \beta_{in}^{hh} xln + \sum_{m=1}^{M} \beta_{in}^{alt} xmn + \epsilon \qquad (1)$$

Where,

U_{in} is the utility of individual i for choosing alternative n; β_{in}^{ind} are the parameters associated with individual specific attributes; β_{in}^{hh} are the parameters associated with household specific attributes; β_{in}^{alt} are the parameters associated with alternate specific attributes; k, l, m is are the total number of variables related to the individual, household and alternatives respectively and ϵ is the error term.

This study describes a sequential estimation of Nested Logit (NL) model. A NL model assigns all the alternatives to different nests. It first predicts a nest (top-level) and then an alternative (lower level) within the nest. The sequential estimation is a special form in which a NL model is decomposed into two MNL models. Here, unlike the NL model, the lower models are estimated first and then its results fed into the top level model. The models are linked together by feeding the logsums i.e. a measure of consumer surplus of the lower model into the top model. The model structure details are described in section 4.2.

4. DATA ANALYSIS

4.1 Socioeconomic Characteristics

TABLE **1** summarizes the socioeconomic attributes of the respondents. Most of the motorcycle users (71%) marked motorcycle convenience as normal or above. This suggests the positive relationship associated with a motorcycle. Interestingly, Only 10% of the users preferred motorcycle for E-hiring services. This may be because E-hiring services are usually used by families to visit together, which is certainly not possible via motorcycle.

4.3 Stated Preference Choice Set Selection

In the SP questions, 8% of the times a private vehicle was chosen, E-Hiring constituted 26% while BRT was selected 66% times. 14% chose BRT with walk, 22% with feeder bus at one end, 10% BRT with motorcycle sharing, 10% BRT with park and ride and 15% with mixed access and egress modes. For sequential estimation, a two-level model structure is applied. The top model (model 1) is an aggregate model that predicts the choice between a private vehicle (motorcycle/ car), E-hiring and BRT as alternatives. The lower model (model 2) predicts the specific access/egress combination for BRT users (FIGURE 2).

Table 1: Basic Statistical Description of Survey Questions

Parameter	Basic description
Age	Majority of the individuals are between 18 to 45 years of age. The mean age is 24 years. There are no responses from individuals below 18 years of age. 3% of the respondents are above 38 years of age.
Education level	The respondents are holding an undergraduate degree (64%), few of them are high school pass (15%) and the rest (22%) have a higher education degree
Marital status	A high majority of the respondents are unmarried (80%) the rest were married.
Income	26% of the respondents have income below (Rs 40k), 30% of the respondents are between 40k – 100k, a small fraction of the respondents (8%) have higher income, the rest mentioned no-income
Profession	A small percentage of respondents (11%) are self-employed. 30% are full-time job while the rest are students
Vehicle ownership	35% of the respondents own only motorcycle while 32% own motorcycle as well as a car.
Frequent transport mode	An overwhelming 70% of the respondents are frequent motorcycle users while others use their car more frequently than a motorcycle
Household head	Only a small per cent of individuals are household head (10%)
Time of Day	68% of the respondents perform their main trip between 7:00 am – 9:00 am
Travel time	The average travel time of respondent is 35 minutes. 70% of the respondents have travel time between 15 and 50 minutes
Travel Cost	The average travel cost of the respondent is Rs 115. 70% of the respondents have travel cost between Rs 35 to 150
Motorcycle convenience	Only a minority (22%) of respondents consider the motorcycle convenience to be poor. 36% of the respondents Consider to be *normal*, 41% of the respondents consider a motorcycle to be *very convenient*.
E-hiring	38% of the respondents use only car for E-hiring and only 10% of the respondents use a motorcycle. 20% of the respondents use any of the services

5. MODEL ESTIMATION RESULTS

5.1 Lower Model

The model consists of BRT alternatives categorized according to the access/egress mode. As expected, access time and transfer have a negative influence on choice. Increase in age reduces the probability to use feeder and motorcycle sharing, which suggests youngsters prefer multiple access/egress modes. Being the household head significantly increases the preference towards park and ride as the household head has priority on vehicle usage.

5.2 Top Model

In the top model, motorcycle intercept has the highest negative coefficient than car and E-Hiring services which confirms that an attractive BRT network has a high potential to reduce motorcycle usage. Time and cost have negative coefficients as per intuition. Age significantly increases the probability to use private vehicle over BRT. This suggests that the individuals tend to follow a specific behaviour which gets perpetual as they get older. Household having five or more members significantly prefer BRT over car and E-hiring services whereas the number of individuals earning in a household significantly increases the probability to use E-hiring and motorcycle over BRT.

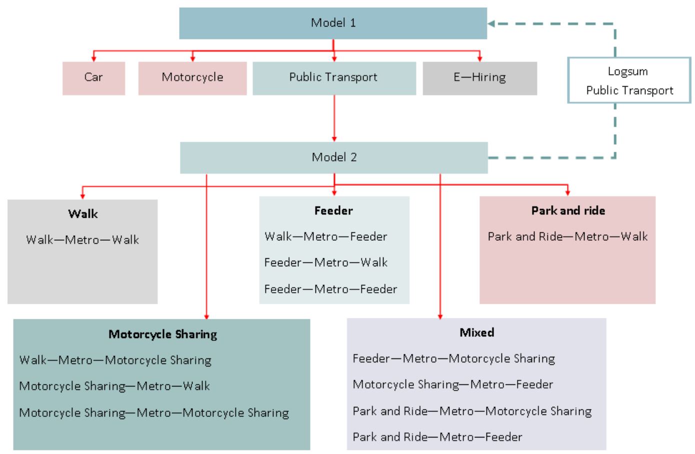

Figure 2: Sequential Estimation Model Structure

6. CONCLUSIONS

The study described the potential of efficient travel options on reducing motorcycles usage in Karachi city. These travel options are sensibly defined such that they are already available (e.g. hiring services) or will be available in near future such as BRT along with various access/egress options. The results describe interesting trends, for instance, although motorcycle usage is very common, most of the individuals do not prefer an E-hiring service motorcycle. Motorcycles are common among students and part-time workers while full-time workers and self-employed prefer a car over a motorcycle.
The access/egress modes are specifically defined for BRT in the SP questions and a sequential estimation of a NL model is built on the data. The results show that motorcycle usage is strongly related to the individuals' socioeconomic characteristics such as age, earning capacity, household size, education and profession. Furthermore, the availability of an efficient BRT substantially reduces motorcycles followed by car and E-hiring services. Motorcycle sharing is not considered as an attractive access/egress option except for youngsters.

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February 23-24, 2019, Karachi, Pakistan.

International Drivers' Comprehension of Traffic Control Devices: A Case Study for Foreign Drivers Living in South Korea

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Abstract

Traffic signs are generally used traffic safety tools, primarily developed to provide critical information to ensure the safe driving. It is believed that traffic sign comprehension has a great effect on safe driving. South Korea being an isolated country in terms of direct access by land has, traffic signs that somewhat differs from the one internationally defined in UN Convention. Unfamiliar road environment increases the involvement of international drivers in potential traffic related incidents while driving in foreign country. This study evaluated the traffic safety signs comprehension by foreign drivers in South Korea. The objective of the study was achieved by survey questionnaire among the foreign drivers residing in South Korea. The results of the study showed that, foreign drivers had a better understanding of signs having both Korean and English text followed by the symbolic signs and traffic signs with Korean text. Numeric traffic signs ranked 4th and signs with Korean only test ranked 5th. Comprehension of three different traffic signal display condition were also tested. Findings of the study would help road traffic authorities to better understand foreign drivers' behavior and contribute to road safety sign design standards serving both domestic and foreign drivers.

Keywords
Traffic Safety, Traffic control devices, Comprehension, Foreign Drivers, South Korea,

1. Introduction

Traffic signs are generally used traffic safety tools, primarily developed to provide critical information within a shortest possible time to ensure the safe driving. It is generally believed that traffic sign comprehension has a great effect on safe driving. Despite their importance they are not always understood correctly. South Korea being an isolated country in terms of direct access by land has, traffic signs that somewhat differs from the one internationally defined in UN Convention (2008a). Previous studies show that domestic drivers are more familiar with the traffic signals and signs. Unfamiliar road environment increases risk of potential traffic related incidents among drivers while driving in foreign country.
The primary objective of this study was to find the comprehension levels of Korean traffic control devices among the foreign drivers having a valid Korean license. Due to the time and financial constraints this study was limited to following. Total of 69 responses are considered in this study which is relatively low

compared to the actual number of foreign drivers. Only comprehension of traffic signals and signs is considered in this study. Comprehension of road markings are excluded from this study. Questionnaire survey is developed only in English language, assuming that every foreign driver can respond in English easily.

2. Literature Review

Shinar et al. (2003) studied the comprehension level of standard symbolic signs in four countries and found that comprehension levels widely among the different signs' countries and drivers' populations. Al-Yousafi (1999) found that comprehension level of some signs is very low. Shinar and Vogelzang (2013) examined the effect of signs having different display conditions (Text based, symbol based, text and symbol based). Their study showed that display conditions of signs had an impact on drivers' comprehension and reaction time.

Dissnayake and Lu (2001) compared traffic control device comprehension between domestic and international drivers in Florida, United States. They found that, international drivers performed below domestic drivers in understanding traffic signs, markings and traffic signal indications.

Ward et al. (2004) tested 100 international signs on 100 domestic participants in North Carolina for their road sign comprehension. The findings indicated that many international road signs could not be understood.

Kasem et al. (2017) conducted study on international tourists in Thailand. Their findings were; majority of international road users in Thailand did not feel safe while using road as pedestrian or as drivers. In foreign settings text-based signs in local language worsen the drivers' comprehension. An earlier study conducted by Kim et al. (2018) on Korean drivers showed that if the drivers see unusual traffic signal states he might have a different reaction time.

The literature showed that there is a significant difference of comprehension of traffic control devices among the domestic and international drivers. In case of foreign drivers, the situation found is even worse when it comes to comprehension of text-based signs in local language. This study is the first of its kind in South Korea. No other study is conducted in this regard in to address this issue.

1. Research Method

The methodology used in this study in described by the flowchart the figure 1.

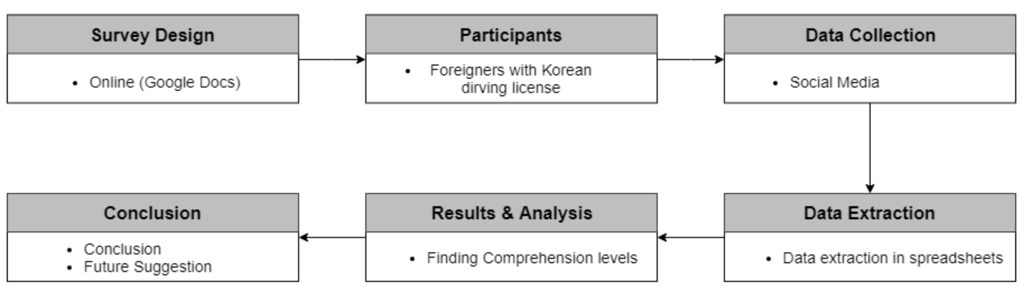


Figure 1 Methodology

The questionnaire form was divided into three parts. First part contained descriptive information of the drivers such as, nationality, Korean language proficiency level, gender, driving license type, driving experience in Korea. The second part of the survey presented the three different display scenarios of traffic lights. The third and last part presented the 12 traffic signs. Respondents were asked to select the right answer among the four choices.

ID	Sign	ID	Sign
1	 Children crossing	7	 Slow
2	 Ped. & bicycle only	8	 Yield
3	 Road works	9	 Maximum Speed
4	 No entrance	10	 Minimum Speed
5	 No stop and parking	11	 Unprotected left turn
6	 Stop	12	 One way

Figure 2 Traffic Signs used in study

Figure 3 shows the different traffic signal displays with their respective meaning.

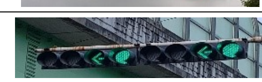
ID	Direction	Display
1	Left turn only	
2	Left turn & through	
3	Prepare (caution)	

Figure 3 Traffic signal display

In the first stage, contact details of foreign drivers residing in the Korea were obtained using social media and personal contacts. In the later stage questionnaire survey was distributed to them. Participants were informed about the survey and privacy of their data will be secured.

4. Data Collection & Extraction

A questionnaire survey was developed in both paper-based and electronic format (Using Google forms). The responses were later exported to an excel spreadsheet for the further analysis.

A total 69 foreign drivers from the 20 different nationalities participated in the survey. Table 1. shows the participants nationality and their frequency in descending order.

Table 1 Nationality-wise categorization

No	Nationality	Frequency
1	Pakistani	17
2	American	15
3	British	8
4	Canadian	6
5	Indian	4
6	French	2
7	Filipino	2
8	Malaysian	2
9	Zimbabwean	2
10	Chinese	1
11	Japanese	1
12	Saudi Arabian	1
13	Jordanian	1
14	Tunisian	1
15	Turkish	1
16	Russian	1
17	Mongolian	1
18	German	1
19	Irish	1
20	Nepalese	1
Total		69

Figure 4 shows the participants proportions according to their gender.

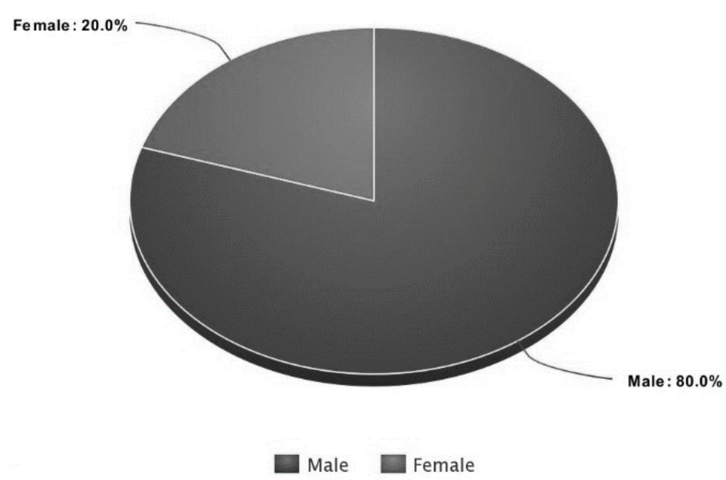


Figure 4 Gender wise participants

South Korea has two types of driving license; the level 1 (Large Vehicles) and level 2 (Small Vehicles). In this study we also collected information regarding the license type of the drivers. Temporary license and other licenses category is also considered in order to include the drivers having temporary or other (International Driving license). Figure 5 shows the proportions of respondents having different types driving licenses.

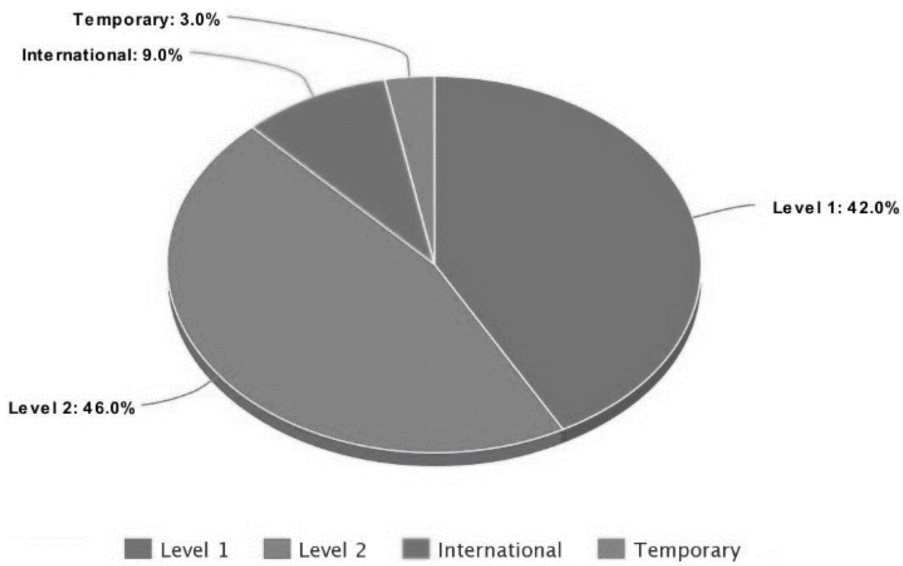


Figure 5 Driving license wise participants

5. Results & Analysis

Result are divided into two parts, i.e. level of comprehension of traffic signs and level of comprehension of traffic signal display conditions All the collected responses were later extracted to a Microsoft (MS) excel spreadsheet for the further analysis.

Twelve different signs were presented in questionnaire form. The signs were divided in 5 different categories as shown in table 1.

Table 2 Comprehension of traffic signs

Rank	Category	Meaning	Correct responses (%)	Average
1	Korean & English text	Stop	94.40	94.40
		Slow	90.10	
		Yield	98.60	
2	Symbolic	Children crossing	87.10	94.30
		Ped & bicycle only	100.00	
		Road works	95.80	
3	Symbolic & Korean text	Unprotected left turn	80.90	81.30
		One way	81.70	
4	Numeric	Maximum speed	88.70	76.50
		Minimum speed	64.30	
5	Korean only text	No entrance	74.60	66.18
		No stop & parking	57.70	

Most of the respondents correctly interpreted the meaning of text-based signs having both Korean and English text (94.40%) followed by the symbolic signs (94.30%). In the symbolic signs, pedestrian & bicycle only sign was interpreted correctly by 100% of the respondents.

Traffic signs with Korean text and Symbol together was understood by 81.30%. However, in the comprehension of numeric signs, (76.50%) a difference can be seen between maximum & minimum speed signs. Maximum speed sign had high comprehension (88.70%) than minimum speed sign (64.30%). Text-based signs having only Korean text found to have a low comprehension level about 66.20%.

In the second part of the questionnaire respondents were requested to respond three different traffic signal display conditions as shown in figure. For the yellow and red signal states respondents were asked to write the answer. The results are presented in table 3.

Table 3 comprehension of traffic signal display

ID	Direction	Correct (%)
1	Left turn only	73.20
2	Left turn & Through	90.00
3	Yellow & Red	50.00

The above results show that, all foreign drivers had very low understanding of the display condition in which red and yellow shown on same signal face. About 90% respondents correctly figured out meaning of left turn & go through signal light. The green arrow with red signal (for Exclusive left turn signal) was comprehended by 76.20% foreign drivers.

Conclusion

Highway safety is regard as national agenda of South Korea. Given the fact that international travelers and residents are mostly neglected in road safety consideration.

Since there is shortage of research studies conducted in highway safety of foreign drivers this study provides some useful insights. In this study, questionnaire survey was conducted from the foreign nationals having Korean driving license to find their comprehension level of Korean traffic control devices.

When tested about comprehension of traffic control devices, foreign drivers performed better in traffic signs having both Korean and English text (94.40%) followed by the symbolic signs (94.30%). Comprehension of traffic signs with Korean text and symbol ranked 3rd with 81.30%. Numeric traffic signs ranked 4th with 76.50% comprehension level. The results show a difference (about 24%) in comprehension within numeric signs.

The comprehension level of traffic signs having Korean only text was lowest among all 5 categories. This could be due to the lack of Korean language proficiency among foreign drivers.

Meaning of three different signal indications were also tested in this study as defined in results section. All the foreign drivers had a very low understanding about the signal state having red & yellow indicated on same signal face. Only about 50% foreign drivers interpreted correctly. The green arrow for making left turns with through yielded better understanding (90%) compared to other. The green arrow with red signal (for Exclusive left turn signal) was comprehended by 76.20% foreign drivers.

From the results of study, it was evident that, some of the traffic signs, even if they are number based are not easy to be interpreted by a foreign driver. For example, the “Minimum speed sign’ was interpreted as maximum speed by many foreign drivers. Further research studies are required on how certain traffic signs could be improved. In addition to that, standardization of traffic signs would be very helpful not only for the foreign drivers but also throughout the Korea.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Codes Comparison for the Seismic Response of SMRF: A Case Study Of Quetta Balochistan

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Abstract

Seismic provisions of Building Code of Pakistan (BCP 2007) are adopted from Uniform Building Code (UBC 97), although the seismic provisions of other codes like Euro code 8 are more prominent and applicable as per the local conditions of Pakistan. Euro code 8 is applicable for all EU member countries and is very general design code for structures. Additionally, EU regional tectonic plate has more similarity with the Pakistan region. For this purpose the authors have worked on the comparison of seismic provisions of BCP 2007 with that of Euro code 8. This study considers the seismic responses of Special Moment Resisting Frames (SMRFs) under the code compatible ground motions for Quetta city. A 2D frame is analyzed under code compatible ground motions in addition to gravity loading. The ground motions are generated synthetically compatible with UBC 97 and Euro code 8. The comparisons of structural responses based on Euro code 8 and UBC 97 indicate that Euro code 8 gives greater structural responses as compared to UBC 97. As the design for greater structural responses increases the degree of safety for the building against external loading, therefore, Euro code 8 is more satisfactory for the dynamic responses, as compared to UBC 97.

Keywords
Codes comparison, Special moment resisting frame (SMRF), Seismic response, Synthetic ground motions.

1. Introduction

Moment Resisting Frames (MRFs) are widely used frames for resisting moment through rigid joint action. The types of MRFs depends upon the ductility detailing provided to them. Special Moment Resisting Frame (SMRF) is a kind of moment resisting frame provided with larger ductility detailing. SMRFs are used to overcome the intense inelastic deformations caused by lateral forces. They can resist inter-story drift angle up to 0.04 radians. They are used in regions with seismic activity of mid-to-high range (Whirlwind, 2015).
Concrete SMRFs were introduced in the U.S. starting around 1960 (Blume, Newmark et al. 1961) and were officially used after the Uniform Building Code (ICBO, 1973) adopted it. Many research studies have been conducted for the develoment of special moment conrete frames like, Babak Alavi and Krawinker (2004) studied near-ground motion effects on concrete frames, Siva Prasad et al. (2013) conducted a comparative study for SMRFs and OMRFs and Curt B. Haselton et al. (2007) studied the

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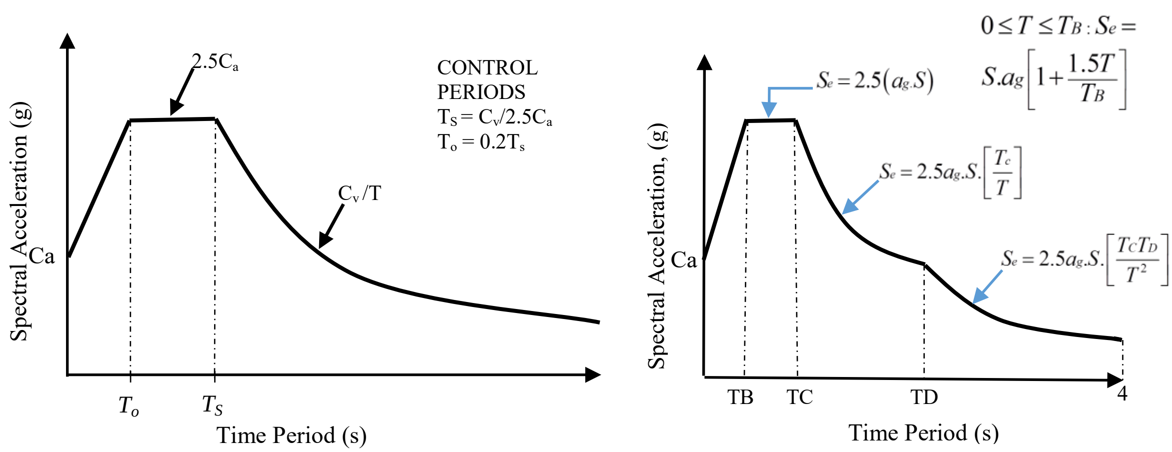
modern SMRFs and provide safety techniques for extreme earthquakes. Many other papers have been written on special moment frames but the earliest design requirements for concrete SMRFs are almost similar to those which are adopted today.
This research work presents the comparison of structural responses for seismic loading based on UBC 97 and Euro code 8 for Quetta city. Seismic ground motions have been generated synthetically and applied as multi-support excitations. The comparisons of structural responses based on Euro Code 8 and UBC 97 are presented and the compatible code is discussed.

2. Ground Motions

Synthetic Ground Motions (SGM) are generated, based on Euro code 8 and UBC 97. The horizontal component of the ground motions is more dominant in most of the cases, therefore, only horizontal spectra, for both the codes, are generated by the following procedure.
First design spectra are obtained for horizontal components by applying the input parameters according to Quetta region in the equations provided by Euro code 8 (Euro Code, 2005) and UBC 97 (UBC, 1997). These input parameters are dependent on the soil properties, tectonic details, seismic zones and seismic source types. The design spectra for horizontal component based on UBC 97 and Euro code 8 are shown in Fig 1.



(a) (b)

Figure 1: Design spectrum based on (a) UBC 97 (b) Euro code 8

The comparison of design spectrum and response spectrum and corresponding synthetic ground motion histories based on Euro Code 8 and UBC 97 are shown in Fig. 2. The design spectrum and response spectrum closely agree for both the codes. The comparison of spectra and the corresponding synthetic ground motion histories were obtained through the SeismoArtif tool.

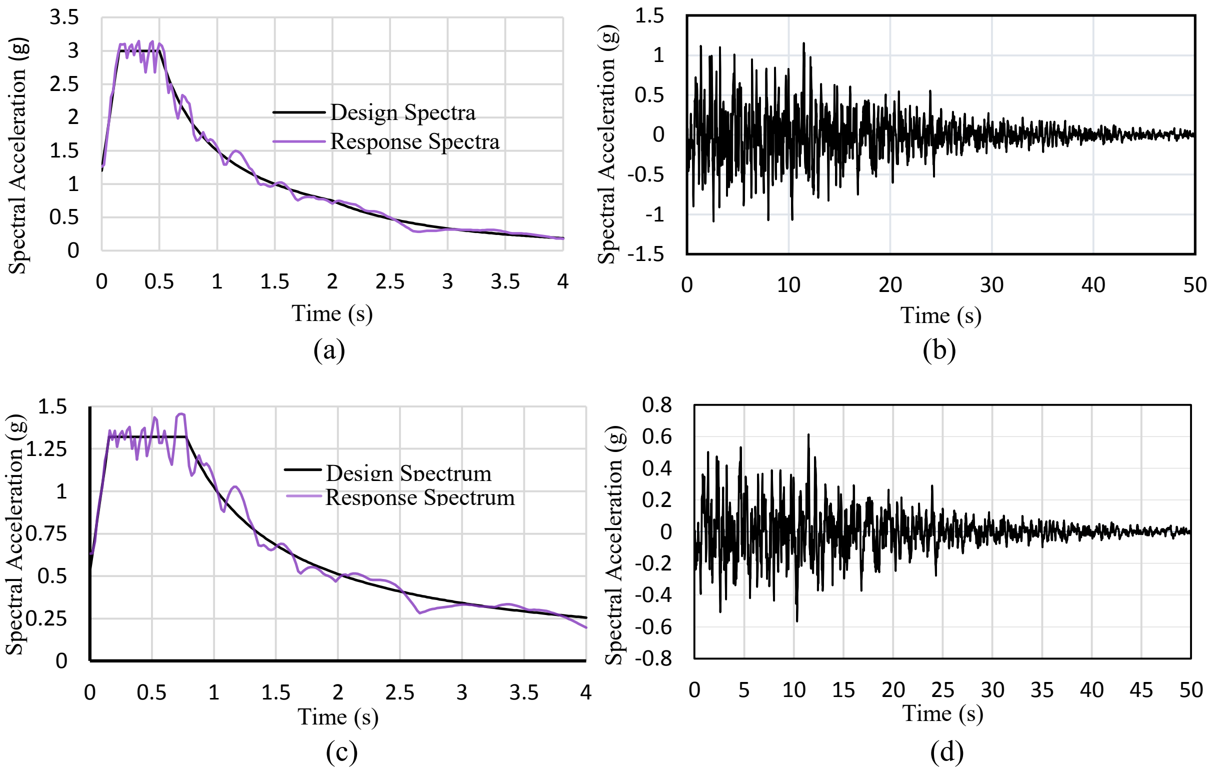
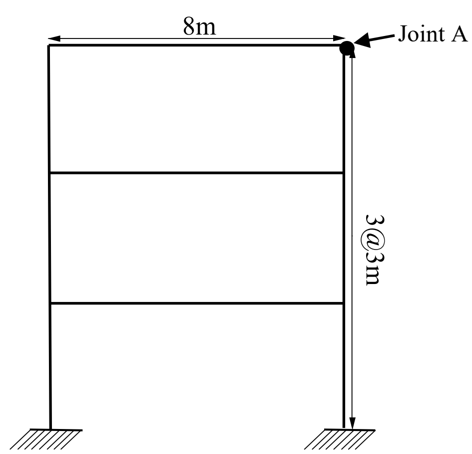


Figure 2: Comparison of design spectrum and response spectrum and corresponding synthetic ground motion history (a) Comparison of design and response spectrum based on Euro Code 8 (b) Time history of the synthetic ground motions based on Euro Code 8 (c) Comparison of design and response spectrum based UBC 97 (d) Time history of the synthetic ground motions based on UBC 97.

3. Finite Element Model

The 2D frame is modelled using the finite element commercial software Sap-2000. The frame was modeled with 9 beam elements. The 2D frame used for numerical simulations is shown in Fig.3, and the section properties and material properties are given in Table 1.



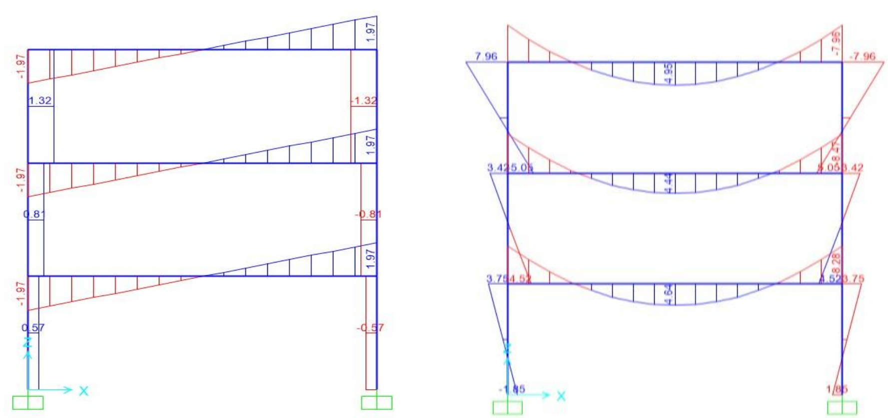
` **Figure: 3 2D frame**

Table 1: Input parameters for Beams and Columns

	Parameter	Value
Section Properties	Cross section	12” × 12”
	Moment of inertia	1728 in^4
	Shear area	120 in^2
	Torsional constant	2920.32
	Section modulus	288
	Plastic modulus	432
	Radius of Gyration	3.46
Material Properties	Modulus of Elasticity of Concrete	3122 ksi
	Modulus of Elasticity of Steel	29000 ksi
	Compressive Strength of Concrete	3 ksi
	Yielding Strength of Steel	60 ksi

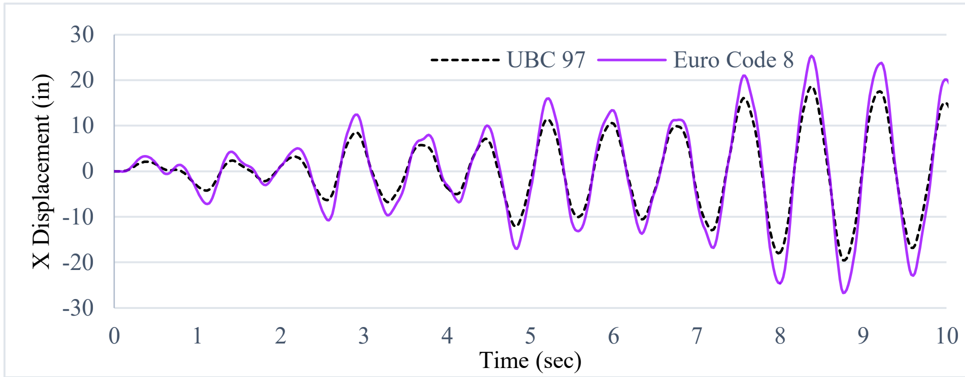
4. Results and Discussions

The frame (Fig. 3) is analyzed under gravity loading as shown in Fig. 4, and the ground motions are applied at the base of frame as multi-support seismic excitations. The gravity loads consist of only dead loads while for the dynamic loading, ground motions are applied as support excitations. The horizontal components of the ground motions, based on UBC 97 and Euro code 8, are applied in the horizontal longitudinal direction (X direction). The linear dynamic analysis of the frame is performed by integrating the equations of motions using Newmark’s β-method, through Sap-2000.
The response time histories based on UBC 97 and Euro code 8 are compared to check the competency of these codes. Figs 7 & 8, show the x displacement, shear force and bending moment time histories comparison at point A, based on UBC 97 and Euro code 8, respectively. Euro code 8 gives larger response s as compared to UBC 97 for all the cases.

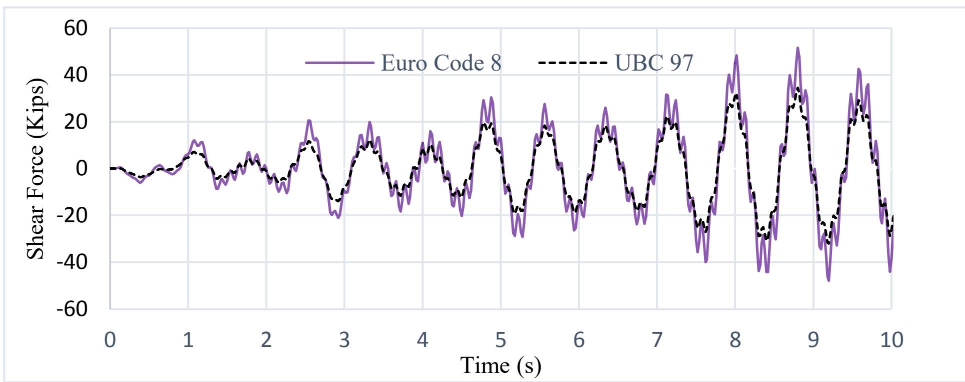


(a) (b)

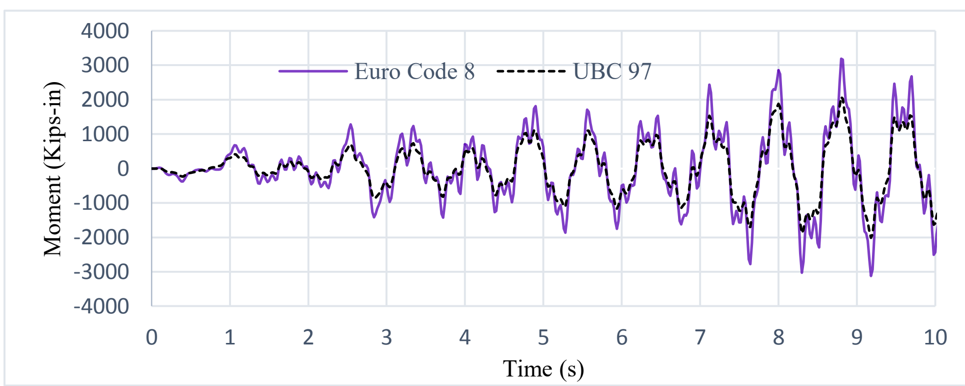
Figure 4: Structural responses against gravity loads (a) Shear force (b) Bending moment



(a)



(b)



(c)

Figure 5: Structural responses based on Euro code 8 and UBC 97 (a) Shear force (b) X displacement (c) Bending moment

The comparative study of static analysis and dynamic analysis at joint A as shown in Fig.6, indicates that the static analysis give very small structural responses as compared to dynamic analysis. Ratio of the displacements for applied static and dynamic loads is almost 1:40237.6 which is a huge difference. If a structure, lying in seismically more or less hazardous region, is designed only for static loads, the structure may fail. The most effective structural response in this study is the displacement. The maximum

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structural response comparison between Euro Code 8 and UBC 97 are shown in Fig. 7. Euro code 8 gives larger structural responses as compared to UBC 97, because Euro code 8 is relatively more focused on the geological properties of ground and the rector scale magnitude of earthquake.

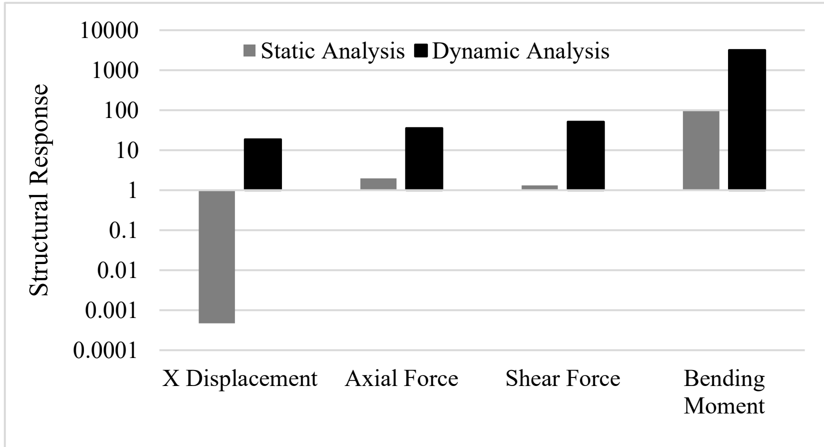

Figure 6: Comparison of structural responses between static analysis and dynamic analysis

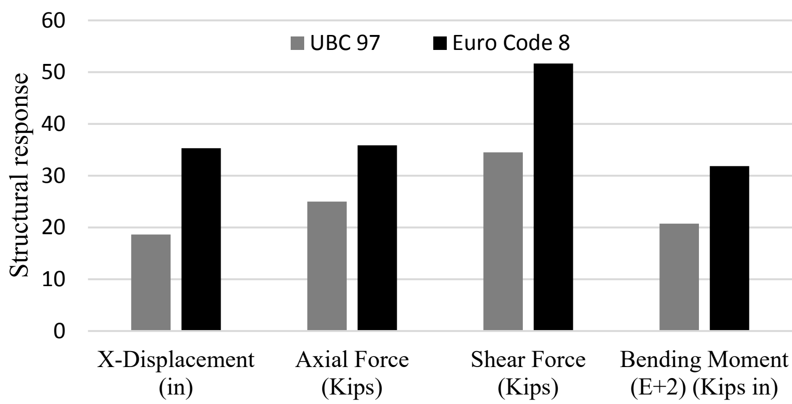

Figure 7: Comparison of maximum structural responses for horizontal ground motions based on UBC 97 and Euro code 8

5. Conclusions

The special moment resisting frame (SMRF) is modelled using finite element method. Static analysis is performed under gravity loads, while dynamic analysis is performed using synthetic ground motions. The ground motions are generated synthetically compatible with Euro code 8 and uniform building code 1997 for Quetta city. The dynamic time history analysis is performed and the equations of motions are integrated using Newmark's β-method, through the commercial FEM software Sap-2000.
Comparative studies are conducted for static and dynamic structural responses; and comparison of the structural responses based on Euro code 8 and UBC 97. The dynamic analysis gives greater displacements and internal forces as compared to static analysis. Similarly, the code compatibility of Euro code 8 is higher than that of uniform building code 1997 for Quetta region because the Euro code 8 gives greater values for structural responses.

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10th International International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Seismic Performance Analysis Of An Irregular Existing Building Using The Future Seismic Code RPA 2018 And Non Linear Dynamic Analysis

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Abstract
After the El Asnam earthquake which struck Algeria in 1980, the first national Algerian Seismic Code for new buildings was adopted in 1981 and called RPA 1981. These regulations were the primary source of seismic design requirements for new buildings throughout the nation. The goal of these regulations is to assure that seismic performance will avoid serious injury and loss of life, loss of function in critical facilities and minimize structural and nonstructural repair costs. Since the creation of the National Earthquake Engineering Research Center (CGS) in 1985, a national earthquake hazard reduction program has been sponsored by the governmental authorities and the Algerian seismic regulations have known five developments and improvements (1981, 1983, 1988, 1999 and 2003).
Because reinforced concrete is the most common building material in Algeria, this paper will deal with the main provisions of the new proposed code RPA 2018 which is in line with the current generation of seismic codes. A comparative study of an irregular strategic existing RC building is performed. Demand and capacity are compared in terms of base shear forces. A nonlinear dynamic analysis is performed to also compare the story displacements. Finally, the paper concludes with a discussion of the specific results.

Keywords
Base shear force, Inter story displacements, Seismic demand, Seismic capacity, Non linear dynamic analysis.

1. Introduction

The northern region of Algeria lies in an active seismic zone (Messaoudi et al.,). Consequently, all structures must designed to resist the earthquakes likely to occur in the future. Many colonial nonconforming existing buildings are still in use, and some are considered as existing strategic buildings (Mehani et al., 2013; Kibboua et al., 2011; Kibboua, 2012; Kibboua et al., 2017). Because of the importance of changes in the new seismic code version, it is opportune to make a comparative study of a strategic existing RC building according to the new proposed seismic code RPA 2018 (CGS, 2018) which will be edited in the near future (Belazougui, 2017), and a nonlinear time history analysis. This paper is aimed to compare some of the seismic design provisions in terms of shear base forces and inter story displacements.

2. Design Base Shear Force

The horizontal seismic action is described by two orthogonal components considered as independent and represented by the same response spectrum. According to the new proposed RPA 2018 the seismic base shear forces obtained by the equivalent static analysis method is given by Eq. (1).

$$V = 0.7\frac{AISDQ}{R}W \tag{1}$$

Where:
- V: seismic base shear force.
- A: peak ground acceleration estimated at the bedrock for the reference return period of 475 years, expressed as a fraction of the gravity $g = 9.81\ m/s^2$, and to be adopted in the different seismic zones.
- I: importance factor. Buildings are classified in four importance classes according to their functions.
- S: soil amplification factor independent of the vibration period.
- D: f (T), mean dynamic amplification factor, function of the fundamental period, taking into account viscous damping ratio and damping correction factor.
- Q: quality factor depending on structural simplicity, uniformity, symmetry and redundancy.
- R: global behavior factor to take into account energy dissipation capacity.
- W: total seismic weight.
- T: fundamental natural period.

2.1 Vertical distribution of base shear force

The total base shear force distribution is linear to each story in proportion to the story mass with its height from the base. The seismic horizontal force is given by Eq. (2).

$$F_k = \frac{(V - F_t)\,W_k\,h_k}{\sum_{i=1}^{i=n} W_i\,h_i} \tag{2}$$

Where:
F_k: seismic horizontal force at the K_{ith} level.
F_t: for long period buildings greater than 0.7 sec, an extra force is applied to the top in addition to F_n equal to 0.07 TV and not exceed 0.25 V. Otherwise it is assumed to be zero.
W_k: seismic weight at level k.
h_k: height of level k from the base.

2.2 Design spectrum for elastic analysis

To avoid explicit inelastic structural analysis in design, nonlinear behavior of structural elements is taken into account by performing an elastic analysis based on a response spectrum reduced with respect to the elastic one. This reduction is accomplished by introducing the behavior factor R which permits a design for forces smaller than those corresponding to a linear elastic response.
According to new proposed seismic code RPA 2018, the horizontal components of the seismic action, the design spectrum Sa/g (T), is defined by the following Eq. (3).

$$\frac{S_{ad}}{g} = \begin{cases} AIS\left(\frac{2}{3} + \frac{T}{T_1}\left(\frac{2.5\eta Q}{R} - \frac{2}{3}\right)\right) & 0 < T \leq T_1 \\ \frac{2.5\eta AISQ}{R} & T_1 < T \leq T_2 \\ \frac{2.5\eta AISQ}{R}\left(\frac{T_2}{T}\right) & T_2 < T \leq T_3 \\ \frac{2.5\eta AISQ}{R}\left(\frac{T_2 T_3}{T^2}\right) & T_3 < T \leq 4s \\ \text{With } \frac{S_{ad}}{g} \geq 0.2AI & \end{cases} \tag{3}$$

Where:
T_1, T_2 and T_3: limit periods for each ground type.

3. Non Linear Dynamic Analysis

To emphasis our study, a nonlinear dynamic analysis has been performed. The nonlinear dynamic analysis is used to compute deformations, stresses and section forces more accurately by considering the time dependent nature of the dynamic response to earthquake ground motion. It is also conducted to avoid many limitations of simplified response methods. The overall objective is to develop a set of time histories that are representative of site ground motions that may be expected for the design earthquake and that are appropriate for the types of analyses planned for specific structures. According to the new concept in the Algerian seismic code, during major earthquakes, structures are allowed to undergo deformations beyond the elastic limit state to absorb deformation energy (Chowdhury and Dasgupta, 2009). A nonlinear dynamic time history analysis using step by step integration method is a very useful tool to determine the most appropriate realistic response of elements, and hence the performance of the whole structure. Dynamic response analysis of structures represents a numerical computation of structural systems with defined characteristics of masses, stiffness, damping, etc, and defined ranges of elastic (linear) and plastic (non linear) behavior expressed via displacements, velocities, accelerations and forces (Chopra, 2001). The most general approach for solving the nonlinear dynamic response of structural system is the direct numerical integration of the dynamic equilibrium equations. This involves the attempt to satisfy dynamic equilibrium at discrete equal time intervals after the solution has been defined at time zero (Chowdhury and Dasgupta, 2009). The solution of the nonlinear dynamic equilibrium equations is carried out in incremental form using the following Eq. (4).

$$[M]\{\Delta\ddot{U}\} + [C]\{\Delta\dot{U}\} + [K]\{\Delta U\} = -[M]\{I\}\ddot{U}_g \tag{4}$$

Where:
$[M]$: Mass matrix.
$[C]$: damping matrix.
$[K]$: Stiffness matrix.
$\{\Delta\ddot{U}\}$: Incremental acceleration vector.
$\{\Delta\dot{U}\}$: Incremental velocity vector.
$\{\Delta U\}$: Incremental displacement vector.
$\ddot{U}_g$: Ground acceleration.

To determine the non-linear response of the structure, the D.R.A.B.S (Bozinovski and Gavrilovic, 1993) program is used and the bilinear model is adopted. The figure (1) represents the relationship force-displacement (F-δ).

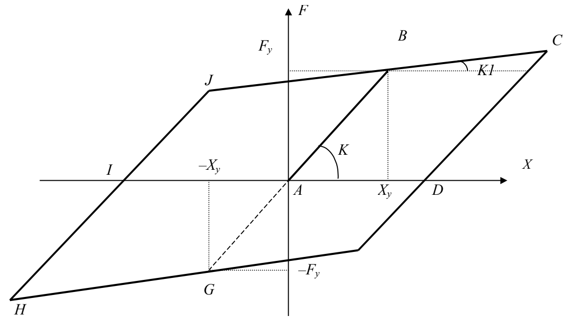

Figure 1: Bilinear model

Where:

$K_1 = (F_u\text{-}F_y)/(X_u\text{-}X_y)$ and $L_p = K_2/K = \alpha K/K$

Three real ground motion records are used in the nonlinear dynamic analysis taking into account the soil conditions, frequency content and the aspect of near field and far field.

- Ulcinj (Albatros, Montenegro) N-S 1979.
- El Centro (California, USA) N-S May 8th, 1940.
- Cherchell (Algeria) N-S October 29th, 1989.

The figure (2) shows the selected recorded earthquakes.

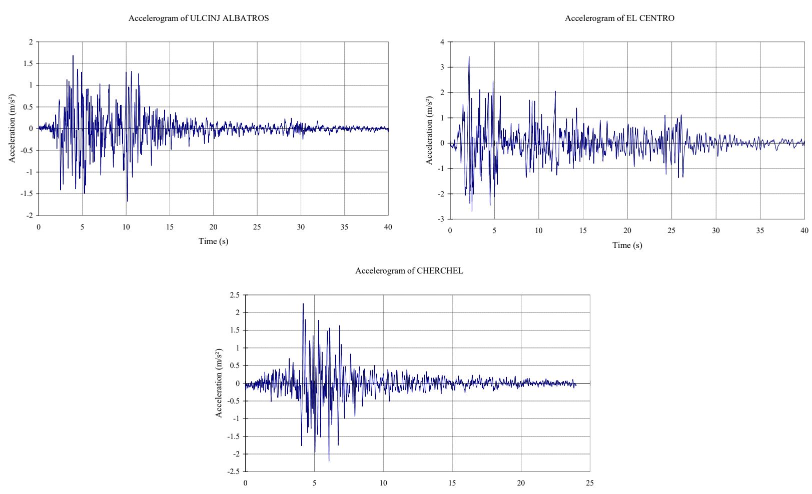

Figure 2: Selected earthquake accelerograms

4. Limit State

There are numerous limit states that can be considered in seismic vulnerability studies. In the traditional approaches, two limit states are considered. The elastic and the ultimate limit states (Bozinovski and Gavrilovic, 1993). The first is defined in terms of strength and calculated using the building material properties, whereas the second is estimated in terms of displacements using a given ductility factor, eventually converted to forces using a reduction factor (Wagh *et al.*, 2016). More recent approaches consider multi-linear behavior relationships for the elements and define different damage states as break points in the behavior curves either in displacement or rotation (drift). The structural performance level considered for the system assessment carried out in the present study is for a major earthquake (475 years return period). The limit inter story displacement for major earthquake is given by the following equation (IZIIS and CGS, 1993).

$$\Delta_M = \left\lfloor \frac{H}{150} \& \frac{H}{125} \right\rfloor \quad (5)$$

5. Case study

To better show the differences between the analysis with the new proposed seismic code RPA 2018 and the nonlinear time history analyses, a comparative study has been performed considering a strategic existing reinforced concrete building.

5.1 Mechanical characteristics of the materials

Mechanical material characteristics were defined using a range of in-situ and laboratory testing and inspection techniques to obtain the necessary information.

Concrete

- Characteristic compressive cylinder strength at 28 days: f_{c28} = 20 Mpa
- Design tensile strength: σ_t = 1.8 Mpa
- Yield strain: ε_e = 0.002
- Ultimate strain: ε_u = 0.0035

Steel

- Characteristic tensile yield strength of reinforcement: f_e = 400 Mpa
- Characteristic tensile strength of shear reinforcement: f_t = 235 Mpa
- Yield strain of reinforcement: ε_y = 0.002
- Yield strain of shear reinforcement: ε_e = 0.0018
- Ultimate strain: ε_u = 0.010

5.2 Description of the building

The analyzed building is the general surgery building belonging to the Beni Messous University Hospital Complex, located in the Wilaya of Algiers and set up on a medium soil or ground type (S3). It was built in the fifties. Our focus will be on the Bloc 02 of the building. It is a four (04) story irregular existing reinforced concrete and a basement. The partition and exterior enveloping walls are made of hollow clay bricks. The structural system is a reinforced concrete resisting moment frames, which consists of reinforced concrete columns and beams. Floors are in reinforced concrete slabs. The figures 3 and 4 show the different drawing in plans of the irregular existing building.

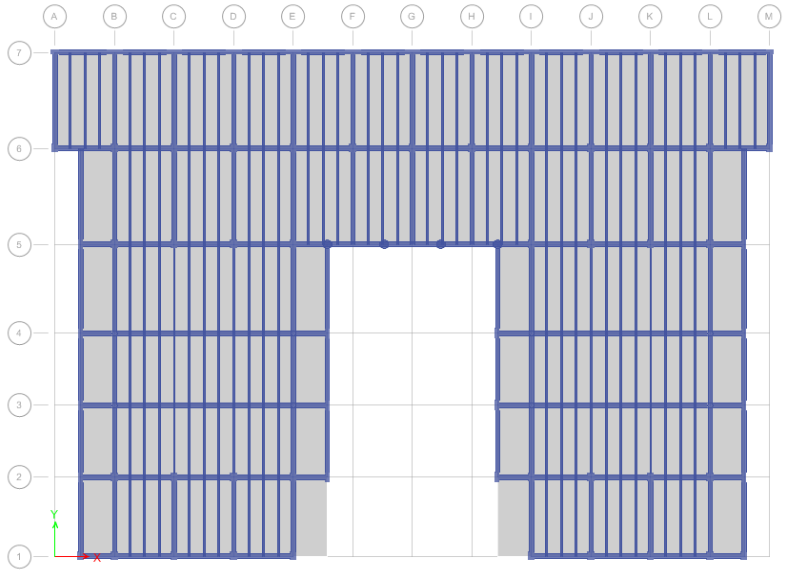

Figure 3: Plan view of the first floor

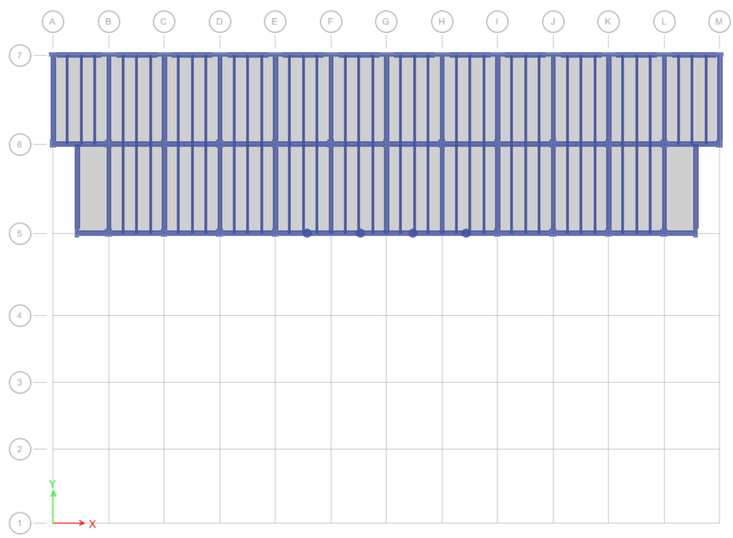

Figure 4: Plan view of current floors (2nd, 3rd and 4th)

5.3 Structural analysis

Considerable advances in computer technology and availability of increased computational resources brought more detailed approach for modeling reinforced concrete structures using finite elements. For this purpose and based on existing drawings and the site inspection, the structure was modeled in 3D space frames with rigid diaphragms and a fixed base, using the nonlinear computer program (Wilson and Habibullah, 2015). The figure 5 shows the structural system in plan and three dimensional view of the existing structure.

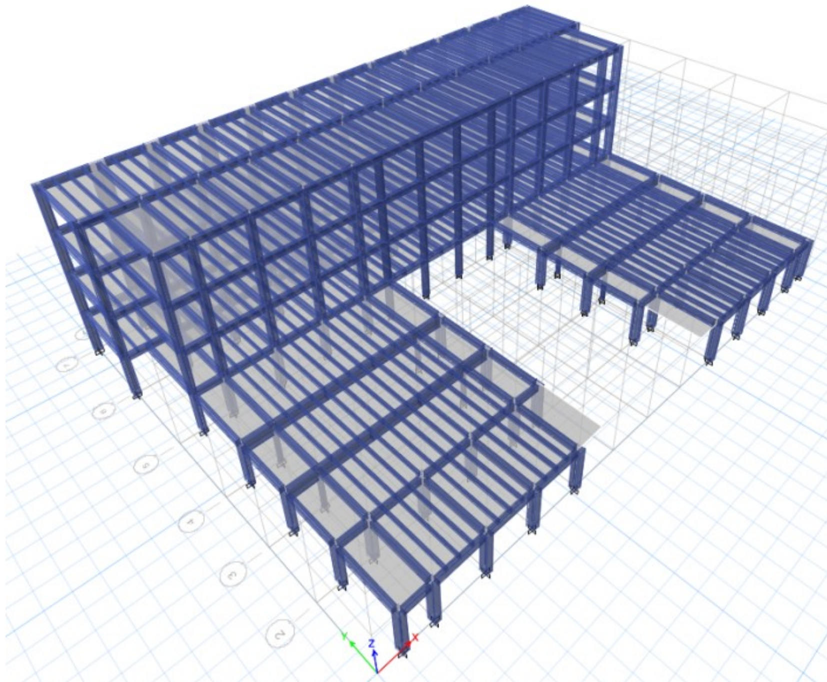

Figure 5: 3D Model of the structure

6. Seismic assessment by the new code RPA 2018

The main change is the upgrade of the Wilayates from a low (IIa) to a high (III) seismicity zone. Consequently, the peak ground acceleration becomes higher. Table (1) shows the different seismic parameters taken into account for this study.

Table 1: Seismic parameters

Seismic parameters	RPA 2018
Zone	III
Group	1A
A (%g)	0.35
I	1.40
S	1.20
ξ	7
η	0.88
T(s)	0.49
D	2.20
Q	1.20
R	3.5
T_1(s)	0.20
T_2(s)	0.60
T_3(s)	2.00

Table (2) shows the seismic demand in terms of shear forces for both main directions according to the new proposed seismic code RPA 2018.

Table 2: Demand and capacity in terms of shear forces for RPA-2018

Level	RPA 2018					
	F_{xi} (KN)	V_{xi} (KN)	Q_{uxi} (KN)	F_{yi} (KN)	V_{yi} (KN)	Q_{uyi} (KN)
4	3056.381	3056.381	5525.133	3056.381	3056.381	4052.291
3	2342.544	5398.925	5861.935	2342.544	5398.925	4096.414
2	1561.696	6960.621	6112.881	1561.696	6960.621	4314.732
1	1785.723	8746.344	8283.338	1785.723	8746.344	7995.744

Figures (6) and (7) show the capacity and the demand in terms of shear forces in main longitudinal (XX) and transversal (YY) directions according to the current RPA99/version 2003 [16] and the future RPA 2018.

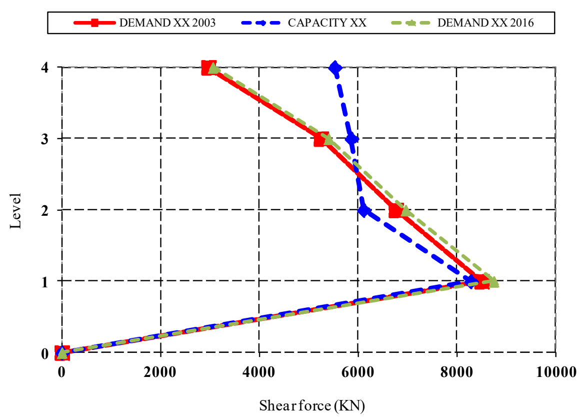

Figure 6: Capacity and demand in terms of shear forces in longitudinal (XX) direction

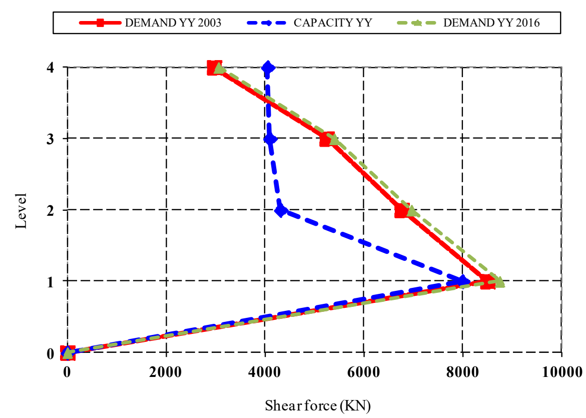

Figure 7: Capacity and demand in terms of shear forces in transverse (YY) direction

Tables (3) and (4) resume the main results in terms of inter story displacements in main longitudinal (XX) and transverse (YY) directions.

Table 3: Capacity and demands in terms of inter story displacements (cm) in the longitudinal direction (XX)

Level	Earthquake	Δ_x (cm)	Δ_{xcap} (cm)	1.5% h_i (cm)	Δ_{xmeth} (cm)
4	Ulcinj	0.87	3.63	4.80	2.32
	El Centro	0.78			
	Cherchell	0.84			
3	Ulcinj	2.49	3.22	4.80	2.32
	El Centro	2.20			
	Cherchell	1.70			
2	Ulcinj	3.97	2.74	4.80	2.32
	El Centro	3.37			
	Cherchell	2.32			
1	Ulcinj	4.13	**2.28**	4.80	2.32
	El Centro	3.17			
	Cherchell	2.08			

Table 4: Capacity and demands in terms of inter story displacements (cm) in the transverse direction (YY)

Level	Earthquake	Δ_y (cm)	Δ_{ycap} (cm)	1.5% h_i (cm)	Δ_{ymeth} (cm)
	Ulcinj	1.50			
4	El Centro	1.28	5.46	4.80	**2.32**
	Cherchell	1.35			
	Ulcinj	4.53			
3	El Centro	3.58	4.23	4.80	**2.32**
	Cherchell	3.26			
	Ulcinj	5.82			
2	El Centro	4.69	2.63	4.80	**2.32**
	Cherchell	3.92			
	Ulcinj	2.92			
1	El Centro	2.23	**2.27**	4.80	2.32
	Cherchell	1.63			

Figures (8) and (9) show the capacity and the demand in terms of inter story displacements in main longitudinal (XX) and transverse (YY) directions, obtained through the nonlinear time history analysis for a major earthquake.

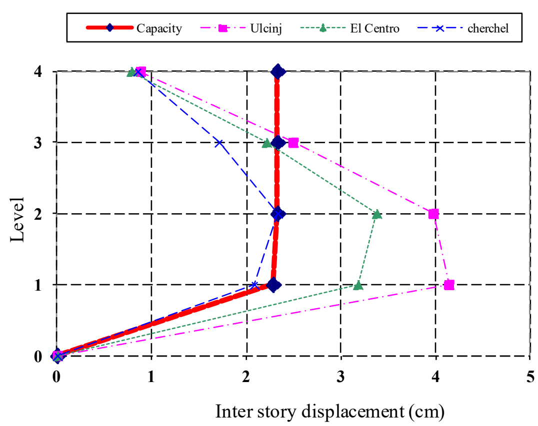

Figure 8: Capacity and demand in terms of inter story displacements in longitudinal direction (XX)

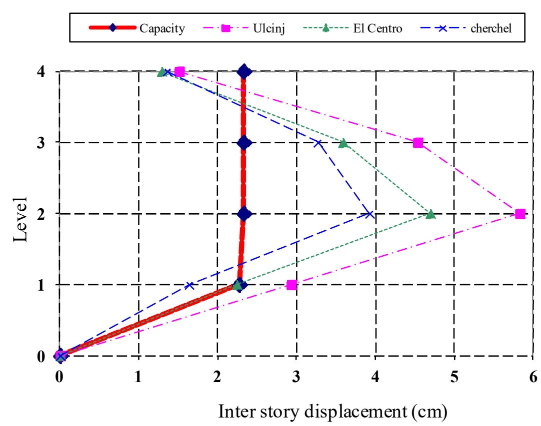

Figure 9: Capacity and demand in terms of inter story displacements in transverse direction (YY)

Figures (10) and (11) show the capacity and the demand in terms of absolute displacements in main longitudinal (XX) and transverse (YY) directions, obtained through the nonlinear time history analysis for a major earthquake.

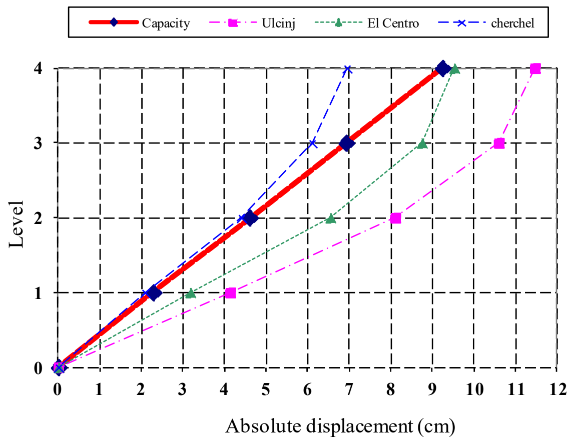

Figure 10: Capacity and demand in terms of absolute displacements in longitudinal direction (XX)

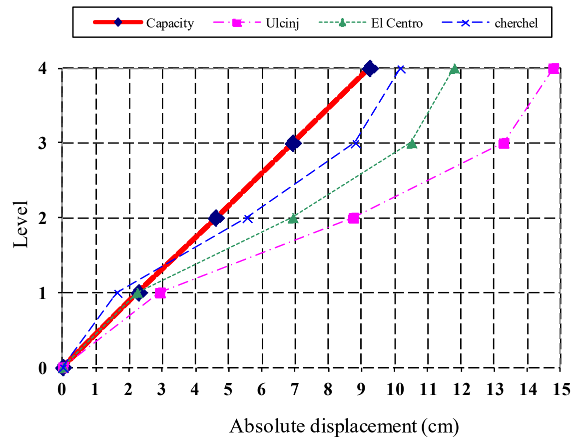

Figure 11: Capacity and demand in terms of of absolute displacements in transverse direction (YY)

7. Conclusion

This comparative study has concluded the following:

1. Considerable differences in parameters on determining shear forces in the new code.
2. Considerable differences are pronounced in design response spectrum and spectral accelerations which leads to major differences in the assessment of base shear forces.
3. Base shear force with version 2018 > 2.89% than base shear force with the version 2003.
4. Inter story displacements demand exceed capacity at all levels in both main directions in case of a strong earthquake motion.
5. Absolute displacements under considered earthquake motions exceed considerably the expansion gap of 05 cm between blocs in the two main directions in case of a strong earthquake motion.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Dynamic Response Analysis of Submerged Floating Tunnel under Waves and Earthquakes

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Abstract

Submerged floating tunnel (SFT) is a new solution for the transportation infrastructure through sea straits, fjords, and inland waters and is a good alternative to long-span cable-supported bridges, immersed tunnels or underground tunnels. SFT is a massive cylindrical structure that floats at a certain depth below the water surface and subjected to extreme environmental conditions. The identification of dominant structural response of SFT becomes more important due to intended environmental conditions for the design of SFT. The time domain dynamic problem of SFT moored by vertical and inclined mooring cables/anchors is formulated. The dynamic analysis of SFT subjected to hydrodynamic and seismic excitations is performed. The SFT is modeled by finite element 3D beams and the mooring cables are modeled by truss elements. Based on the dynamic analysis, the displacements and internal forces of SFT were calculated. The transverse internal forces of SFT were the maximum compared to the vertical direction, for both hydrodynamic and seismic cases; this indicates that the cable system provides very small stiffness in the transverse direction as compared to the vertical direction of SFT.

Keywords
Submerged floating tunnel, hydrodynamic analysis, Seismic responses, Design responses

1. Introduction

Submerged floating tunnel (SFT) is a novel structural solution for waterway crossings. It floats at a specified depth and is anchored by mooring cables. SFT is subjected to sea waves, currents, tsunamis and earthquakes. The SFT is supposed to be a good alternative for waterway crossing as compared to long span suspension bridges and immersed tunnels especially for deep and wide crossings because the cost of SFT per unit length remains almost constant by increasing length (Ahrens 1997, Faggiano, Landolfo et al. 2005). SFT is supported by the mooring cables, the balance between the net positive buoyancy (Residual buoyancy) and the pre-tension in the mooring cables maintains the structural stability of SFT; and it is the main source to provide restoring capacity to SFT.
The research efforts for development of the SFT solution began in 1923 from Norway. Since then, many case studies and proposals have been made for different proposed projects, such as Hogsfjord in Norway (Skorpa 1989), Funka Bay in Japan (Maeda, Morikawa et al. 1994, Lu, Ge et al. 2011), Messina Strait in Italy (Bruschi, Giardinieri et al. 1990, Faggiano, Landolfo et al. 2001), Qindao Lake in China (Mazzolani, Landolfo et al. 2008, Muhammad, Ullah et al. 2017, Muhammad 2018), and Mokpo-Jejo SFT in South Korea (Han, Won et al. 2016).

Most of the SFT models developed so for, consider the dynamic response of SFT subjected hydrodynamic waves and seismic loadings (Fogazzi and Perotti 2000, Di Pilato, Feriani et al. 2008, Di Pilato, Perotti et al. 2008, Lee, Seo et al. 2016). A comparison of the structural response for hydrodynamic and seismic loadings to determine the dominant structural response for the design of SFT is thus very important for this new structural solution.
This study presents the response comparison of the submerged floating tunnel for hydrodynamic and seismic loading. The dynamic problem of SFT is solved considering the modeling of cables, SFT tunnel, hydrodynamic waves and currents and seismic loadings. The comparison for displacements and internal forces are presented, and the dominant structural responses have been discussed..

2. Waves and Currents Modeling

The ocean waves and currents are modeled by Airy wave theory, and the wave forces are calculated from the modified Morison's equation, which is given as (Chakrabarti 1987, Muhammad, Ullah et al. 2017):

$$\left\{ f(q,t)\right\} = \frac{1}{2} C_D \rho_w D \left\{ \left| \dot{v}_{\perp} \pm U - \dot{q}_{\perp} \right| \left(\dot{v}_{\perp} \pm U - \dot{q}_{\perp} \right) \right\} + C_M \rho_w \frac{\pi D^2}{4} \left\{ \ddot{v}_{\perp} \right\} - C_A \rho_w \frac{\pi D^2}{4} \left\{ \ddot{q}_{\perp} \right\} \qquad (1)$$

where subscript $\perp$ denotes the perpendicular components with respect to element axis. ρ_w is the density of water, D is the external diameter of SFT, C_D is the drag coefficient, C_M is the inertia coefficient, $C_A = C_M - 1$ is the added mass coefficient, $\dot{v}$ and $\ddot{v}$ are water particle velocity and acceleration, while $\dot{q}$ and $\ddot{q}$ are structural velocity and acceleration respectively.

3. Equations of Motion

The equation of motion for the dynamic problem of SFT (Fig. 1) subjected to hydrodynamic, and seismic loads can be written in matrix form as follows (Muhammad, Ullah et al. 2017, Muhammad, Ullah et al. 2017):

$$\left[M + M_a\right]\left\{\ddot{q}\right\} + \left[C\right]\left\{\dot{q}\right\} + \left[K_e + K_m\right]\left\{q\right\} = \left\{f\right\} + \left\{f\left(q,t\right)\right\} - \left[M + M_a\right]\left\{I\right\}\left\{\ddot{q}_g\right\} \qquad (2)$$

Where $\left[M\right]$ is the structural mass matrix of SFT, $\left[M_a\right]$ is the added mass matrix, and $\left[C\right]$ is the system-damping matrix. $\left[K_e\right]$ and $\left[K_m\right]$ are the elastic stiffness of SFT and the mooring stiffness matrices, respectively. $\ddot{q}$, $\dot{q}$, and q are the vectors representing structural acceleration, velocity, and displacement, respectively. $\left\{f(q,t)\right\}$ is the vector of time-dependent hydrodynamic forces and $\left\{f\right\}$ is the vector of the net permanent loads acting on the SFT. $\left\{\ddot{q}_g\right\}$ is the vector of ground motions. $\left\{I\right\}$ is the influence coefficient vector, having 1 for elements corresponding to degrees of freedom in the direction of the applied ground motion and zero for the other degrees of freedom.
The vector $\left\{q\right\}$ for an element is given as follows:

$$\left\{q\right\} = \left[u_1 \quad v_1 \quad w_1 \quad \theta_{Y1} \quad \theta_{Z1} \quad u_2 \quad v_2 \quad w_2 \quad \theta_{Y2} \quad \theta_{Z2}\right]^T \qquad (3)$$

where u, v, and w are displacements along the *X, Y,* and *Z* directions, respectively, while θ_Y and θ_Z are the rotations about the Y-axis and Z-axis, respectively. The subscripts *1* and *2* represent the first and second node of an element, respectively.

Masses are lumped at the nodes. The added mass $\left[M_a\right]$ is applied in the transverse and vertical direction only (calculated from Eq. (1)).
The elastic stiffness $\left[K_e\right]$ is calculated using the 3D beam element and $\left[K_m\right]$ is the nonlinear mooring stiffness calculated, using truss elements. In the modeling of the mooring cables, the residual buoyancy were used as pretension in the cable element. The damping matrix $\left[C\right]$ is calculated using the Rayleigh damping model.

4. Case Study

The dynamic behavior of SFT is simulated for the SFT model shown in Fig. 1 (Muhammad, Ullah et al. 2017). The input parameters used are given in Table 1. For the static analysis, the net residual buoyancy and maximum fluid forces are applied as uniformly distributed loads, in the analysis. For the dynamic response, the equation of motion was solved by Newmark average acceleration method for each time step. The term hydrodynamic analysis is used in this paper when the dynamic analysis of SFT is performed under the waves and currents according to environmental conditions listed in Table 1.

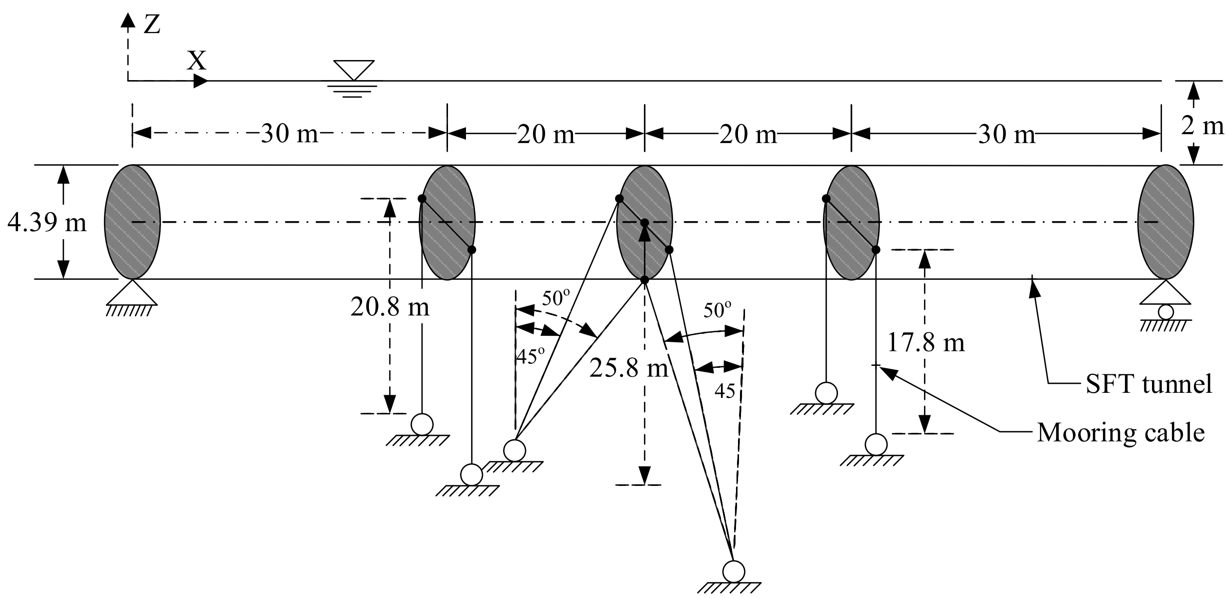


Figure 1: Structural model of SFT used for numerical simulations

5. Results and Discussions

The dynamic displacements and internal forces for the SFT numerical model are presented. The hydrodynamic analysis of SFT corresponds to the environmental conditions of Qindao Lake of Peoples Republic of China. For the seismic response of SFT, the three-dimensional ground motions of El-Centro (1940) are assumed for the SFT numerical example. The El-Centro ground motions used as input motions are not shown for simplicity; the ground motion components and peak ground acceleration are shown in Table 2. The ground motion component S90W was applied in longitudinal (X-direction), component S00E is applied in the transverse (Y-direction) and vertical component was applied in the vertical (Z-direction) of SFT, respectively. All three components of ground motion were applied simultaneously. For both hydrodynamic and seismic analysis, 5% damping was assumed for calculating structural-damping matrix using Rayleigh damping model.

Table 1: Parameters of SFT tunnel, mooring cables, and hydrodynamics (Muhammad, Ullah et al. 2017)

	Parameter	Symbol	Value
Tunnel	Tunnel equivalent density	ρ_t (kg/m^3)	2,451
	Elastic modulus	E_t (N/m^2)	$3x10^{10}$
	Area	A_t (m^2)	5.1
	Moment of inertia	I_t (m^4)	12.3
	Length of tunnel	L_t (m)	100
Mooring cables	Elastic modulus	E (N/m^2)	$1.4x10^{11}$
	Diameter of cable	D (m)	0.06
	Moment of inertia	I (m^4)	$6x10^{-7}$
	Cable density	ρ_c (kg/m^3)	7,850
Hydrodynamics	Wave height	H (m)	1
	Time period	T (s)	2.3
	Current velocity	V_c (m/s)	0.1
	Depth of water	h (m)	30
	Distance of SFT from free surface	h_1 (m)	2
	Density of water	ρ_w (kg/m^3)	1,050
	Drag coefficient	C_D	1
	Inertia coefficient	C_M	2

Table 2: Ground motion input, El-Centro 1940, site Imperial Valley irrigation district

Component	PGA
S00E	0.35g
S90W	0.21g
Vertical component	0.13g

The structural response of SFT for hydrodynamic analysis is shown in Fig. 2; The SFT response in longitudinal direction (X-direction) is very small as compared to transverse (Y-direction) and vertical (Z-direction) direction and therefore is not shown. The displacements and bending moment times histories are shown for the center of SFT. Figs. 2a and 2b represent transverse (Y-direction) and vertical (Z-direction) displacements respectively. Both transverse and vertical displacements show a periodic pattern resembling the wave force model. Figs. 2c and 2d, represent transverse and vertical bending moments, respectively. The vertical bending moments of SFT is very large as compared to the transverse. The shape of the response curves for hydrodynamic analysis (Fig. 2) shows that the transient motions of SFT are small as compared to the steady state motions.

The seismic response of SFT is shown in Fig 3. The transverse (Y) and vertical (Z) displacement of SFT are shown in Figs. 3a and 3b, respectively. The seismic response of SFT is very large as compared to hydrodynamic response. The relative difference of SFT centered point maximum transverse and vertical displacements in seismic case are 91 % and 27% as compared to the hydrodynamic case. The transverse and vertical bending moments are shown in Figs. 3c and 3d, respectively. The relative difference of SFT centered point maximum transverse and vertical bending moments in seismic case are 91 % and 32 % as compared to the hydrodynamic case. A comparison of maximum absolute displacements and bending moments for hydrodynamic and seismic analysis are shown in Table 3; same trend can be seen as described above.

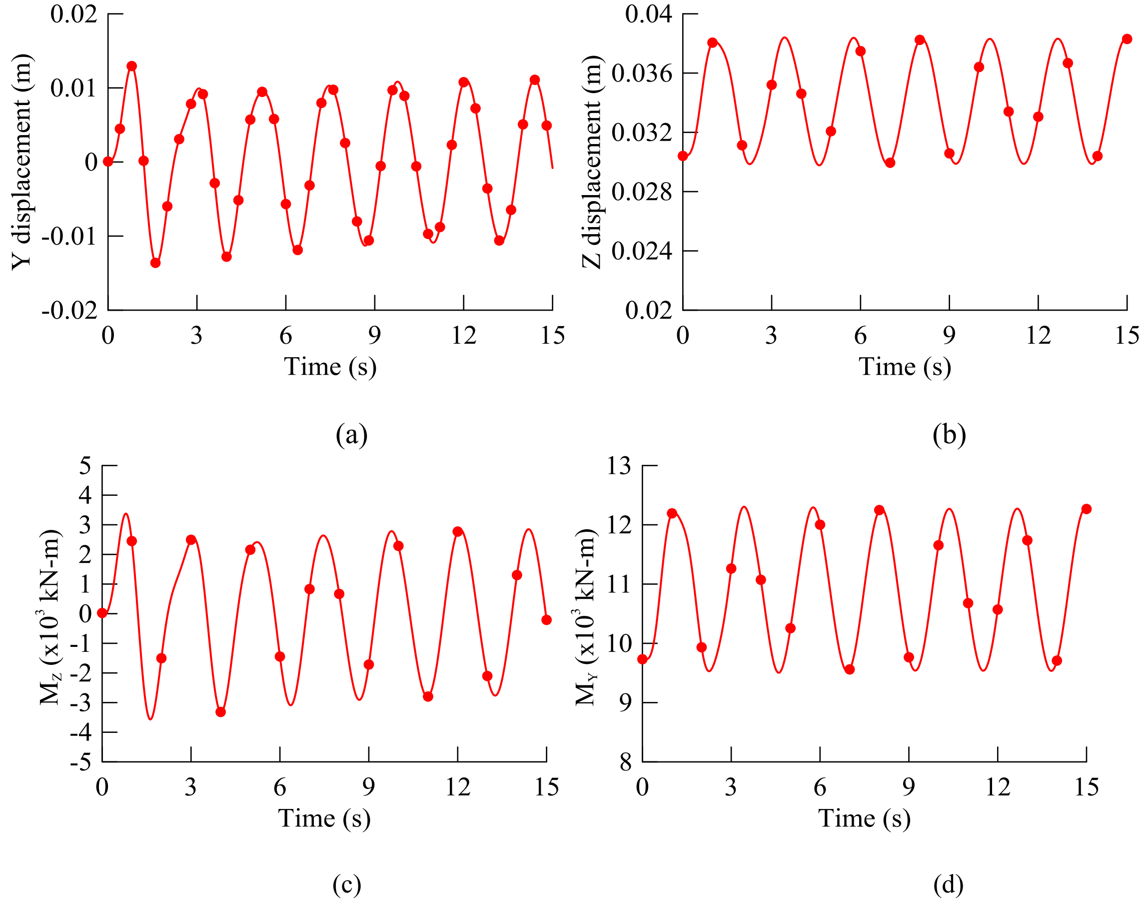
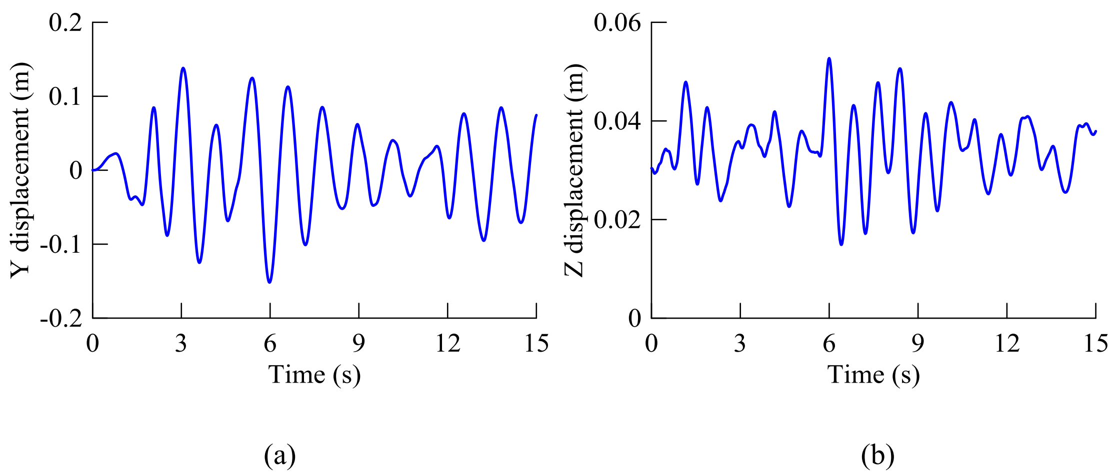
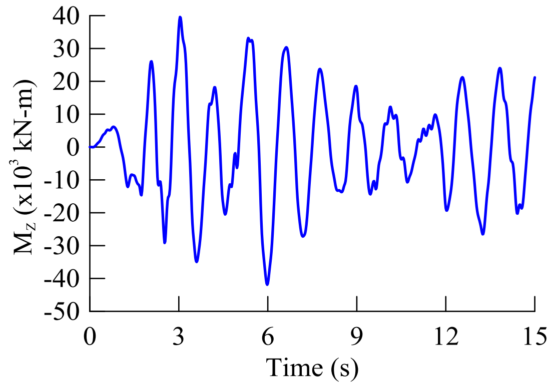
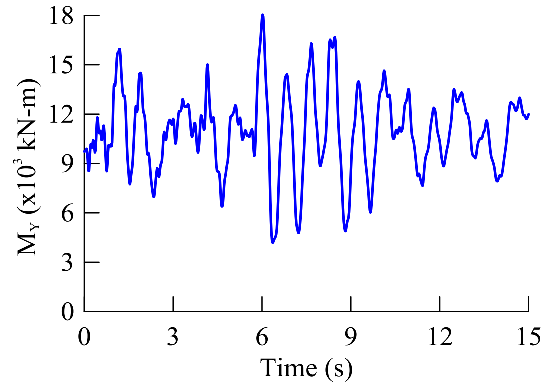


Figure 2: Time histories of SFT displacements and bending moments at the center of tunnel, using hydrodynamic analysis : (a) Transverse displacement (b) Vertical displacement SFT (c) Transverse bending moment (M_Z) (d) Vertical bending moment (M_Y).





(c)



(d)

Figure 3: Seismic response, time histories of SFT displacements and bending moments at the center of tunnel: (a) Transverse displacement (b) Vertical displacement SFT (c) Transverse bending moment (M_Z) (d) Vertical bending moment (M_Y).

Table 3: SFT absolute maximum displacements and bending moments at center of tunnel

	Transverse displacement (m)	Vertical displacement (m)	Vertical bending moment M_Y ($\times10^3$ kN-m)	Transverse bending moment M_Z ($\times10^3$ kN-m)
Hydrodynamic	0.0137	0.0384	12.31	3.57
Seismic	0.152	0.0528	18.04	41.92

6. Conclusions

The Dynamic problem of the submerged floating tunnel (SFT) is formulated considering the modeling of structure and cable system. This problem is solved numerically using Newmark's average acceleration method. The time history analysis of SFT is performed for the hydrodynamic and seismic excitations.
Waves and currents are modeled by the Airy wave theory and wave forces are calculated using modified Morison's equation. The displacements and bending moments results are presented for hydrodynamic analysis and seismic analysis based on the El-Centro ground motions, 1940. The seismic response of SFT is very large compared to hydrodynamic response, due to two reasons (1) hydrodynamic action is small because the wave height of the site is one meter only; for practical design, the SFT need to be checked for a wide range of wave heights (2) SFT is a massive structure. The transverse bending moments of SFT are found to be larger than all the three directions of SFT, and this could be attributed to the smaller cable stiffness in the transverse direction.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Reasons and Remedies for Time and Cost Overruns on Construction Projects: A Live Case Study

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Abstract

Clients, Architects, Consultants, Project Managers and Contractors all over the world experience time slippages and cost overruns on their projects. Even though, unwanted, they are unavoidable although state of the art tools and techniques are available/ used. No matter, how hard the teams work yet about 85% of projects end up with time and cost overruns. It is quite annoying and frustrating for all the stake holders especially where the delays are unjustifiable.

Highly experienced project management professionals and researchers all over the globe have documented their experiences and researches on this particular problem and arrived at identifying typical reasons and possible methods to harness the problems.

For Pakistan which has a different set of circumstances, some of them typical to Pakistan only, it is high time that root causes of such time delays and cost overruns be addressed explicitly and efforts be made to identify possible remedies based on an objective analysis. This particular study aims at documenting real life experiences of 16 out of 28 projects executed by the author during the years 2008-2014 at Institute of Business Administration Karachi Pakistan. The paper includes analysis and recommendations from the experience of these projects, majority of which have been found to be identical when compared with the findings of the researches carried out by eminent professionals and authors in many countries.

Keywords

Construction; Cost Overruns; Delays; Impact; Reasons; Remedies

1. Introduction

Dealing with the topic envisaging reasons for project delays and cost overruns is not so simple. Projects get completed in time with cost or no cost overruns and also there are projects which are delayed but without cost overruns. These are rare examples, however in real life it is about 80% of the projects which suffer delays and consequently the cost overruns. Here the delays are defined as the excess period over the contracted period of project completion and the cost overruns as the excess cost over the contracted cost of the Project.

Research review highlights reasons under various situations attributed to Project Consultants, sponsors /Owners, Project Managers, Contractors and external factors. A comprehensive list of factors cannot be prepared and generalized as the projects are of unique nature, type and extent undertaken in project environments quite different from each other. This paper is therefore based on the real life study of 16 projects costing Pak Rupees 4.2 Billion, completed at Institution of Business Administration Karachi (Owner/Client) during the year 2008 to 2014 with a peculiar project environment involving one common Project team from the owner's side. managing projects through multiple teams of Architects, Consultants and Contractors. Independent Project Managers were engaged on one or more projects for detailed supervision and project management as per the policy of the Owner and the Project donors. The owner being a Government organization it had to follow very strict procurement rules under the law called Sindh Public Procurement Regulatory Authority. Government of Sindh That involved a lengthy process of decision making through multiple committees having different technical and financial authorities at different levels.

The objective of this paper was thus to investigate the reasons of the delays and the cost overruns and to address possible remedies. To obtain independent opinions a survey questionnaire was sent to as many as 50 stake holders of the projects comprising Donors, Owners, Architects, Consultants and contractors. The response was 30% which was considered valid as the respondents were all Engineers and Managers. The rest of the paper is organized as follows. Section 2 provides review of literature search. Section 3 describes the survey results, analysis and findings. Results are discussed in section 4 whereas conclusions are made in section 5. Suggested remedies have been outlined under Section 6.

2. Review of Literature

Literature search was conducted as it was highly essential to know the comparative standing of this paper's research and findings. There was a myriad of research papers and documentation available on the net, however a few were selected based on the commonality of researchers' focuses and findings. Instead of making the references as part of running text, they have been tabulated for ease of references and to provide an easy comparison of factors causing delays and the cost overruns.

Table 1: Summary of Literature

Reference	Author(s)	Findings
[1]	Alinaitwe, H., Apolot, R., Tindiwensi, D. (2013).	Five most important causes of delay were found to be: (1) Changes to the scope of work (2) Delayed payments (3) Poor monitoring and control (4) High cost of capital (5) Political insecurity and instability
[2]	Alnuaimi, A. S., Al Mohsin, M., A. (2013, Dec 25-26).	For projects undertaken in 2009-10 in Oman top five reasons were listed as : (1) Planning and programming construction works (2) Poor construction experience (3) Shortage of material (4) Failure in practical application of work programs (5) Changes in initial design
[3]	Ambituuni, A. (2011).	Five causes were documented in the text as : (1) Design errors (2) Poor site investigations (3) Poor project planning (4) Scope changes (5)Poor contract conditions
[4]	Hamidreza, A., Shahrzad, K., Abbas, G., Mahdi, B., Mahbod, V. (2011).	Top three non-excusable delays were identified as : (1) Not selecting competent sub-contractors (2) Poor management of project changes (3) Lack of mechanism for recording , analyzing and transferring lessons learned
[5]	Odeh, A. M., Battaineh, H. T. (2002).	Major factors highlighted were : (1) Labor productivity (2) Inadequate experience of contractors (3) Owner

		interference (4) Financing (5) Delays caused by sub-contractors (6) Slow decision making by owners
[6]	Owolabi, J. D., Amusan, L. M., Oloke C., , Tunji-Olayeni, O., Dele, Owolabi, Peter Joy; Omuh Ignatious	Fifteen factors were identified ranked using mean index score. Top on the list were: (1) Lack of funds (2) Changes in drawings (3) Lack of effective communication (4) Lack of adequate information from consultants (5) Slow decision making (6) Contactors 'insolvency
[7]	. Prakash, R. B., Culas, J. C., (2014, June).	Identified four most critical factors that contributed to causes of delays were : (1) Late in revising and approving design documents (2) Delays in sub-contractors' works (3) Poor communication and coordination (4) Change orders
[8]	Ronak, C. (2012, Oct 26).	Four major reasons were highlighted as : (1) inaccurate estimates (2) Lack of real time visibility and control (3) Poor methods to determine project progress (4) Insufficient historical information
[9]	Samarghandi, H., Tabatabaei, S. M. M. P., Hashemi, T. A. M.,	Had outlined major causes and classified them into groups being responsible for the delays. Following is the abstract. MAJOR FACTORS CONTRIBUTING 50% TO OWNER DEFECTS. (1) Inefficient budgeting schedule (2) Incomplete drawings and plans (3) Improper selection of contractors MAJOR FACTORS CONTRIBUTING MORE THAN 60% TO CONTRACTORS DEFECTS. (1) Inaccurate budgeting and resource planning (2) Adherence to outdated construction methods (3) Inaccurate pricing and bidding MAJOR FACTORS CONTRIBUTING MORE THAN 57% TO CONSULTANTS DEFECTS.(1) Inaccuracies in technical drawings such as electrical or mechanical drawings (2) Inaccurate first drafts that cause confusion (3) Delay in updating project status MAJOR FACTORS CONTRIBUTING MORE THAN 55% TO GENERAL DEFECTS (1) Outdated standard mandatory terms in contracts (2) Outdated standard mandatory items in cost lists (3) Financial difficulties stemming from governmental budgeting
[10]	Shubham, V.	Seven factors were identified , top 5 being (1) Lack of daily target & review (2) Lack of Strategic planning (3)Quality of material get damaged due to poor storage area (4) Payment (5) Decision making power,

3. Results Analysis and Findings

The live case study of IBA projects completed during 2008-14 is presented.

The investigation of the reasons of delays and cost overruns and recommendations for the remedies is the main focus of this paper. The delays and cost overruns considered in this live study had occurred during three major phases of projects 'life cycle viz: Planning and Designing, Procurement and Execution and close up. Based on the similarity of the physical size, nature and cost, 16 projects were selected out of 28 projects completed between the years 2008 to 2014 at IBA. A questionnaire was designed on the basis of a list of causes of delays and cost overruns compiled using project records and personal experiences. A separate section was included wherein suggestions for remedies were solicited. Fifty sets were circulated to the Engineers and Managers working on the sides of clients, architects, consultants, project managers and contractors. In all 15 responses were received and their validity was confirmed as all of them were experienced engineers, managers and technicians. The respondents were asked to give frequency of each of 48 factors using a standard 5-point scale. They were also asked to attribute a severity (impact factor) to the causes of delays to arrive at the cost overrun ranking. All the factors were assigned identification of the responsible group as Architects and Consultants (A/E), Project Managers (PM), Owners/Client (O/C),Contractors (C)and General factors (G). Ranking scale were taken as:

1-1.9 Not important, 2-2.9 Important, 3-3.9 Serious, 4-5 Very serious

Severity (Impact factors) were taken as:

0-0.19 No impact, 0.20-0.39. Somewhat severe. 0.40- 0.69 Severe. 0.70- 1.0 Very severe

Using mean ranking method all the 48 factors were tabulated and using the impact factor corresponding ranks were attributed to the time and cost overrun factors, out of which top 15 factors were listed against each.

3.1 Results Analysis

Out of 48 factors causing delays, 15 factors are listed below as per ranking 1 to 15

REASONS FOR DELAYS (TOP 15)

FACTORS	**DUE TO**	**FREQ**	**RANK**
Poor Cash flow Management	C	4.26	1
Wrong/ Incomplete Variation Orders.	C	4.00	2
Delayed Drawings	A/E	4.00	2
Weak Monitoring	PM	3.93	3
Delays by Vendors	C	3.86	4
Conflicts Mishandling	PM	3.73	5
Poor Management of Material & Equipment	C	3.73	5
Inaccurate BOQs	A/E	3.73	5
Unrealistic Schedules	O/C	3.67	6
Difference in BOQ, Specs. and Drawings	A/E	3.66	7

Inadequate Manpower	C	3.60	8
Poor Labor Productivity	C	3.60	8
Poor Coordination of Sub-Contractor's Works	C	3.53	9
Poor Selection of Sub-Contractors	C	3.46	10
Poor Communication	PM	3.40	11
Delays in Submittal Approvals	A/E	3.33	12
Flaws in Construction Planning	C	3.20	13
Incomplete Details on Construction drawings	A/E	3.20	13
Wrong and incorrect Submittals	C	3.06	14
Delayed responses to RFIs	A/E	3.06	14
High Turnover of Manpower	C	3.00	15
Re-work due to Poor Quality	C	3.00	15
Interferences by Users	O/C	3.00	15

Similarly top 15 factors causing cost overruns are listed below as per ranking 1 to 15

REASONS FOR COST OVERRUNS (TOP 15)

		Freq	**Rank**
Delayed Drawings	A/E	3.20	1
Scope Changes	O/C	2.98	2
Unrealistic Schedules	O/C	2.94	3
Difference in BOQ, Specs. and Drawings	A/E	2.93	4
Wrong/ Incomplete V.O.	C	2.80	5
Weak Monitoring	PM	2.75	6
Innaccurate BOQ	A/E	2.61	7

Poor Management of Material & Equipment	C	2.61	7
Poor Cashflow Management	C	2.56	8
Holdups of Sub-Contractor Payments	C	2.56	8
Selection of Inefficient Contractors	O/C	2.47	9
Delays in Submittal Approvals	A/E	2.33	10
Delays by Vendors	C	2.32	11
Last Minute Changes in built works	O/C	2.29	12
Repeated Mockups & Samples	A/E	2.29	12
Conflicts Mishandling	PM	2.24	13
Incomplete Details	A/E	2.24	13
Inadequate Manpower	C	2.16	14
Poor Labor Productivity	C	2.16	14
Poor Coordination of Sub-Contractor's Works	C	2.12	15

Considering top three reasons in each category of Delays and the Cost overruns following concise listing has been developed showing which group of the stake holder was responsible in each category.

DELAYS

RESPONSIBILITY	**Freq**	**Rank**
CONTRACTORS		
Poor Cash flow Management	4.26	1
Wrong/ Incomplete Variation Orders.	4.00	2
Delays by Vendors	3.86	4
ARCHITECTS AND CONSULTANTS		
Delayed Drawings	4.00	2
Inaccurate BOQs	3.73	5
Difference in BOQ, Specs. and Drawings	3.66	7
DUE TO PROJECT MANAGERS		
Weak Monitoring	3.93	3
Conflicts Mishandling	3.40	11

DUE TO OWNERS/CLIENTS/DONORS

Scope Changes	3.73	5
Unrealistic Schedules	3.67	6
Interferences by Users	3.00	15

DUE TO EXTERNAL FACTORS

Approvals from Civic Authorities	2.66	19
Law and Order	2.50	22
Geotech Surprises	2.46	23

COST OVERRUNS

RESPONSIBILTY

DUE TO CONTRACTORS	Freq	Rank
Wrong/ Incomplete V.O.	2.80	5
Poor Management of Material & Equipment	2.61	7
Poor Cash flow Management	2.56	8
A/E TO ARCHITECTS AND CONSULTANTS		
Delayed Drawings	3.20	1
Difference in BOQ, Specs. and Drawings	2.93	4
Inaccurate BOQ	2.61	7
DUE TO PROJECT MANAGERS		
Weak Monitoring	2.75	6
Conflicts Mishandling	2.24	13
Poor Communication	1.70	26
DUE TO OWNERS/CLIENTS/DONORS		
Scope Changes	2.98	2
Unrealistic Schedules	2.94	3
Selection of Inefficient Contractors	2.47	9
DUE TO EXTERNAL FACTORS		
Law and Order	2.00	20
Geotechnical Surprises	1.97	21
External Pressures to Stop Work	1.70	26

3.2 Findings

1. The survey results have yielded most critical factors causing delays and cost overruns on IBA projects as follows
    (a) Contractors were responsible for wrong/ incomplete variation orders, poor management of material & equipment, poor cash flow management, and delays by their sub-contractor and vendors.
    (b) Architects and Consultants were responsible for delayed drawings, inaccurate BOQs, lack of detailing and differences in BOQs, Specifications and Drawings.
    (c) Project Managers were responsible for weak monitoring, mishandling of conflicts (indecisions) and Poor Communication
    (d) Owners and Clients were responsible for untimely scope changes, dictation of unrealistic targets , interferences by Users and selection of inefficient contractors
    (e) General factors included approvals from civic authorities, law and order, geotechnical surprises and external pressures to stop work

2. Under a very well designed multiple projects monitoring and control system, Projects were executed smoothly. 12.5% were completed on time, 75% projects got delayed by 8-66% and 12.5% got delayed by 100 %. Cost overruns on 43% projects were contained within 4% whereas 57% projects faced maximum of 16% cost overrun.

3. Survey results clearly showed that responsible groups for delays and cost overruns in terms of composite percentages have been:-

    Contractors 23%
    Architects and Consultants 23%
    Project Managers 17%
    Owners/clients 22%
    General factors 15%

4. Discussions

4.1 Delays and cost overruns due to Contractors

Statistical analysis based on real life data showed that the contractors contributed 23% to delays and cost overruns. Major causes had been wrong/ Incomplete V.Os. Poor Management of Material & Equipment, Poor Cash flow Management, and delays by their Sub Contractors and Vendors.

Variation orders were found to be inevitable as they were directly linked to scope changes and defective and inaccurate Bill of Quantities. Variation orders were also generated when there were excusable delays and the contractors were granted extension in time because of which contractors claimed for their extra overheads and sometime cost escalations including the foreign exchange parity. It was also found that contractors normally submitted overinflated, incomplete and inaccurate variation orders for extra items. It not only consumed lots of management time but and unnecessary hold ups and delays.

Poor management of Material and equipment. In majority of cases the contractors failed to bring in the right material and the right equipment at the right time. They did not engage full time planning engineer and relied on the single Quantity Surveyor who was given multitasks including preparation of bills, variation orders and material & equipment orders for sending to head office for procurement. Incoordination between site and head office always resulted in delays.

Poor Cash flow Management. Poor cash flow management on the part of contractors has been the main cause of contractors' bad performance. They failed to manage payments to their vendors and sub-contractors on time resulting stoppage of works by subs and hold ups of materials by the vendors ultimately affecting progress of works. In certain cases special advances issued as per the contract terms were not even helpful in overcoming their mismanagement.

Delays by Vendors. In majority of cases vendors had promised for timely delivery of material and equipment. However , they failed to do so giving reasons for late shipment or non-availability of required quantities because of their misplanning, delayed payments, delays in obtaining approvals of samples and submittals from Architects and Consultants.

4.2 Delays and cost overruns due to Architects and Consultants

Architects and Consultants contribution to delays and cost overruns came out to be 23% on account of Delayed Drawings, Inaccurate BOQs and difference in BOQ, Specs and Drawings.

Delayed Drawings. Most of the projects got delayed due to delayed construction drawings or issuance of part drawings. Main reasons identified were poor coordination between sub consultants of civil, electrical and mechanical discipline. Rectification of errors in detailing took considerable time and coordination efforts on the part of the contractors, fabricators, equipment suppliers resulting undue delays. Multiple revisions in drawings had to be made by the consultants due to scope changes. That handicapped the contractor to develop an accurate plans for material procurement and delivery.

Inaccurate BOQs. Inaccurate quantities and estimates had severe effects on both time and cost of the project. This could be attributed to the fact that the estimates were based on tender drawings called preliminary estimates having allowance for plus minus 15%. The bids were compared with these estimates and the works awarded to the one being lowest and near to the estimates. Accuracy of the estimate could not be ascertained as tender drawings missed many details although the consultants claimed the tender drawings to be as good as construction drawings. This resulted sometime in exorbitant variation in quantities and multiple variation orders.

Difference in BOQ, Specs and Drawings. A major cause which considerably affected the physical progress as well as the cost, were the discrepancies in nomenclatures of items , specifications and the drawings. Confusions prevailed on many projects until the consultants issued the clarifications. That consumed most of the time of the Project managers in dealing with the conflicts and the dispute resolution. In certain cases contractors took the advantage of claiming extra time and cost which could not be avoided.

4.3 Delays and cost overruns due to Project Managers

Their contribution to delays and cost overruns was to the tune of 17%. Major contributing factors were weak monitoring, conflicts mishandling and poor communication.

Weak monitoring. On many IBA projects weaknesses in proper monitoring resulted in repeated slippages of targets and milestones. This happened with those project managers who could not depute skilled and trained professionals or the turnover of the project team leaders was high. Another contributing factor was their extreme focus on detailed supervision and quality control, giving little consideration to critical aspects of project management.

Conflicts mishandling. Major conflicts encountered were on approval of shop drawings and technical submittals. The responsibility rested with the Architects and their sub Consultants. Conflict arose when Project Managers objected certain technical approvals from the point of view of practical implementation at site. Handling these kinds of disputes needed professional approach which was absent and resulted in unnecessary hold ups at site. Major disputes arose on quality of works and workmanship for which PM were fully responsible but at times Architects and Consultants rejected the quality and made the contractors to redo the job. The delays occurred when PM could not handle the situations.

Poor communication. It is the responsibility of the Project Managers to ensure that everyone stake holder of the project is promptly informed on project performances especially the time, cost, quality and scope. On IBA projects those projects suffered setbacks where Project Mangers failed to maintain a proper communication with the Owners/Clients, Architects, Consultants and the Contractors. These Project managers only acted as post offices and did not take initiatives for a responsive. Surveys concluded that 70% of projects experienced time overrun and found that 45 out of 76 projects considered were delayed.

4.4 Delays and cost overruns due to Owners/Clients.
Contribution by the Owners and clients to the project delays and cost overrun was to the tune of 22% main causes of which were: Scope Changes, Unrealistic Schedules, Interferences by Users and Selection of Inefficient Contractors.

Scope Changes. Scope changes during the execution period are inevitable where changes in building plans had to be accommodated for improvement of the facilities and convenience of the users. Major changes were made to meet the budget constraints where sizeable reductions had to be made and value engineering exercises had to be carried out. The scope changes affected the schedules badly and made rooms for the contractors to raise variation orders as scope changes involved extra / additional works sometime

Unrealistic Schedules. Unrealistic schedules are enforced only in cases where the sponsors or the donors dictates their timeline. In many cases owners fixe a completion time period based on their experiences which times do not match the actual planning. In such cases the time period is mentioned in the tender documents and the bidders do not show resistance to the schedule just to remain in competition. It is a miscalculation on the part of the Owners and their project team because of which projects show completion beyond expected completion target. Use of correct historical record could avoid such situations especially incorporating impact of religious holidays in the schedules.

Interferences by Users. Instances of users' interference were experienced when the project had taken shape and the users started understanding the final product on ground. This was the worst time ever faced during project implementation when the users wanted changes in their already approved plans. Their demands were accommodated where major re work was not involved , yet the re work on small adjustments affected schedules of completing punch list items and delayed the technical closures, although it had minor cost variations.

Selection of inefficient Contractors. Working under a Government regulatory body, procurement laws had to be followed. One of such rules was to prequalify those contractors having registration with Pakistan Engineering Council under defined categories with specific limits of Project costs. Although very strict criteria were laid down for prequalification yet it was found difficult to filter out the inefficient contractors at prequalification stage especially when their presentation of facts met the laid down criteria.

Their inefficiencies were only exposed once they had reached the difficult parts of the project. Inefficiencies were found in deployment of inadequate manpower, in experienced engineers and staff, using antiquated methods of construction and poor construction management. Such contractors did not have respect for any schedule and dragged the works on false promises. Out of 16 projects under study this had happened on two projects. On one project, the contractor abandoned the project and the works were carried out through his sub-contractors on his risk and cost. On the other project special contractual arrangements were made by inducting a nominated sub-contractor highly experienced in the job who was paid through the main contractor on the same rates. Both the projects suffered delays while project costs were controlled through strict monitoring.

4.5 Delays and cost overruns due to General factors.

General factors included approvals from Civic Authorities, law and order situations, Geotechnical Surprises and External Pressures to Stop Work. These along with other factors contributed 15% towards the delays and cost overruns

Approvals from Civic Authorities included approvals of project plans and approvals of supply of bulk utilities such as power, gas, water, and connection to main sewers. Bureaucratic hurdles consumed lots of time and in case of a project approvals from authorities were so late that the utilities could not be provided to test the installed electrical and mechanical system resulting extraordinary delay on that project. On the same project the approvals of plan from the concerned authority took one year and project started late by one year suffering cost increases.

Geotechnical Surprises. Although detailed soil investigations were held through professional Geotechnical companies yet the unpredicted underground strata posed construction problems resulting into time delays and cost overruns. This happened on a few projects where underground works were more than 20 feet deep. On IBA projects the nature of works did not warrant geological mapping which was very expensive.

External Pressures to Stop Work. The projects were carried out in two busy campuses where teaching classes continued during working hours. Major noisy works were scheduled to be performed at night yet the very slight noises disturbed the ongoing classes and works had to be stopped for hours. Other factors included work stoppages due to law and order situations, unannounced closures of markets, transportation strikes and non-availability of fuel for transports. The schedules had to be repeatedly adjusted on these accounts. Because of a typical case of external pressure a project suffered badly when the neighbors repeatedly stopped the work by force .The situation had to be handled very carefully to avoid legal battles.

5. Conclusion

This paper studied the reasons for delays and cost overruns in construction projects. A live case study was conducted of IBA Karachi projects completed during the year 2008-14. In this paper an open questionnaire was used along with an extensive research review to have a comparison of the live case study results with those findings emanating from similar studies outside Pakistan. It was found that 40% of causes matched with those found in the literature review on International projects.
Statistical analysis of the survey results yielded ranking of all 48 factors out of which 15 most critical factors were chosen which resulted delays and cost overruns. They were further classified into groups who were responsible for those factors. Contribution to delays and cost overruns by Contractors was 23%, Architects and Consultants 23%, Project Managers 17%, Owners/clients 22% and General factors contribution was 15%.

Finally it was concluded that major factors causing delays and cost overruns were, wrong/ Incomplete Variation orders, Poor Management of Material & Equipment, Poor Cash flow Management, and delays by Vendors on Contractors side.

Delayed Drawings, Inaccurate BOQs and difference in BOQ, Specifications and Drawings, part of Architects and Consultants. Project Managers were responsible for, weak monitoring, conflicts mishandling and Poor Communication whereas the Owners and Clients were responsible for scope Changes, unrealistic Schedules, interferences by users and selection of inefficient contractors. General factors included approvals from civic authorities, law and order situations, geotechnical surprises and external pressures to stop work

6. Suggested Remedies

Fifteen critical factors as identified fairly represent the problems faced in projects' execution and provide enough input to prepare prescription for remedial actions.
As experienced, delays have serious impact on cost and often creates disputes and claims impairing the feasibility of the project consequently losses to the Owners and Financiers. These need to be addressed seriously and handled jointly by all stake holders whenever a project is undertaken. Suggested remedies to harness the problems are:

a. Criteria for prequalification of contractors and sub-contractors be carefully chosen and strictly followed. Owners/Clients and Consultants should not only rely on certification of contractors by Pakistan Engineering Council (PEC) only. Owners/Clients should visit ongoing projects or projects recently completed by the contractors. Reports from consultants and owners be obtained about the performance of the contractors being considered for prequalification. Strict ranking system be enforced. At the time of evaluation of bids more weightage be assigned to contractors' ranking as compared to weightage given to pricing.

b. Setting of overly aggressive or optimistic schedules be avoided. The Architects/Consultants/ Project Managers should prepare a workable schedule at the tendering stage which should take into consideration the project complexity, capacity, experience and capability of contractors, sub-contractors and vendors. Due consideration be given to availability or time frame work for delivery of required material and equipment and all the factors affecting the progress adversely.

c. To avoid cash flow problems of contractors it is better to screen out all those contractors having poor financial record. That is determined through careful analysis of their audited financial statement of past three years. In practice it has been noted that even financially healthy contractors face cash flow problems and that is only because of their poor cash flow planning and management. To fight the menace of sub-contractors payment hold ups by the main contractor, special clauses be provided which could allow Owners to pay a percentage of the certified payment directly to the sub-contractors/vendors

d. For a project to be successful it is strongly recommended that Project Management Company be engaged at the planning and designing phase of the project. Alternatively if the Owner/ Client Organization has the required manpower "Project Management organization (PMO) "be created to assume the complete responsibilities of the management of the project. To avoid conflicts the

Architects, Consultants and Contractor should sign the agreements with the Project Managers. In order to ensure transparency Owner/Client can engage external auditors for periodic audits.

e. Inaccurate estimates and discrepancies in Bill of Quantities, specifications and drawings are chronic problems. To avoid this, professional companies of quantity surveyors or highly experienced quantity surveyors and cost engineers be engaged from the beginning till final completion of the project. It is highly recommended that Earned Value Management (EVM), be used for close monitoring of both physical and financial progress in an objective manner.

f. Poor monitoring and control by the Project Managers can only be addressed by prescreening of the PM's staff to be deputed on the project. Only knowledgeable and qualified staff having practical experience should be allowed to handle the project. Continuous training and skill enhancement should be mandatory for such staff. Project progress review meetings be taken seriously instead of making it a routine functions. Project managers should focus all their attentions on controlling the timeline instead of just tracking the progress. They should periodically update the schedule and identify reasons for anticipated delays (proactive approach) and take immediate measures to harness the problem before it is too late.

g. Technically speaking scope changes are one of the major contributors to projects going over budget and missing achievement targets. Owners /Client need to make up their mind once the execution starts. If changes are inevitable, which practically are, a well-designed change management system should be in place which should be able to process the changes in a manner to minimize their effect on project costs.

h. All problems as discussed in research reviews and the live case study stem from one most critical issue which is getting right people for the job. In other words there is scarcity of quality of human resources with all the project players. With more and more projects in execution the mobility of good resource is rapidly causing serious problems to consultants, project managers, contractors and the client. Construction Industry has faced this problem now more severely than past decade as human capital found better paying jobs outside Pakistan. This is the high time to independently address this problem on war footing for which concerted efforts are sincerely required. This should include proper human development and management policies in the companies offering career jobs and incentive packages to retain them on long term basis. They should pay more attention on their skill development and training of modern methods.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

A Study on the Impact of Leadership Styles on Employee Motivation in Construction Projects of Lahore

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Abstract

Leadership of a project manager plays a vital role in motivation and good performance of the project team which leads to the success of project. Leadership is categorized into three basic types as transformational, transactional and laissez-faire. The success of a project may be altered by knowing the impact of leadership style on employee motivation. Lahore is currently a hub of construction projects, contributing a lot to the progress of Pakistan. There is no previous research available on the impact of leadership on employee's performance. Current investigation is conducted for relationship of leadership style and motivation in Lahore construction projects. This is a quantitative research where a structured and closed ended questionnaire survey was conducted using Multifactor Leadership Questionnaire (MLQ) for leadership identification and Work Extrinsic Intrinsic Motivation Scale (WEIMS) for motivation level study and data collection. More than 500 questionnaires were distributed and 192 responses were received. After the collection of data, data validation tests were performed. Analysis shows that transformational leader has strongest impact while laissez-faire has the weakest impact on the employee motivation.

Keywords
Leadership Style, Employee Motivation, Construction Projects, Transformational Leader.

1 Introduction

Leadership is often called as a specific or particular behavior shown by a manager to motivate his subordinates to achieve goals and get maximum output in aspect of work efficiency and satisfaction (Halaychik, 2016; Trivellas & Drimoussis, 2013). Leadership has a significant impact on how employees perform and how they grow, leading to a positive outcome of an organization (Skeepers & Mbohwa, 2015). Leadership is a subject of great concern since a long time and how leadership evokes response from the followers is an immense aspect of it. In the corporate world, leader and the led; these two play an important role in shaping the destiny of an organization (Wu, Fang, & Li, 2015). It is much significant in success of an organization from any sector in today's competitive global market (Tao, Song, Ferguson, & Kochhar, 2018; Toor & Ofori, 2008; Tyssen, Wald, & Spieth, 2014). Effect of leadership is vital in almost every organizational scale, from a small business to the largest corporations in the world. When leadership is weak, organizations are susceptible to losing credibility as well as profitability (Skeepers & Mbohwa, 2015; Tabassi, Argyropoulou, Roufechaei, & Argyropoulou, 2016; Tabassi, Roufechaei, et al., 2016; Zhang, Cao, & Wang, 2018).

In construction industry, it is observed that majority of project team members is from other cities and is staying at the project site. Motivation of such a team is vital in projects as the motivation of employees or project team has direct influence over the employee performance and thus on projects' success (Shao, Feng, & Hu, 2017; Yu, Vaagaasar, Müller, Wang, & Zhu, 2018). The key influencers for effectiveness of an organization are leadership and employee motivation. Leadership is among the key factors which could drive any business, project or organization towards failure or success (Wu, Wang, Zou, & Fang, 2016). It is important to find out which leadership style has what effect on employee motivation so that the required motivation level could be achieved through the suitable leadership style and a better work performance could be obtained (Wu, Li, & Fang, 2017).

As the construction sector is the backbone of a country's development and progression; current study focuses on all three types of leadership and their impact on employee motivation in construction projects of Lahore to find out the most suitable leadership practice to be followed in this area. Escalation and growth of construction industry is beneficial for all aspects of an economy and also for the benefit of human resource involved in this industry like labor, workers, contractors, architects, financers and local people etc.

Work has already been done on the effects of three leadership styles (participative, autocratic, and democratic) on the employee performance in Pakistan. But no work is done on the effect of transformational, transactional and laissez-faire leadership styles on team/employee motivation in Pakistan. Moreover, a project field is much different in nature from a conventional type of organization and motivation level needed in it is considerably more. It has more challenges than an ordinary or production organization. Therefore, it is important to know the motivation level of an employee and improve it in project sector but there is a gap in literature in this sector and no one has done work in Pakistan in any project field on motivation level of employees. As current construction industry hub of Punjab (Pakistan) is Lahore, therefore some work in this aspect is needed in this geographical location.
The aim of this research is to assess the impact of transformational leadership style, transactional leadership style and Laissez-faire leadership style on employee motivation.

2 Research methodology

Research methodology followed for this study is quantitative and closed ended, structured questionnaire is used for data gathering. Data when gathered through a questionnaire is in its raw form, processing is required to retrieve meaningful information from it. Data was gathered from all the construction projects of Lahore. The sample size against the selected population was 150. In order to get the required number of responses; more than 300 forms were circulated and 205 forms were submitted. Out of these 505 questionnaires, 192 were appropriately answered and were selected for data analysis. Some preliminary data validation tests were performed to check the validity of data. Data was collected through online forms and then organized in MS excel workbook. This data was then entered in SPSS software for statistical analysis.

2.1 Research Questionnaire

Similar researches have been used two standardized techniques, the Multifactor Leadership Questionnaire (MLQ) refined by (Pilkienė, Alonderienė, Chmieliauskas, Šimkonis, & Müller, 2018), that gives the

relations between the leadership style and Work Extrinsic and Intrinsic Motivation Scale (WEIMS;), by measuring the level of employee's motivation. Cumulative score from the MLQ questionnaire and WEIMS would provide data required to determine the correlations between the variables (Liphadzi, Aigbavboa, & Thwala, 2015; Scott, Jiang, Wildman, & Griffith, 2018).
Likert scale with a width of 5 from 0 to 4 is used for MLQ and Likert scale with 7 width, from 1 to 7 is used for WEIMS. These are the same as designed in real questionnaire and used by previous researchers.

2.2 Sample Size

The involved population for this study is Project Employees of Construction Projects sector of Lahore, Punjab, Pakistan. Project employees of construction projects being executed in Lahore are selected for this research. All the relevant projects were included and questionnaire was floated through google forms. As per expert judgment and discussion with professionals, an estimate of approximately 30,000 employees is taken as the total population. So, the sample size was considered equal to 0.5% of the total population which numbers to 150. The selected sample size in the beginning of this study was 150 respondents but the actual responses that were received were 192 in numbers as a greater number of questionnaires were distributed keeping in mind the survey response rate.

3 Data Analysis and Results Discussion

3.1 Reliability Analysis

Reliability of collected data is verified by finding its value of Cronbach's Alpha Coefficient. Value of Cronbach's Alpha should be greater than 0.7 for reliability check. If it's greater than 0.7, the items are reliable. This test is performed individually for every variable. Multiple items of one variable are selected and test is performed on them.

Table 1: Reliability Statistics

Sr No.	Independent Variables	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
1	Transformational Leadership	.914	.916	10
2	Transactional Leadership	.763	.767	5
3	Laissez-faire Leadership	.843	.843	3
4	Dependent Variable; Team Motivation	.814	.820	18

Table 1 shows the values of Cronbach's Alpha for independent and dependent variables and it can be inferred that data is reliable.

3.2 Correlation Analysis

Correlation has possible values from -1 to 1, where negative values indicate a negative or indirect relationship and positive values indicate a direct relationship. Correlation analysis was performed on all the variables with their computed items and results showed relationship of all the variables with each other as given in Table 2.

Table 2: Correlation Analysis

		TF_C	TS_C	LF_C	TM_C
TF_C	Pearson Correlation	1	.783**	.642**	.523**
	Sig. (2-tailed)		.000	.000	.000
	N	192	192	192	192
TS_C	Pearson Correlation	.783**	1	.435**	.474**
	Sig. (2-tailed)	.000		.000	.000
	N	192	192	192	192
LF_C	Pearson Correlation	.642**	.435**	1	.253**
	Sig. (2-tailed)	.000	.000		.000
	N	192	192	192	192
TM_C	Pearson Correlation	.523**	.474**	.253**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	192	192	192	192

Correlation is significant at the 0.01 level (2-tailed).

The results show that the correlation value for transformational leadership and motivation is 0.523, for transactional leadership and motivation it is 0.474, and for laissez-faire leadership and motivation it is 0.253. All these values are statistically significant at 0.01 level (2-tailed) so all the variables have a significant correlation.

3.3 Regression Analysis

Regression analysis is a statistical test to investigate the possible relationship between the independent and dependent variables. The impact of one variable on the other is found out by this test. Regression analysis shows the strength of relationship and it also tells the type of relationship whether it is positive or negative. The results are shown in Table 3.

Table 3: Multi Regression Analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	3.191	.253		12.630	.000		
Transformational	.561	.135	.486	4.158	.000	1.000	1.000
Transactional	.200	.135	.148	1.482	.000	1.000	1.000
Laissez-faire	-.122	.080	-.123	-1.521	.000	1.000	1.000

Multi Regression Test for all three independent leadership styles and motivation shows a direct relationship with strength of 0.486, 0.148 and -0.123 respectively. All the values are significant. Tolerance level is below 10 with a value of 1.000 and VIF value is equal to zero, which are up to the mark.

3.4 Discussion of Results

From the current study, it is proved that leadership has a significant and positive relationship in construction sector of Lahore, Pakistan. Three types of leadership were tested against employee motivation and it is found that transformational leadership, transactional leadership and laissez-faire, all have a significant relationship with employee motivation. Transformational leadership has strongest positive relationship with employee motivation and is proven to be the most effective for motivating the individuals in construction projects in Lahore.

Transactional leadership also has a positive relationship and its strength is intermediate. Laissez-faire leadership has a weak and indirect relationship with employee motivation. Thus, it can be stated here that with transformational and transactional leadership, motivation of employees will increase. But if the laissez-faire leadership style is used, the motivation level of employees will increase. Thus, most effective leadership style is transformational leadership.

The results are similar to the results shown by previous studies. Same trend was observed in Indian oil sector. They also found that Transformational leadership has the strongest direst relationship with employee motivation and transactional leadership having a weak direct relation while laissez-faire leadership having an indirect relationship with employee motivation (Gopal, 2014).

4 Hypothesis Testing

H11: There is a substantial relation between transformational leadership style and motivation of employees.

This hypothesis has been proven true as per the regression and correlation analysis and is accepted for construction sector of Lahore

H12: There is a substantial relation among transactional leadership style and motivation of employees.

This hypothesis has been proven true as per the regression and correlation analysis and is accepted for construction sector of Lahore

H13: There is an important relation among Laissez-faire leadership style and motivation of employees.

This hypothesis has been proven true as per the regression and correlation analysis and is accepted for construction sector of Lahore

Below three null hypotheses are proven false and invalid as the three relationships exist.

H01: There is no noteworthy relation among transformational leadership style and motivation of employees.

H02: There is no noteworthy relation among transactional leadership style and motivation employees.

H03: There is no noteworthy relation among Laissez-faire leadership style and motivation employees.

5 Conclusions

Employees motivation plays a vital role in the progress and productivity of the construction industry. Motivated employees yield better productivity at the construction sites and help the organization to earn more and more profit. From the discussion of results, it is concluded that transformational leadership has the most positive effect on employee motivation in construction sector of Lahore. Thus, this motivational method must be followed if we want the employees to get motivated. Transactional leadership also has a positive effect on employee motivation but its impact on employee motivation is less as compared to the transformational leadership. On the other hand, laissez-faire leadership has a negative impact on the employee motivation and it should be avoided as it can decrease the motivation level of the employees in construction sector.

5.1 Limitations of the Study

Limitations do exist in every study but if those limitations are addressed properly, they do not detract from the value of study (Bernard, 2013). This research also has some inevitable limitations.

1. Since this study concerns with a specific sector, its results could be changed if applied in any other sector. (The study is currently limited to the construction projects sector of Lahore, Punjab, Pakistan.)
2. The leadership styles and the influences of these styles on employee’s motivation is the basic limitation of this research work. It means these findings can not be used on the other factors that affect the motivation.
3. This research work has been carried out in the year 2017-2018 and it may not be similar for the other years as there are lots of factors that affect the motivation of employees including the market condition.

5.2 Recommendations

From the results obtained through analysis of primary data, it is concluded that transformational leadership is the most effective type of leadership in construction sector of Lahore. Hence, it is recommended for the project managers to exhibit transformational leadership to motivate their employees.

For future research recommendations, work on leadership styles and its impact on employee or team motivation in other fields or in other areas would be helpful in leadership style adoption in the respective discipline or area for better motivation in employees. Moreover, studies of all major disciplines could be compared and singular research could be conducted which would have generalized results in all the disciplines. Furthermore, relationship of leadership could be determined with other factors which contribute to project success.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Impact of China Pakistan Economic Corridor (CPEC) on Supply and Demand of Construction Materials

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Abstract

In the development of any country, the construction industry plays a vital role. This industry not only improves the infrastructures of a country but also increases the overall economy of the country by increasing the gross domestic products (GDP). Almost 60% to 70% of the overall GDP of a country depends on construction industry. China Pakistan Economic Corridor (CPEC) is a megaproject of trade route between China and Pakistan which includes several mega constructions of infrastructure which after completion will provide China with a quick access to Central Asian, African and Middle Eastern markets. CPEC is expected to impact Pakistani economy positively after its completion but during its construction phase which is now on going, it seems to have a vast impact on construction materials market. This research has been carried out with an intent of determining the construction material's price escalation by the end of year 2027 influenced by CPEC. This study includes expert's interviews for real time data and a statistical analysis was used to forecast the construction material's price escalation. The study suggests that a good number of construction materials will have their prices increased by more than 30% in 2027 which is very distressing. The government of Pakistan is recommended to take serious actions to put a check on construction material's price and also new construction material industries should be developed to fulfil the demand of material.

Keywords
China Pak Economic Coridor, Construction Industry, Construction Material, Price Escalations and Suply and Demand.

1 Introduction

The Chinese government promised to finance CPEC with investment, out of which around $11 billion is estimated to being spent on building roads and railways infrastructure, while the remaining $35 billion would be poured in energy projects. CPEC is a part of China's 'One Belt, One Road' initiative (Rahman, Aziz, Hongbo, Jianwe, & Yang, 2018). CPEC is also attracting domestic investors to invest in construction related industries such as steel, cement, electric cable and glass. It is expected that there will be further small steel rolling mills for longs steel around the CPEC route (Hussain, 2016).

The demand of construction materials due to CPEC has increased in Pakistan which resulted into price escalation of construction materials. The markets where cost reduction is not an important subject, new techniques and ideas takes place (Asif, 2018). Construction industry is always bound to cost constraints and there has been a strict competition in the market. This research will examine the existing trends in demand and supply of construction materials due to CPEC in Pakistan. The price escalation of materials will be found out and accordingly, a 10 years construction material price trend will be presented as a final output of this research. This will help the material supplying firms to alter their production and cope with the upcoming demand. The demand for construction material is on the rise due to economic corridor and the activities outside CPEC. Construction sector took loans worth Rs1 billion in 2014 which jumped to 13.7 billion rupees in 2015 and went up to 31.5 billion rupees in 2016. However, the latest reports suggest that the sector is facing some contractions as well (Bahoo, Saeed, Iqbal, & Nawaz, 2018).

According to (Muhammad Kundi, 2017), a country's 30% capital is invested in construction industry and almost 20% of its total workforce is involved here. However, (Oesterreich & Teuteberg, 2016) showed in his study that construction industry takes more than half of a country's capital budget each year. As this industry hold a big chunk of a nation's capital money, it should undergo thoughtful progress (Saurugger, 2010).

Although construction is principally defined by the concept of assembling materials and products, it is in fact multi-tasked. Just as divergent materials come together to form a structure, so too does a diverse group of people come together to make the project possible. To bring together numerous independent businesses and corporate personalities in to one goal oriented process is the particular challenge of the construction industry (Long, Ogunlana, Quang, & Lam, 2004).

(Faridi & El‐Sayegh, 2006) construction project is a mission, undertaken to create a unique facility, product or service within the specified scope, quality, time, and cost.

The guide to the Purchasing Managers' Index (PMI)' (2016) defines project as a temporary endeavor undertaken to provide a unique product or service. As (Collier, 1999) suggested that not only building construction, Construction project in general is completed as a result of a combination of many events and interactions, planned or unplanned, over the life of a facility, with changing participants and processes in a constantly changing environment (Horvath, 2004).

(King, 2004) noted that a vital transformation is happening inside the construction industry which need to be examined and the trends of development and background behind such transformations are crucial for recognition. Escalation in the construction market in recent years has been extremely volatile, and this trend is expected to continue in the near future due to competition for resources and skilled workers. This situation has created a great deal of uncertainty and nervousness among construction field. The financial success of a construction project can be uncertain and at risk due to changes in escalation rates during construction (Oladinrin, Ogunsemi, & Aje, 2012).The success of a building construction project is mainly influenced by to what extent of cost escalation identified and allocated to the construction project. Budgeting for cost escalation is a major problem in the planning phase of projects (Abubakar, Abdullahi, & Bala, 2018).

Literature shows that wide varieties of risk factors influence construction costs and result in considerable upsurge of project expenses than initially accounted. Cost escalation is usually included in project cost as a percentage of total estimated cost to manage any cost overrun which may occur due to multiple reason and one of them is increased material prices. Other risks are also involved which may change the total construction cost of a projects but they are intrusive to this industry. The conflicting progress is perceived as soon as there is a descending monetary trend (SCI, 2017) (Pipenbrink, A. Cumming, & Mortuary, 2019). Similarly, the huge construction firms and organizations despite their forte seems powerless in maintaining and controlling supply chains (Khan, 2005). The escalation in price is a universal issue which lies equally in developing and developed nations. The constructions industry's price escalation is influenced by various factors which also includes hard to predict and even harder to control factors (Shane, Molenaar, Anderson, & Schexnayder, 2009). This escalation is not bound to time or phase of a construction project and can occur during any phase and course of ongoing construction project (Frey & Oberholzer-Gee, 1997).

2 Research methodology

Price forecasting can be broadly categorized into Fundamental Analysis methods and Technical analysis methods. Fundamental Analysis establishes a systematic and formal procedure for exploring demand-supply in real markets. It attempts to both anticipate changes in supply/demand information, and to evaluate the direction and range of price movement resulting from new information. Some of these methods are Market research, Anticipation Survey, Panel Consensus. Technical analysis methods are used when historical data can be relied upon to predict future price. These methods are scalable to large product catalogues as they are largely driven by algorithms and mathematical models. The frequently used Technical analysis methods are Predictive Modeling and Time Series modeling. In this research, author has used the exponential smoothing to predict the future value of construction materials.

The designing pattern of questionnaire usually advanced on the basis of communication. It was arranged into profile of the respondent and several elements that affect labor productivity. Questions in the profile of respondent were asked to gather concerned data such as job situation, work experience, positioning of the current operations and contact information. It was analyzed that questions asked in the survey had very significance regarding research by studying loss of productivity from sort of dissimilar profiles of respective areas.

The set of questions was pointing out the factors in the different groups which have significant impact on demand and supply of material in country. It is consisted upon factors affecting demand and supply of material. Respondents had simply provided the factors affecting material supply according to demand for given condition. Hence, each respondent had an option to choose single alternative for each factor. The responses were depending on the interpretation, technical familiarization of the respondents and were not associated with any defined task. This simplified form of methodology was adopted to set up ways of formulating a list of factors which have impact on increase in the demand of construction material due to mega project like CPEC and how production industries fulfill this demand within country.

Seventeen construction materials, as listed, were shortlisted as the principal materials to gather the price data and forecast through experts in the field. (Cement, Steel, Crush, Lawrencepur sand, Chenab sand, Ravi sand, Bricks, Brick ballast, Back filling (Ghasu), 3" thick crush (Bajer), 2mm thick aluminum, Brick tile for roof, Wood (Deodar), Aluminum (General), Stainless steel, Granite, Tile work
The price list for all these materials for year 2017 to 2017 have been estimated based on feedback from different government departments and private sector. Among these 17 construction materials four of them namely 3" thick crush, 2mm thick aluminum, Wood (Deodar) and Aluminum (General) showed constant price throughout a period of 10 year from 2017 to 2017. Such type of data cannot be forecasted as it gives the same value for coming years as well.

The period of forecast is also next 10 years duration starting from 2018 to 2027. To solve this issue a questionnaire was prepared and emailed to expert professionals of construction industry of Pakistan who are working on CPEC project. The questions were related to the price of above-mentioned materials and also the effect of CPEC on demand and supply of all construction materials. The statements of questions and their response are presented in next chapter along with material price forecast results. The technique of simple exponential smoothing has been used to forecast from the data thus available. The Equation (1) indicates the simple exponential smoothing formula as follows;

$$\mathbf{F(t+1) = F(t) + \alpha\,[Y(t) - F(t)]} \quad \ldots\ldots \quad \textbf{Eq. (1)}$$

α (alpha) is a smoothing constant.

3 Results and Discussion

The data is analyzed and future price of selected materials have been predicted for next 10 years which has been represented in both tabular and graphical forms. Moreover, this chapter also describes the opinion of construction industry professionals about demand and supply trend of construction materials due to CPEC and reason behind the constant price of some materials.

Total seventeen materials have been selected for this study and they are Cement, Steel, Crush, Lawrencepur sand, Chenab sand, Ravi sand, Bricks, Brick ballast, Back filling (Ghasu), 3" thick crush (Bajer), 2mm thick aluminum, Brick tile for roof, Wood (Deodar), Aluminum (General), Stainless steel, Granite and Tile work. The prices of these materials for years 2017-2017 are given in the Table 1 below. These prices have been used to forecast the price of these materials for next 10 years i.e. from 2018 to 2027. For materials whose price is not varying with time, expert opinion has been considered which was collected through industry professionals by posting them questionnaire which comprises of the questions available after the Table 1.

Total four simple questions were asked in the email from construction industry professional which are the impact of CPEC on Demand and supply of Construction material, the factors that impact on supply and prices of construction material, the reasons for some minor variation in prices of Crush, Aluminum, and Wood and the Impact of CPEC on Prices of Construction material. The response against all these questions is presented below because depending upon this response the price of crush, wood and aluminum has been predicted. Experts revealed that the growth of construction sector in Pakistan is due to mega projects like CPEC and mass transit services. There is also an increase in building construction for residential and commercial usage which has put a stress on material demand in the industry. A good number of small industries are directly and indirectly linked to construction industry and any development in construction sector brings a growth in these industries alongside. Pakistani construction industry countersigned 11.31% year to year (y/y) progress in the present fiscal year because of augmented government expenditure, even though the GDP of country has exceeded anticipated guesstimates, mounting by approximately 4.14%.

The on-going mega development projects in Punjab under CPEC including various Power Plants and Motorways etc. have created massive demand for construction raw material (crush stone). The Government of Punjab intends to ensure stable supply of crush stone to government driven mega projects. Table 1 is showing construction materials price for year 2007-2017 and there seems an acceleration of material price variation. All are highly important construction materials; their cost highly affects the cost of the project as a whole. Table 2 represents the price forecast of construction materials for time period of 2018-2027.

Table 1: Construction Materials price for year 2007-2017

Items	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cement	Bag	415	415	425	425	400	400	425	425	465	490	550
Steel	Kg	76	76	78	78	78	78	78	78	80	80	85
Crush	Cft	55	55	55	55	60	60	65	65	70	70	78
Lawrencepur sand	Cft	70	70	70	72	72	85	85	85	80	70	70
Chenab sand	Cft	23	23	23	25	25	25	25	25	25	25	25
Ravi sand	Cft	12	12	12	12	15	15	15	15	15	15	15
Bricks	Rate of 1 brick	6.5	6.8	6.8	7	7	7.5	7.5	8	8.2	8.2	8.5
Brick ballast	Cft	45	45	45	45	50	50	50	50	50	55	57
Back filling (Ghasu)	Cft	12	12	12	12	12	15	15	15	15	15	15
3” thick crush (Bajer)	Cft	45	45	45	45	45	45	45	45	45	45	45
2mm thick aluminum	Sft	700	700	700	700	700	700	700	700	700	700	700
Brick tile for roof	Sft	5000	5000	5000	5200	5200	5200	5200	5500	5500	5500	5500
Wood (Deodar)	Cft	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Aluminum (General)	Sft	500	500	500	500	500	500	500	500	500	500	500
Stainless steel	Sft	1500	1500	1700	1700	1800	1800	1800	1900	1900	1900	2200
Granite	Sft	650	700	750	800	850	900	950	1000	1050	1100	1150
Tile work	Sft	1200	1400	1550	1700	1900	2100	2300	2500	2800	3000	

Table 2: Forecasted price of construction materials for 2018-2027 period

Items	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Cement	Bag	603	566	551	546	614	626	640	659	671	686
Steel	Kg	83	83	83	84	86	87	87	88	88	89
Crush	Cft	80	82	83	88	88	95	96	99	103	105
Lawrencepur sand	Cft	78	78	78	77	75	75	74	74	75	75
Chenab sand	Cft	26	26	26	26	26	26	26	27	27	27
Ravi sand	Cft	16	16	17	17	17	17	18	18	19	19
Bricks	1 brick	9	9	9	9	9	10	10	10	10	11
Brick ballast	Cft	56	58	59	60	62	63	65	66	68	68
Back filling (Ghasu)	Cft	16	17	17	17	18	18	19	19	19	20
3” thick crush (Bajer)	Cft	46	46	47	48	48	49	50	50	51	52
2mm thick aluminum	Sft	718	735	753	770	788	805	823	840	858	875
Brick tile for roof	Sft	5736	5730	5731	5720	5994	5995	5993	5989	6240	6234
Wood (Deodar)	Cft	6180	6360	6540	6720	6900	7080	7260	7440	7620	7800
Aluminum (General)	Sft	513	525	538	550	563	575	588	600	613	625
Stainless steel	Sft	2111	2144	2263	2280	2313	2448	2471	2558	2646	2660
Granite	Sft	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650
Tile work	Sft	3412	3636	3847	4069	4294	4517	4734	4953	5172	5391

4 Conclusions

Following conclusions can be driven from the data analysis. The percentage increase expected in year 2027 in price of construction materials can be represented graphically in Table 3.

The Table 3 and Figure 1 represents that the three most critical materials whose price will rise more than 30% by the year 2027 are tile work, granite, crush, back filling and wood. It shows that construction of building is increasing rapidly besides CPEC which have affected the price of construction materials.

Table 3: Percentage increase in construction materials price by 2027

Sr no.	Items	Unit	2017	2027	% increase
1	Steel	Kg	85	89.02	4.73%
2	Lawrencepur sand	Cft	70	74.83	6.91%
3	Chenab sand	Cft	25	26.82	7.27%
4	Brick tile for roof	Sft	5500	6234.48	13.35%
5	3” thick crush (Bajer)	Cft	45	51.75	15.00%
6	Brick ballast	Cft	57	68.48	20.14%
7	Stainless steel	Sft	2200	2660.46	20.93%
8	Bricks	Rate of 1 brick	8.5	10.60	24.67%
9	Cement	Bags in kg	550	685.89	24.71%
10	2mm thick aluminum	Sft	700	875.00	25.00%
11	Aluminum (General)	Sft	500	625.00	25.00%
12	Ravi sand	Cft	15	18.81	25.40%
13	Wood (Deodar)	Cft	6000	7800.00	30.00%
14	Back filling (Ghasu)	Cft	15	19.91	32.72%
15	Crush	Cft	78	105.36	35.07%
16	Granite	Sft	1150	1650.00	43.48%
17	Tile work	Sft	3200	5390.83	68.46%

5 Recommendations

This study is very valuable for stakeholders of material and construction industry because it may help them to consider this price escalation problem at their foremost bull and develop stringer strategies to manage the ever-increasing material prices. Material whose prices are rising are those which are used in construction of houses which shows that for average person of this country it would be difficult to construct a house or even large buildings would become very expensive in terms of their construction cost. Government needs to strictly control these prices as buildings are one of the basic needs of economy and cost of infrastructure affects living costs.

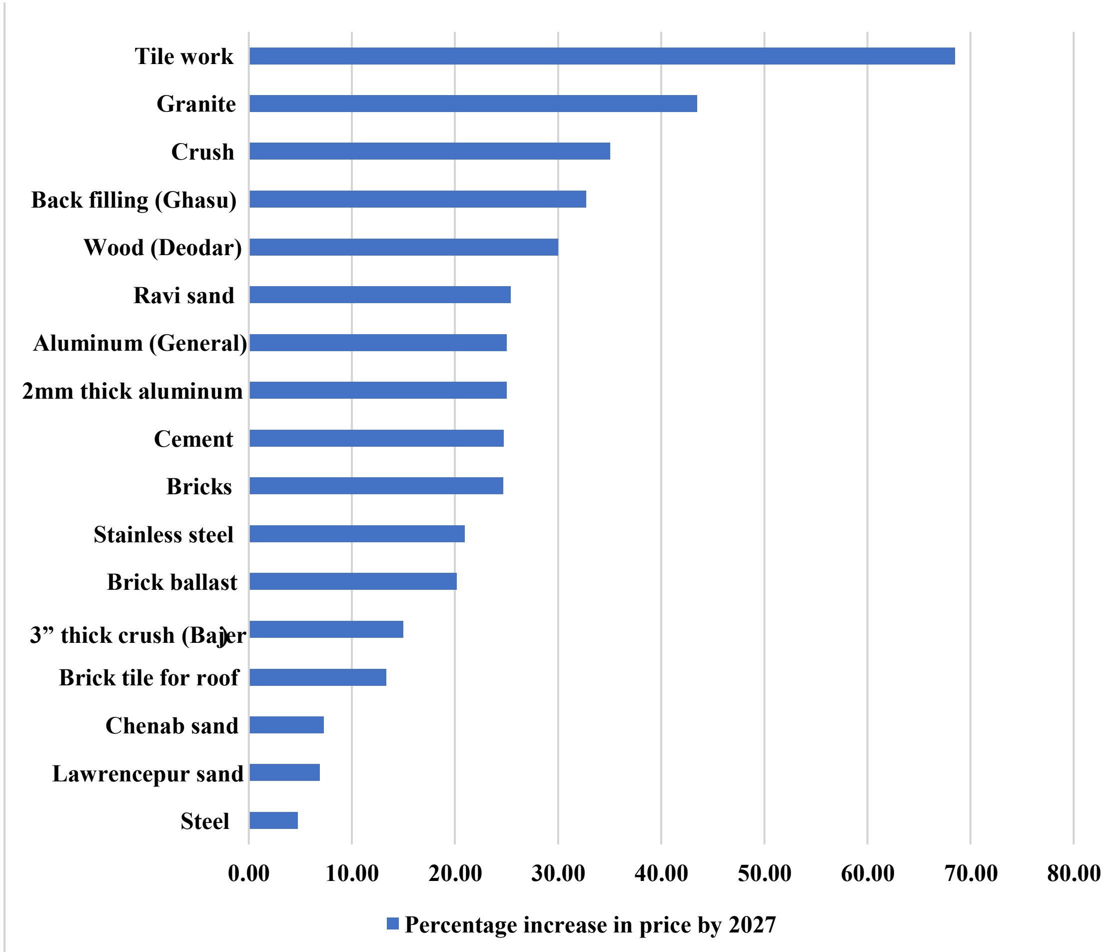

Figure 1: Percentage increase in price of materials by the year 2027

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Analysis of Key Factors Affecting Labor Productivity in General Construction Projects in Pakistan

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Abstract

Construction is widely regarded as a labor-intensive industry. In most countries, 30 to 50% of the total project's cost comprises of labor wages and related expenditures. Thus, improving construction labor productivity gives rise to economic success and profitably of a construction project. The construction industry of Pakistan greatly depends upon its general labor. Among many challenges faced by this industry, Low labor productivity is the most crucial. Pakistan thus needs well formulated strategies to enhance and control this rising challenge. The aim of this research therefore, is to identify and rank the critical factors affecting labor productivity in general construction projects in Pakistan. To achieve this aim, a total of 52 factors, classified under six primary groups; Management/Organizational Group, Technological Group, Labor Group, Location Group, Weather Group, and Tool Group, were identified considering past researches in different countries. A structured questionnaire was then formulated in which respondents were asked to rate the factors with predefined criteria using their experience and knowledge. The target group was Project Managers/ Senior engineers of constructing & consulting firms possessing diverse experience in the construction industry. The results estimated the Management group factors as the most critical, followed by Labor group, and finally the Material/Tool group. The top evaluated factors are found to be: Lack of Construction manager's leadership ,Skill of labor, Unavailability of required material on site, Payment delays, Lack of proper tools and equipment on site, Slack/ neglectful/ irresponsible attitude of labor towards work, Communication problems between site management and labor, Lack of labor supervision , Shortage of material in the market, Late arrival, early quit, and frequent unscheduled breaks.

Keywords
Construction Labor Productivity, Labor productivity factors, Efficiency, Pakistan, Relative Importance Index.

1. Introduction

Human resource is the most crucial aspect of a construction project. A large proportion of overall project's cost is consumed by labor, and thus improving the productivity of labor may increase the profitability of the project. Horner et al. (1989) showed that a 10% increase in construction labor productivity would save billion to the British economy. And since construction labor productivity is the only productive resource, it can be perceived that construction productivity is mainly dependent upon human efforts and performance.
Currently, Pakistan is facing a lot of challenges and problems in its construction industry. Most of the projects are overbudgeted and extremely delayed form their estimated completion time. One of the foremost reasons behind it is Lack of labor productivity and its rising inefficiency. Despite of all the

resources, technological advancements, equipment, and financial means available to constructors, construction costs are continuously rising, completion duration of projects are increasing, and majority of the projects are overflowing their estimated budgets.
This study includes the evaluation and ranking of crucial factors affecting the labor productivity of construction projects in Pakistan. The paper proceeds with a literature review of the researches relevant to this study, provides the research method and survey design, data analysis and results obtained, and concludes with recommendations towards enhancing the construction labor productivity in Pakistan.

2. Literature Review

The origin of the word productivity can be traced back to 1766 when it was first mentioned in an article by Quesnay (Vaggi 1987). There is no universal definition of productivity; the term has different meanings for different people (Adrian, 1987). Littre defined productivity as the "faculty to produce", that is, the desire to produce (Jarkas 2005) Generally, productivity is the relationship between the output produced and one or more of the associated inputs devoted to the production process (National Research Council, 1979). Productivity may be defined as the ratio of output to input, via the arithmetical ratio between the amounts produced (output) and the amount of any resources used during the process of production (input) (Chan & Kumaraswamy, 1995).

Previous studies show the number of factors affecting the productivity are still anonymous and need to be further studied even in developed countries (Makulsawatudom and Emsley 2002). Polat and Arditi (2005) arranged the factors affecting productivity according to their characteristics such as, design, working time, owner/consultant, material, execution plan, supervision, project factor, quality, equipment, leadership and coordination, labor, health and safety, organization, and external factors.

Previous studies also indicate that working overtime decreases the productivity. Working 7 days per week without holiday has a high effect on labor productivity, while working additional hours during the working day has an average effect (Enshassi et al., 2007). Some of the reasons caused by overtime are increase in accidents, moral decreased, supervision effectiveness reduces, increase in absenteeism and quality of work decrease which cause higher rework.

Supervisors' skills and approaches have an essential effect on Productivity. In some companies the productivity is very low however they use latest machinery and hire the skilled labor (Gundecha 2012). Incompetence Supervisors become a problem in large companies in line with the increasingly high demands of the project (Soekiman et al). Motivation is one of the important factors affecting construction labor productivity. The relationship between motivation and productivity can be summarized as that productivity is directly linked to motivation, and motivation is, in turn, dependent on productivity (Kazaz, et al., 2008). Motivation can best be accomplished when labors personal ambitions are like those of the company. Factors such as payment delays, a lack of a financial motivation system, non-provision of proper transportation, and a lack of training sessions are grouped in this topic (DeCenzo and Holoviak 1990).

Some of the natural factor can affect labor productivity. Previous studies indicate some natural factor which Job-site weather condition and geographical location is. Labor is also affected poorly by unfavorable weather conditions. For instance, when weather apparel such as raincoats or heavy jackets is necessary, labor is hindered (Mincks and Johnston, 2003). Other factors like water, fuel and minerals can affect productivity to some extent. Psychologically workers tend to become restless and irritable. Physiologically they can acquire heat cramps, heat stroke, heat exhaustion, etc. (Kuykendall, 2007).

3. Scope

This research enlists only those factors related to management, technological, labor, location, environmental, and tool group. A total of 52 factors were identified considering the previous studies on the similar topic after reviews, modifications, and revisions by local exerts and supervisors. The participants of the survey possessed experience in the construction industry ranging from 0 to 20 years, and more than 20 years. The sample size was 40. Most of data was collected from the participants belonging to Hyderabad, Karachi, Islamabad, and Lahore. Some participants form UAE also participated in this survey. Therefore, it is perceived that the results portray the overall picture and true reflection of Construction labor productivity of Pakistan.

4. Research Objective

The objective of this research is to evaluate and rank the critical factors which influence the construction labor productivity in Pakistan and provide a meaningful approach to counteract them. This study also intends to provide guidance to construction managers and senior engineers for efficient utilization of the labor force which may assist in successful completion of a construction project.

5. Research Methodology

The methodology/ steps of this research are stated below.

1. A throughout literature review was done the topic of factors affecting Labor productivity in various countries including Kuwait, Iran, Thailand, and India.
2. Key Factors were identified influencing labor productivity considering the previous studies on the similar topic after reviewing, modifications, and revisions by local exerts and supervisors.
3. A structured questionnaire was designed which included those factors.
4. The questionnaire was distributed to project managers, senior engineers possessing experiences in the construction industry.
5. Results were calculated, and conclusions were drawn.

The survey was constructed and was forwarded to project managers and senior managers. The data were collected and identified using a statistical technique namely RII (Relative Importance Index). The RII was calculated using the formula:

$$5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1 / 5(n_5 + n_4 + n_3 + n_2 + n_1)$$

Where,
n_1 = No of respondents who selected for 'No Effect"
n_2 = No of respondents who selected for 'Little Effect"
n_3 = No of respondents who selected for 'Moderate Effect"
n_4 = No of respondents who selected for 'Strong Effect"
n_5 = No of respondents who selected for 'Very Strong Effect"

6. Survey Design

The relevant data for this research was collected by a structured questionnaire consisting of two parts. The first part collected the personal information of the participant, while the second part asked the participant to tick the relative effect of the stated factor.
There were 52 factors arranged in six groups. 17, 8, 8,11, 4, and 4 factors were included in Management, technological, Labor, Location, Weather, and Tool group respectively. The participants were required to rank the different factors according to their effect on a five-point scale. The scale included 1, for no effect; 2, for little effect; 3, for moderate effect; 4, for strong effect; and 5, for very strong effect.

7. Respondents Characteristics

The questionnaire was distributed among the potential consultants, senior engineers, and project managers possessing enough experience and knowledge to deliver accurate results. The respondents were approached via Personal references, LinkedIn, emails, and Social Media groups. The survey sample was 40 which was achieved successfully.

8. Results and Discussion:

The perceived results of 52 productivity factors are discussed below as follows:

1. Management/Organizational group
2. Technological group
3. Human/Labor group
4. Location group
5. Weather group
6. Tool/Material group

8.1 Management/Organizational Group:

The management group comprises of the factors related to the administrative/organizational/ managerial department of the project. This is the topmost department of any construction project which coordinates different departments with each other. The RII of 17 factors and their rank under this group are given as:

Table 1: RII (Relative Importance Index) of factors arranged rank-wise under Management Group

Factor	RII (%)	Rank
Lack of Construction manager's leadership	83.5	1
Payment delays	81	2
Communication problems between site management and labor	78	3
Lack of labor supervision	77.5	4
Late arrival, early quit, and frequent unscheduled breaks	75	5
Unrealistic scheduling and expectation of labor performance	73	6
Inspection delays by site management	69.5	7
Accidents because of poor site safety program	69	8
Lack of incentive schemes	67.5	9
Lack of training offered to operatives	67.5	10
Inappropriate proportion of work subcontracted	66.5	11
Crew size and composition	66	12
Sequencing problems	63.5	13
Labor interference and congestion	62	14
Working overtime	60	15
Lack of transportation facilities for labor	58.5	16
Lack of suitable rest area offered to labor on site	58	17

The perceived results show lack of construction manager's leadership as the topmost factor affecting the labor productivity under this group with RII 83.5%, followed by payment delays with RII 81%, followed by communication problems with RII 78% as so on. It can be perceived that the leadership skills of the construction manager play the most crucial role in improving the labor productivity of a construction project. Similar results were also obtained by (Abdulaziz M. Jarkas, 2011) in which lack of labor supervision was ranked first under the management group and lack of construction manager's leadership was ranked forth.

8.2 Technological Group:

The relative important index of each factor is given under the Table 2.

Table 2: RII (Relative Importance Index) of factors arranged rank-wise under Location Group

Factor	RII (%)	Rank
Clarity of technical specifications	73.5	1
Variation/change orders during execution	69.5	2
Coordination level among design disciplines	69.5	3
Design complexity level	68.5	4
Reworks	68.5	5
Strict inspection by the Engineer	67.5	6
Delay in responding to requests for information (RFI)	67	7
Compatibility and consistency among contract documents	66	8

The results indicate the clarity of technical specification as the most crucial factor affecting the labor productivity with RII 73.5% under this group. Research by (Abdulaziz M. Jarkas, 2011 also placed clarity of technical specifications as the top ranked factor which also confirm the results.

8.3 Human/Labor Group:

This group comprises of the most critical factors which directly affects the productivity of general labor. The RII and rank of each factor under this group are mentioned under the Table 3.

Table 3: RII (Relative Importance Index) of factors arranged rank-wise under Labor Group

Factor	RII (%)	Rank
Skill of labor	81.5	1
Slack/ neglectful/ irresponsible attitude of labor towards work	79	8
Physical fatigue	74.5	2
Motivation of labor	73.5	3
Shortage of experienced labor	73.5	4
Availability of Labor/ Absenteeism	68.5	5
Age of Labor	68	6
Education/ literacy of labor	52	7

The obtained results indicate that the skill of the labor is the most important factor while considering laboring productivity with RII 81.5%, followed by the neglectful behavior of the labor towards work with RII 79 %, which is quite observable attitude of the labor in Pakistan. Skill of the labor was also place at the top by (Khaled Mahmoud El-Gohary, 2012) which confirms the surveyed results.

8.4 Location Group:

While planning a project of any scale, location plays the most crucial role in its success and efficient completing. Thus, the location of the site/project directly influence the overall labor productivity of the construction project as well. To calculate the influence of location under this group, a total of 11 productivity factors were included in it and their relative RIIs and Ranks were calculated which are listed in the Table 4.

Table 4: RII (Relative Importance Index) of factors arranged rank-wise under Location Group

Factor	RII (%)	Rank
Disruption of water services	73.5	1
Disruption of power services	70.5	2
Low level of lighting/poor ventilation/poor housekeeping/limited accesses	70	3
Inadequate water coolers, toilets, convenient store or covered rest area onsite	69	4
Political/ Governmental influence on the project	68.5	5
Site restricted access	68	6
Insufficient site investigation data	65.5	7
Site Layout	63.5	8
Unsuitability of storage location	63	9
long distance from home or camping site to jobsite	62	10
Theft Issues	56	11

Water, which is the most essential element for life, tops the group with an RII of 73.5% followed by power disruptions with RII 70.5%. Both factors are quite common in Pakistan where the shortage of water and unscheduled power losses plays the biggest influence on the overall labor productivity. Water is used for drinking, preparing of concrete and mortar, and curing purposes. Whereas electricity is required commonly for operating essential machinery, pumps and lightening purposes. This, it is quite evident that both the factors are of utmost importance along with the other factors as mention in the table rank-wise.

8.5 Weather Group:

The RII of 4 factors under this group are mentioned under the Table 5 below:

Table 5: RII (Relative Importance Index) of factors arranged rank-wise under Weather Group

Factor	RII (%)	Rank
Frequent Rainfall	74.5	1
Very High/ low temperatures	72.5	2
Heavy winds	62	3
Noise / Dust pollution	55.5	4

8.6 Material/Tool Group:

Material and equipment/ tools the most important resource of any construction project. The factors under this group along with their RII are listen under the Table 6 below.

Table 6: RII (Relative Importance Index) of factors under Material/Tool Group

Factor	RII (%)	Rank
Unavailability of required material on site	81.5	1
Lack of proper tools and equipment on site	80	2
Shortage of material in the market	77	3
Frequent tools/equipment breakdowns due to aging or poor maintenance	74.5	4

8.7 Top 10 Overall Productivity Factors:

Table 7 shows the overall productivity factors among all the groups arranged w.r.t their respective RII. The table shows the following factors as the top 10 labor productivity factors: Lack of Construction manager's leadership ,Skill of labor, Unavailability of required material on site, Payment delays, Lack of proper tools and equipment on site, Slack/ neglectful/ irresponsible attitude of labor towards work, Communication problems between site management and labor, Lack of labor supervision , Shortage of material in the market, Late arrival, early quit, and frequent unscheduled breaks.
Among the top 10 Labor productivity factors, 5 belong to Management group, 2 belong to Labor group, and 3 belong to material/tool group. No factor from technological, location, and weather groups is included in the table. Among these factors, 3 were included in the study by (Abdulaziz M. Jarkas, 2011)

Table 7: RII (Relative Importance Index) of the Top 10 overall productivity factors

Productivity Factors	RII (%)	Rank
Lack of Construction manager's leadership	83.5	1
Skill of labor	81.5	2
Unavailability of required material on site	81.5	3
Payment delays	81	4
Lack of proper tools and equipment on site	80	5
Slack/ neglectful/ irresponsible attitude of labor towards work	79	6
Communication problems between site management and labor	78	7
Lack of labor supervision	77.5	8
Shortage of material in the market	77	9
Late arrival, early quit, and frequent unscheduled breaks	75	10

9. Conclusions

Based on the perceived results, following conclusions can be drawn:

1. The management/organizational group highly affects the overall labor productivity of any construction project. Lack of construction manager's leadership (management factor) is the top ranked factor among the overall 52 productivity factors.
2. The skill of the labor (Labor factor) is the second most critical factor among all and needs proper consideration. Labor without having sufficient skills also found to be unwilling towards work since they must utilize more energy to complete a task as compared to the labor having good skills.
3. Unavailability of material (Tool/material group) is the third most influencing factor among all. Material is the most important resource of a project and thus could have a larger impact on the labor productivity. Unavailability of material may promote idle-sitting of labor which adds up delay in project duration.
4. Money is one of the biggest motivation factors at work. Delaying in making payments/wages of the labor ultimately triggers low work motivation at site and affects the labor productivity.
5. Tools/ equipment are as important resource of a project as material or Human. Unavailability of proper equipment promotes manual works which increased time duration to complete that activity.
6. Most of the labor on sites are found to have neglectful/ slack attitude towards their assigned work. Such behavior induces delay in works and halt labor productivity.
7. Communication is one the biggest hurdle among the construction team of the project. Lack of communication of labor with site management provides greater chances of reworks/ work flaws and minimize labor productivity.

8. Lack of labor supervision creates greater chances of faulty works and thus decrease the overall labor productivity.
9. The shortage of required material in the market results in the shortage of that material on site, thus produces the same results.

10. Recommendations

Based on the above stated conclusion and their analysis, following recommendations/ advices/solutions can be implemented to improve the labor productivity in Pakistan.

1. Construction mangers must be provided with proper trainings to improve their leadership qualities. Moreover, the most competent person among the industry must be hired/ promoted for this position. Promotions based on favoritism must be avoided.
2. The skill of the labor must be preferred by the contractors. Moreover, strict supervision must be made to rectify errors on the spot. Their behavior must be identified and should be counseled by the site supervisor to have a progressive attitude.
3. The labor/ workers must be motivated by means of incentive schemes, bonuses, recognition and appraisals among their fellows. Payment delays must be avoided.
4. The arrangement of the material must be made before sufficient time from the start of an activity. If the material is unavailable in the market, the most suitable alternative material must be considered instead of waiting for its availability.
5. Proper means of communication between the functional and administrative part of the project must be maintained. Moreover, a productive environment must be established between the people, so the communication gap could be avoided.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

The Effect of Soil Reinforcement with Crumb Tyre Rubber on of the Strength of Silty Sand

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Abstract

Nowadays, in order to increase the load carrying capacity of soil researchers are using the polymers, geogrids and other reinforced materials. These materials which are used as a stabilizer are enhancing the strength parameters of the soil. Therefore, in this research study, the crumb rubber tyre of a size of 10mm to 1mm with proportions 5%, 10%, 15% and 20% by weight was mixed with the riverbed silty sand soil taken from the Indus River, Near Jamshoro. The shear strength parameters were investigated using direct shear tests under the vertical stresses of 0.681kg/cm^2, 1.236kg/cm^2 and 1.792kg.cm^2. The results showed that the shear strength increased significantly as compared to untreated silty sand when crumb tyre rubber was mixed between 5% to 10% of the weight of soil.

Keywords
Soil reinforcement, crumb tyre rubber, direct shear text, shear strength

1. Introduction

In the world, scrap tyre wastes are increasing and the main problem is to dump them. It causes the problem related to environment when they are burnt. In most of the countries, their stockpiling is banned. Furthermore, it is economical as compared to other geogrid reinforced material and easily available in the market with different sizes. Two different materials are used to reinforce the soil having compressive and tensile strength. It is an effective and reliable method to stabilize the soil layers for shear strength and bearing capacity, it increases and decreases in settlement in the embankments, walls and pavements. It was observed that soil can be reinforced in ancient times by using tamarisk branches and woven mats. (Tahsina Mahmood, 2009), Therefore, in this study the effect of crumb tyre rubber to reinforce the soil when compared with un-reinforced soil was investigated.

2. Literature Review

In the present era, engineers are exploring the ways to reuse the locally available waste materials to minimize the project's cost and its impact on environment. Now a day, waste materials are also used to improve geotechnical properties of soil. There are various waste materials which causes various hazardous to the environment, i.e. Tyres waste. Researchers have shown the tyre chips, shreds and crumbs are highly compressible. The soil often is weak and cannot enough strong to bear the heavy loading. The aim of the study is to use the waste material, with respect to cost and environment efficient. As per literature crumb tyre rubber can be used as light weight material. The overview has taken out from various researchers work, which are somehow related to the topic.

(Umar Jan *et al., 2015)* studied to reinforce the weak soil by using shredded rubber tyres. It extensively used shredded rubber tyres having sizes ranges from 30mm to 50mm (length) and 15mm to 50mm (width). Rubber tyres were added in variation according to the proportion of 4%, 6%, 8%, and 10%. Results showed that increasing the percentage of rubber tyre CBR had got the improvement up to 50%.

(Purushotham G. Sarvade, 2012) studied to used recycled tiles and tyres with or without any other admixture to improve the bearing capacity and strength of soil. Results show these admixtures have a great influence on the index properties, compaction parameters, strength, settlement and compressibility of soft soil. This research showed that the recycle tyre rubber used as a filler to fill the voids of soft soil to improve the strength of soil. The study shows by increasing the percentage of rubber content in soft soil the strength has increased.

(Ghazavi M, 2004) studied to calculate the shear strength parameters by using the direct shear tests of sand-tyre mixtures and it was concluded that sand reinforced with crumb rubber mixture exhibits higher shear strength than sand.

(Rao G.V and Dutta R.K 2001) studied on the mixture of sand with rubber chips. The Triaxial tests and compressibility tests were conducted. In this study, the stress strain relationship parameters were studied. The results showed that the value of cohesion and internal fraction of sand increased with increased in percentage of rubber up to 15%.

(Chien-Jen Chu, 1998) studied to used shredded tyre rubber as a stabilizer in two different soil types to determine the following parameters: compaction characteristics, permeability, unconfined compressive strength, and shear strength. The shredded tyre rubber contained the three different sizes. After determined all the parameters, the results show the improvement in engineering properties of soil.

3. Material Properties

The Soil was taken from the Indus River Bed and Crumb Tyre Rubber from the Korangi, Industrial Area, Karachi.

3.1. Soil Type

The study was conducted on the Sandy soil taken out from the Indus river bed. The soil is classified by the Sieve Analysis Method. In Sieve Analysis following sieves were considered 4.75mm, 2mm, 0.425mm and 0.075mm sieves. The results show in the as per AASHTO Classification that the soil is A-3 Type. The following graph shows the grading of the soil.

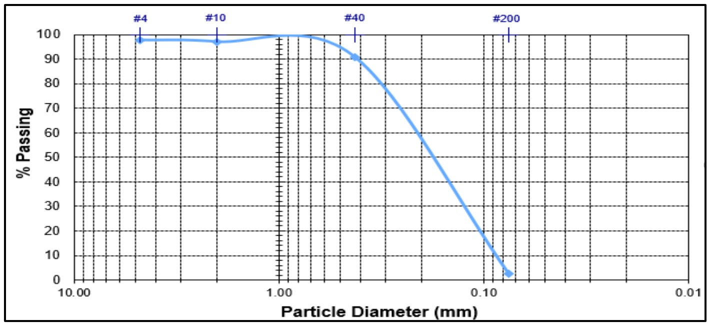

Figure 01: Grading Curve of Soil

The Table 01 shows the results of the sandy soil. After Sieve Analysis, Specific Gravity test was conducted on the soil. Pycnometer method adopted for the measuring Specific Gravity. Then, Compaction characteristics test was conducted to determine minimum dry density and maximum dry density.

Table 01: Properties of Soil

SOIL TYPE	TEST TYPE	Value
A-3	Minimum Dry Density	1.34 (g/cc)
	Minimum Dry Density	1.69 (g/cc)
	Specific Gravity	2.54

3.2. Reinforcement Material

The Crumb Rubber Tyre material is used to reinforcement the soil. It has a dimension of 1mm to 7mm. The Material is obtained from the Tyre Rubber Factory, Karachi. The Material has a Specific Gravity of 1.10.

4. Methodology

In this research the investigation is carried out to know the behavior of soil after reinforcement with crumb rubber tyre. The Crumb rubber tyre mix with the soil on following proportion 5%, 10%, 15% and 20% weight. To perform this, the Direct Shear Box Test performed under the under the vertical stresses of 0.681 kg/cm2, 1.236 kg/cm2 and 1.792 kg/cm2.

5. Results and Discussions

The Following figures shows the result of Shear stress versus shear strain of unreinforced sand and reinforced soil with Crumb Tyre rubber with 5%, 10%, 15% and 20% weight under the vertical stresses of 0.681 kg/cm^2, 1.236 kg/cm^2 and 1.792 kg/cm^2.

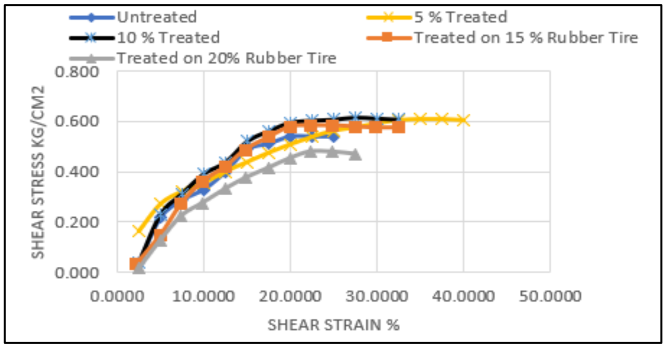

Figure 02: Shear Strain versus shear stress on the vertical stress of 0.681kg/cm^2.

In the above figure, it shows that by increasing the amount of tyre rubber content the shear stress of the reinforced material increases. The result indicates under the vertical stress of 0.681kg/cm^2. In terms of percentage, the shear stress increases with the increases of crumb tyre rubber content up to 10% after it starts to decrease.

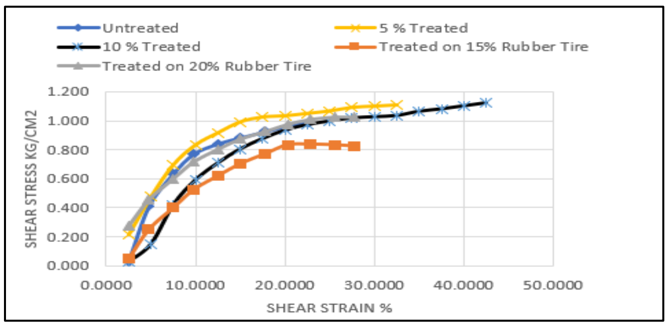

Figure 03: Shear strain versus shear stress on the vertical stress of 1.236kg/cm^2.

In the Figure 3, The vertical stress 1.236kg/cm^2 applied on the unreinforced and reinforced soil mixed with proportion of 5%, 10%, 15% and 20% by weight. It also shows same behavior as first shear strength increases with respect to unreinforced soil and then gradually decreases.

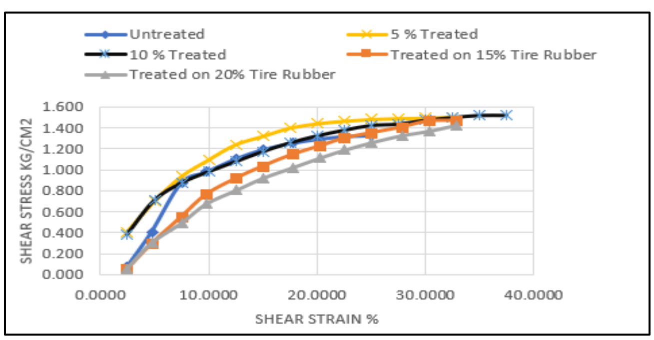

Figure 04: Shear strain versus shear Stress on the vertical stress of 1.792kg/cm^2.

The above figure shows the behavior on vertical stress of 1.792 kg/cm^2. In which unreinforced and reinforced soil mixed with the above-mentioned proportions. The result shows with the increase of crumb rubber content the shear strength parameters first increase that it starts decreases.

In following Table 2 and Figure 5 show that by increasing the percentage of crumb tyre rubber, the shear strength of soil increases as compared to unreinforced soil. The Table-2 summaries the whole work that the maximum shear strength of reinforced soil came at the proportion of 10% at the load of 1.73kg/cm2.

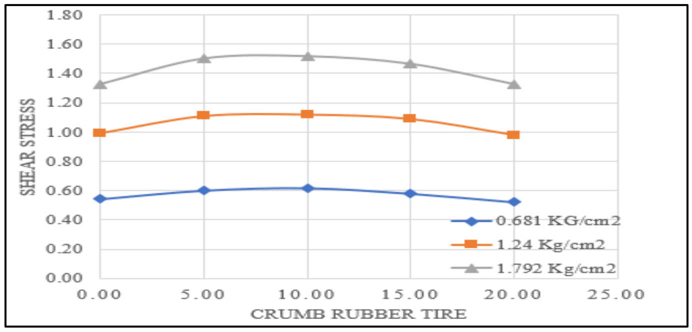

Figure: 05: Crumb tyre rubber versus shear stress.

Table 02: Shear strength changes with the increase of percentage of crumb tyre rubber

Increase Percentage	0.68kg/cm^2	1.24kg/cm^2	1.73kg/cm^2
5.00	11.11	12.12	13.10
10.00	14.26	13.13	14.29
15.00	7.22	10.10	10.28
20.00	-3.55	-1.01	-0.38

6. Conclusion

1. In this research, first shear strength parameters of all samples were determined through the direct shear box test and was concluded that the internal friction and dilation angle first increased up to 10% of reinforced soil and then started to decrease.
2. Increasing crumb tyre rubber from 5% to 10%, peak shear strength of the sample increased and then it decreased from 15 to 20 %.
3. A maximum increase of shear strength is 14.29% by mixing 10 per cent of crumb tyre rubber with soil at the vertical load of 1.73 kg/cm^2
4. The weight percentage of crumb rubber for increasing maximum shear strength is between 5% to 10%.
5. After increasing the weight above the 10 % the peak shear strength of reinforced soil started to decrease.

7. Recommendations

1. The dimension of crumb tyre rubber should be changed as it affects the results.
2. In this research, A-3 soil was taken, the effects on other soils should be studied.
3. In this research element testing was conducted. Physical models of geotechnical structure such as embankment, foundations and others should be prepared and analyzed.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Effect of Lime and Wheat Straw on the Shear Strength Characteristics of Clayey Soils

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Abstract

The importance of shear strength of clayey soil cannot be undermined since it helps in the determination of behaviour of soil within its system. Shear strength of soil has a direct relationship with cohesion and friction angle thus, the shear strength of soil mainly depends on cohesion and friction angle. Greater the values of shear strength parameters higher will be the shear strength, thus soil stabilization results in changing the shear strength of soil. The present study focuses on the shear strength parameters of clayey soil using wheat straw as reinforcing and lime as a stabilizing agent to investigate the potential use of wheat straw fibre and lime in improving the shear strength of compacted clayey soils. During this study several unconsolidated undrained (UU) triaxial tests were conducted on soil specimens with different percent contents of lime and wheat straw as stabilizing agents to observe their effect on shear strength of clayey soil and obtained results have shown that with the addition of wheat straw the shear strength of clayey soil increases but for the lime it increases up to some extent and then decreases hence showing the unpredictable behaviour of clayey soil. UU-Triaxial tests were also conducted at three different confining pressures to observe the effect of confining pressure also on the maximum deviator stress of soil. It can be concluded that both lime and wheat straw are significant for the stabilization of soil since their effects are remarkable.

Keywords
Lime, wheat straw, shear strength, UU-Triaxial, clayey soil.

1. Introduction and background

Shear strength is a term used in geotechnical engineering to define the amount of the shear stress that soil can bear. The shear resistance of soil is the outcome of friction (ϕ) and cohesion of particles (c), and possibly cementation or bonding at a particle to particle contacts. The addition of chemicals such as lime, cement, fly ash and other admixtures and fibrous materials such natural and artificial fibre into the soil for the improvement of its geotechnical properties often alters the shear strength properties. An understanding of the shear strength of soils is necessary for the design of pavements, embankments for dams, roads, excavations and levees etc. The safety of a geotechnical structure is dependent on the shear strength of soil.

Several studies in the past have been conducted for the determination of the effect of various stabilizing and reinforcing agents on the shear strength parameters of soils. For instance, the effect of sisal fibre on friction angle (Prabakar and Sridhar 2002), effect of the fibre content on the cohesion and friction angle of fibre–lime treated soil specimens (Cai et al. 2006), effect of coconut fibre on cohesion and angle of internal friction (Ayininuola and Oladotun 2016), effect of coir fibre on cohesion and friction angle of soil (Khatri et al. 2016), effect of cement and micro-silica on cohesion and frictional (Sadrjamali et al. 2015), by using the triaxial compression test Lin et al. (2007) found that the shear strength parameter of cohesive soil, cohesion c, rose with an increased amount of additives and improved from 30 to 50−70kPa.

For the usefulness of natural fibre and organic materials in ground improvement, it has been a general perception that using soil as an engineering material, the presence of natural and organic materials in the soil should be minimum (Abdi et al. 2018). However, several studies have been conducted to investigate the natural fibres effect on the mechanical properties of soil and it is reported that natural fibres improve many of the engineering properties of the soil. Particularly, the usefulness is more prominent in the fine-grained cohesive soils as compared to coarse-grained materials. Therefore, the potential use of natural and synthetic fibres is gaining more interest in the geotechnical community for addressing many of the geotechnical related issues.

According to Abou Diab et al. (2016) reinforcing clay with natural fibres is a routine practice in various applications, such as the repair of shallow slope failures, construction of steep slopes, improving the performance of landfill covers, strengthening of roadbeds, etc. According to Ma et al. (2018), the shear strength of flax fiber-reinforced clay is greater than that of pure clay. According to Qu and Sun (2016), the addition of wheat straw fibre leads to a significant increase in shear strength and friction angle of the natural soil and there is an optimum wheat fibre content that makes this increase maximal. Several other studies (Al-Akhras et al. 2008; Attom et al. 2009; Chee-Ming 2011; Sarbaz et al. 2014; Danso et al. 2015) have also indicated improvement in some of the mechanical properties of clayey soils due to the addition of natural fibres.

The existing literature indicates that not many studies have been conducted in the past to explore the effect of wheat straw and wheat straw-lime combination on the cohesion and friction angle of clayey soils. The dependence on the use of wheat straw is the result of its excessive production, little engineering use and increasing demand for incorporating sustainable materials in construction. Wheat straw fibres are natural fibres derived from the wheat crop. Being an agricultural country the wheat crop production in Pakistan is with an increasing trend, therefore, the investigations about the use of wheat straw for the stabilization of clayey soils is of significance. The blend of lime and wheat straw for the improvement of clayey soils would be interesting.

Without getting biased with the existing literature, the investigations of the effect of lime and wheat straw on the strength parameters of clayey soils to overcome the existing local issues would be a valuable addition in the existing body of knowledge.

2. Methodology

2.1 Materials

The major materials in this research study consisted of soil, wheat straw, and lime. The soil was taken as a base material; while lime and wheat straw were used as soil stabilizing and reinforcing agents. The other materials like cement, polypropylene and gypsum are used for some specific testing.

2.1.1 Soil as a base material

The base soil was collected in the form of lumps as shown in Figure 1. After oven drying, the lumps of the soil were pulverised using a mallet hammer for the preparation of the specimens. The pulverized soil obtained after breaking the lumps is shown in Figure 2. The gradation curve (based on sieve and hydrometer analysis) and soil composition based on particle size are shown in
Figure 3 and Figure 4 respectively. Based on the gradation and consistency limits values; the soil as per the USCS system is classified as ML-CL. The summary of the soil parameters is given in Table 1.

Figure 1 Clayey soil lumps in the stock.

Figure 2 Fine clayey soil pulverized for sample preparation.

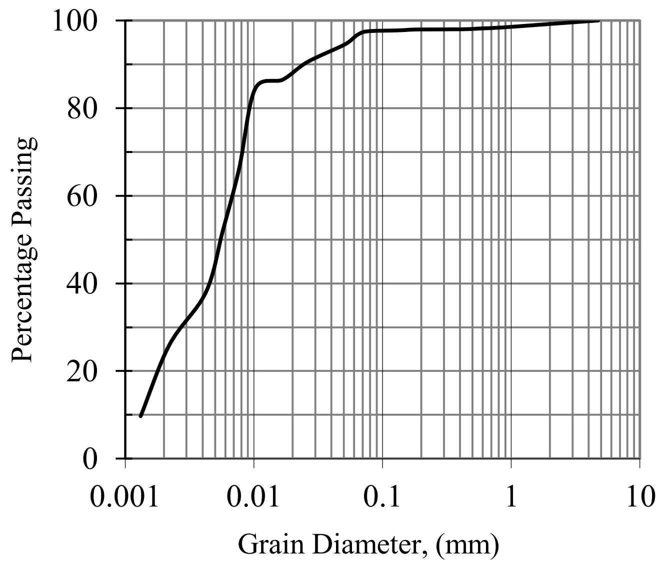

Figure 3 Particle size distribution curve

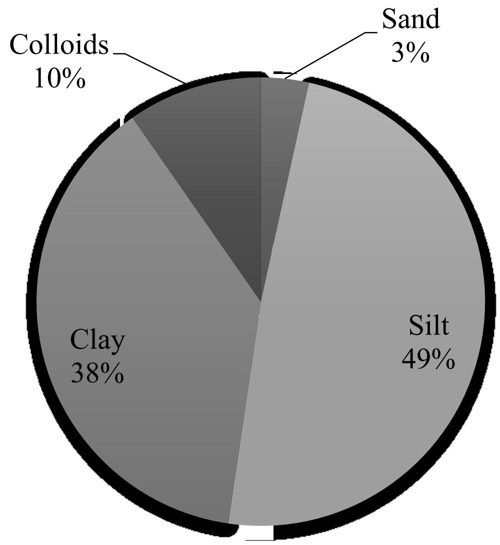

Figure 4 Soil composition

Table 1 Soil parameters

Percent Passing No. 10	99.2
Percentage Passing No. 40	98.2
Percentage Passing No. 200	96.5
Sand, passing No. 4 sieve and retained on No. 200 sieve	3.45%
Silt size, 0.074 mm to 0.005 mm	48.88%
Clay size, smaller than 0.005 mm	37.98%
Colloids, smaller than 0.001 mm	9.70%
Liquid limit (LL)	23.85
Plastic limit (PL)	16.08
Plasticity Index, (IP)	7.77
Shrinkage limit (SL)	13.14
Specific Gravity	2.60
USCS Classification	ML-CL

2.1.2 Water used for specimen preparation

Potable water was used for the preparation of the specimens. The chemical properties of the water used for the sample preparations are given in Table 2.

Table 2 Chemical properties of potable water

pH	Hardness (mg / L)	TDS (ppm)
7.0	150	1190

2.1.3 Soil modifiers

Many soil reinforcing and stabilizing agents are used usually for ground improvement. The lime and wheat straw was the main soil stabilizing and reinforcing agents in this study which are used through testing on the other hand cement, gypsum, polypropylenes were used for some specific testing (Figure 5).

(a) Wheat Straw (b) Lime

Figure 5 Soil stabilizing and reinforcing agents

2.1.3.1 Wheat straw

Wheat straw is agricultural by-product consisting of the dry stalks of cereal plants (as shown in Figure 6. After the grain and chaff have been removed using thresher machines as shown in Figure 7, the threshed wheat straws were used for reinforcement (as shown in Figure 8). Some of the basic and index properties of wheat straw were already reported in Muhammad and Marri (2018).

Figure 6 Un-threshed wheat straw

Figure 7 Wheat straw being threshed using a thresher machine

Figure 8 Threshed wheat straw

2.1.3.2 Lime

Powdered lime is obtained after crushing lumps of limestone followed by sieving and collection of fine fraction, the process is shown in Figure 9 (a to d). The chemical composition of the lime used is reported in Muhammad et al. (2018).

(a) Lumps of lime (b) Powdered lime (c) Sieving of lime (d) Fine Powdered lime

Figure 9 Lime powder collection process

2.2 Experimental setup

Dynatriax triaxial testing setup as shown in Figure 10 was used for unconsolidated and undrained triaxial compression tests. The system is equipped with a data logger and a real-time display system with automatic data recording facilities. Monotonic and cyclic triaxial testing can be conducted on this system.

Figure 10 Dynatriax triaxial testing system

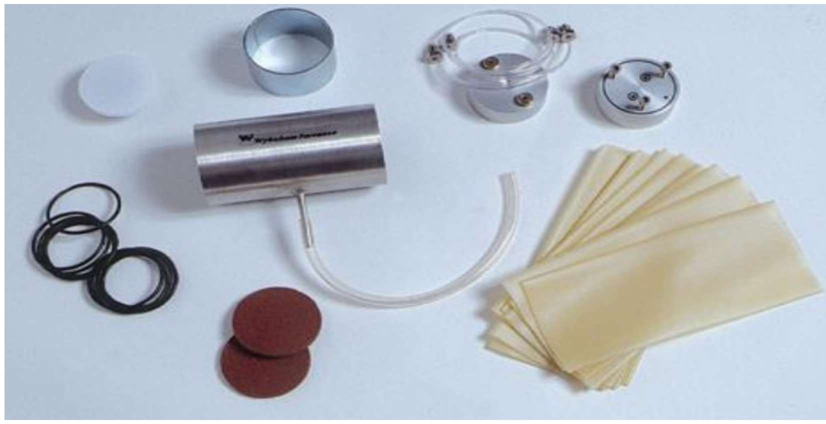

Figure 11 Testing accessories

2.3 Sample preparation and testing procedure

Various percentages of wheat straw and lime by dry weight of soil were added into the soil and mixed by "dry mixing method" and thereafter added with water and mixed again thoroughly by "wet mixing" in a closed bucket for a homogeneous composition. The amount of water added into the soil mass nearing the liquid limit for acquiring a workable paste which could be moulded without crumble. During mixing and blending the water absorption factor is important as this amount of water can be used for the soaking of the materials in the later part. The cylindrical samples of 50 mm diameter and 100 mm height were prepared in the modified split moulds specially designed for this purpose. The split moulds were provided with colours and the compaction of the samples was done with the help of rammer with controlled compaction efforts to achieve the specimens with controlled density. UU-Triaxial compression tests on remoulded soil samples stabilized with lime and wheat straw were conducted as per the standard procedure under deferent confining pressures to develop Mohr circles and subsequent Mohr-Coulomb failure envelops.

3. Results and discussion

3.1 Effect of lime on the deviator stress

The effect of lime content on the deviator stress was analysed for 69 kPa (10 psi), 138 kPa (20 psi) and 207 kPa (30 psi) of confining pressure(CP). The results are summarized in Table 3 and graphically represented in Figure 12. From the figure, it can be seen that there is a gradual increase in the maximum deviator stress (q_{max}) by the increase in the lime content up to 4%. Further, the increase in the lime content resulting to decrease the q_{max} value.

Table 3 Effect of lime on maximum deviator stress

Lime content (%)	Maximum Deviator Stress q_{max} (kPa)		
	σ_3 = 69 kPa (10 psi)	σ_3 = 138 kPa (20 psi)	σ_3 = 207 kPa (30 psi)
0	108	149	190
2	159	213	267
4	171	232	293
6	131	181	231
8	102	141	181
10	81	113	145

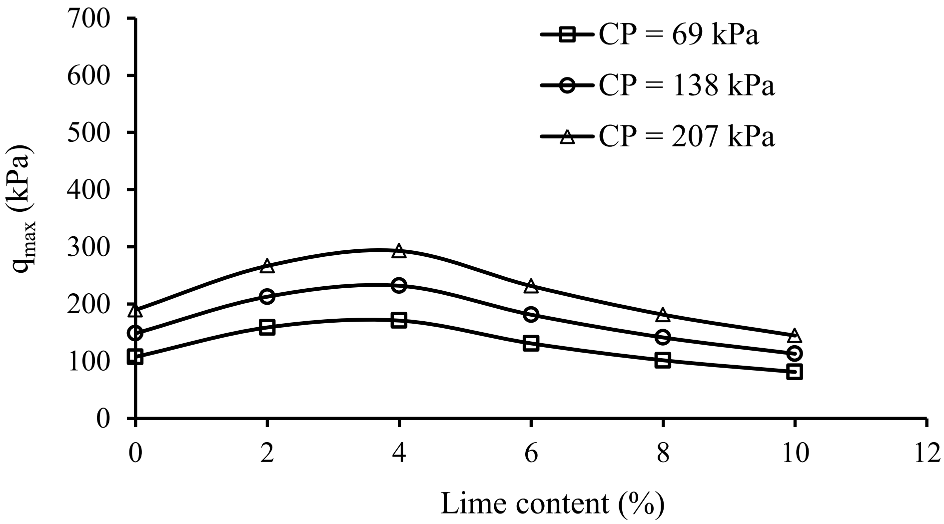

Figure 12 Effect of lime on the maximum deviator stress at various confining pressures

3.2 Effect of wheat straw on the deviator stress

The effect of wheat straw content on the deviator stress was analysed for 69 kPa (10 psi), 138 kPa (20 psi) and 207 kPa (30 psi) of confining pressure (CP). The results are summarized in Table 4 and graphically represented in Figure 13. From the figure, it can be seen that there is a gradual increase in the maximum deviator stress (q_{max}) by the increase in the wheat straw content there is a gradual increase in the deviator stress with a higher increase rate up to 4% and relatively lesser increase rate beyond 4% wheat straw content.

Table 4 Effect of wheat straw on the maximum deviator stress (q_{max})

Wheat straw content (%)	Maximum Deviator Stress q_{max} (kPa)		
	σ_3 = 69 kPa (10 psi)	σ_3 = 138 kPa (20 psi)	σ_3 = 207 kPa (30 psi)
0	108	149	190
2	191	263	334
4	304	393	482
6	311	413	515
8	322	421	520
10	358	467	577

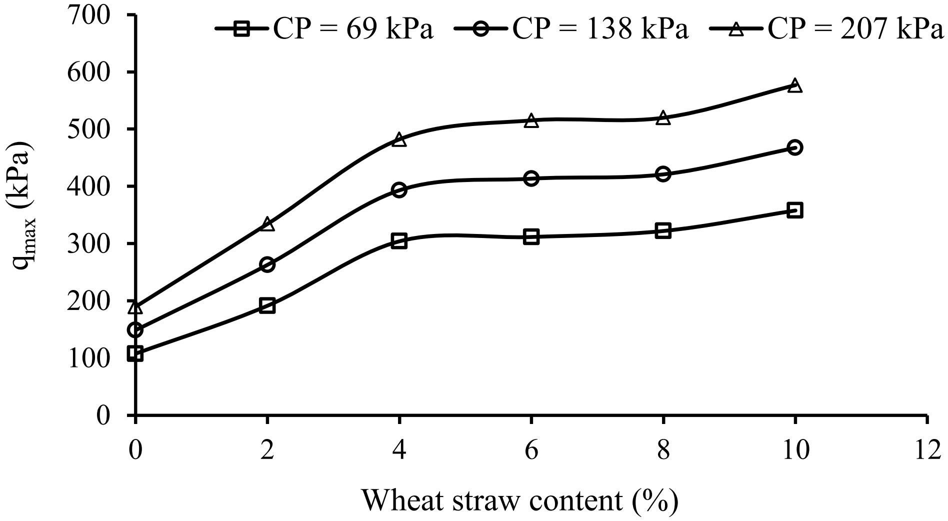

Figure 13 wheat straw on the maximum deviator stress

3.3 Effect of lime and wheat straw on deviator stress

the effect of lime and wheat straw on the deviator stress q_{max} value is shown in Figure 14. From the results, it can be seen that for both lime and wheat straw there is a gradual increase in the q_{max} value up to 4%, further increase in the lime and wheat straw contents having almost opposite effect on the q_{max} value; i.e., increase in the lime content beyond 4% resulting to gradual decrease in the q_{max} value and increase in the wheat straw content beyond 4% resulting to gradual increase in the q_{max} value. Nevertheless, at 4% the increase in q_{max} value due to the addition of lime is 55.7% and that of wheat straw is 163.7%. Similarly, at 10% the lime content resulting to decrease the q_{max} value by 24% whereas wheat straw resulting to a 213% increase in the q_{max} value.

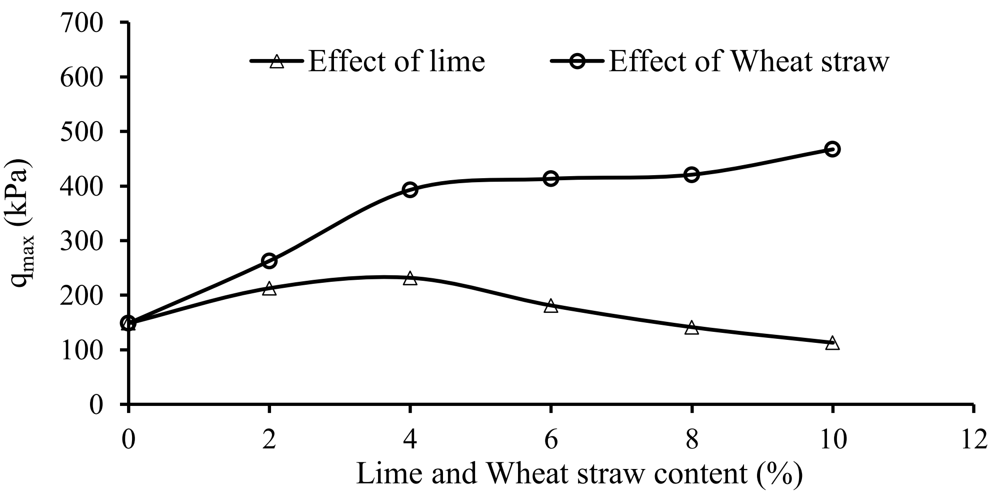

Figure 14 Effect of lime and wheat straw on q_{max} at 138 kPa (20psi) of confining pressure

3.4 Effect of lime and wheat straw on clay cohesion

Figure 15 represents the effect of wheat straw and lime on the cohesion of clayey soil. From the results, it can be seen that by the increase in the lime content there is a gradual increase in the cohesion of clayey soil up to 4%. Further, the increase in the lime content resulting in a gradual decrease in the cohesion value. Therefore, the optimum lime content for the improvement of the cohesion of clayey soil is 4%. Similar trends were reported by Sadrjamali et al. (2015) for Nano-silica content in the clayey soils. Similarly, the increase in the wheat straw contents resulting in an increase in the cohesion of clayey soils up to 4% and further increase resulting in a sharp decrease in the cohesion value. It suggests that the cohesion characterises of clayey soils are sensitive near 4% wheat straw content on either side of the optimum value there is a sharp decreasing trend. The comparative analysis of the effect of lime and wheat straw indicate that 4% lime addition resulting to an increase of 52% in the cohesion of clayey soils whereas, the 4% wheat straw addition resulting to an increase of 374% in the cohesion of clayey soils. The increase in the cohesion of the clayey soils due to the wheat straw content might be due to the induction of ductility in the soil mass.

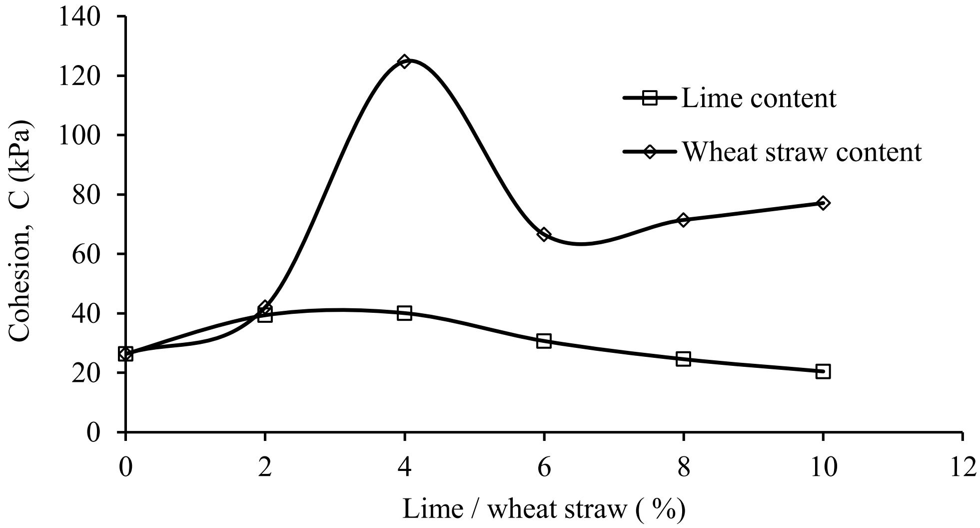

Figure 15 lime and wheat straw effects on the cohesion value

3.5 Effect of lime and wheat straw on friction angle

The comparative analysis of the effect of lime and wheat straw on the friction angle of clayey soils is shown in Figure 16. From the figure it can be seen that by the increase in the lime content up to 4% there is gradual increase in the friction angle of clayey soils, further increase in the lime content resulting in decrease in the friction angle, therefore, an optimum lime content for the friction angle of clayey soils is 4%. On the other hand, the effect of wheat straw content on the friction angle of clayey soils is fluctuating, for instance up to 2% there is an increase, from 2% to 4% there is decrease and again from 4% to 6%, there is an increase in the friction angle of clayey soils. The 4% lime and wheat straw contents at on the friction angle of clayey soils indicate an opposite trend; i.e., at 4% lime content there is an increase in the friction angle by about 34.5% whereas, 4% wheat straw addition resulting in to decrease the friction angle by about 44.7%.

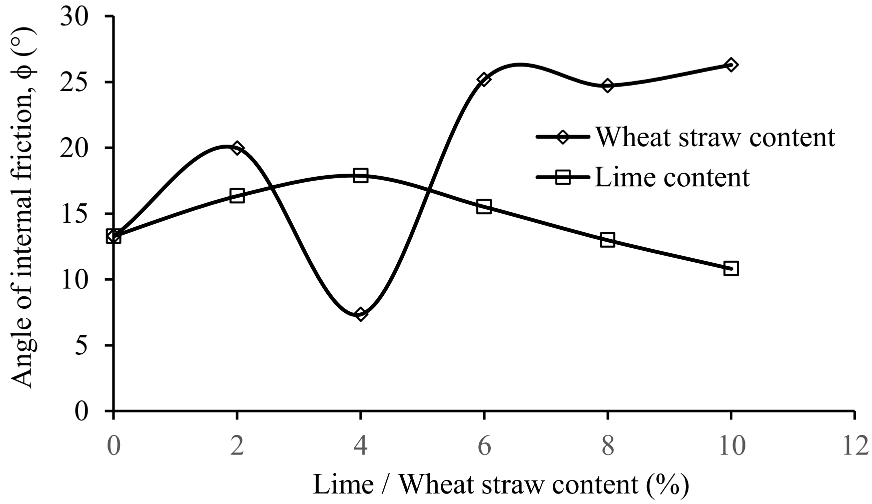

Figure 16 Effect of lime and wheat straw on the friction angle

4. Conclusions

From the analysis of the results the following conclusions can be drawn:

The general perception that the presence of natural and organic materials in the soil should be minimum is not always true. As from the literature and present studies, it is evident that wheat straw is a natural fibre and lime as a natural resource is going improve the strength parameters of clayey soils when used intelligently at optimum contents; for instance,

1) Both lime and wheat straw resulting in an increase in the deviator stress of clayey soils under unconsolidated and undrained triaxial compression tests. At 4% lime and wheat straw contents respectively the increase in q_{max} value due to the addition of lime is 55.7% and that of wheat straw is 163.7%.
2) The optimum lime content resulting in a maximum increase in the friction angle and cohesion of clayey soils is about 4%. Moreover, similar trends were noticed for cohesion and friction angles due to the addition of lime content into the clayey soils. 4% lime addition resulting in an increase of 52% in the cohesion of clayey soils whereas the 4% wheat straw addition resulting in an increase of 374% in the cohesion of clayey soils.
3) The optimum wheat straw content for the cohesion is around 4%, however, the least friction angle is obtained at 4% wheat straw content. Nevertheless, at 4% lime content there is an increase in the friction angle by about 34.5%; whereas, 4% wheat straw addition resulting to decrease the friction angle by about 44.7%.

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10th International International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

River Flow Forecasting Using Artificial Neural Network and Distributed Hydrological Modelling

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Abstract

Pakistan being an agricultural-based country depends largely on its irrigation system, however, it faces a severe challenge in terms of water shortage because of inefficient irrigation system and reduction in dam storages. Due to the unavailability of data in Pakistan, the data used for this analysis was of Wilmot Creek, ON, Canada. The objective of this study is to simulate and compare surface runoff using two different approaches. The first approach used was Artificial Neural Network (ANN) which was trained using feed forward back propagation. While, the second approach used was Distributed Hydrological Model (DHM) where the software program used was Annualised Agricultural Non-Point Source (AnnAGNPS) pollution model. Additionally, AnnAGNPS was used to determine the sediment and nutrients yield for the watershed. The comparison of these models was done using two different warm up periods; four years (1976-1979) and ten years (1976-1985), from an observed data of 1976-1986 and were calibrated accordingly. Since, AnnAGNPS was not able to produce the water balance for the watershed, Soil and Water Assessment Tool (SWAT) was used to determine the water balance and sediment yield. Accuracy of the models was determined using statistical coefficients and it was found that ANN performed better than AnnAGNPS. However, AnnAGNPS can be used for sediment and nutrients yield.

Keywords: Surface-runoff, Neural Network, Hydrological Model, Statistical Coefficients, Sediment Yield

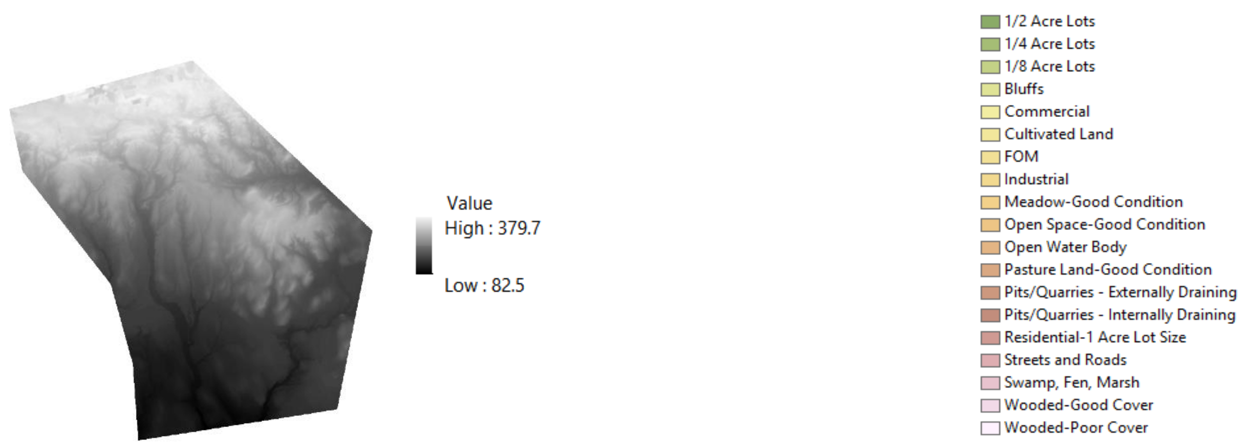
1. Introduction

In the last 70 years, Pakistan has experienced 20 large scale floods that have caused a monetary damage of over 39 Billion Dollars, 11,239 casualties were incurred and 600,000 sq.km of area was affected (Ansari, 2017).
From the years 1995-2016 there have been multiple floods globally, affecting 2.3 billion people and killing around 157000 people. Also, the monetary loss incurred due to these floods was 1.891 trillion USD. The stats also revealed that for the following time period 56% of all the natural disaster were flood (Davies, 2016).

For the sake of study, models are created with help of different techniques which are the simplified representation of real-world system. These models are simulated to predict the respective values and the best model is the one which produces result closest to the reality. In modern world, the most used approach for forecasting river flow is Artificial Neural Network (ANN). ANN works and behaves on similar principle as brain. It has the ability to learn from its mistakes, recognize patterns and adapt solutions providing more accurate results as data is augmented. ANN structure consists of non-biological neurons interconnected to each other in three different layers: Input, Hidden and Output.
Hydrological Modelling is a mathematical model that is used to analyse or design naturally occurring water. Distributed Hydrological modelling (DHM) uses the data by means of grids and cells, where each cell contains different set of data (land use, soil type and slope).
Sedimentation damages aquatic life, recreational resources and aesthetics of any morphological feature. However, the most significant damage is the reduction in capacity of dams and reservoirs due to accreditation of sediment on the bed. It has been observed there has been a sharp decrease in capacity of dams, in Pakistan alone Tarbela has lost 24.6% of its live storage, Mangla dam has lost 13.2% of its storage, Chashma barrage reservoir has lost 39.3% of its storage.

1.1 Study Area

The study basin under consideration is a watershed located in Wilmot Creek, ON, Canada. The Figure 1, shows the Digital Elevation Model (DEM) and Land use map of the watershed, which were generated by ArcGIS.



(a) **(b)**

Figure 1: Spatial Data. (a) DEM; (b) Land use map

2. Literature Review

Various researches have been conducted individually on the two methods, ANN and DHM. Therefore, to familiarise with the problems associated with the floods and droughts due to river, different researches were done to acquire knowledge about the sets of data needed to develop and train ANN, and available software programs for forecasting using DHM for such conditions. The reviewed papers were summarised with the necessary information that will help to compare and determine the better method.

Sun and Kim (2014) used real-time calibration method for updating skill of state variables, hence it can be said that distributed hydrological watershed modelling is applicable for multisite real-time river flow analysis.

Lekkas et al. (2005) compared four different ANN models which consisted of adaptive linear neuron network, Elman network and two types of feed forward network. It was concluded that feed forward trained under backpropagation algorithm produced the best results.

Perrone and Madramootoo (1997) developed rainfall-runoff model using AGNPS with respect to runoff, peak flow and sediment yield. The study concluded that AGNPS was found reliable for prediction of runoff.

Matamoros et al. (2005) used SWAT and AGNPS for hydrological modelling of an Ecuadorian river basin. The paper concluded that AGNPS produced better results.

Hu and Zhang (2008) determine that back propagation artificial neural network (BPANN) performs better than the conventional inverse distance weight method.

Bao et al. (2017) concluded that the newly developed distributed hydrological 2D model produced better results as compared to distributed hydrological 1D model, Shanbei (mixed runoff generation) model and the Xin'anjiang (one-dimension kinematic wave flow) model.

3. Methodology

This section discusses the methodology adopted to forecast river flow using ANN and AnnAGNPS. Both models use different approaches and take different sets of input data. Details about the input data are described along with its procedure.

The meteorological and flow data required for the simulation of Wilmot Creek watershed were obtained from two sources; National Oceanic and Atmospheric Administration (NOAA) and Environment Canada (EC). The data were gathered via station number allocated to Wilmot Creek weather station.

3.1 ANN

The input parameters that are fed into the neural network are multiplied by a weight factor, which represents the significance of each parameter. The neural network must be trained in order to find the values of the weight factors, to the highest degree of accuracy as possible. The neuron calculates the sum of its input, i.e. the weight factor multiplied by the input parameters. This sum is passed through an activation function before being transferred to the next layer. Figure 2 shows the node structure of ANN.

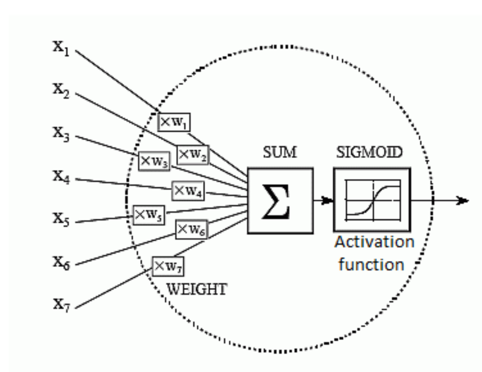


Figure 2 Node Structure

MATLAB software was used to develop ANN model, where, it makes use of neural network toolbox to run time series model. Trainlm was selected as the training function due to its many advantages over other algorithms. It is a training function that updates weight and bias values according to Levenberg-Marquardt (LM) optimization. It is an iterative method that reduces the sum of the squares of the errors between the function and the measured data points through a sequence of updates to parameter values, hence it always reduces performance function in each iteration of the algorithm. While, the activation function defines the output of a specific node given a set of inputs. It decides whether the node will 'fire' or not i.e. whether the output of that node will be carried to the next node or not. The output of that node then serves as an input for the adjoining node in the next layer. Without the activation function the output would simply be a linear function and the neural network will not be able to learn complex set of data.

3.1.1 Data Set

The input data set required to forecast the river flow will be divided into three sub-sets; warm up, validation and testing. It included data set, ranging from 1976-86. 60% of data were used for training while 20% were used for validation and testing, respectively. The input parameters used were mean temperature, precipitation, month number and snow melting factor. Figure 3 shows creation of a network.

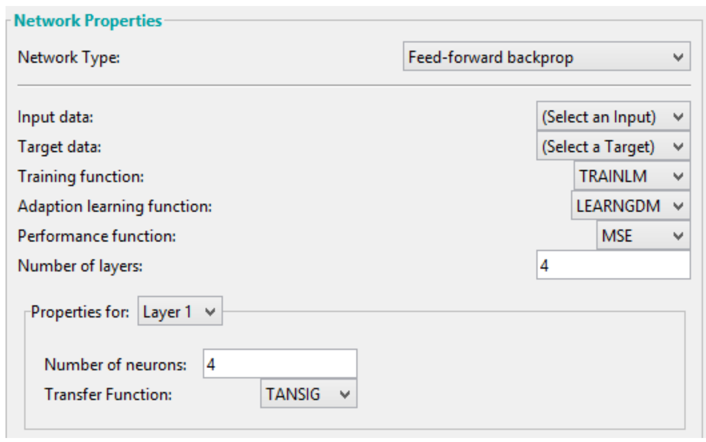


Figure 3 Creation of Network

3.2 Distributed Hydrological Model

3.2.1 Data Set

AnnAGNPS is a distributed hydrological model that does not only predict flow rates (surface flow, intermittent flow, base flow), but also estimates sediment and nutrition yield from a non-point source. Data requirements for AnnAGNPS can be divided into two categories:

i. **Geographic Information System (GIS) data**

   Which includes, DEM, Land use and Soil use.

ii. **Climate Data**

   Which includes daily precipitation, maximum and minimum temperature, dew-point temperature, wind speed, sky cover

3.2.2 AnnAGNPS

For the execution of AnnAGNPS, TopAGNPS must be first executed. TopAGNPS will generate an excel file with their corresponding heading and values for use in execution. The cells generated and assigned by TopAGNPS are used to determine the properties of each cell. The GIS properties are overlapped using the AGNPS GIS Tools and generate the file required for execution of AnnAGNPS. For the execution of

AnnAGNPS, the data files are prepared. A master file containing their respective file path is made since reads the master file in order to select the specified files. Figure 4 shows the watershed reach ID.

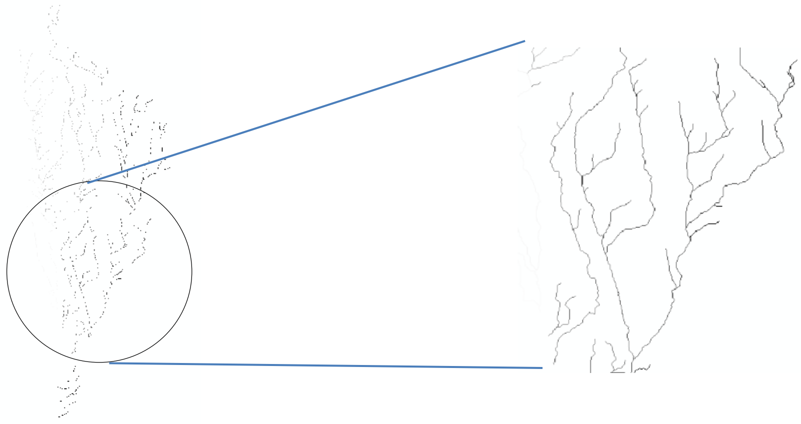


Figure 4 Reach IDs of the watershed

3.2.3 Calibration and Validation

To obtain a desired output and to minimize the amount of variation between observed and simulated values, four year of data were used as a warm up period from a given data of eleven years.

3.3 Model Performance Criteria

The performance of the model is evaluated on the basis of statistical parameters such as:

- **Root Mean Square Error (RMSE)**
  It is a measure of the average squared difference between the observed and estimated values, where, lower value indicates a better fit.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(p_i - a_i)^2}{n}}$$

- **Coefficient of Correlation (R)**
  The coefficient of correlation is a statistical tool which indicates the relationship between dependent and independent variable. It is represented by "R" and its scale is from -1 to +1.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

- **Coefficient of Determination (R^2)**
  It is a statistical tool which is used to measure variance, the range of R^2 is from 0 to 1 where a value closer to one indicates higher efficiency.

$$r^2 = 1 - \frac{\Sigma (y - y')^2}{\Sigma (y - \overline{y}')^2}$$

- **Nash-Sutcliffe Efficiency Coefficient (NSE)**
  It is a value that assess the predictive power of hydrological models.

$$E = 1 - \frac{\sum_{t=1}^{T} \left(Q_m^t - Q_o^t\right)^2}{\sum_{t=1}^{T} \left(Q_o^t - \overline{Q_o}\right)^2}$$

4. Results and Discussion

The results generated through the simulation of ANN and AnnAGNPS for Wilmot Creek watershed are presented below. It was found that AnnAGNPS does not give water balance equation, which was later confirmed after contacting the developers of the software. Hence, Soil Water Assessment Tool (SWAT) was used to produce the water balance equation. Furthermore, the sediment yield produced from both models were compared to authenticate the accuracy of the results.

4.1 First Simulation

The performance of the model was checked using different statistical tools. The Table 1 shows the accuracy statistical values for the model performance, where it shows RMSE, R, R^2 and NSE values. The first simulation is with a warm-up period of 4 years (1976-79), and a simulation period of 7 years (1980-86).

Table 1 Model performance using statistical coefficients for 4 years of training

MODEL	R	R^2	RMSE	NSE
ANN (Daily Flow)	0.846	0.715	0.099	0.690
ANN (Monthly Flow)	0.949	0.900	0.145	0.889
AnnAGNPS (Daily Flow)	0.607	0.368	0.059	0.279
AnnAGNPS (Monthly Flow)	0.711	0.505	0.336	0.184

4.2 Second Simulation

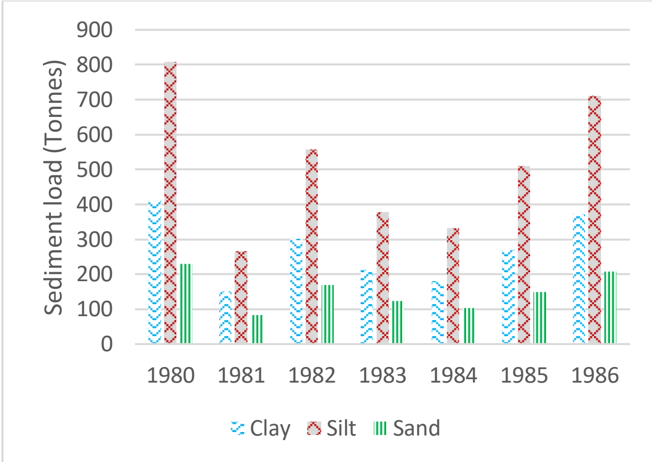
The second simulation is with a warm-up period of 10 years (1976-8s5), and a simulation period of a year (1986). Table 2 shows the accuracy statistical values for 10 year training period.

Table 2 Model performance using statistical coefficients for 10 years of training

MODEL	R	R^2	RMSE	NSE
ANN (Daily Flow)	0.717	0.514	0.042	0.482
ANN (Monthly Flow)	0.798	0.636	0.135	0.559
AnnAGNPS (Daily Flow)	0.592	0.351	0.112	0.187
AnnAGNPS (Monthly Flow)	0.670	0.450	0.467	0.076

4.3 Sediment and Nutrients Yield

Since, AnnAGNPS is also a sediment modelling software, the following sediment loadings were simulated. The value of silt being transported through river is high in comparison to the two other soil textures (clay and sand), which is expected since silt particles are easily transported than the heavier sand and the cohesive clay particles. Similarly, the identification of non-point source nutrients such as nitrogen and phosphorus, is done effectively considering the graph produced. The Figure 5 shows two hyetographs, one for annual sediment transport that is classified for three soil textures and the other for the nutrients transport, which is classified for two nutrients.



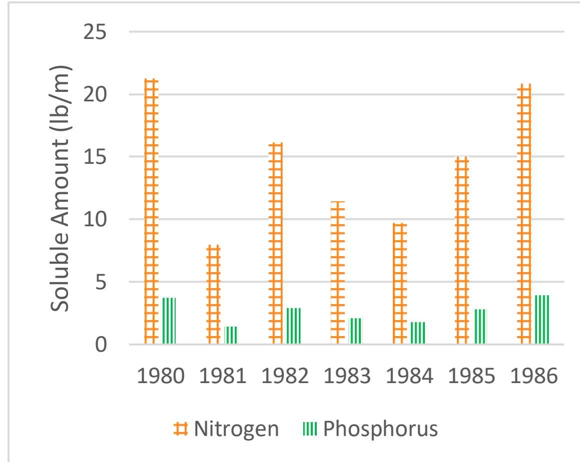


Figure 5 Annual sediment and nutrients transport by texture

4.4 SWAT Simulation

The simulation done on SWAT gave a general water balance of the watershed. Table 3 below shows the sediment yield produced by both the models.

Table 3 Comparison of Sediment Yield using AnnAGNPS and SWAT

Sediment yield AnnAGNPS simulation (ton/ha)	Sediment yield SWAT simulation (ton/ha)
13.5	11.8

5. Conclusion

The results obtained from ANN and AnnAGNPS are compared on the basis of statistical coefficients, which indicate the accuracy of results produced by checking the homogeneity between observed and simulated run-offs. Also, the sediment loading and nutrient discharge from the AnnAGNPS is analysed in order to minimise sedimentation and maximise sediment trap efficiency.

The comparison of the results is done on the basis of RMSE, NSE, R and R^2 values. For daily flows with 4 years training/warm up period, the values of RMSE for ANN and AnnAGNPS were 0.042 and 0.059, respectively. The values of NSE for ANN and AnnAGNPS were 0.482 and 0.279, respectively. The values of R for ANN and AnnAGNPS were 0.717 and 0.607, respectively. While, the values of R^2 for ANN and AnnAGNPS were 0.514 and 0.368, respectively. For monthly flows produced by ANN, the values of RMSE, NSE, R and R^2 were 0.135, 0.559, 0.798 and 0.636, respectively. While, the values for AnnANGPS monthly were 0.336, 0.184, 0.711 and 0.505, respectively.

Similarly, for daily flows with 10 years training/warm up period, the values of RMSE for ANN and AnnAGNPS were 0.099 and 0.112, respectively. The values of NSE for ANN and AnnAGNPS were 0.690 and 0.187, respectively. The values of R for ANN and AnnAGNPS were 0.846 and 0.592, respectively. While, the values of R^2 for ANN and AnnAGNPS were 0.715 and 0.351, respectively. For monthly flows produced by ANN, the values of RMSE, NSE, R and R^2 were 0.145, 0.889, 0.949 and 0.900, respectively. While, the values for AnnANGPS were 0.467, 0.076, 0.670 and 0.450, respectively.

On the basis of the results produced, it is concluded that ANN performs better than AnnAGNPS. This was determined by comparing two simulations for both the approaches. When the training and warm-up period was increased, the accuracy of both approaches improved. The results also confirm one of the limitations of ANN that, on decreasing training data set from ten years to four years, its accuracy decreased. On the other hand, AnnAGNPS accuracy decreased with increase in warm-up period.

One constraint in AnnAGNPS is that it does not generate flow when temperature is below zero degrees, while in actual, flow occurs due to temperature difference between land and atmosphere, and also due to human activities. Moreover, AnnAGNPS is not user-friendly since, not much can be changed from its default setting and many new software programs can simulate flow with lesser amount of data and less complexity (such as SWAT). AnnAGNPS did not give water balance equation, therefore SWAT was used to delineate the water balance, and sediment yield predicted by SWAT was compared with sediment yield predicted by AnnAGNPS to check accuracy of the two models.

Although, due to extensive data requirement that was not available in Pakistan, the results produced in this analysis used data of Wilmot Creek, however, the results and analysis have targeted issues that need to be taken care of in Pakistan. And upon availability of data, these models can produce abundantly fruitful results in Pakistan which can help mitigate water crisis and its symptoms for the years to come.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Comparison of Narrow Bed and Wide Bed Irrigation Systems in Perspective of Water Saving and Crop Yield for Cotton Crop

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Abstract

Cotton is an important commercial crop of Pakistan. However, its production is less by limited farm resources, unavailability of fertilizers at proper time, costly inputs, water logging, salinity, the shortage of irrigation water and its inefficient usage. Mismanagement of irrigation water through traditional irrigation method has further constrained the cropping intensities and crop yields. Thus, without judicious use of irrigation water and other farm resources, the yield potential of cotton crop cannot be obtained. To improve water use efficiency (WUE) on the basis of increasing crop yields there must be a proper irrigation scheduling strategy. Different techniques of irrigation for water saving are used worldwide in agriculture sector now a days to minimize the water losses. In Tando Jam different types of irrigation systems are being adopted but mostly farmers are using narrow bed irrigation system for cotton crop which requires comparatively larger quantity of water than wide bed furrow irrigation system and can lead to water logging and salinity in the area. Therefore this research work was conducted to compare narrow bed irrigation system and wide bed irrigation system for cotton crop in terms of water use efficiency and crop yield in Tando Jam.

Keywords
Cotton, Irrigation, Pakistan, Water Logging, Salinity, Water Use Efficiency.

1. Introduction

Fresh water scarcity is one of the leading challenges of this era. The availability of the adequate water for irrigation purpose guarantees the sufficient production and yield of the crops. The agricultural products prove to be fundamental tool for the rise of economy of any country having irrigable land. Growing food demands of the world can also be met by effective production of crops that is directly influenced by the availability of fresh water for irrigation. *Gossypium*is the cotton genus. It belongs to the tribe *Gossypieae,* in the family Malvaceae native to the tropical and subtropical regions. Available commercial species of cotton plant are *Gossypiumhirsutum* (more than 90% of world's production), *Gossypiumbarbadense* (3-4%), *Gossypiumarboreum* and *Gossypiumherbaceum (*together 2%). Cotton is perennial shrub with a plant height of 1-2 m high and sometimes higher especially in traditional cropping system.

In total the annual worldwide production of cotton is about 25 million tonnes. This amount of production occupies 2.5% of the globe's arable land. China is the largest producer of the cotton and uses most of it domestically. For many years, United States of America has been the largest exporter of the cotton. Cotton in Pakistan is grown as an industrial crop in 15% of the country's irrigable land. Pakistan is at fourth number among cotton producing countries and at third number among the exporters of the raw cotton. So cotton is considered as a major crop in perspective of growth in national economy.

Provision of water at the right time in adequate amount to the cotton crop is of great consideration. There are numerous methods to supply water to the cotton crop. One of them is furrow irrigation method. Furrow method of irrigation is further divided into two methods. Two conventional furrow irrigation methods adopted for the cultivation of cotton crop are wide bed or raised bed and narrow bed irrigation systems. The furrow methods are generally adopted while keeping in view the factor of water saving. Because in furrow irrigation method the amount of water required for the plant is mainly delivered through seepage to the plant roots. The area of study in this research is the comparison of narrow bed and wide bed furrow irrigation systems for cotton crop in perspective of water saving and crop yield.

2. Aims and Objectives of Study

Aims and objectives of this research are as below:

1. To determine water saving by comparison of wide bed and narrow bed irrigation systems.
2. To calculate the crop yield through wide bed and narrow bed irrigation systems.
3. To suggest the appropriate irrigation system to farmers for maximum cotton crop productivity on the basis of research results.

3. Literature Review

Raised bed or wide bed irrigation system and narrow bed irrigation system have been studied by several engineers and scientists. Practically, all investigations aim at maximum yield with minimum available inputs.

Abdel Rahman *et al*. (1977) studied the wide bed and alternate furrow method for the cotton crop in the United States of America. The wide-bed cultural practice and alternate furrow irrigation systems had similar water use efficiencies, expressed as lint yield per inch of applied water. These systems increased the water use efficiency about 23 percent over the every furrow irrigation system.

Hobs and Sayre (2003) stated that growing of crops on raised beds certainly provide those benefits which cannot be achieved using flatbed crop planting. Rain fed system seems helpful in conserving moisture and in irrigation methods application of water use efficiency and water distribution was improved. The major advantages of this system include mechanical weed control, water saving up to 30%, ability to place fertilizers, low seed rates , reduce in water logging losses and water use efficiency.

Gill *et al*. (2010) worked in detail on Evaluation of crops on permanent raised beds in Punjab, Pakistan. These resource conservation technologies mainly include bed planting of wheat and cotton, sowing of wheat using zero-tillage technology, and laser land levelling of fields. A study over a period of 4 years was conducted on farmers' fields to compare yields, water application requirements and net income for cotton sown on flats versus beds in Punjab. It has been observed that crops can successfully be grown on raised beds only if requisite equipment and technologies are available for modification and re-shaping of beds and sowing of crops on beds. It has been observed that planting of wheat, cotton and other crops on beds may save up to 50–60% of irrigation water.

Akbar *et al.* (2010) finalized that the usage of Permanent raised beds typically result in higher yields, lower water consumption, and greater total water use index (IGP) than conventional basin systems. In the experiment, a wide bed produced 15% more wheat and 26% more corn than flat basin treatments.

Ahmad *et al.* (2010) conducted a detailed study on field of farmer for different irrigation techniques namely "border irrigation method and furrow irrigation method" and their efficiency over crop yield and water saving in field at 4 different sites. Results showed that furrow irrigation system consumed 35.60% less water than that of flat border irrigation system.

Hari *et al.* (2011) concluded that raised beds are widely used with successive positive outputs. Experiments were conducted to study the effects of field design on the corn-wheat system. Corn and wheat crop yields are the same over a four year period under different treatments. Maize and wheat were grown in elevated beds about 7.67% and 22.70% higher, respectively, than the water efficiency of the graphic design. The final return on corn and wheat systems is greater than in conventional farming.

Ghane *et al.* (2013) determined a research work on optimization of irrigation method to obtain better water productivity "WP" and wheat yield. Three experimental plots having size 4, 8 and 12 m^2 were constructed for research study. Results showed that furrow irrigated raised wavy beds (FIRWB-60) had low soil salinity than flat planting (FP) and FIRWB-60 produces higher yield with lowest irrigation requirements. The results showed that FIRWB-60 had low soil salinity than flat planting in the top soil. Therefore water productivity increased by 14.90% and 18.40% respectively in resemblance with flat planting system, conclusively FIRWB-60 is most suitable procedure for irrigating reasonable agricultural production in salty areas with shortage of water.

Ahmed *et al.* (2014) explained research work in the Sultanate of Oman. Main objective of the experiment was to improve/moderate the furrow irrigation method to furrow bed irrigation method and to analyze the WUE in collation to the drip method. Results showed that better yield is obtained by drip irrigation as compared to furrow irrigation. However, better results were observed for water productivity for furrow irrigation system. Overall results showed that furrow irrigation is best for good yield and productivity while drip irrigation method is best for less water consumption.

Busaidi *et al.* (2014) reported that the agriculture of Sultanate of Oman is mostly depends on groundwater. Like furrow (conventional surface irrigation system) remains the most recognized system of irrigation covering very nearly about eighty percent of the farming soil. This technique has low WUE, enhances the soil erosion if the furrow system could adapt and improved to a stage that could raise the water saving and efficiency, which will gives the growers major benefits. Purpose of this experiment was to adopt the furrow system to a furrow bed system and compare WUE with drip irrigation system. Better production of wheat was calculated by drip as compared to furrow bed system. According to results, drip irrigation could be best in minimizing the water evaporation whereas getting greater production with less cost and high productivity was obtained from furrow beds.

4. Research Methodology

The research study was carried out on an area of 2 acres at the study field in Tando Jam, District Tando Jam. Experimental field is situated at latitude 25°25′35.68″N and longitude 68°32′22.31″E at about 26meters above mean sea level. Surface water and minor watercourses were the sources of irrigation at the study area. Before the start of experiment, the samples of soil were randomly collected from the study area before from the depth of soil i.e. 0 to 15 cm, 15 to 30 cm, 30 to 45 cm and 45 to 60 cm for chemical and physical analysis. Soil at the study area was silty clay loam and class is medium in texture.

First of all preparation of land was done with the help of machinery for Raised bed and narrow bed Irrigation System. Fertilizer doze was applied before sowing of seed in the study field. The seed of cotton i.e. Sindh-1 was then sown manually on sides of beds of both irrigation systems in the month of April. Cotton variety was seeded on 1st April 2018. A seeding rate of 35000 seeds/acre was used in narrow bed irrigation system and 30000 seeds/acre for wide bed Irrigation Systems. Cotton takes 130 days between sowing and picking at the study area. Manual Picking of cotton crop in the study area started from the first week of October.

5. Results

A complete record of quantity of water applied and the précised yield obtained from both the experimental fields was collected and compared in terms of efficiency. The records and data is provided below and represented graphically.

1. Comparison of Quantity of Irrigation Water for Narrow Bed and Wide Bed Irrigation Systems

Table 1: Comparison of Quantity of Irrigation Water for Narrow Bed and Wide Bed Irrigation Systems

S.No	Date	Rainfall (mm)	Irrigation Interval (days)	Irrigation (mm) Narrow Bed (2.5ft width)	Irrigation (mm) Wide Bed (3ft width)
1	1/4/2018	0	4	20	18
2	4/4/2018	0	4	18	14
3	9/4/2018	0	5	17	15
4	14/4/2018	0	15	18	16
5	29/4/2018	0	15	20	15
6	13/5/2018	0	15	15	13
7	27/5/2018	0	15	15	13
8	10/6/2018	0	15	20	15
9	24/6/2018	15	15	10	10
10	8/7/2018	18	15	0	0
11	22/7/2018	17	15	0	0
12	5/8/2018	14	15	12	10
13	19/8/2018	19	15	0	0
14	2/9/2018	0	15	19	17
15	23/9/2018	0	15	17	17
Total		83		201	173

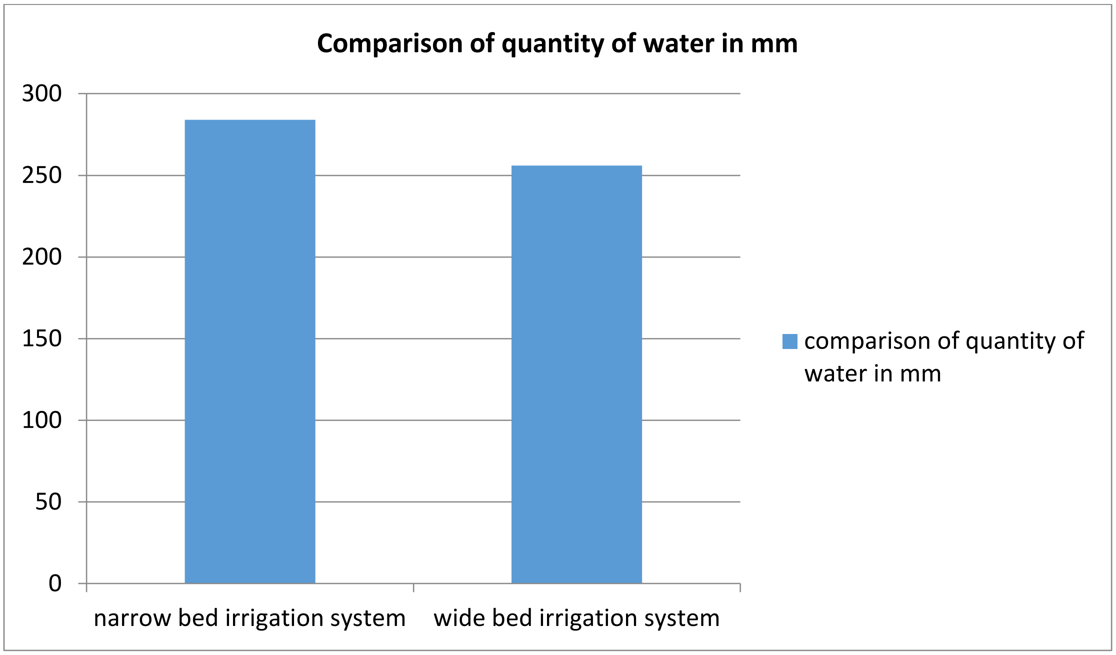

Figure 1: Comparison of Quantity of Water in mm

2. Comparison of Fertilizers Usage for Narrow and Wide Bed Irrigation Systems

Table 2: Comparison of Fertilizers Usage for Narrow and Wide Bed Irrigation Systems

Fertilizers	Fertilizer Dosage for Narrow Bed (bags/acre)	Fertilizer Dosage for Wide Bed (bags/acre)	Time of Application of Fertilizers
Di-ammonium phosphate (DAP)	1.5	1	At the time of sowing
Single Superphosphate (Ssp)	4	3	At the time of sowing
Sulphate of Potash (SOP)	1	1	At the time of sowing
Urea (46% N)	4	4	½ bag per irrigation

3. Comparison of Yield of Narrow Bed Irrigation System and Wide Bed Irrigation Systems

The yield of narrow bed Irrigation system was 49 kg/acre obtained and 45 kg/acre was obtained in the field of wide bed Irrigation System. Comparison of both irrigation systems in terms of yield is determined as below in the graph:

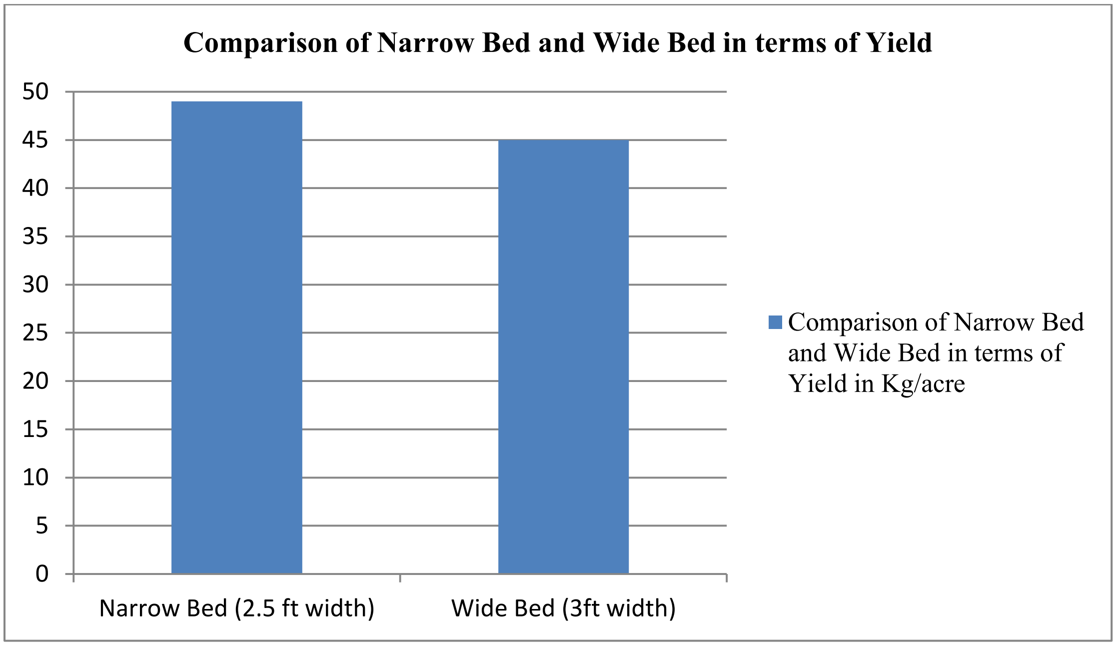

Figure 2: Comparison of Narrow Bed and Wide Bed in terms of Yield

6. Conclusions

In this comparative study of Narrow and Wide Bed Irrigation Systems, the following conclusions are revealed:

1. The net irrigation was applied 201 mm for narrow bed irrigation system and 83 mm rainfall occurs in the field, and for wide bed irrigation system, 173 mm of net irrigation was calculated and 83 mm rainfall occurred.
2. The yield production of narrow bed irrigation system was 49kg/acre and 44kg/acre was obtained in the field of raised bed irrigation system.
3. The yield to irrigation water ratio of the wide bed irrigation system was found to be 7% more than that of narrow bed irrigation system.
4. The yield of narrow bed irrigation system was calculated 10.2% greater than wide bed irrigation system.
5. The wide bed irrigation system saved 9.8% of the water applied to narrow bed irrigation system.

7. Future Recommendations

Based on this research, further studies that can be carried out in future are as follows

1. Comparison of Sprinkler Irrigation System and Drip Irrigation System for Cotton crop at Tando Jam and nearby areas.

2. Irrigation frequency impact on Cotton water productivity with sub surface drip irrigation system in Tando Jam and nearby areas.
3. Precise agricultural monitoring based on sensor network and satellite remote sensing: saving water usage of cotton crop in Sindh.
4. Irrigation scheduling for surface rotational irrigation with limited water in Sindh.
5. Additional research and development are needed to work in connection with Automatic Meteorological Station, Remote Sensing Techniques, and GIS.

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10th International International Civil Engineering Conference (ICEC-2019)
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February 23-24, 2019, Karachi, Pakistan.

Evaluating water quality of Malir river for detrimental effects on vegetables and ground water

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Abstract

In this research, an effort has been made to evaluate the detrimental impacts of Malir river wastewater on groundwater and vegetables along with the determination of antibiotics resistance in wastewater. Samples of wastewater, groundwater, and vegetables were collected from five different points. The primary focus is on the chemical, biological parameters and heavy metals analysis. Results indicate that all chemical and biological parameters are above the allowable limits of National Environmental Quality Standards (NEQS) and WHO. Concentration of four heavy metals are above the permissible limit including 2 mg/L lead, 0.31 mg/L manganese, 0.02 mg/L mercury and 0.21 mg/L of chromium. Negligible concentration of heavy metals found in vegetables except iron having 213 mg/L and 38mg/L concentration in spinach and ridge gourd, respectively. Chemical parameters of groundwater are below the permissible limit except electrical conductivity and total dissolved solids having concentration of 4500 µS/cm ana 3033 mg/L. Antibiotic resistance test indicates that Erythromycin, Tetracycline, and Sulfamethoxazole are no longer effective against bacteria. The results depict degradation of environment and public health, for which serious steps must be taken by government.

Keywords

Malir River Wastewater, Heavy metals, Antibiotic resistance, Vegetables, Ground water

1. Introduction

The increasing trends of economic, social development and mass urbanization are deteriorating the ecosystem . Water the basic need of life is rapidly being used and the wastewater being generated at the same rate. The reuse of wastewater is also rapidly increasing worldwide, due to increase in population and the financial conditions of the farmers of developing countries.This is being used as an alternative source for cultivation of crops because of the scarcity of freshwater and also it can fulfill the nutrient requirement of crops hence reducing the cost for the farmers of the developing countries. Therefore, evaluation of water quality that is being used for irrigation has become a crucial matter.

The total area irrigated by direct wastewater in Pakistan is 32,500 hectares (Murtaza et al., 2012). Production of sewerage in Karachi is 472 MGD but the wastewater treatment rate is only 16 percent. Karachi has three wastewater treatment plants with an optimum capacity of 150 MGD but only 50 MGD of wastewater is treated (KWSB, 2017). This depicts that substantial amount of untreated sewage is being used for irrigation.The vegetables and fodders absorb heavy metals from contaminated water and soil, polluting the food chain at all stages. Lead, mercury, cadmium, copper, chromium, iron, zinc and other heavy metals are also present that are carcinogenic and cause psychological disorder, respirational problems and hormonal discrepancy.

Alongwith the above mentioned threats to the human health due to untreated wastewater farming ; there is one more crucial issue that must be brought to notice of the concerned authorites. Malir River recieves all kinds of effluents including domestic, industrial and pharmaceuticals which contain major concentration of antibiotics. When this wastewater is used for irrigation it tends to produce antibiotic resistance in humans and animals that are consuming it through wastewater irrigated vegetables and fodder. Thus the conditions demand to characterize the parameters of wastewater that govern the pollution capacity, its range and type. The present evaluation aims, to the analysis of wastewater samples so as to determine the pollution entering into the Malir river and causing threats for public health and environment.

2. Methodology

2.1 Study Area

The study area is located along the Malir River starting from the Mullah essa goth, upstream point of Malir River which flows down to the KPT interchange before it finally disposes into the Arabian Sea. The five sampling locations of Malir River as shown in Fig. 1, from where the samples were collected are mentioned below;

1. Mullah Essa Goth (Upstream)
2. Quaidabad Bridge
3. Shah Faisal Colony
4. EBM causeway
5. Near KPT interchange

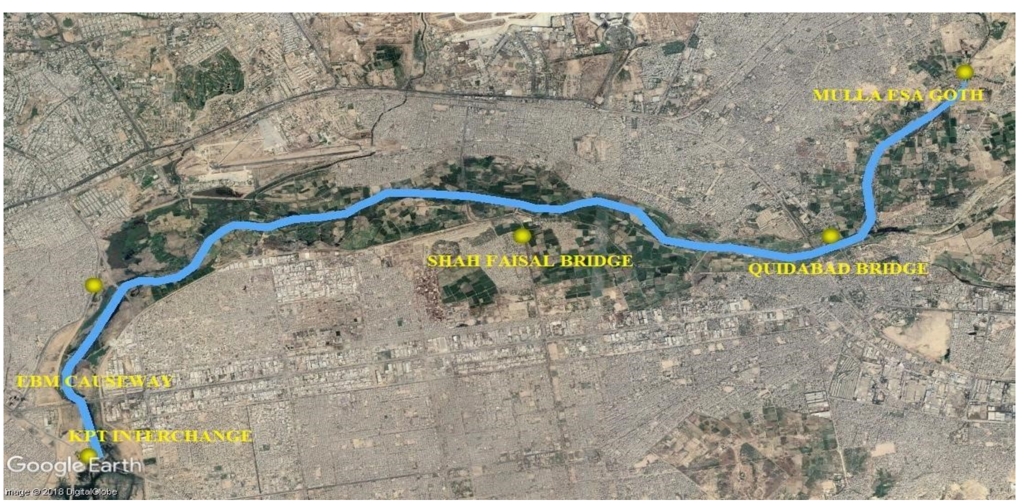

Figure 1 : Map showing sampling points along Malir River

2.2 Sampling , testing and analysis

Samples of wastewater were collected for 9 months starting from December, 2017 to August, 2018 to evaluate the basic pollutants, heavy metals and fraction of antibiotic resistance . Water samples, for testing of basic pollutants were collected manually at each site in 1.5 Litres pet bottles while 0.5 Litres glass bottles were used for heavy metal testing. Both pet bottles and glass bottles kept in an ice box to maintain the temperature. Groundwater and vegetable samples seasonally were acquired to investigate the existence of heavy metals of relative spots. The ground water samples were also collected in the same way from Mullah Esa Goth and near Shah Faisal bridge.Spinach and ridge gourd were taken from the fields adjacent to river bank at Mullah Esa Goth and Quaidabad bridge points.
Testing on the acquired samples was conducted for analyzing the physical, chemical and biological water quality parameters. Some basic parameters like pH, TSS, TDS, EC, Chloride, Hardness, Calcium, Nitrate, Sodium, Potassium, Magnesium, Total Nitrate, and Total Phosphate tests were conducted for the examination of physical and chemical characteristics of wastewater. Biological parameters for wastewater were evaluated using BOD, COD and antibiotic resistance tests. Heavy metal test were also 9conducted according to the requirements.
After testing, different chemical, physical, and biological parameters were compared with National Environmental Quality Standards and WHO standards then results generated through the tests were used to identify the contamination level and the harmful effects on human health and environment. Conclusion and Recommendations were generated according to results.

3. Results and Discussions

This study was intended to monitor the environmental and marine pollution which is caused by wastewater irrigation along the Malir river. Through physical, chemical, and biological tests it became evident that the anthropogenic activities, uncontrolled and illegal irrigation activities are becoming a major threat to human health and environment. The presence of heavy metals are the dark horses for us which we are consuming through vegetables, milk, and meat. The following results were obtained from this study;

From Fig. 2-12, results of chemical, physical and biological parameters are attached, the results depict that huge variations have been occurred throughout the study period, pH ranges from 3.56-9, TSS ranges from 46-368 mg/l, highest value of TSS is observed at Esa Goth in the month of June. Similarly, different patterns are observed in all the parameters.

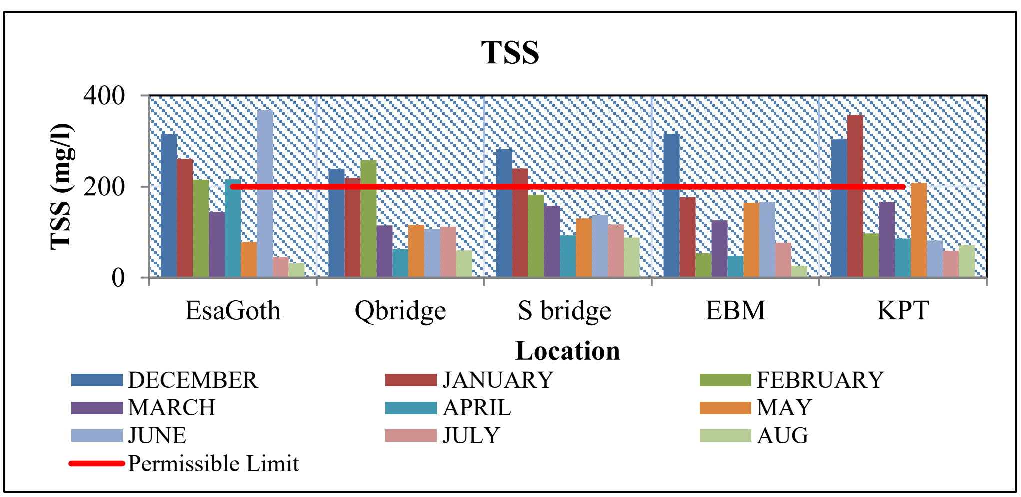

Figure 2: Variation in the concentration of TSS along Malir River

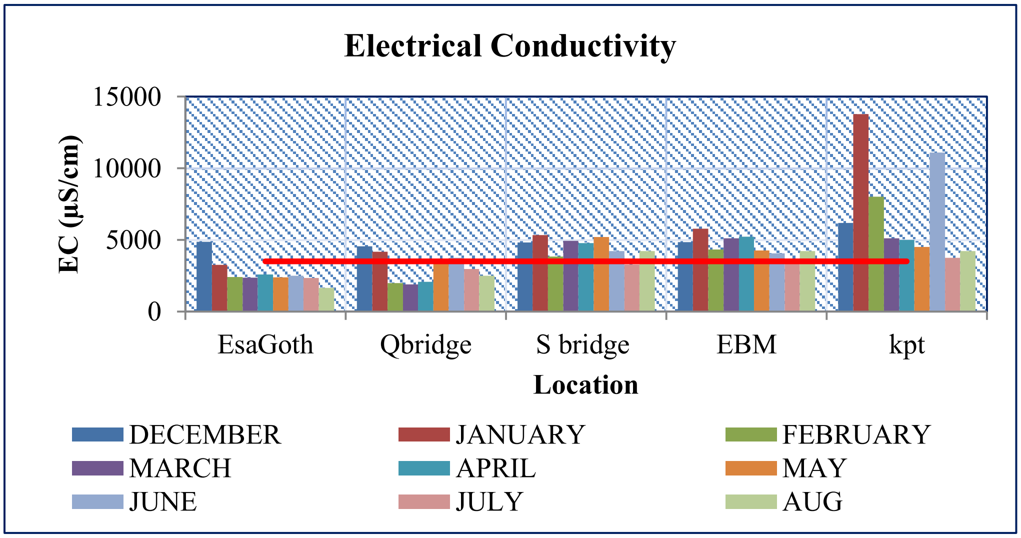

Figure 3: Variation in the concentration of EC along Malir River

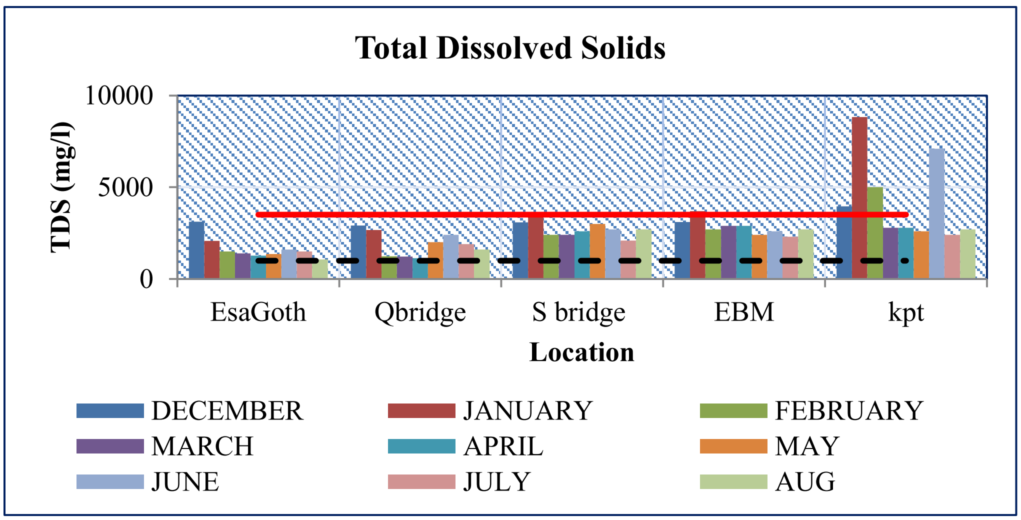

Figure 4: Variation in the concentration of TDS along Malir River

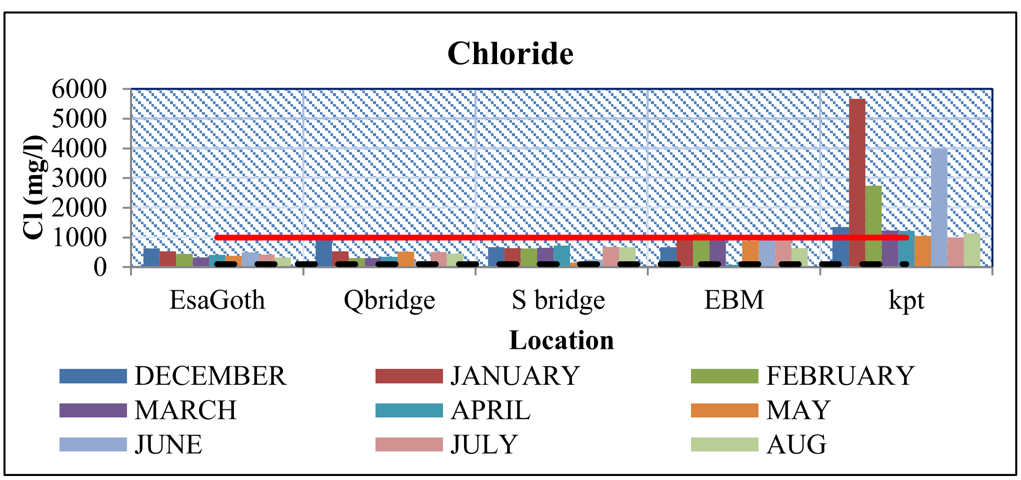

Figure 5: Variation in the concentration of Chloride along Malir River

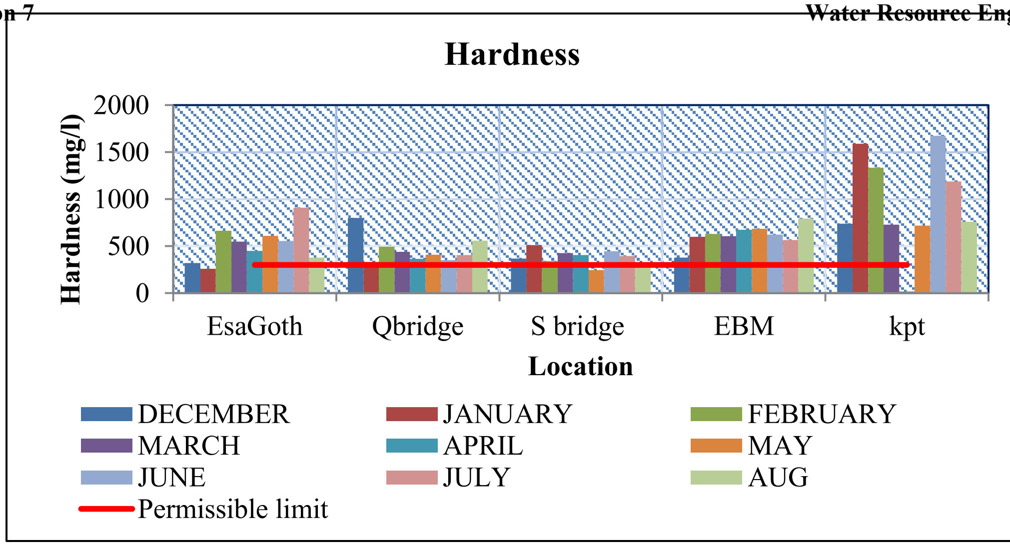

Figure 6: Variation in the concentration of Hardness along Malir River

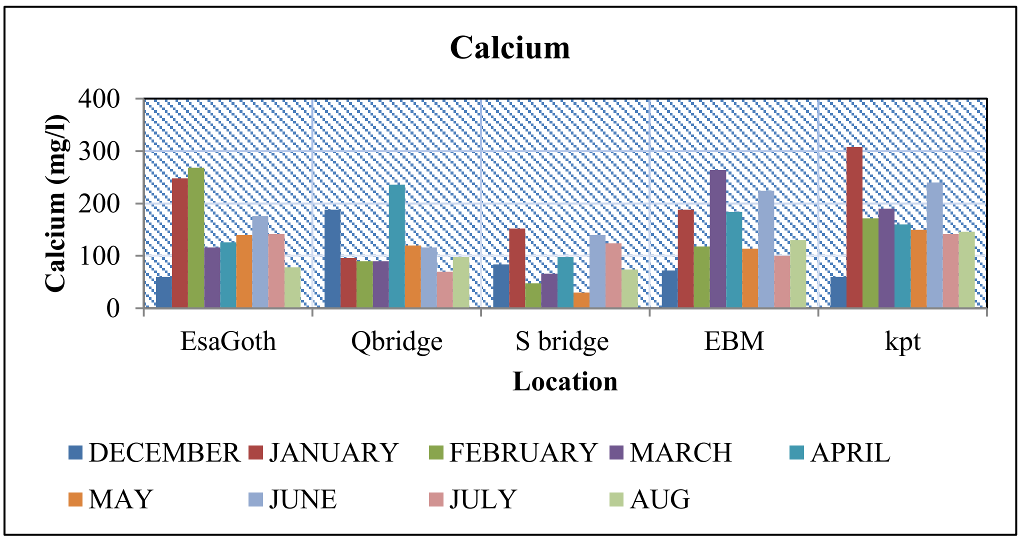

Figure 7: Variation in the concentration of Calcium along Malir River

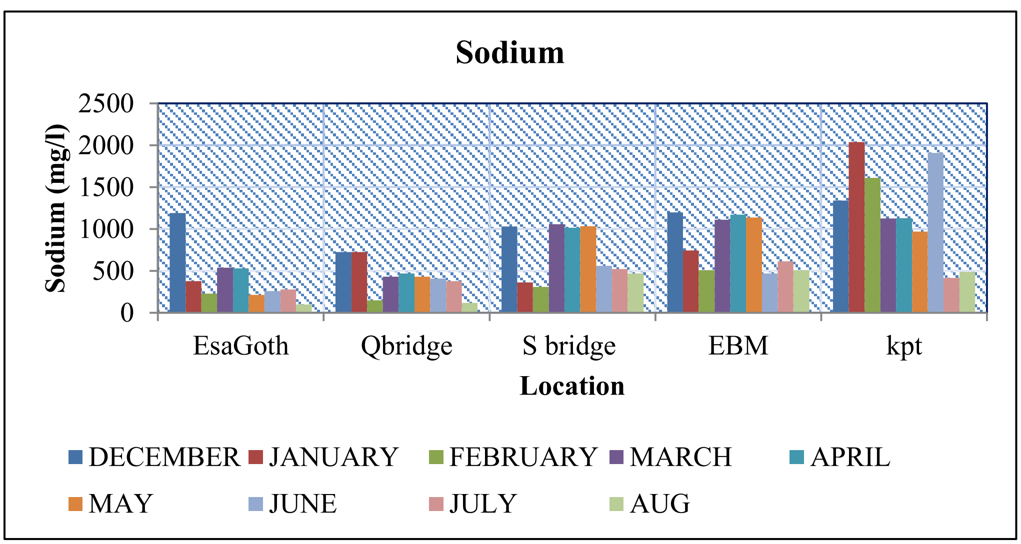

Figure 8: Variation in the concentration of Sodium along Malir River

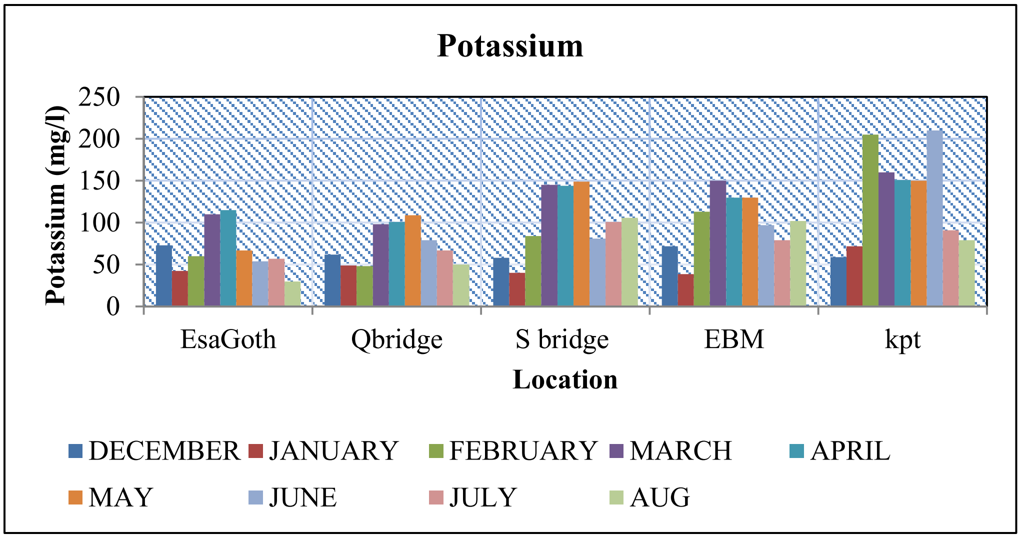

Figure 9: Variation in the concentration of Potassium along Malir River

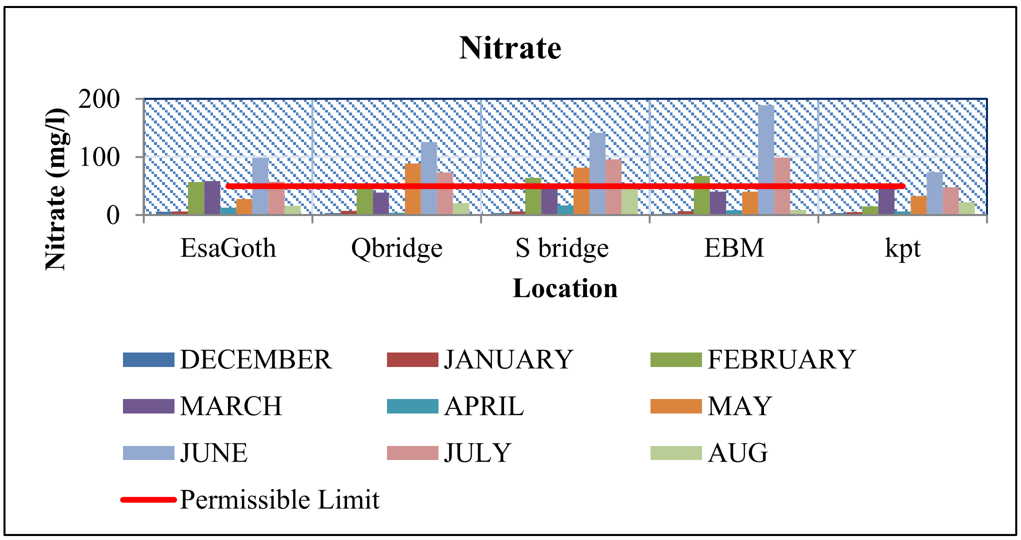

Figure 10: Variation in the concentration of Nitrate along Malir River

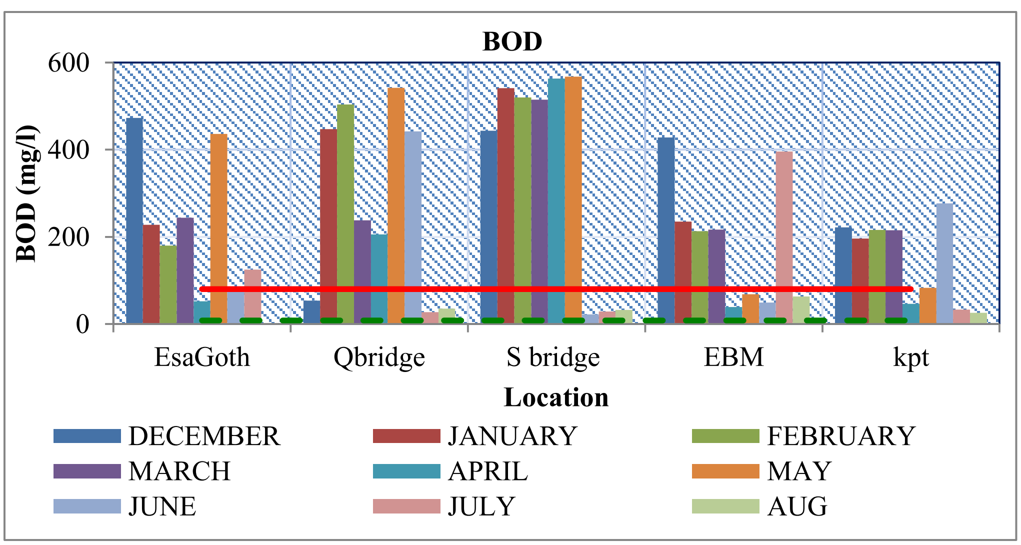

Figure 11: Variation in the concentration of BOD along Malir River

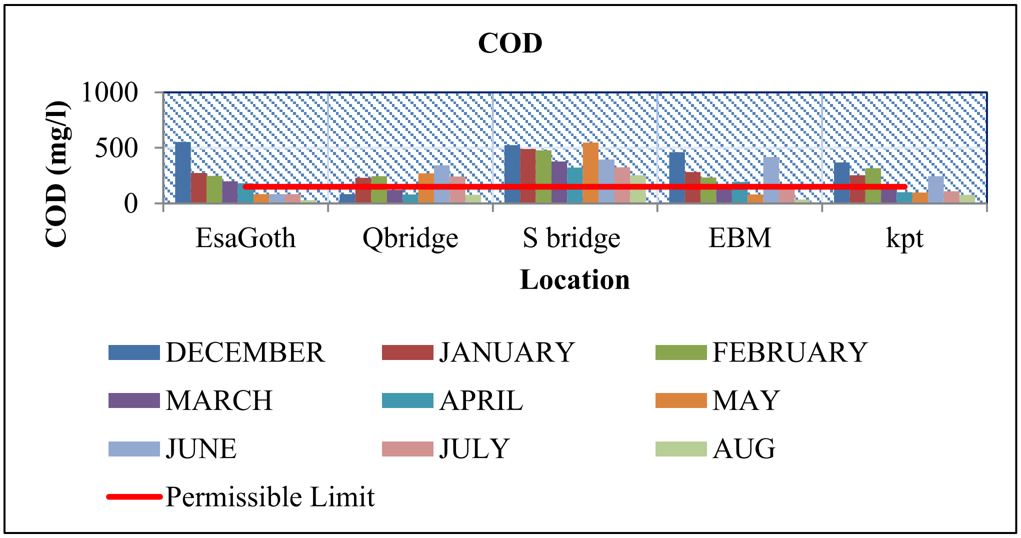

Figure 12: Variation in the concentration of BOD along Malir River

The targeted heavy metals are lead, chromium, mercury, manganese, and iron. Concentration of four heavy metals are observed above the WHO irrigation guidelines including 2 mg/L lead, 0.31 mg/L manganese, 0.02 mg/L mercury and 0.21 mg/L of chromium while concentration of iron is observed below the permissible limit. These heavy metals are causing kidney problems, neurological disorders, cardiovascular, bone diseases, and several other diseases which impact on human health and environment. Results are mentioned below from Fig. 13-17. The heavy metals in vegetables have also been analyzed, the selected vegetables are spinach and ridge gourd. Negligible concentration of heavy metals found in vegetables except iron having 213 mg/L and 38mg/L concentration in spinach and ridge gourd, respectively as shown in Fig. 18.

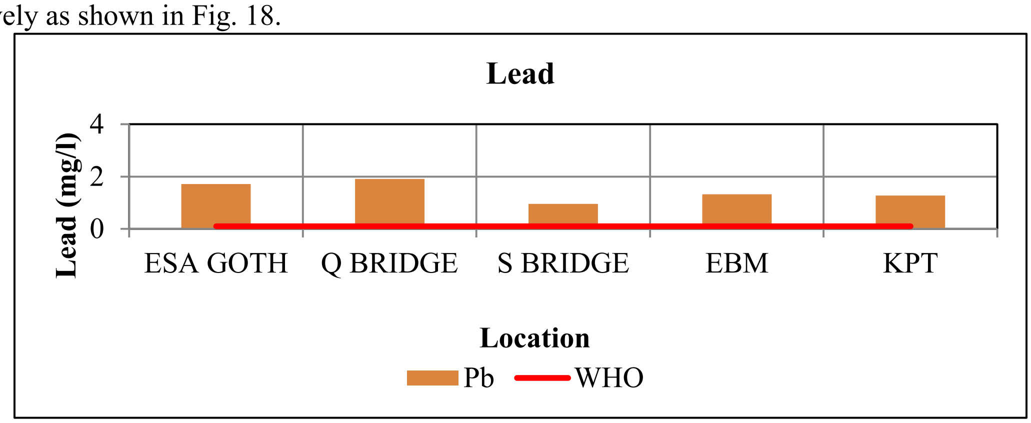

Figure 13: Variation in the concentration of Lead along Malir River

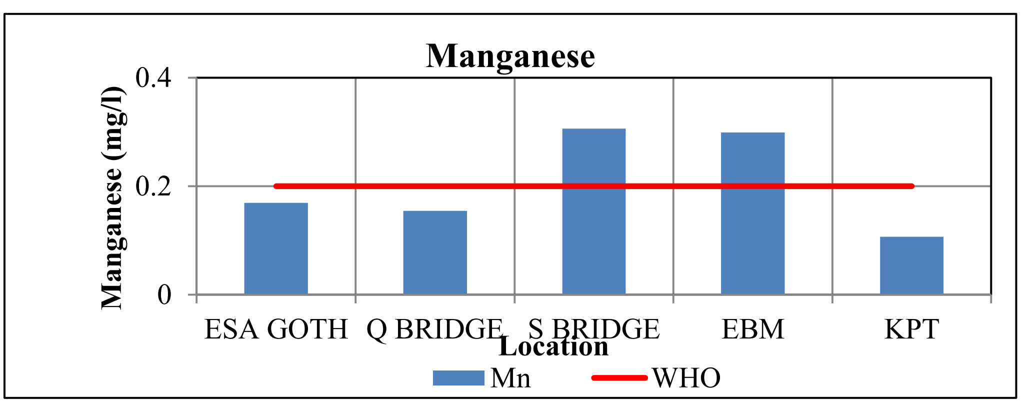

Figure 14: Variation in the concentration of Manganese along Malir River

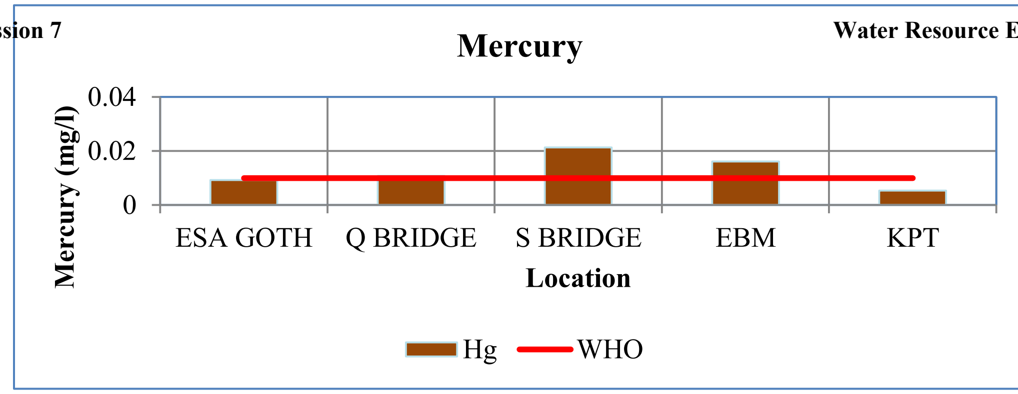

Figure 15: Variation in the concentration of Mercury along Malir River

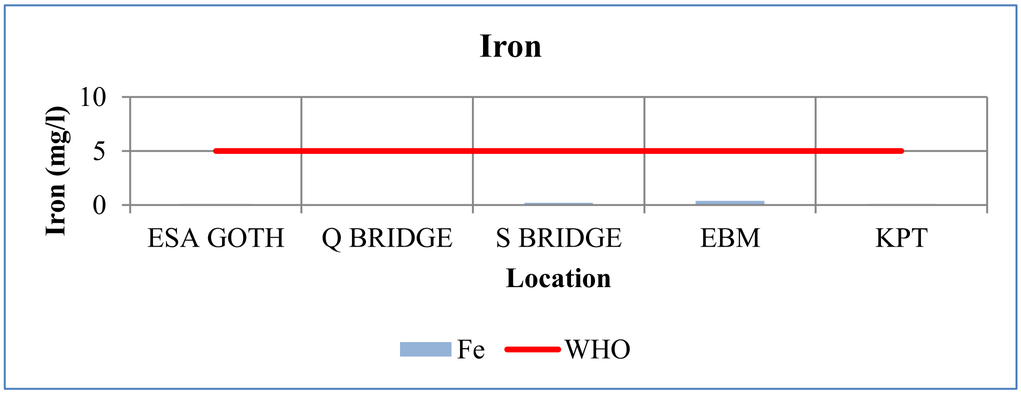

Figure 16: Variation in the concentration of Iron along Malir River

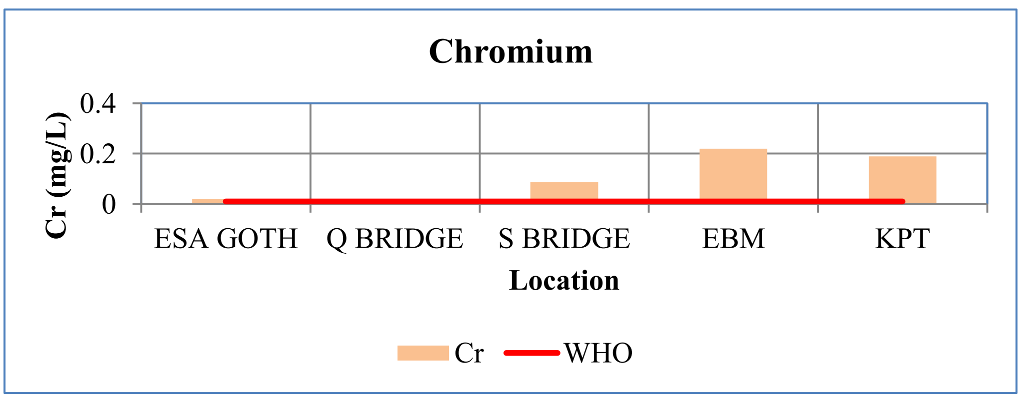

Figure 17: Variation in the concentration of Chromium along Malir River

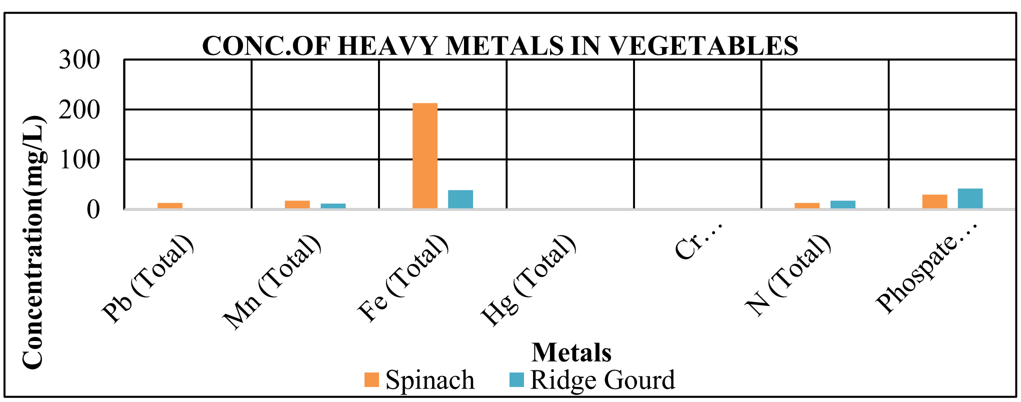

Figure 18: Concentration of heavy metals in Spinach and Ridge Gourd

Chemical parameters in groundwater have also been analyzed, variation in parameters have been shown in Fig. 18 and 19. It is concluded that chemical parameters of groundwater are below the permissible limit except electrical conductivity and total dissolved solids having concentration of 4500 µS/cm and 3033 mg/L.

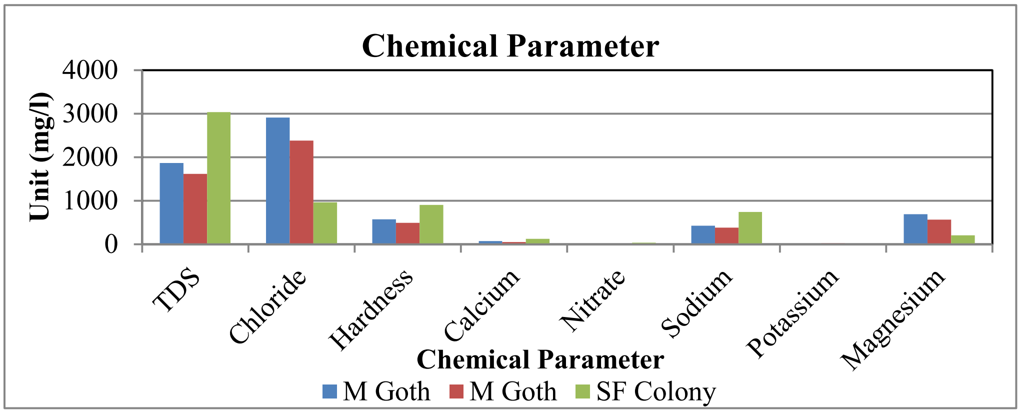

Figure 19: Variation in chemical parameters in groundwater

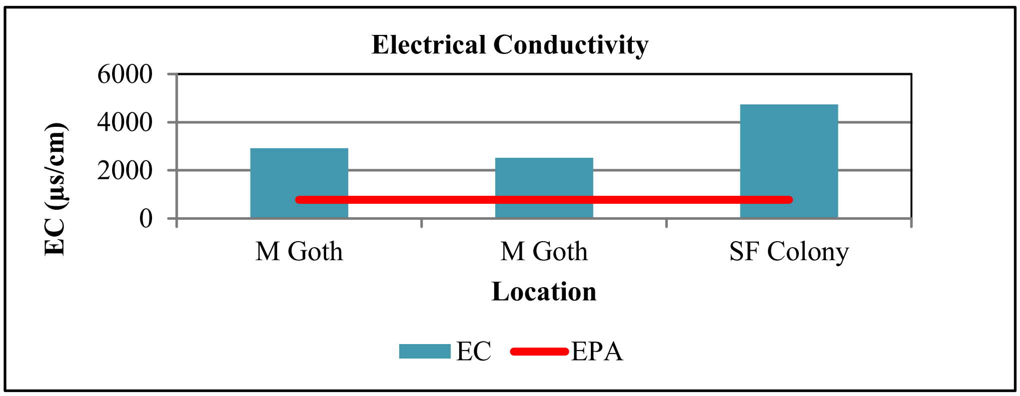

Figure 20: Variation in concentration of EC in groundwater

4. Conclusion and Recommendation

The conclusions drawn from this study are that wastewater irrigation has detrimental effects on groundwater and vegetables. Analysis of wastewater samples shows that almost all chemical parameters exceed the permissible limit set by NEQS and WHO Irrigation water guidelines. The ground water is found to be less affected by the wastewater irrigation because the wells were deep. Heavy metal analysis shows that Mercury, Lead and Chromium concentration are more than permissible limits quoted by WHO Irrigation water guidelines. Antibiotic resistance analysis shows that Erythromycin, Tetracycline and Sulfamethoxazole are no longer resistant against bacteria. As the study indicates that serious and immediate measures need to be taken to save human health and environment, here are some of the ways to make the prevailing conditions better;

- Provision of wetlands, since it can be provided in areas where large unused land is available like in Shah Faisal Colony. It is cost-effective and treatment process is also natural.
- The government and related authorities should work for the implementation of laws regarding environment.
- Rehabilitation of Treatment plants, Karachi has 3 Wastewater Treatment Plants and if they are rehabilitated they might treat about 150 MGD of wastewater which is 31% of the total wastewater generated.

- The effluent from industries should be treated prior to discharge and latest technology must be used to control the pollution.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformations of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Artificial Lightweight Aggregate Production through Cold Bonded Pelletization Using Industrial By-Products

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Abstract

Depleting resources and ever increasing demand for building materials direct their artificial production for sustainability. Millions of tons of waste being generated worldwide everyday also demands scanty utilization of resources and waste recovery. In this study, lightweight aggregates (LWA) were produced through cold bonding by using both cement and geopolymer as a binder. Two industrial by-products, coal fly ash and ground granulated blast furnace slag (GGBFS) were used for LWA production. LWA physical and mechanical properties were investigated and compared both with each other as well as with natural aggregate (crushed stone). Test has also been carried out to assess alkali silica reactivity of LWA both in cement or geopolymer based mortars. Results of investigations showed that produced LWA were having good properties and can be adopted for sustainable availability of aggregates.

Key Words
Artificial lightweight aggregate, Cold-bonded Pelletization, ASR Reactivity, Geopolymer aggregates

1. Introduction

Concrete is most widely used material due to its durability and strength characteristics. Properties of concrete depend on its constituents. Aggregates constitute 60-70% of total volume of concrete and hence play very important role in deciding concrete properties(Gesoğlu, Güneyisi et al. 2012). Engineers look for durable and stronger structures with lightweight materials so that more stories can be added with same weight of structure. Natural aggregates are durable, have good strength and less water absorption but add significant weight to concrete. Idea of using lightweight aggregates (LWA) in concrete as a replacement of natural coarse aggregate is a way forward to construct more economical and lightweight structures. LWA have benefits of low thermal conductivity, heat insulation and sound proofing. As most of the weight of concrete is due to coarse aggregates, replacing coarse aggregates by LWA can help to reduce structural weights, earthquake loads, transportation and handling costs (Huang, Chang et al. 2007; Ke, Beaucour et al. 2009).

Lightweight aggregates can be produced either by natural raw materials (expansive clays, slate, shale, limestone) or by waste materials (sewage sludge, blast furnace slag etc.) (Bernhardt, Tellesbø et al. 2013). Applying industrial and municipal wastes in production of building materials is not only a solution to waste management and environmental problems but also a way to sustainable and economical construction. Many publications have reported manufacturing of artificial aggregates using waste materials like municipal solid waste incineration bottom ash, fly ash, blast furnace slag, metakaolin, sewage sludge and sewage sludge ashes either by cold bonding or sintering process(Chiou, Wang et al.

2006; Huang, Chang et al. 2007; Yüksel, Bilir et al. 2007; Arellano Aguilar, Burciaga Díaz et al. 2010; Cioffi, Colangelo et al. 2011; Gesoğlu, Güneyisi et al. 2012; Colangelo, Messina et al. 2015). Sintering is a process which requires high temperature burning to produce materials, which render sintering as less desirable approach to waste recovery. Cold bonded pelletization as an alternate waste recovery method is more feasible, as production process take place at room temperature conditions with no emissions problem and energy requirements. In this technique cement or geopolymer as a binder are applied to produce materials like aggregates and bricks. Geopolymers are new inorganic binders which are produced by alkaline activation of silica and alumina rich materials of geologic origin or by-product materials. Geopolymers have fairly less CO_2 emissions than Portland cement and possess excellent properties (Yliniemi, Nugteren et al. 2016). Geopolymer LWA have also been produced by different waste materials like fluidized bed combustion ash, mine tailings, wood ash, GGBFS and fly ash (Bui, Hwang et al. 2012; Yliniemi, Nugteren et al. 2016; Yliniemi, Paiva et al. 2017)

In this study, LWA were produced by two different solidification/stabilization methods i.e. cement based cold bonded pelletization and geopolymer based cold bonded pelletization. Primary materials applied were two industrial by-products, fly ash and ground granulated blast furnace slag. Pakistan is a country which lacks natural resources of lightweight aggregate and neither artificial production of lightweight aggregate has ever been tried before. The over-stressed natural aggregate resources and the demand and benefits of lightweight construction are the stimulator behind this research program. Different types of aggregate were produced; their physical and mechanical properties were investigated. Comparison of cementitious-cold bonded aggregate and geopolymer aggregate is made by observing the aforementioned properties of LWA so that the feasibility of production of aggregates is confirmed. For comparison purpose, a natural, locally available, normal weight aggregate sample (crushed stone) was also considered for every property to check whether produced LWA come near to NWA in stability and strength.

2. Materials and Methodology

2.1 Materials

In cement based cold bonded pellets, ASTM type I ordinary Portland cement was used as binder. The Blaine fineness and specific gravity of cement were 3250 cm^2/g and 3.15 respectively. Fly ash which is a by-product of coal burning power plant was provided by DG Cement Production Plant. The composition of fly ash suggested it to be Class F fly ash according to ASTM C618.

Table 1: Chemical composition of ground granulated blast furnace slag, fly ash and cement used

Oxide (%)	GGBFS	Fly Ash	Cement
CaO	40.85	9.02	63.6
MgO	1.63	1.70	2.2
SiO_2	37.42	56.34	20.3
SO_3	0.645	-	2.8
Al_2O_3	13.25	23.08	4.9
Fe_2O_3	1.29	6.43	2.8
K_2O	0.014	0.56	0.70
Na_2O	0.417	0.28	0.40
Cl	0.016	0.025	0.01
LOI	2.30	<3	2.5
Moisture Content	1.428	<1	<1

Another industrial by-product, ground granulated blast furnace slag (GGBFS) was applied as primary material in cement based pellets production along with fly ash. ASTM C989 Grade 80 GGBFS was collected from Dewan Cement Limited. The chemical composition of raw materials used for lightweight aggregate production is presented in Table 1. Solutions of two industrial chemicals, sodium hydroxide and sodium silicate, were used as alkaline activators for geopolymer based LWA production. Sodium hydroxide in flakes form was obtained from Sitara Chemical Industries having concentration of 98.0 ± 1%. Sodium silicate was having molar ratio (SiO_2/Na_2O) of 2.5 and water content 65% approximately.

2.2 LWA Production Method and Curing Conditions

Lightweight aggregates (LWA) were made using cold bonded pelletization process. Two types of pellets were produced; 1) cement based LWA, 2) geopolymer based LWA

Pelletizer machine used in this study is shown in Figure 1. This pelletizer machine consists of a pan in which a shaft of about 20 kg rotates about an axis within the pan. Holes of 8.125mm diameter are punched in the base plate of pelletizer machine. When shaft rotates at certain speed it presses the material and cylindrical pellets are punched out of these holes and are collected at the inclined platform later on.
In cement based pellets quantity of cement was varying from 10-20% and remaining portion include equal percentages of both class F fly ash and GGBFS by weight (40-45%). Water to solid ratio opted was between 0.25-0.30. Desired amounts of fly ash, GGBFS and cement were dry mixed thoroughly for 1.5-3 minutes, and then water was added and mixed for further 2-3 minutes to produce a homogeneous mixture. Mixture was submitted in the pelletizer to make pellets of cylindrical shape, having fix diameter of 8.125mm and maximum length of 25mm.

Figure 1.Pelletizer machine used for LWA production

For production of geopolymer based LWA, fly ash quantity varied from 80-90% by weight and GGBFS was added in 10-20%. Alkaline activator was added from 25-30% of total weight of solid precursors. $Na_2SiO_3/NaOH$ ratio of 1.5 was adopted and both the solutions were mixed prior to adding in the dry mass.

After production, pellets were kept for 24 hours at $23^oC \pm 5^oC$ to make them strong enough so that they can bear handling stress. Two curing conditions were applied for cement based LWA; 1) water curing at room temperature until testing (after 7 and 28 days) (W-20), b) hot water curing in oven at 70°C for 24 hours and then water curing until testing (W-70). Geopolymer based pellets were wrapped in plastic bags and cured in oven at 70°C for 24 hours (D-70). After 24 hours pellets were placed in laboratory at ambient conditions (23°C ± 5°C) till they have been tested. Table 2 provides information for batch compositions of LWA production.

Table 2: Batch formulations for LWA produced

Sample Designation	Solid Constituent (%)			Liquid Portion (%)			Curing Conditions
	Fly Ash	Slag	Cement	Na_2SiO_3	NaOH	Water	
10C-W-20	45	45	10	-	-	100	W-20
20C-W-20	40	40	20	-	-	100	W-20
10C-W-70	45	45	10	-	-	100	W-70
20C-W-70	40	40	20	-	-	100	W-70
10S-D-70	90	10	-	60	40	-	D-70
20S-D-70	80	20	-	60	40	-	D-70

2.3 ASR Sample Preparation

For ASR potential observations, prisms of size 40 x 40 x 160 mm were prepared. Binder to aggregate ratio for prisms preparation was modified according to relative density of different LWA used, as directed by ASTM C1260. Water or alkaline activator to binder ratio applied was 0.47. Specimens were prepared using two different lightweight aggregates; 20C-W-70 and 20S-D-70 both using cement as binder and geopolymer as binder. Control specimen using natural coarse aggregates (crushed stone) were also prepared for comparison.

2.4 Testing

Lightweight aggregates were tested for their physical (water absorption, density and specific gravity), mechanical (impact value, ten percent fines value, crushing strength) and durability properties (ASR potential).

2.4.1 Physical Properties

Water absorption, density and specific gravity of aggregates were measured in accordance with ASTM C127. Aggregates were soaked in water for 3 days to find their water absorption, density and specific gravity. The formulas used to find these physical properties are as follows.

$$\text{a te a so ption ( )} \; \frac{\text{-a}}{\text{a}} \; 100 \tag{1}$$

$$\text{pe i i G avity, ven y ( )} \; \frac{\text{a}}{\text{-}} \tag{2}$$

$$\text{ensity o a e ates (oven y, o e)} \; \frac{\text{wei t}}{\text{volu e}} \; {}^{3}) \tag{3}$$

Where: a = oven dry mass of sample (g), b = SSD mass of sample, in air (g), c = SSD mass of sample, in water (g)

2.4.2 Strength tests

In this study, ten percent fines value test was conducted as per BS 812-111, both for LWA and crushed stone aggregate, to assess crushing strength of LWA under compressive loads. Ten percent fines were produced (m) and corresponding actual load was noted at the maximum plunger penetration of 24mm and 20mm for LWA and crushed stone respectively. Impact value test was conducted as per standard test procedure of (BS 812-112) to find the impact load resistance of LWA. Following equations were used to calculate ten percent fines value (TFV) and aggregate impact value (AIV).

$$(\quad) \quad \frac{2}{1} \quad 1\ 00 \tag{4}$$

$$(\quad) \quad \frac{14}{4} \tag{5}$$

$$(\quad) \quad - \ 100 \tag{6}$$

Where: M_2 = weight of sample passing 2.36mm sieve after test (g), M_1 = Initial weight of sample taken (g), f = Actual load at specified penetration of plunger (KN), A = Initial weight of sample (g) before impact test, B = Weight passing 2.36mm sieve after impact test

2.4.3 Alkali-silica reaction (Expansion of specimens)

Prisms were placed in 1 molar NaOH solution at 80^{o}C and readings were taken for length change measurement after 3, 7, 14, 21 and 28 days. Following formula was used for length change measurements.

$$\frac{{}_{t} - {}_{i}}{{}_{i}} \quad 100 \tag{7}$$

Where: Lt = Length of prism at t days,   Li = Length of prism initially (at start of test)

2.4.4 Petrographic analysis

Petrographic analysis was conducted following ASTM C295 to get an idea about the presence of alkali silica reactive minerals, and to compare the results of mortar bar test. Thin sections of standard thickness (0.03mm) were prepared using metkon GEOFORM thin sectioning system and studied using petrographic microscope, OLYMPUS BX51, under 4x-6x magnification. Modal analysis was being conducted for crushed stone to find the relative percentage of different rocks present in the aggregate sample.

3. Results and Data Discussions

3.1 Density and Water Absorption

Density of aggregate is an important property which decides the weight addition to concrete. Table 3 shows the physical properties of aggregates produced after 7 days of curing except water absorption, which was assessed both at 7 and 28 days of curing. In cement based LWA, density of aggregates is increasing by increasing cement percentage. Similar results have been reported previously (Gesoğlu, Güneyisi et al. 2012). This is due to the higher specific gravity of cement. In geopolymer-aggregate, the density of aggregate is increasing by incorporating higher quantity of GGBFS. The difference of densities for 10S-D-70 (698 kg/m^3) and 20S-D-70 (809 kg/m^3) was more significant than cement based aggregates. Densities of LWA produced were within the range specified by ACI report on lightweight aggregates (ACI 213R-03), which says that LWA density should be less than 880 kg/m^3 . Moreover the density of LWA produced is almost half of the density of crushed stone (Table 3).

Water absorption value of cement based aggregates and geopolymer aggregates after 7 days of curing ranged between 18.73% - 23.10% and 28.305 - 42.52% respectively. Water absorption of cement based pellets were well within the range (5 – 25%) as per ACI-213R, but geopolymer aggregates exceeded that limit. Results of Water absorption were in agreement with the lower density of geopolymer aggregate, hinting towards the porous nature of aggregates and incomplete hydration reactions. Water absorption of aggregates improved as curing days were increased. After 28 days curing, all aggregates showed water absorption within normal range (less than 25%).

Table 3: Physical properties of LWA produced and crushed stone, after 7 days of curing

Sample Name	Specific Gravity (OD)	Water Absorption (%)		Density (OD) (kg/m^3)	Density (SSD) (kg/m^3)
		7 days Curing	28 Days Curing		
10C-W-20	1.69	21.92	14.53	867	1057
20C-W-20	1.82	18.73	12.50	872	1036
10C-W-70	1.68	23.10	15.74	876	1078
20C-W-70	1.73	20.25	10.00	878	1056
10S-D-70	1.34	42.52	25.00	698	994
20S-D-70	1.60	28.30	24.09	809	1038
NWA	3.10	0.14	0.14	1602	1604

3.2 Aggregate Impact value

Impact value of different LWA produced is presented in Table 4. Strength tests were carried out both at 7 days and 28 days of curing to observe the strength change with time. According to test results, by increasing cement quantity the resistance of aggregates was increasing against impact loads. Cement aggregates performed better than geopolymer aggregates under impact test. Impact resistance of aggregates was improving with curing days as it is clear from test results after 7 and 28 days of curing. According to BS-812-12, the aggregate impact value (AIV) for normal weight aggregate fit for use in concrete must be less than 30%. Most of the produced aggregates met this criterion even after 7 days of curing except 10C-W-20 and 10S-D-70 whose AIV were higher (32.34%, 43.4% respectively). 's after 28 days were improved and only aggregate that failed to meet the criterion was 10S-D-70.

Table 4: Impact value and ten percent fines value of different aggregates developed, after 7 and 28 days of curing

Sample Name	Impact value (%)		Ten percent fines value (KN)	
	7 Days	28 Days	7 Days	28 Days
10C-W-20	32.34	29.52	46.27	79.84
20C-W-20	28.24	22.12	71.64	103.95
10C-W-70	27.78	23.89	59.74	83.44
20C-W-70	21.00	18.77	92.59	105.99
10S-D-70	43.4	39.64	45.61	48.00
10S-D-70	28.53	26.30	77.26	79.75
NWA	10.08	10.08	183.83	183.83

3.3 Ten percent Fines Value

Ten percent fines value (TFV) is the test method used to judge the crushing strength of weak aggregates instead of " e ate C us i n alue" test -812-110). Ten percent fines value of aggregates under consideration is shown in Table 4. All the aggregates showed almost similar trend for TFV as for AIV. Cement based aggregates performed better than geopolymer aggregate. Strength of pellets was improving for both cement and geopolymer based aggregates by increasing replacement ratios of cement and slag respectively. It is interesting to note that the improvement in TFV from 7 days curing to 28 days curing was more than the aggregate impact value, which shows that aggregate produced would better sustain compressive loads than impact loads. Maximum improvement of aggregate impact value was observed for 20C-W-20 (21.67%), whereas, 10C-W-20 showed maximum improvement of 72.55% for ten percent fines value. Geopolymer aggregate showed slight improvement in strength from 7 to 28 days, which reveals, geopolymer based aggregate attained maximum strength within early 7 days of curing.

3.4 Alkali-silica reaction (Expansion of specimens)

ASR test results are quoted in Table 5. It is clear from tabulated results that none of the specimen experienced deleterious expansion during the test after 28 days exposure. All the expansions were within limits specified by ASTM C1260 (maximum expansion <0.2%). Geopolymer based specimens observed more stability as compared to cement based specimens. Similar trend has been observed by previous authors also (Kupwade-Patil and Allouche 2011; Kupwade-Patil and Allouche 2012). In geopolymer based specimens, maximum expansion occurred in a specimen which was formulated using cement based aggregates; similarly, in cement based specimens the maximum expansion occurred in a specimen which was formulated by adding geopolymer based aggregates. This shows that there was some compatibility issue between different binder and aggregates which stimulated the expansive reaction. 20S-C specimen was worst to perform as micro cracks have been observed in the sample even after 14 days of exposure to solution. Some other specimens only showed leaching out of powdered material on surface of specimens without any cracks or bloating.

Table 5: Average expansion of specimens for ASR test at different time duration

Sample Type	Sample Name	Expansion (%)				
		3 days	7 Days	14 Days	21 Days	28 Days
Geopolymer Based Mortar Prisms	20C-GP	0.022	0.045	0.070	0.072	0.074
	20S-GP	0.039	0.043	0.062	0.066	0.064
	NWA-GP	0.032	0.048	0.066	0.072	0.072
Cement Based Mortar Prisms	20C-C	0.039	0.058	0.072	0.086	0.097
	20S-C	0.038	0.077	0.109	0.119	0.132
	NWA-C	0.010	0.039	0.102	0.118	0.125

3.5 Petrographic Analysis

Thin sections of crushed stone and two selected lightweight aggregate produced, 20C-W-70 and 20S-D-70 (maximum strength aggregate from each class), were studied under petrographic microscope for identification of different minerals. Crushed stone consisted of 5 different rocks, instead of a single rock type. So, total of seven thin sections have been made for investigation purposes. None of the aggregate sample had ASR reactive silica mineral like opal, cristobalite, trydymite and cryptocrystalline quartz. Artificial aggregate showed presence of 5-10% crystalline or polycrystalline quartz and 95-90% portion was clay size portion which may be hydraion reaction products. Particle count for similar rocks in the crushed stone sample revealed that, crushed stone sample consisted of different rocks like blackish grey meta-dolerite (20.9%), greenish grey meta-dolerite (8.9%), brown sandstone (23.1%), dark grey sandstone (37.7%) and white granite (9.5%). In thin sections study, minerals identified in these rocks were pyroxene, plagioclase, altered chlorite, altered sericite, quartz, epidote, feldspars, hematite, and ilmnite. Only threat for ASR was higher percentages of sandstone (60%), major portion of which, was qaurtz (crystalline to polycrystalline). However, expeirmental results for expansion of specimens containing crushed stone exhibited no deletrious expansion and cracks. Concluding, all the aggregates (artficial and natural) were safe to use both with cement and geopolymer binders.

4. Conclusions

Both cement based and geopolymer based aggregates presented good properties. Density and water absorption of cement and geopolymer aggregates ranged between 698-878 kg/m^3 and 10-25%, respectively. Cement based aggregates had better mechanical properties than geopolymer based aggregates, and properties were improving for higher percentage of cement added. However, geopolymer-aggregates were lighter than cement-aggregates. Aggregates performed better in resisting compressive loads than impact loads. None of the aggregate showed deleterious expansion of mortar prisms indicating that they are safe to use in concrete both with cement and geopolymer binder. Petrographic study of thin sections revealed absence of any deleterious alkali-silica reactive mineral. Concluding, manufactured LWA showed acceptable properties, and feasibility of their production using industrial by-products.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Seismic Characterization of Peshawar Region using Ambient Noise

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Abstract

The Ambient noise study was carried out in Khyber Pakhtunkhwa, District Peshawar that is seismically active. Ambient noise method is time and cost effective, is very convenient in built-up areas with high noise level and gives stables response curves for site characterization. The field measurements are taken using seismometer sensors, for a period of 1 hour at each station point. The data is analyzed using MATLAB and FORTRAN software's for the quantitative assessment of site effects associated with local surface geology, to determine shear wave velocity and engineering bedrock depth and the estimation of the fundamental resonance frequency using Nakamura method, a simple investigational technique based on ambient noise recording. The result of various stations at union council level is divided into different categories based on the shape of site response, resonance frequency and soil type for engineering application. Since the detailed (borehole data) soil profile is available at some of the stations, a comparative analysis between numerical and actual analysis is carried out for the refinement of numerical models.

Keywords
Seismic Micro-zonation, Site effects, ambient noise studies, Resonance frequency of soil.

1. Introduction

Pakistan is a seismic prone area which has affected by major earthquakes in the past like and the more overwhelming Kashmir earthquake 2005 and Quetta Earthquake 1930 (Indo-Pak), Kashmir. It has been proficient that more human casualties and economic loss is due to inadequate existing structures that may not resist seismic loading during an earthquake. In the wake of the devastation caused by the earthquakes tremendous research have been carried out to understand the behavior, performance and assess the feasibility of existing and new proposed structural systems, with the aim to achieve an optimum design solution (safe and economical). During an earthquake, the response of structure is not same for all the time but changes. The changes in the response of structure is because of local site effects. Site effect is the modification of the ground motion perceived at the surface due to different properties of surficial geology. A qualitative and numerical assessment of site effects is frequently articulated by the amplification factor and resonance frequency. Resonance frequency of the soil media fluctuates depending upon its physical nature and depth of the bedrock. For the quantitative assessment of these surficial geology different method has been used. In this research non-destructive method is used for the quantitative assessment to these properties, associated with local surface geology, shear wave velocity, engineering bed rock depth

and the estimation of the fundamental resonance frequency. Therefore, the site response and site characterization have become the most important tasks in seismological studies.
The ambient noise study was carried out in Khyber Pakhtunkhwa, District Peshawar which is seismically active. The profoundly inhabited city has number of manmade buildings might be prone due to an earthquake of substantial magnitude. Ambient noise method which is time and cost effective, is very convenient in built-up areas with high noise level and gives stable response curves for site characterization. The aim of this study is to evaluate resonance frequency using Nakamura method, a simple investigational technique based on ambient noise recordings.

2. Field Testing Program for Data Sets

It is clarion that ambient noise method is convenient for determining local site effects in seismically dynamic regions such as District Peshawar, where ground motion recordings are few, and the noise level are high due to different activities. This study was carried out in District Peshawar at different stations and the measurements were recorded using high velocity sensors (seismometers) for a period of 1 hour at each station point. The locations of the tests are shown in **figure 1**.

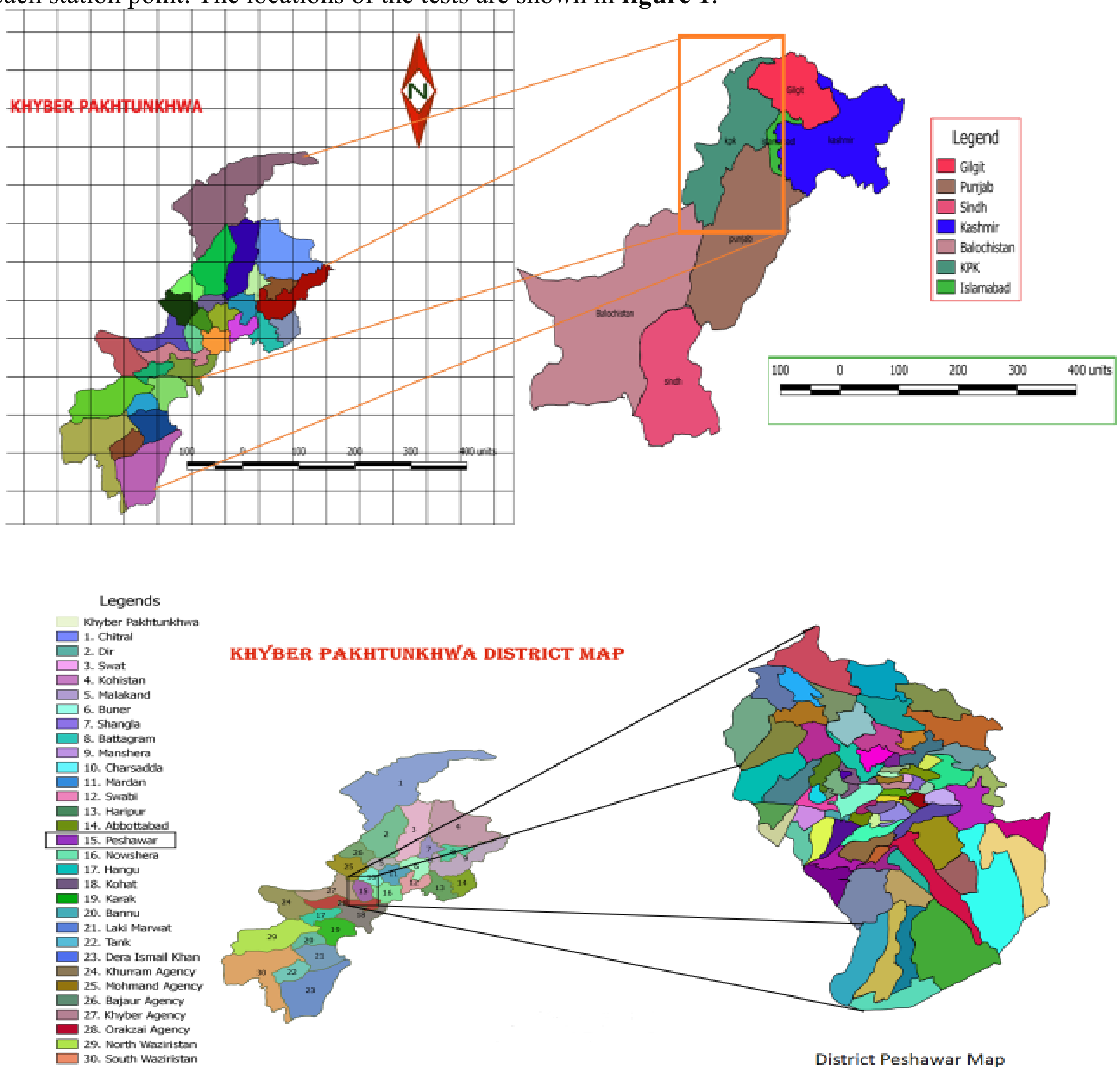

Figure 1: KPK and District Peshawar UC Map

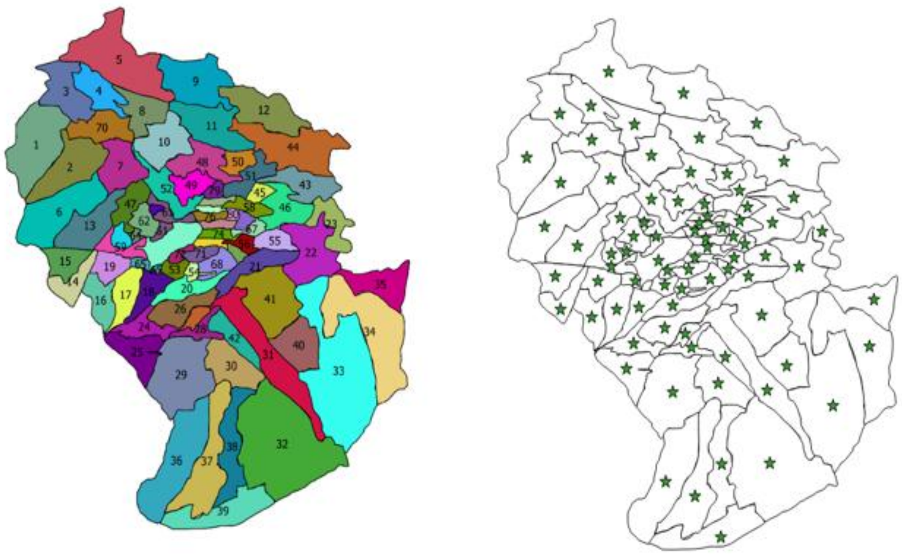

Figure 2: District Peshawar UC Map Along with Station Marked

3. Data Acquisition System

The ambient noise tests were carried out using DR-4000 Portable Multi-Channel strong motion Data Acquisition System from St. Louis US, which certify precise, consistent vibration measurement and extensive term monitoring. The DR-4000 Data Acquisition System is easy to handgrip and organized to use. The instruments has two main units i.e., one is eight channel acquisition system which shows and take the ground motion, further one is the recorder in which all the data will get stored. The seismometer is extremely sensitive with three perpendicular components that is two horizontal (N-S and E-W directions) and one vertical (up and down). **Figure 2** shows the field arrangement of the ambient noise apparatus. First the seismometer is placed on the level ground. Both the seismometer and the recorder are linked using sensor cable and the recorder is coupled to the field laptop using communication cable. The data was recorded after letting the instrument stabilized for about 15 minutes.

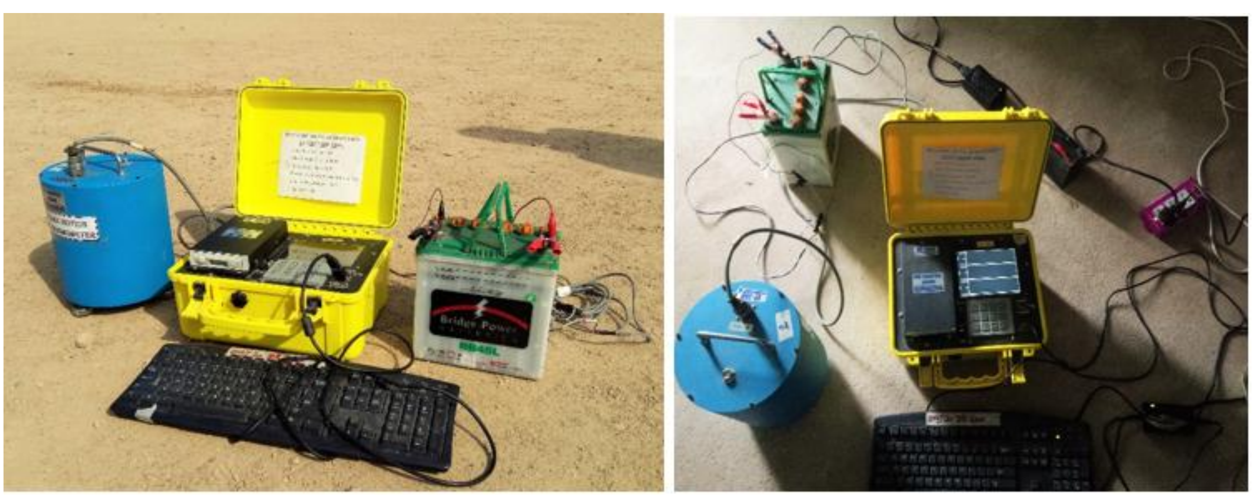

Figure 3: Recording of Data at Each Stations

4. Data Processing

The recorder accounts the ground motion uninterruptedly and generates different files. The data is continuously recorded for one hour at each station. The detailed events can be viewed and shifted during the test. After the tests all the binary data files can be relocated to the laptop using data export option. The binary recorded data having two horizontal and one vertical components is then analyzed using DADISP software, which converts it into American Standard code for Information Interchange (ASCII) file as shown in the **Figure 3**. A baseline correction is applied to the recorded data which means that the recorded signal is adjusted about zero even if sensor is not 100% level. The noise data was processed using Matlab software. The continuous data was converted into small window lengths of 50 seconds according the SESAME (2004) guidelines. The guidelines are given in table 1. The small windows are further tapered at both ends using 5% Cosine windows. Furthermore, after the Fourier Transformation, the spectra are smoothed using Konno-Ohmachi smoothing windows.

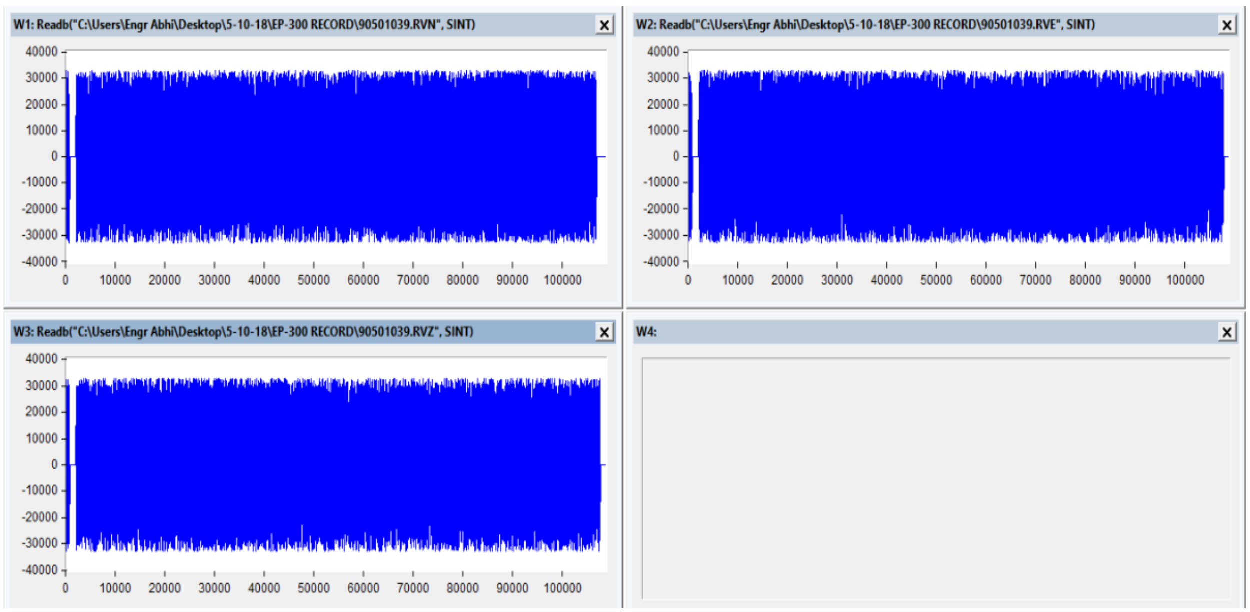

Figure 4: Conversion of binary data into ASCII format using DADISP

Table 1: Recommended recording duration (SEASAME, 2004)

Minimum expected f_o [Hz]	Minimum Window Length, l_w [s]	Minimum number of significant cycles (n_c)	Minimum number of Windows	Minimum useful signal duration [s]	Recommended minimum record duration [min]
0.2	50	200	10	1000	30'
0.5	20	200	10	400	20'
1.0	10	200	10	200	10'
2.0	5	200	10	100	5'
5.0	5	200	10	40	3'
10.0	5	200	10	20	2'

5. Results and Conclusions

Plots of H/V of different stations are shown in figure 5. It is interesting to see that all the plots show more or less similar behavior although they represent different union councils. The coordinates of these union council are shown in table 2. Plots of H/V also do not show a clear peak, but have almost a flat response. Furthermore, the results also some scatter as is seen from the plot of standard deviation.
The absence of clear peak in the H/V plots could also indicate about the absence of strong bedrock in the near surficial materials. Beside the flat response, a low amplitude peak at frequencies between 0.2 to 0.3 Hz could also represent a low contrast bedrock at large depth. Furthermore, an overall low amplitude spectra also reveal about the stiff soil. To have a more accurate detailed knowledge of the region, further studies including the bore hole and array analysis shall be incorporated in the research work.

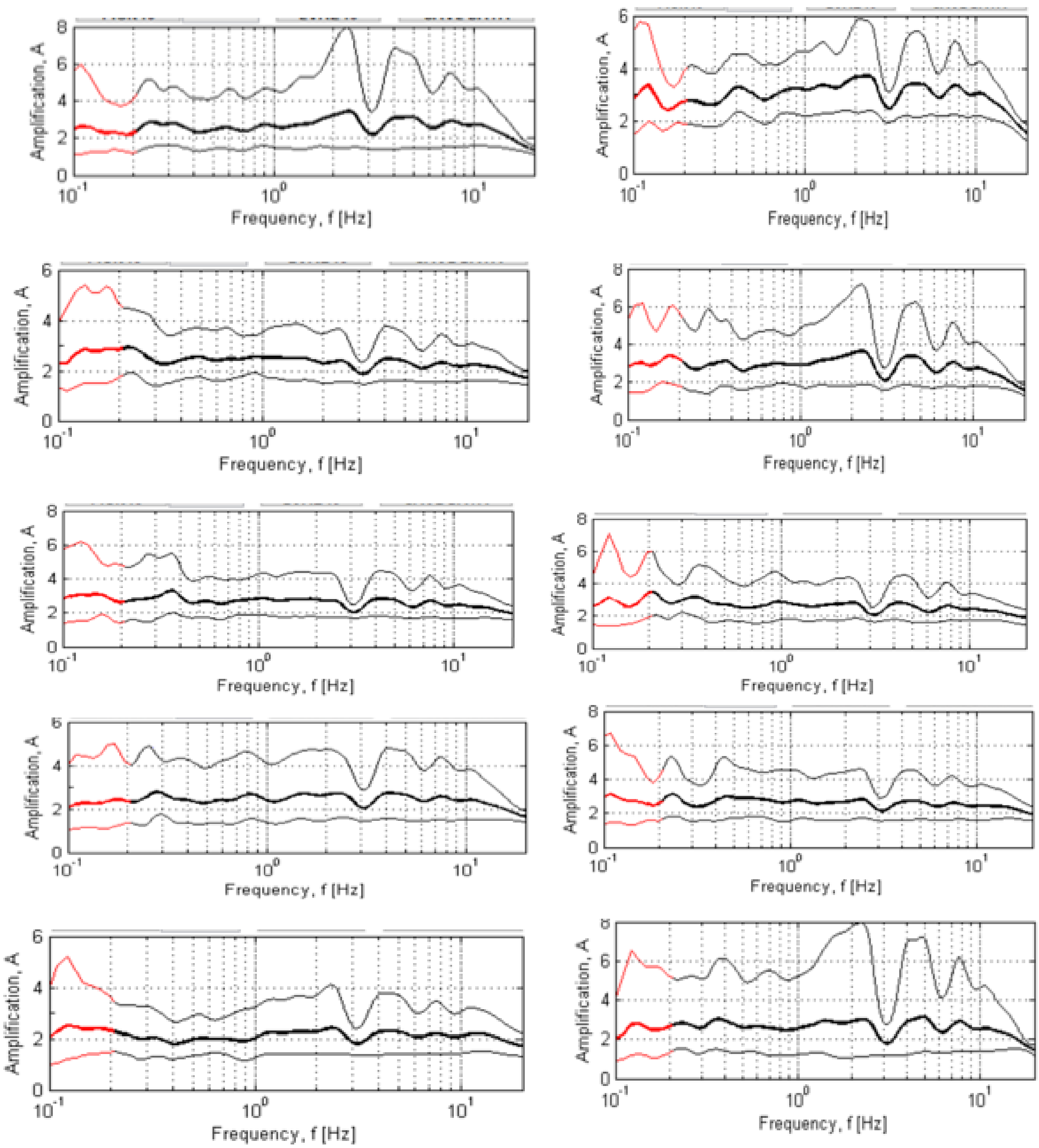

Figure 5: First 10 UC Amplification factors and respective frequency

Table 2: Results on the UC basis along with Coordinates

S.No	Coordinates(degrees)		Amplification Factors	Frequency (Hz)
	Latitudes	Longitudes		
01	34.02399	71.53317	2.70	0.21
02	34.01512	71.50171	2.10	0.28
03	34.00489	71.49755	2.90	0.37
04	34.11982	71.64965	3.10	0.23
05	33.97797	71.44962	2.40	0.30
06	33.98726	71.45301	2.90	0.40
07	33.95845	71.46749	2.40	0.22
08	33.96987	71.54012	2.90	0.18
09	33.80160	71.55981	3.10	0.13
10	33.77369	71.58653	2.00	0.37

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Compressive Membrane Action (CMA) and Its Application to Structures

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ABSTRACT

The paper predominantly presents the conceptual and theoritical understanding of the Compressive Membrane Action (CMA) its significance in the slab of structural system.The comparison of unrestrained slab system versus a restrained slab system is explained.The approach of yield line theory and different models to calculate the arching moment resistance and load carrying capacity by Compressive Membrane Action.To further elaborate the areas of practical consideration,the effects of CMA in the fire resistance of building system how this action is used to increase the fire resistace and provide mitigation against the disaster situation.The most important and practical application of CMA is in the Bridge Deck Slab System where there are small displacements.

Keywords
Compressive Membrane Action(CMA) ,mitigation,displacements,fire, yield line theory

INTRODUCTION :

The Compressive membrane action (CMA) which is known as the arching action which occurs in slab. If we consider reinforced concrete slab under transverse loads, as the slab deflects under load, the concrete on the tension face cracks and the reinforcement is stretched. Typically, the strain on the tension face will be greater in magnitude than those on the compression face. The net tensile strain resulting at the slab mid- depth causes the slab to expand producing outward horizontal displacements at the slab ends. The tendency to expand is prevented to some degree by the lateral stiffness of the supporting columns, beam and shear walls. The Compressive membrane action only takes place in laterally supported slab system and if the slab is simply supported and unrestrained slab there is no such phenomenon. The strength of laterally restrained reinforced concrete slab is significantly enhanced by the effect of arching or Compressive Membrane Action. The CMA exists near the boundary or supports of the slab system where as in the middle ring there is tensile membrane action which is not the scope.The restrained slab develop high axial compressive forces which result in a significant increase in flexural stiffness and load capacity. The codes have not incorporated the effect of compressive membrane action which results in over conservative design.

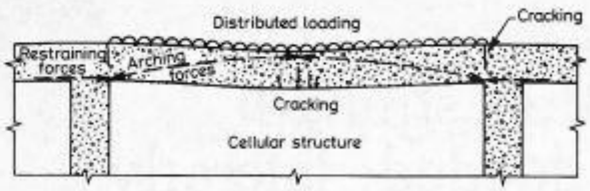

Fig 1. Compressive membrane action in laterally restrained slab

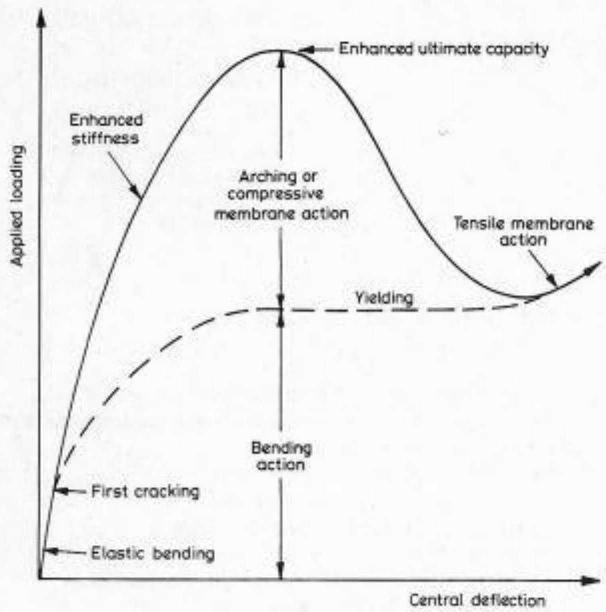

Fig 2. Qualitative illustration of enhanced behaviour of a laterally restrained slab[3]

Fig 1 : Behaviour of a laterally restrained slab

OBJECTIVE

The objective of the current research is to understand the concept and behaviour of compressive membrane action through yield line theory and different models its significance,application and role in the structural system like for fire resitance of slab and beam-slab bridge system .The understanding to incorporate the effect of compressive menbrane action would have a great effect on the capacity of the slab there by reducing the reinforcement that is required by ordinary design based calculations and hence optimizing the need of design and hence making the structure economical by considering the phenomena of Compressive Membrane Action.Although the codes have not taken the effect of Compressive Membrane Action in slab which have a significant effect on the reinforced concrete slab which there by increase the strength and stiffness property.

SCOPE

Since the topic is very general the scope of the current research is limited to the following area of interest

- Comparison of Restrained Slab vs Non Restrained Slab for CMA action
- Ultimate Load Capacity and Moment Resistance by Yield Line Theory for CMA
- Models to take into account CMA
- Applications of Compressive Membrane Action which include the follwing :
    - Compressive Membrane Action in Bridge Deck Slabs
    - Effects of CMA on fire resistance of Slab of Building System

METHODOLOGY

The methodolgy adopted to complete the research is to read the literature and to have a critical understanding of the phenomena happening and develop the conceptual understanding of the facts.

1) Comparison of Restrained , Rigid Slab Vs Non- Restrained Slab for CMA action :

The strength of a restrained slab is much greater as compare to unrestrained or simply supported slab system as shown by the work of Rankin[1] the test results are shown to elaborate its effect in Fig.5.Furthermore, the load vs cental deflection plot are shown to illustrate the behaviour of CMA at different load levels and transition from compressive to tensile state of loading in Fig.2.The compressive membrane action in a building framed structure is shown to elaborate its effect in Fig.3 respectively.

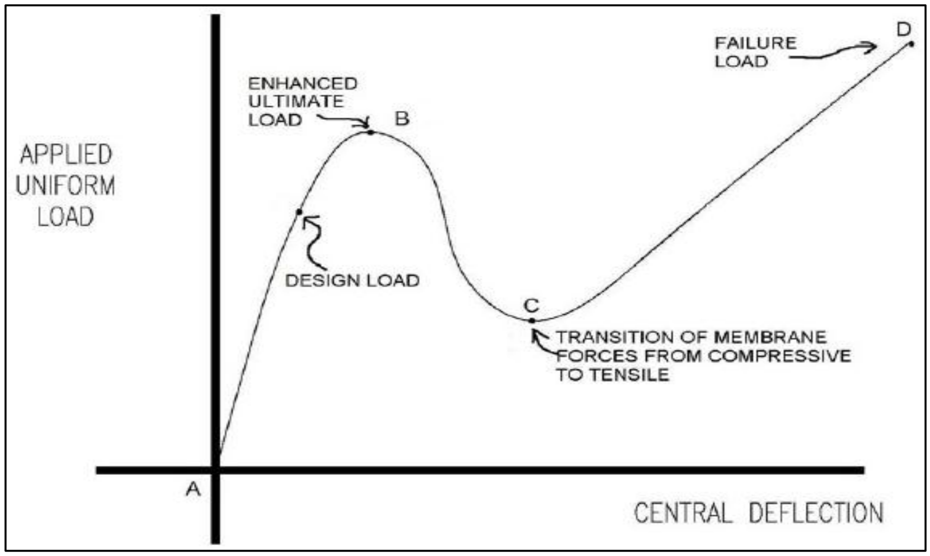

Fig2: Load vs Central Deflection

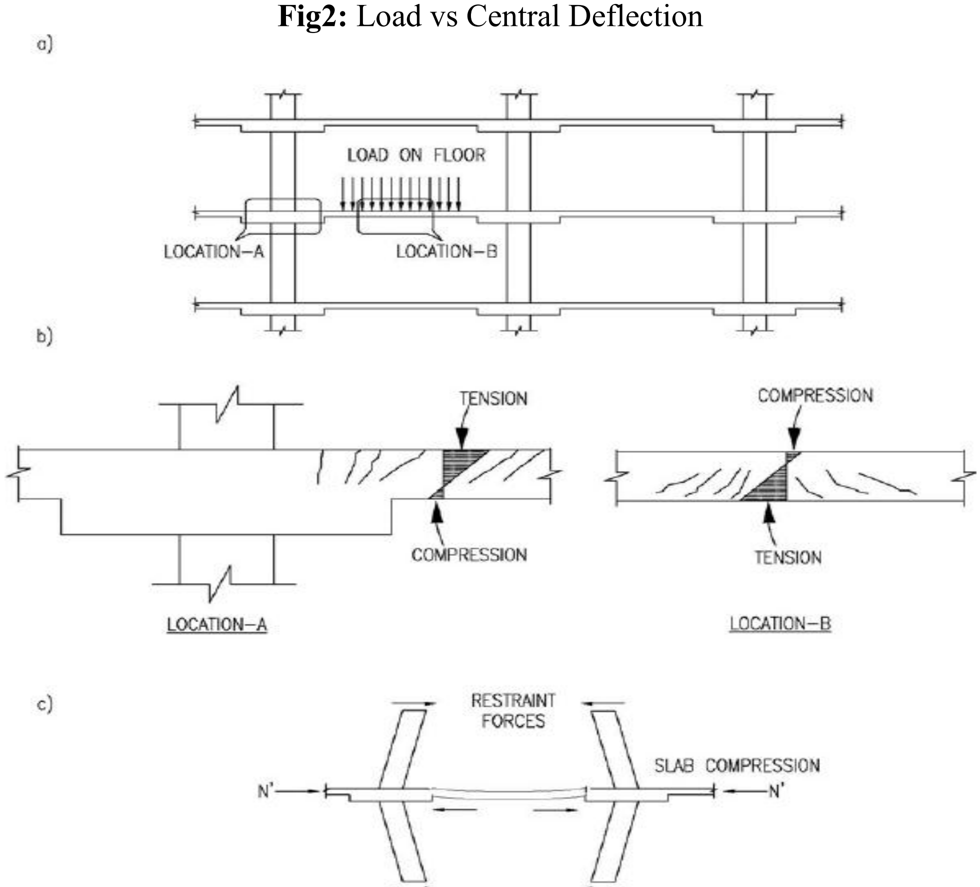

Fig-3: Axial forces developed in laterally restrained slab: a) slab subjected to transverse loading, b) slab elongates upon cracking, c) restrained elongation induces axial compression

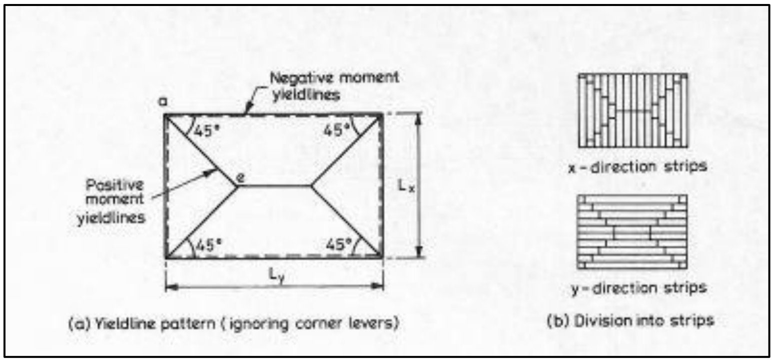

Fig 4: Yield line pattern for Slabs and division of strips

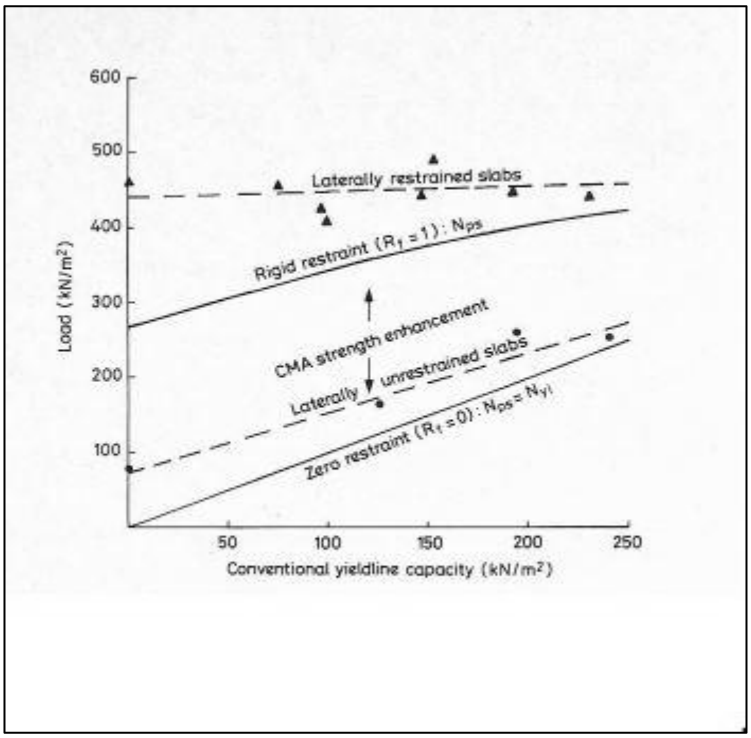

Fig 5. Load vs the Conventional Yield line Capacities

From the above results of graph of Fig5. of Rankin[1] developed from the yield line theory in Fig4. for two way slab the following could be concluded :

- In case of a zero restrained or simply supported slab the load carrying capacity is lower and no Compressive Membrane Action.

- In case of a laterally unrestrained slab the the load carrying some what higher but there is no Compressive Membrane Action.

- In case of a rigid restraint there is a increase in the load carrying capacity of the slab due to the CMA.

- In case of a laterally restraint slab there is a significant increase in the load carrying capacity as the CMA governs in this scenario.

2) Moment Resistance and Ultimate load Capacity by Yield Line Theory for CMA :

The yield line theory method[7,10] is most convenient method to take into account the arching action by dividing the slab into strips at the failure and then determining the arching moment action which causes positive moment resistance and collapse load for the figure shown above :

Assumptions of the theory :

1. A yield line pattern is assume to develop at failure

2. Corner lever can be ignored and single positive moment yield line are assumed to run into each corner of the slab at 45 degree to the slab boundary.

3. A constant average arching moment of resistance "Mav" is assumed to act at all point along the yield lines.

a) For Moment Resistance by Yield line Theory :

From the conventional yield line theory[7,10] the energy dissipation along a length l of a yield line
Is given by:

M(Projection of 1 on an axis) X (Rotation of rigid region about that axis)

If the slab shown in above **Figure 4.** is given a unit virtual displacement,the total energy dissipation along the yield lines is as follows :

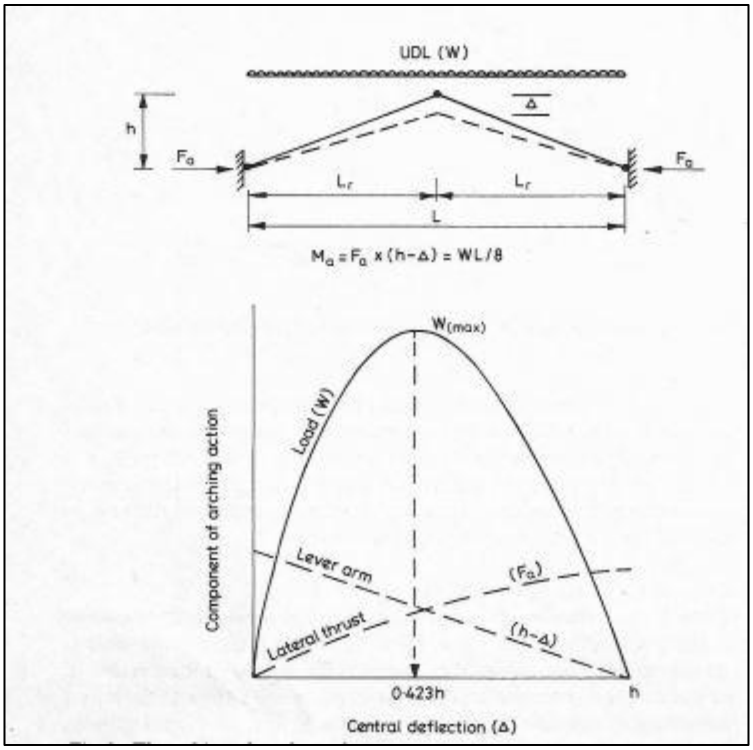

Fig 6. Three Hinged Arch Analogy

$$4M\left[2Xae\cos 45°X\frac{1}{L_X/_2}\right]+2M\left[\frac{(L_Y-L_X)}{L_X/_2}\right]+2M'^{\left[L_YX\frac{1}{L_X/_2}+L_XX\frac{1}{L_X/_2}\right]} \qquad (\mathbf{1.1})$$

$$4M\left[4X\frac{ae\cos 45°}{L_X}+\frac{(L_Y-L_X)}{L_X}\right]+4M'^{\left[\frac{(L_Y+L_X)}{L_X}\right]} \qquad (\mathbf{1.2})$$

$$ae\cos 45° \;=\; L_X/_2 \qquad (\mathbf{1.3})$$

$$8(M+M')+4(M+M')\left[\frac{(L_Y-L_X)}{L_X}\right] \qquad (\mathbf{1.3})$$

Therefore the internal workdone by bending action is given by :

$$I_b = \; 8(M_b+M'_b)+4(M_b+M'_b)\left[\frac{(L_Y-L_X)}{L_X}\right] \qquad (\mathbf{1.4})$$

The arching moment causes only positive moment resistance and is given by :

$$I_a = \; 8(M_{av})+4(M_{av})\left[\frac{(L_Y-L_X)}{L_X}\right] \qquad (\mathbf{1.5})$$

$$M_{av} = \frac{WL}{8} \qquad (\mathbf{1.6})$$

$$(M_b + M'_b) = \frac{WL}{8} \quad (\mathbf{1.7})$$

$$I_W = I_a + I_b \qquad (\mathbf{1.8})$$

Therefore, the total workdone by the moment is the sum of arching moment and the bending moment of the slab.The slab bending resistance is calculated in similar manner as its when containing tension and compression steel while the only add on is of the arching moment which causes positive moment resistance and calculated by above equation based on energy principles and yield line theory.

b) For Ultimate load Capacity by Yield line Theory [7,10] :

For a unit virtual displacement the external workdone on the loading area on the slab is given by :

$$2N\left[L_X X \frac{L_X}{2} X \frac{1}{3}\right] + 2N\left[(L_Y - L_X) X \frac{L_X}{2} X \frac{1}{2}\right] + 4N\left[L_X X \frac{L_X}{2} X \frac{1}{3}\right] = N\left[\frac{{L_X}^2}{3} + \frac{L_X}{2}(L_Y - L_X)\right] \quad (\mathbf{1.9})$$

$$E_W = N(3L_Y - L_X).\frac{L_X}{6} \qquad (\mathbf{2.0})$$

The predicted ultimate load capacity of uniformly loaded laterally restrained slab by equating internal workdone and external workdone is given by :

$$N_u = \frac{6I_W}{L_X(3L_Y - L_X)} \qquad (\mathbf{2.1})$$

This expression gives the predicted ultimate load capacity of isotropically reinforced concrete slab with four sides laterally restrained.

3) Different Models to take into account CMA :

c) Model of Christiansen and Kirkpatrick etal :

It is reasonable to assume that the depth of concrete section available for arching can be calculated from the overall depth of the section minus the depth of the bending compressive stress block and the elastic deformation necessory to cause yielding of the reinforcement.However, for the yield line analysis the elastic deformation necessory to cause yield can be ignored and hence the depth of the section available for arching is given by :

$$d_a = h - (\rho + \rho').\frac{f_y d}{o.85 f_c} \qquad (\mathbf{2.1})$$

From the Kirkpatrick[9] etal the total arching moment of one way strip slab can be expressed in terms of depth of the slab available for arching and the compressive strength of the concrete

$$M_a = kf_c{d_a}^2 \quad (\mathbf{2.2}) \quad (k_{max} = 0.21)$$

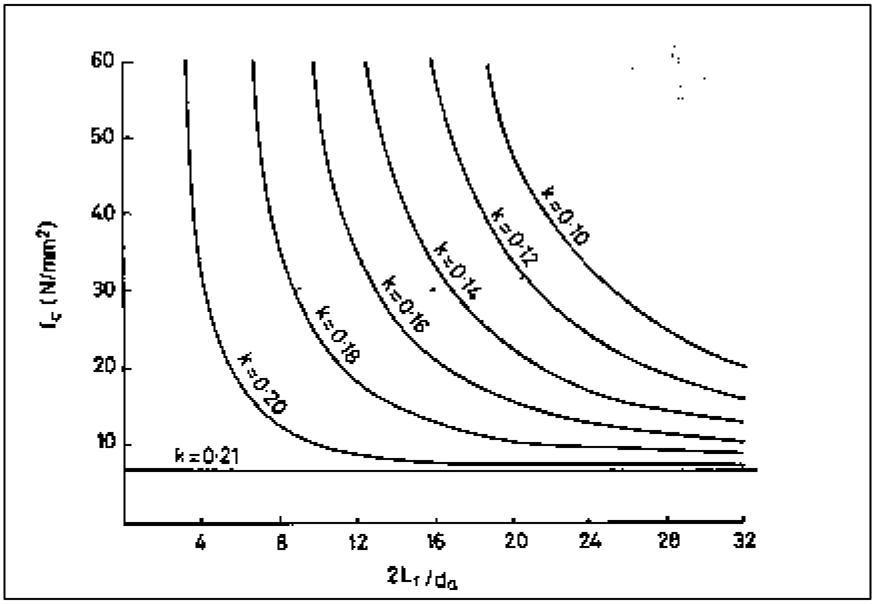

Fig 7. Variation of Arching Moment Coefficient with concrete strength and arching length/depth ratio

d) Balanced Moment Capacity Model :

In order to comply with flexure limitation criteria for a concrete section an upper limit to the total internal workdone is imposed.This can be achieved by assuming that maximum possible internal workdone cannot exceed when the balance moment capacity of the section is attained

$$\boldsymbol{I_w \ngtr 8(M_{bal}) + 4(M_{bal})\left[\frac{(L_Y - L_X)}{L_X}\right]} \qquad (\mathbf{2.3})$$

The model proposed by Whitney[12] to calculate balance capacity is given by
:

$$\boldsymbol{M_{bal} = 0.333f_c d^2} \qquad (\mathbf{2.4})$$

For a section where d = 0.8h since the maximum value of k = 0.21 the expression becomes

$$\boldsymbol{M_{bal} = 0.21f_c h^2} \qquad (\mathbf{2.5})$$

4) Compressive Membrane Action in Bridge Beam- Slabs Deck :

Compressive membrane action (CMA) often exists in the deck of reinforced concrete beam-and-slab bridges[6], hence enhancing the deck strength above that determined using a normal flexural and punching shear strength theory. Approximate methods to account for compressive membrane action have been developed by previous researchers. Hence, compressive membrane action is usually not taken into account when determining the strength of reinforced concrete slabs. The design method for assessing the restraint stiffness that exists for the slab of typical beam-and-slab bridge decks and the strength enhancement due to compressive membrane action. This gives a more accurate prediction of the strength of the slab. The method has been developed through the laboratory testing of concrete specimens and the use of nonlinear finite element modeling. The calculations are shown that how to incorporate and calculate the effect of Compressive Membrane Action (CMA) or the arching action on moment and the load capacity.

Currently, methods that are commonly used in the strength assessment of reinforced concrete slabs where horizontal translational restraint is present, underestimate the slabs failure load because the beneficial effects of compressive membrane (or arching) action are not taken into account. Compressive membrane action exists in the slabs of typical reinforced concrete beam-and-slab bridge decks significantly increasing the slab's stiffness and strength in both flexure and punching shear. There are two requirements for compressive membrane action to develop in a reinforced concrete slab. First, some form of horizontal translational restraint must exist for the slab. In the case of a beam-and-slab bridge deck. This consists of the longitudinal beams, the adjacent slabs and the surrounding slab area. The other condition is related to the strain compatibility along the length of the slab, in that the net tensile strain along a longitudinal fiber must be non-zero if there is no horizontal restraint. The presence of a rigid horizontal restraint (at the depth of a longitudinal fiber that would have had non-zero net tensile strain) forces the strain back to zero, which induces membrane forces in the slab. If the restraint is less than rigid, the net longitudinal strain will not be zero and a lesser amount of membrane action will develop in the slab. Compressive membrane action develops transversely in the slab because cracks develop at midspan and at the slab ends. This causes an extension in the longitudinal fibers of the slab which is restricted by the horizontal restraint. In this case, the concrete in the surrounding beams and adjacent slabs provides the horizontal restraint. Therefore, the two conditions necessary for compressive membrane action to develop are satisfied.

e) Calculations for Analytical Investigation for Compressive Membrane Action of Beam–Slab Bridge Deck :

The method proposed by Rankine and Long[1] has been used to calculate the effect of compressive membrane action on the beam slab bridge the calculation for the moment resistance and ultimate load capacity for specimen is shown below:

Horizontal translational restraint stiffness :

Effective width = $\boldsymbol{b_{eff} = x + 2.4a\left(1 - {}^{a}/_{L}\right)} \qquad (\mathbf{2.6})$

Where "a" is the distance from load to nearest support

"x" is the load width

"L" is the clear span

Horizontal translational restraint stiffness = $\mathbf{k_t} = {KL_e}/{E_C d}$ (2.7)

d=0.5h (assumed to be half slab depth)

Compressive Membrane Capacity:

Effective area of arch leg = $\mathbf{d}$ **X** b_{eff} **(2.8)**

Equivalent length of rigidly restrained arch = $L_r = L_e\left[\frac{EA}{k_t * L_e}\right]$ (2.9)

Plastic concrete strain=$\in_C$ **= (-400 + 60f'$_c$ -0.33f$_c$'^{2})X10^{-6}** **(3.0)**

R = $L_r^{\,2} \in_C / 4d^2$ (0 < R < 0.26) **(3.1)**

$$M_r = 4.3 - 16.1\left(3.3X10^{-4} + 0.1243R\right)^{\frac{1}{2}} \quad (3.2)$$

Arching Moment Rigid restraint = $M_{ar} = (M_r 0.85fc'd^2)/4$ (3.3)

Arching Moment Elastic restraint = $M_a = M_{ar}\left({L_e}/{L_r}\right)$ (3.4)

Effective reinforcement ratio = $\rho_e = \frac{M_a}{f_{ye}X0.75d^2}$ (3.5)

M_u = Ultimate moment capacity (Calculated in a similar manner for slabs containing compression and tension reinforcement)

The total Moment capacity of the bridge deck is :

Total Moment= **M = M$_u$ +** M_a **(3.6)**

Hence, by taking into account the Compressive Membrane Action the reinforcement in the deck can be reduced to certain extent and advantage of CMA can be utilized.

5) Compressive Membrane Action on Fire Resistance :

The behavior of reinforced concrete slabs in fire conditions[5,13] strongly depends on the support conditions and the interaction of the slabs with the surrounding structure. The compressive axial restraint forces from the surrounding structure can increase the fire resistance of heated slabs, and fire resistance can also be considerably increased.

It is concluded that one-way slabs with flexural continuity at the end supports and low axial restraint have excellent fire resistance. Compressive membrane action can increase the fire resistance of pin-supported slabs if the axial restraint stiffness is very high and if the line of thrust at the supports is located near the slab soffit.

The concept of Compressive Membrane Action can be utilized to increase the fire resistance property of the slab the controlling is the lateral restraint stiffness which is equivalent to the axial compressive stiffness k = AE/L.Hence, the compressive membrane can be used to mitigate the pre and post disaster situation caused by fire by having a understanding of the phenomena.

CONCLUSION:

The Compressive Membrane Action plays a very important role in the slab of the structural system by incorporating the effect of CMA there is a significant increase in load carrying capacity and moment resistance.The models presented above can be used to take effect of compressive membrane action which is not incorporated in design codes. Some practical examples of CMA is discussed highlighting the dominating effect of CMA in strength enhancement of Beam –Slab Bridge System and how the effect of compressive membrane action plays a pivotal role in fire resistance of slab of building by controlling the restrained stiffness and prevent disaster situation.Although from the above research the most important finding is to incorporate the effect of CMA would significantly make the design process optimized and economical.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Analysis of Settlement-Induced Building Damage Using Damage Surveys

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Abstract

The ridges are commonly bulldozed into the troughs while developing housing schemes in undulating terrain. Loose deep fills comprising unsaturated silt-clay pose severe settlement problems. Due to varying thickness of the fills and fine grained nature of soil, settlement is usually differential and long term. The situation aggravates much more if water ingress occurs. Structures supported on such fills undergo serious cracking and demand substantial maintenance and in acute cases demolition. Degree of settlement depends on several factors such as; type of soil, structure, and foundation; fill thickness its history and degree of wetting etc. In this research paper a case study considering all these factors has been conducted to analyze settlement induced building damage.

Keywords: Housing scheme**,** unsaturated loose fill, Contours, Settlement, cracking.

1. Introduction

Islamabad the capital of Pakistan is located at the northern edge of the Pothohar Plateau and at the foot of the Margalla Hills**.** Since its establishment, Islamabad has attracted people from all over Pakistan, making it one of the most cosmopolitan and urbanized cities of Pakistan. Because of this reason housing societies like Bahria Town, Gulberg Green, Soan Gardens, Jinnah Gardens, DHA and many others have been developed in Islamabad and its surroundings.

Pothohar Plateau has a typical undulating topography comprising steep crests and deep gorges. Substantial cutting/filling is made to plan infrastructure and residential/commercial plots. The gorges are just filled by dumping the soil bulldozed from the crests without any compaction. Loose fills up to 20-25 ft. and even more deep are quite common. Resultantly, the influence zone of dwellings and commercial buildings lies within the fill thickness. The minimum time lag between the land development and building construction varies from 5-10 years. The top layer up to 3-4 ft depth is slightly densified by collapse of soil resulting from wetting by rain water, making it hard. Due to top hard layer further downward water

percolation and resulting natural densification process is prevented leaving the underlying soil loose and unsaturated.
In the past decade, settlement induced building damage has emerged as a big concern in newly developed societies which demands an elaborate study of the issue. To analyze the problem a case study has been conducted. Rafi Block, Bahria Town, Phase VIII has been selected for the case study. This study can also help the Capital Development Authority (CDA), to consider the issue and enact further building regulations.

2. Literature Survey

Ground settlement is a problem in many parts of the world and is caused by either natural processes such as physical and chemical weathering or anthropogenic activities such as natural soil change from construction, mining and tunneling activities (Holzer, 2009). Notwithstanding the cause of ground subsidence, the amount of settlement to a great extant depends upon the thickness of the soft soil layer. The soft soil layer may comprise peat or loosely filled unsaturated clay. These soil types are characterized with high compressibility when subjected to external loadings (Den Haan and Kruse, 2006). Because of this, buildings and infrastructure may suffer from either absolute or differential settlement. Recent studies have suggested that such structure damages caused by soil subsidence cause losses of billions of dollars each year (Bucx et al., 2015). Therefore, study of settlement induced building damage has become a topic of major concern demanding identification of suitable ways of land use planning and urban management.
To understand the amount of damage occurred on the buildings, it is necessary to understand the building damageability criteria (Bjerrum, 1963; Boscardin, 1989; Burland and Wroth, 1974; Polshin and Tokar, 1957; Skempton and MacDonald, 1956). The building damageability criteria are well understood in geotechnical engineering. According to this, the degree of damage to a structure depends on the subsidence related intensity (SRI) parameter experienced by the foundation system. The SRI parameters cover settlement of the foundation, differential settlement and angular distortion. Moreover, the year of construction, method of construction, time to time maintenance and other features of the building such as building typology can affect the damage severity observed on structures.
The damage severity is divided into six different levels proposed by Burland et al. (1977): D0 = negligible; D1 = very slight; D2 = slight; D3 = moderate; D4 = severe; D5 = very severe. D_1-D_2 severity level presents hair line cracks on the structure causing aesthetic issue and can be easily treated. D_3 level represents moderate settlement damage and here repair is necessary. D_4-D_5 level can bring structure stability into question and certain parts of the structure may collapse.

3. Study of the Cracking Phenomena

3.1 Geological Context of the Area

The geological context of an area is very important as it forms most of the building foundation. The terrain of Islamabad-Rawalpindi metropolitan consists of both plains and mountains formed by deposition and erosion with relief at some points exceeding more than 1,175m. The northern part of the metropolitan is situated at the bottom of Margala hills reaching 1600 m in altitude and contains many ridges. The South of the Margala hills has comparatively low relief but it contains many ridges and valleys. The southernmost part of the area forms the Soan river valley (M. Sheikh, Van S. Williams, 1999).

3.2 Location of the Study Area

The Figure 1 and 2 show the Google Earth images highlighting the location of the study area.

Figure 1: Showing location of Islamabad and Bahria Town

Figure 2: Study area at large scale and town planning of the area

3.3. Damage Survey

The damage survey was conducted in 2015. The survey included visual observation as well as the collection of data from Bahria Town Administration. The type of structures varied, but in most cases it was masonry structures resting on strip foundation which could not resist differential settlement. The survey revealed that most of the structures in the Rafi block have been recently constructed. However the pace of construction reduced as the residents observed cracking in many of the newly built structures. Bahria administration reported that initial cracking appeared after first rainfall season following building completion. Initial repair proved futile as the settlement continued after each rainstorm. The reason for initial cracking being the collapse of shallow fill layer and repeated cracking due to successive collapse of lower layers. The soil collapse and resulting settlement is expected to continue till water approaches the entire depth of the fill. Borings revealed soil structure collapse up to 10 -12 ft. only. Percolation of water and resulting collapse of soil structure of deeper layers may not occur under normal rainstorms. But the building is still not out of risk, since the water can reach deeper levels due to breaking of water supply/sewer lines or heavy rainstorm. Site survey revealed breaking of certain sewer lines and it was observed that cracking was more severe in those areas.

To analyze the problem further, house Nos. 621and 622 shown in Figures 4 and 3 respectively have been selected as the representative of the area. These houses are double storey masonry structures with strip foundation and were constructed in 2012.

Figure 3: House No. 622. Front elevation, Cracks on walls, Settlement of Courtyard floor, Repair work in progress and Cracks on outer wall

Soil under plinth protection has settled more than six inches and is hanging above the ground surface. Boundary wall has been separated from the building and even the courtyard floor has also badly settled. Due to deep water percolation and successive collapse of deeper soil layer resulting in continual cracking, the repair of houses Nos. 621 and 622 did not work and finally they had to be demolished and reconstructed.

Figure 4: House No. 621, showing recently filled cracks, dismantled gate, Settled lawn and broken pipes

To understand the overall effect of this issue, all the dwellings were visited and the data so collected is given in Table 1.

Table 1: Number of Buildings damaged

Buildings in Rafi Block	
Total number of houses constructed	70
Number of houses effected by settlement	65
Number of houses repaired	57
Number of houses demolished and reconstructed	08

Table 2: Classification of damage level

Classification of visible damage at Rafi Block			
Category	**Severity level**		**Number of structures**
D_0	Negligible		5
D_1	Very slight		10
D_2	Slight		15
D_3	Moderate		26
D_4	Severe		10
D_5	Very severe		4

The usual damage included settlement of walls and floors, breaking of sewer and water supply pipes and cracks in roof slab. Table 2 shows the damage level. The damage level varied from negligible to sever and the repair work ranged from slight repair to demolition and reconstruction.

3.4 Type of Foundation

The damaged dwellings usually have masonry structure and strip footings, very few with raft and even less with pile foundation. Foundation type and damage level was noted and given in Table 3.

Table 3: Effect of type of foundation on damage level to the building

Type of foundation	Total number of structures	Percentage of effected structures	Damage level
Strip foundation	59	95 %	Very Severe
Raft foundation	9	35%	Moderate
Pile foundation	2	0%	Negligible

3.5. Contour maps:

The past contour maps of the site are examined. Figure 5 shows the past contour level as well as current elevation level. Different images of the master plan have been zoomed focusing plot Nos. 621 and 622 which have been badly affected by settlement cracks. The writing in red shows the past contour levels while writing in blue shows the present road level.

Figure 5: Past contour levels and present road levels

The images show that in the past contour level was RL-1480; however, the present road level is at RL-1545. Consequently, the Houses 621 and 622 are standing on loose unsaturated soil fill of 65ft thickness. The fill is loose and unsaturated which is liable to collapse.

3.7. Soil Investigation Reports

The reports indicate that the soil is mainly brown color, low to medium plastic silty Clay (CL-ML). The consistency of the fill ranged from soft to medium while for natural soil it ranged from medium to stiff. Summary of test results for houses 621 and 622 is as follows:

Table 4: Summary of test results for houses 621 and 622

House No.	Depth of Bore (ft.)	Soil Type	Range of Moisture Content (%)	Range of Liquid Limit (%)	Range of Plastic Limit (%)	Range of SPT
621	20	CL, CL-ML	6.5 – 18.5	24 -27	16.4-19.5	4 - 16
622	20	CL, CL-ML	7.0 – 15.3	23.6 - 28.3	15. 2 -19.5	6 -18

3.8. Remedial Measures by Local Administration and Cost Analysis

The structures which were severely damaged were demolished and reconstructed. Other structures which received slight to moderate damage were repaired. All new structures were provided with raft foundation or piles. The pile depth ranged from 15 to 25 ft depending upon the availability of hard strata.
The structures with strip foundation, which received moderate level of damage, were strengthened by pile foundation, where piles were connected to the strip foundation.
Furthermore, strict regulations were imposed for any future construction. Soil investigation was made compulsory for every structure and solutions such as provision of basement, raft foundation or pile foundation were suggested. Adoption of such techniques extremely raised the overall construction cost of an ordinary house. Apart from the houses which were demolished and reconstructed, the houses which were strengthened with piles, the overall cost increase was nearly 30%. Similarly, the provision of basement, raft or pile foundation in new construction increased the overall construction cost by about 30%.
All the remedial techniques were focused on foundations while no thoughts were made to stabilize the loosely filled unsaturated soil.

4. Conclusions

The root cause of the settlement induced building damage is the loose collapsible soil fill, comprising unsaturated silty Clay. The collapse of the soil structure occurred due to wetting of the unsaturated loose fill. The initial wetting occurred due to leakage from the temporary underground water tanks made to store water for construction and excess watering for curing. Afterward, post construction wetting took place due to leakage of water supply and sewerage pipes and poor drainage of the lawns and rough soil surface of the undeveloped lawn allowing deep percolation of water. Blocking of storm water due to construction activities was yet another serious cause of wetting. Therefore, all such sources of water should be controlled. Adopting raft or pile option for simple dwellings is a cost overburden. Compacting soil fills in layers in deep ditches by conventional methods is not economically feasible. Pre-wetting of soil up to the influence zone is the most economical solution to avoid post construction soil collapse and consequential cracking of buildings. Relevant construction byelaws should be made, promulgated and strictly enforced.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Potential Drivers for Adoption of Green Procurement in Construction Industry

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Abstract

Construction industry is very fast growing industry to fulfill the basic needs of increasing population of the world. Together with the benefits, construction industry also exerts negative impacts especially to the environment. With increased amount of construction activities, these negative impacts such as emission of geen house gases are also increased which are essentially to be controlled. One of the important measure which can be helpful in overcoming the environmental challenges caused by construction activities is green procurement. Recently, in developed countries like Sweden and Malaysia, green procurement is practiced successfully. However, in developing countries like Pakistan this is emerging strategy. Hence, in order to promote green procurement, several attributes which can enhance the adoption level of green procurement are studied. Review of green procurement concept and practices in different countries lead to identify 35 potential drivers promoting green procurement practices. These drivers were classified in to six categories as Requirements, legislations, and standards (RL&S), Stakeholder involvement (SI), Corporate Factor (CF), Market Factor and industry awareness (MF&IA), Feedback and Building Public Confidence (F&BPC), Principles and Techniques (P&T).

Keywords
Green Procurement, Construction Industry, Environmental Issues, Drivers of green procurement

1. Introduction

Pakistan is a developing country where construction industry is an emerging industry. Construction activities have been proven in fulfilling the needs of shelter, infrastructure and employment (Renata Stasiak-2015). Construction industry has materialized basic need of society and showed many benefits. Together with that, this industry has also affected badly on environment and our natural resources. Activities involved in construction consume huge amount of natural resources. Huge amount of Green House Gasses (GHG) is also a major challenge faced by construction activities such as which transport and the manufacture of building materials (Yan et al., 2010). Therefore there is dire need to take effective measures which can reduce the negative impacts of construction industry on environments. Also, increasing awareness about environmental problems worldwide is exerting pressure on every industry to improve their environmental performance (Zhu and Sarkis 2006). One of mechanics which contributes in controlling these negative impacts of construction works towards environment is the use of green procurement. Hence, this paper is focusing on identifying various drivers which can help in adoption of green procurement in construction works.

2. Green Procurement

Management of environmental issues has evolved from pollution control, which has led to clean production approaches. However, many essential changes are desired for making the shift towards sustainable society (Vernas, 2009). For the sake of improvement in financial and environmental performance of business companies, green procurement has been encouraged as a useful tool (Shen et. al. 2017). Environmental effects can be alleviated with the help of procurement function because it provides a prime opportunity for harmonizing environmental aspects into all sections and all processes of a company. This is the reason that as compared to any other corporate function, purchasing is a stronger medium of change (Appolloni et. Al. 2014). Green procurement is the "purchase of services or products with minimum or positive impacts on environment, achieved by considering environment into major purchasing approaches, policies and instructions'' (Green Council, 2010).

3. Green Procurement in Construction Industry

In construction, green procurement's prime excellence is that it improves both financial and environmental performance of the construction process and buildings, and It is broadly acknowledged (Green Council, 2010; Varnas et al., 2009). Therefore, by implementing green procurement, impacts of construction on environment can be controlled and reduced. Green procurement practices can also result in cost saving from reduced energy consumption, resource use and material management. And, because of green procurement less waste is generated that leads to reduced cost of handling and disposing off that waste.

Both public and private organizations in Sweden construction industry have adopted green procurement (Faith 2005 & Sterner 2002). The Swedish Environmental Management Council specifically guides environmental assessment criteria for the construction sector (Swedish Environmental Management). Similarly Malaysian industry is also familiar with green procurement where in the Tenth Malaysian Plan, for the first time green procurement was introduced (Musa et al., 2013). Malaysian construction industry has been promoted to procure more sustainable services and products because green procurement has its main focus on environmental impacts, in Malaysia (Adham and Siwar, 2012; Kahlenborn et al., 2013). Nowadays green procurement in construction industry and in other industries is gaining interest.

4. Environmental Issues and Green Procurement

Green practices nowadays are much needed in construction industry worldwide. Construction waste comes up from renovation, construction, and demolition activities (Kofoworola and Gheewala, 2009). According to (Salam, 2008) a solution to an environmentally concerned cost-effective conventional business can be achieved by green procurement because green procurement directs selection of services and products that consequently eliminate environmental impacts.

Construction procurement is considered as a useful tool in construction projects for managing environmental issues, by many researchers (Zhu et al., 2013). By executing green procurement we will be provided with advantages which can be allocated into two aspects: i) environmental advantages acquired by getting business advantages to company itself. Green procurement's environmental aspect covers the uses of eco-labelled products with ISO type 1 labels together with the framework of ISO14000 environmental management guidance and to educate all stakeholders to engage in green practices, to prohibit construction firms from creating pollution in the utilization of green purchasing. In the corporate aspect, green procurement can also improve corporate market and reduce the related handling costs by decreasing pollution and improving reusable content, can increase staff awareness of green practices (Jhonny kwok et al 2016). An organization's dedication to considering and minimizing environmental outcomes of its activities can be visualized from the application of green procurement within that organization and also many authors highlight the need for using environmental procurement preferences.

The procurement of a civil engineering project starts from the strategic planning and is in charge until the contract's execution. In execution phase, early decisions are of very importance and prominent and, one of the early decision, procurement is considered as the most influential and prevailing means of change. Many multi-dimensional tools are included in green procurement which have capability of assimilating green practices throughout the execution process (Preuss 2009; Zsidisin and Hendrick 1998; Bratt et. al. 2013; and Hewage 2015). Decision regarding the green performance should happen at the strategic planning stage. At the planning stage, decisions are crucial due to its severe impact on the later part of the development life cycle (abu hassim et. al 2011) and one reason is that they need auditing throughout the execution process.

5. Drivers Enhancing Adoption of Green Procurement in Construction Industry

One of the issues in green procurement is the concern of the practitioners. In motivating the practitioner towards adoption of green procurement, several factors are highlighted which can help practitioners to execute green procurement in their projects (Yu Tao et al 2018). George Ofori (2000) highlighted the initiatives in various categories to increase practitioners' knowledge of green procurement for successful adoption of green procurement in Singapore industry. These categories are, (i) Education, (ii) Case studies, (iii) Support and promotion, (iv) Best practices and reward. According to Varnas et al (2009) some organizational factors like availability of environmental awareness in corporate culture and committed middle managers can be favorable to successful green purchasing in construction industry. Trainings and the availability of an Environmental Management System (EMS) has been considered helpful in the enforcement of the practices of green procurement in construction. Jhonny Kwok et al (2016) mentioned that studied implementation of green procurement in construction industry of Hong Kong and stated that factors of green procurement adoption can be clustered in six aspects as (i) Stakeholder involvement (ii) Requirements, legislation, and standards, (iii) Corporate factors (iv) Feedback and public confidence (v) Principles and techniques, and (vi) Market factors.

5.1 Requirements, legislations, and standards

Policies and regulations of environment are the most important factors for green procurement's successful implementation (Walker et. al. 2008; Diabat and govindan 2011; Yang and Zhang 2012). Establishment of guidelines and standards like green specifications, suppliers' ISO 14000 certification, evaluation criteria and schemes of green label is reflected as an active method in the industry to enhance the green procurement's adoption (Diabat and Govindan, 2011; Salam, 2008). It is the most important and strong step towards the adoption of green procurement if taken properly, because when government of any country will make it mandatory then there will be no excuse to adopt it. In other countries where green procurement has been adopted there are policies and regulations by their governments.

5.2 Stakeholders' Involvement

Involvement of the main stakeholders of any projects is quite necessary in the adoption of green procurement because stakeholders are directly or indirectly involved in project throughout its life cycle. Stakeholders' mutual understanding and mutual commitment between themselves are taken as important factor which facilitates green supply chain management green (Diabat and Govindan, 2011; Salam, 2008). Compliance, monitoring and audit on suppliers are helpful in maintaining the implementation's effectiveness (Salam, 2008; Strandberg, 2012). Adoption of green procurement and green design can be facilitated by the designers (e.g., architects, engineers) which has been shown in past studies (Love et al., 2004; Annunziata et al., 2016; Humphrey et al., 2003). Varnas et al (2009) also emphasized on the importance of good coordination and communication between suppliers and clients and also within the organization. Evolution of goals clearly, approaches for green purchasing or by including the strategies of sustainability in procurement policy documents for successful enforcement of green procurement in construction industry should be considered for adopting new philosophy (Varnas et al 2009). It has been identified that cooperation between designers and cooperation with stakeholders regarding the environment is a factor for green building development's adoption successfully in construction supply chain management (Annunziata et al., 2016).

5.3 Corporate Factors

Inside a corporation there can be lot of factors whose existence is the proof that this corporation is using green procurement and up to which level. These factors include commitments by executive management (Lam et al., 2010; Strandberg, 2012; Salam, 2008; Green Council, 2010) corporate environmental vision (Zhang and Yang, 2012) mid-level managers' support (Salam, 2008; and Zhang et al 2012). Varnas et al (2009) mentioned that organizational factors like availability of environmental awareness in corporate culture and committed middle managers can be favorable to successful green purchasing in construction industry. Trainings and the availability of an Environmental Management System (EMS) has been considered helpful in the enforcement of the practices of green procurement in construction. Adoption of green procurement is possible by awareness, willingness and support within organization.

5.4 Market Factors and Industry awareness

Awareness increase in the industry and in the society concerning the green procurement's value is also a powerful agent in construction industry for its adoption. When it is forced by competitors and there is awareness of global trends then they are considered as supporting factors for green policy's adoption in construction projects (Yang and Zhang, 2012; Green Council, 2010). Industry competitors' and consumers' insistence is taken as another driver which builds companies towards the adoption of green procurement (Carter and Dresner, 2001). Our society has become aware of environmental issues that's why there is more demand for environmental friendly services and products. Pressure is being exerted on developers for the improvement of their competitiveness and for the adoption of green procurement and there is demand of cost-saving building and environmental friendly products (Walker et al., 2008; Sarkis, 2003). If the companies switch towards the environmental friendly products and green procurement then green procurement can build unique status in markets.

5.5 Feedback and building public confidence

According to Kululanga and Price (2005) quality specification of green procurement should be connected to construction disputes and claims directly. Lam et al. (2010) stated that Green product's information should be made available from reliable database, according to specifications potential information from suppliers should be adopted carefully and demands of green characteristics for performance-based specification should be clear.

5.6 Principles and Techniques

It will be a huge facilitator if there is availability of principles and techniques and other resources which help corporation to adopt green procurement. Lam et al. (2010) indicated that when companies desire to adopt green procurement, they green technology for construction purpose, model clauses of green specifications, green procedures or practices should be adopted (e.g. waste management) and guidelines for the green performance assessment. Similarly selection of materials according to their recyclability (Salam, 2008; Yang and Zhang, 2012; Diabat and Govindan, 2011;), selection of materials according to their low risks to the environment and product's design according to its less consumption of material or energy these factors can also be very helpful in the adoption of green procurement.

Various research papers discussing the implementation of green procurement in different countries were studies. Reviewing those research works resulted in identifying 35 different potential drivers which are helpful in promoting the adoption of green procuremnt in construction industry. These drivers was categorized into 6 different groups/factors as summarized in table 1 below.

Table 1: Potential Drivers for Enhancing the Adoption of Green Procurement in Construction

Driver	Factor Code	jhonnykwok (2016)	Sallam (2008)	Ali Diabat (2011)	Patrick (2010)	Liyenshen (2017)	Zhu (2013)	Rajeev (2015)	Vernas (2009)
Requirements, legislations, and standards	**RL&S**								
Government & non-government organization's demand (e.g. green label scheme)	RL&S1	√			√		√		√
Environmental regulation made obligatory by Government	RL&S2	√		√	√	√	√	√	
Formation of Standard (e.g. evaluation criteria, green specification, suppliers' ISO 14000 certification)	RL&S3	√	√	√	√	√	√	√	√
Stakeholder involvement	**SI**								
Requirements of the client in tender	SI1	√		√	√	√	√		
Stakeholders' mutual understanding between themselves on green procurement	SI2	√		√	√				√
Stakeholders' mutual commitment between themselves on green procurement	SI3	√	√	√	√	√		√	√
Compliance, monitoring and audit on suppliers	SI4	√	√			√			
Cooperation with stakeholders regarding the environment	SI5	√		√	√		√	√	√
Corporate Factor	**CF**								
Corporate environmental vision	CF1	√	√	√		√	√		
Commitments by Executive management	CF2	√	√	√	√	√		√	
Mid-level managers' support	CF3	√	√		√	√			
Business benefits understood properly	CF4	√	√			√			
Staff training/green procurement program and sustainability policy by organization	CF5	√	√	√	√		√	√	√

Key staff's incentive programs and implementation of green procurement goal to job description	CF6	√			√	√	√	√	
Availability of sustainability expertise & dedicated resources to support green procurement and decision making	CF7	√	√	√	√			√	√
Coordination within department (e.g. sustainability expertise and procurement staff)	CF8	√	√		√	√		√	√
System of continuous review, monitoring and tracking	CF9	√							√
Market Factor and industry awareness	**MF&IA**								
International trends (e.g. customer awareness)	MF&IA1	√	√	√		√	√		√
Strategies adopted by competitors	MF&IA2	√			√	√	√		
Strategies adopted by affiliated companies	MF&IA3	√			√				
Strategies adopted by other progressive companies (within or outside your sector)	MF&IA4	√					√	√	
Schemes adopted by government (e.g. Housing Authority)	MF&IA5	√		√			√	√	√
Feedback and Building Public Confidence	**F&BPC**								
Green product's information should be available from reliable database	F&BPC1	√		√				√	
According to specifications potential information from suppliers should be adopted carefully	F&BPC2	√		√		√			√
Demands of green characteristics for performance-based specification should be clear	F&BPC3	√			√		√	√	
Principles and Techniques	**P&T**								
Green technology for construction purpose should be available	P&T1	√	√	√	√	√			√
Project's adequate life cycle should be considered	P&T2	√			√				√
Selection of materials according to their recyclability	P&T3	√	√	√	√	√			
Selection of materials according to their low risks to the environment	P&T4	√		√	√	√		√	√
For assessment of building's green performance, facilities of cross reference should be available (e.g. BEAM-Plus)	P&T5	√					√		
Model clauses of green specifications should be available	P&T6	√	√				√		
Green procedures or practices should be adopted (e.g. waste management)	P&T7	√	√	√	√	√		√	√

Product's design according to its less consumption of material or energy	P&T8	√	√	√	√	√	√	
Designing products for recycling, reuse, component parts & recovery of material	P&T9	√	√	√	√	√		
Products being designed to alleviate or lower the environmental impacts during construction	P&T10	√	√		√	√	√	√

Table 1 above presented 35 drivers for adoption of green procurement in construction identified from literature as discussed below:

- **Government & non-government organization's demand (e.g. green label scheme):** Demand of the government and NGOs is very essential component in taking decision for adoption of green procurement (Yang and Zhang, 2012; Green Council, 2010).
- **Environmental regulation made obligatory by Government:** Rules and regulations regarding the environment enforced by government is a very robust factor for the implementation of green procurement (Diabat 2011). In Malaysia for the first time green procurement was introduced by their government in the Tenth Malaysian Plan (Musa et al., 2013).
- **Formation of Standard (e.g. evaluation criteria, green specification, suppliers' ISO 14000 certification):** There should be standards and specification about how to implement green procurement and companies' interest and awareness is increased in green procurement when there is pressure for the implementation of environmental policy (Adetunji et al., 2008). And, when our suppliers are ISO 14000 certified then it is quite clear that they are supplying us environmental friendly material.
- **Requirements of the client in tender:** Client is the main stakeholder in any project that's why clients should be encouraged and supported for using environmental friendly products (Vernas et al 2009;. Jhonny kwok et al 2016) this will boost the adoption of green procurement.
- **Stakeholders' mutual understanding between themselves on green procurement:** All stakeholders should have mutual consensus on green procurement for its successful implementation (Salam, 2008).
- **Stakeholders' mutual commitment between themselves on green procurement:** If all the stakeholders are mutually committed for the adoption of green procurement then it becomes a good facilitator of green procurement's adoption (Diabat and Govindan, 2011).
- **Compliance, monitoring and audit on suppliers:** Monitoring, safeguarding compliance and auditing suppliers are very helpful factors to manage the implementation's efficiency of green procurement (Jhonny kwok et al 2016).
- **Cooperation with stakeholders regarding the environment:** It has been indicated in the research that the stakeholder's cooperation regarding the environment is an important factor that support green procurement's adoption.
- **Corporate environmental vision:** This factor is a proof that the any organization or corporation is using or willing to use the green procurement (Zhang and Yang, 2012).
- **Commitments by Executive management:** When executive management is committed then it is very supportive to adopt green procurement.
- **Mid-level managers' support:** Mid-level managers' supports are also an encouraging and helpful factor. Inside pressure of an organization specially at the management level will force the lower level to adopt management of green procurement due to low or positive environmental outcomes and risks (Koebel et al., 2015:, Adetunji et al., 2008).
- **Business benefits understood properly:** Due to green procurement, there are also business benefits and when these benefits are understood by corporation in good manner, then this procurement approach will be accepted easily in that corporation by their management (Green Council, 2010).
- **Staff training/green procurement program and sustainability policy by organization:** A sound base for a corporation to accept green procurement can be created if there is staff training or programs

of green procurement and policy of sustainability within that corporation (Strandberg, 2012;, Salam, 2008).

- **Key staff's incentive programs and implementation of green procurement goal to job description:** Putting green procurement's acceptance in key staff's job description and providing them incentive for this can be a strong driver for GP's implementation.
- **Availability of sustainability expertise & dedicated resources to support green procurement and decision making:** When resources and experts of sustainability will be available in corporation then adoption of green procurement in that corporation will be much supported by it.
- **Coordination within department (e.g. sustainability expertise and procurement staff):** Coordination between procurement staff and sustainability expertise is of very much importance because they both are very helpful for each other.
- **System of continuous review, monitoring and tracking:** It is necessary to monitor and review the policies, resources and systems of green procurement in organization and how they are working. By checking this continuously we will be able to implement green procurement efficiently.
- **International trends (e.g. customer awareness):** Dresner and Carter (2001) pointed out that there is solid impact of environmental demands by consumers on the application of GP. When consumer wants and force developers to procure more sustainable products then it will be considered as a strong factor of GP's acceptance.
- **Strategies adopted by competitors:** When a competitor adopts skills regarding the GP then he achieves uniqueness in market and it is also considered as an important factor for GP's adoption (Sarkis, 2003).
- **Strategies adopted by affiliated companies:** Marketing benefits can be gained by business companies by implementing green procurement because it makes their products attractive and exclusive (Drumwright, 1994). That's why when companies adopt such type of strategies then it becomes a driving force for GP's acceptance in industry.
- **Strategies adopted by other progressive companies (within or outside your sector):** When progressive companies adopt strategies of green procurement then it promotes GP's adoption because they are progressive companies and mostly consumers rely on them. It is explained by Walker et al. (2008) that the competition is a major factor for companies to practice GP. And according to (Zhang, 2015) there is competition between developers for green performance.
- **Schemes adopted by government (e.g. Housing Authority):** In USA it is observed that developers adopt green procurement to meet the housing market's demands which can be achieved by using housing products which has positive environmental performance such as cross-linked polyethylene water distribution piping, programmable thermostat and high energy efficient window (Sanderford et al., 2015;, Koebel et al., 2015). Pressure and policies from government's housing authority can also be a good factor for GP's implementation.
- **Green product's information should be available from reliable database:** According to (Patrick et al 2010) green specification's formation, quality issues and green specification's reliability should not be kept confidential but it should be clearly known to all stakeholders. Making these things clear will make easy to gain and maintain trust between main stakeholders and claims and disputes will be avoided that's why it is a valuable factor of GP.
- **According to specifications potential information from suppliers should be adopted carefully:** Potential information from suppliers according to specification should be collected, it will be beneficial for suppliers and other stakeholders involved.
- **Demands of green characteristics for performance-based specification should be clear:** We should review the green characteristics demand and performance and make them clear for each other it will support the GP's adoption.
- **Green technology for construction purpose should be available:** Availability of resources for green procurement in corporations is also an important factor, when there is green technology available then it will be easy to adopt GP.
- **Project's adequate life cycle should be considered:** Before applying green procurement we should assess life cycle with consideration of material flow, energy and environmental impacts (Patrick et al

2010). From this we will know that how much project is harmful for environment and how this issue will be resolved by green procurement.

- **Selection of materials according to their recyclability: Material's** selection by considering their recyclability is a helpful factor for the adoption of GP (Jhonny kwok et al 2016).
- **Selection of materials according to their low risks to the environment:** Those materials should be selected whose has low risk toward the environment, this factor will promote the adoption of green procurement (Jhonny kwok et al 2016).
- **For assessment of building's green performance, facilities of cross reference should be available (e.g. BEAM-Plus):** Building's green performance should be assessed so that we can know how better it is on green specifications and by getting and sharing this type of positive data will be supportive towards the adoption of GP.
- **Model clauses of green specifications should be available:** There should be availability pilot projects and model clauses for green procurement, this will help consumers and clients to forecast the effects of green procurement and they will be satisfied. Hence this also proves to be a useful factor for GP (Jhonny kwok et al 2016).
- **Green procedures or practices should be adopted (e.g. waste management):** According to (Lam et al 2010 and Vernas et al 2009) when companies are desired to adopt green procurement then they should also adopt waste management or environmental management system, this will make GP's adoption easy and simple.
- **Product's design according to its less consumption of material or energy:** A product that consumes less material or energy as compare to others then it is considered good for environment and that's why this kind of design will make the application of GP simplify.
- **Designing products for recycling, reuse, component parts & recovery of material:** A product is considered competitive and good for environment when it can be reused, recycle or material from it can be recovered (Jhonny kwok et al 2016). These type of product's design is very helpful in GP's adoption.
- **Products being designed to alleviate or lower the environmental impacts during construction:** There are factors which affect the decision whether to adopt green procurement or not and one of these factors is that the products should be designed to lower or eliminate the negative effects during construction. This is a good facilitator of green procurement's adoption (Jhonny kwok et al 2016).

6. Conclusion

Construction sector is considered a locomotive for social prosperity of any community. With increase in population, building and infrastructural needs are also increased which are fulfilled by construction activities. Hence, construction activities are also increasing fastly. Construction industry together with benefiting the society is also popularized for its negative aspects such as consuming huge amount of natural resources as well as emission of green house gases. To control these negative effects, green procurement is getting popular worldwide. This study focused on identifying potential drivers which can help in enhancing the adoption level of green procurement so that its positive benefits can help the prosperity of society without compromising the environment of the universe. Study of previously published research works for green procurement resulted in determining 35 drivers which were clustered into six factors as Requirements, legislations & standards (RL&S), Stakeholder involvement (SI), Corporate Factor (CF), Market Factor and industry awareness (MF&IA), Feedback and Building Public Confidence (F&BPC), Principles and Techniques (P&T).

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Factors Affecting Selection of Procurement Method in Public Sector Construction Projects

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Abstract
Selection of procurement method for the award of public sector projects is a complex process and has a direct effect on project performance. Since different procurement methods are available for construction projects, hence the right selection of a method for carrying the work is not an easy task. Procurement selection factors can assist the client to choose the best procurement methods among different procurement methods. In this research major factors of selection criteria have been worked out initially from literature and then by conducting several unstructured interviews from experts involved in public sector construction projects. A questionnaire survey was done to collect the data from several professionals working at different projects. Most of the data were collected from professionals engaged in the procurement process. The gathered data was analyzed using SPSS software and average index technique. Identified most influenced factors affecting selection of procurement method as per findings of this study are: client capacity, time and cost overrun, quality certification and control, risk issues, nature and size of project, and government policy issues. Study concludes that the consideration of identified important factors will help public sector clients in the better selection of procurement method for different projects.

Keywords
Construction Industry, Public Sector, Procurement Method, Important Factors, Pakistan.

1. Introduction

Procurement method is a flow of activities starting right from identification of the need to completion of the project. There are many project procurement systems that have been introduced for effective, efficient and better performance and outcome of the system. It has been observed that major stakeholders need the desire to execute their project on fast track aiming to get fast delivery with the early start of work and ensuring better performance in term of cost and time, value for money invested the minimum possibility of risk, early confirmed design and prices. There are many procurement methods but the most commonly used methods of procurement are: traditional method also known as Design-Bid-Build method and non-

traditional method also known as Design-Build method. Besides this, Management oriented and Public-Private Partnership (PPP) is also accessible (Davis.P et al., 2008). and used to some extent. The use of procurement methods vary from country to country. The procurement difference is based on cultural differentiation and reflects the relationship between procurement system and clients' interest (Zeljko.S et al., 2016). Project effectiveness and efficiency are greatly affected by the type of procurement method and it helps to handle the project. It has been felt that the research conducted in Sri Lanka (2007) so far is lacking some aspects with the special reference that how and up to what extent the procurement methods actually impact on project delivery. The use of procurement method helps to avoid problems and it is the key to the attainment of project-specific goals. An approach for procurement selection is essential to achieve the project success and ensure value for the client's interest (Shiyamini.R et al., 2007). Mostly construction projects use local procurement methods but research had been studied in Nigeria (2015) has revealed that project does suffer delays in project efficacy & efficiency due to defects in procurement methods. Hence, it is imperative to improve the procurement methods by focusing and optimizing all the variables involved in project performance viz. cost and time. Also, the same research study has revealed that project delivery is hampered due to defects in procurement methods. It also concludes that the delivery of the design-build method is better than the traditional method (design-bid-build) in terms of cost, time and quality of construction works (Idiake.J.E et al., 2015). Different researchers have suggested different procurement selection factors that can help the client to choose and adopt the best procurement method. For better delivery and maintain the conducive environment in a construction project, it is essential to have effective, efficient and transparent procurement method. To evaluate the efficacy of procurement variables on project delivery revealed that procurement selection criteria of cost, time, quality, quantity, and environmental aspects have a great influence on project delivery (Ogunsanmi.O.E et al., 2013). Research work carried in Nigeria (2013) for exploring the significant impact of procurement method on abandoned projects revealed that there is dire need of adopting innovative procurement methods so as enhance the project delivery to a greater extent (Akilano.J.A et al., 2013). The research study conducted in Nigeria (2013) manifested that the traditional procurement system has been commonly employed in project execution (Oladinrin.O.T et al., 2013).
Above cited literature indicates that the selection of procurement method mostly affects the project performance due to difference in level of importance of different factors in the selection of procurement methods. Many selections criteria factor affect on choosing the appropriate procurement method among conventional and non-conventional method. For finding and selection of appropriate method understanding level of importance of different factors will provide a helping hand to public sector clients.

2. Factors Affecting Selection of Procurement Method

A study was conducted on factors affecting the performance of public procurement in Kenya. The study focused on three major aspects of public procurement. These aspects were information technology, competency of staff and ethical issues. From the study, it has been adduced that the use of information technology, deployment of competent staff and using the fair transparent mechanism in procurement has enhanced the delivery of all procurement organizations (Wanyonyi and Muturi, 2015). Research focused on factors affecting the implementation of procurement policies in Kenya, in which study reveals about delay in procurement is due to lack of competence in staff, different procurement policies, estimated cost, size of economic projects, responsibilities of client (Kimote and Kinoti, 2018). Manthonsi and Thwala (2012) conducted study on factors influencing the selection of procurement method in construction industry of South Africa in which the identified factors were: knowledge and influence of client in life cycle of project, nature of client, political consideration, corruption and self enrichment, size and technical complexity of project, delivery time and time related constraints, funding arrangement, familiarity of procurement method, government policies and competition, risk allocation, client requirement and cash flow, lack of sources, market condition, unskilled labour, technology globalization. A research conducted on an appraisal of project procurement method conducted in Nigerian construction industry in which identified factors having an effect on selection of procurement were reported as: estimated cost and time at project completion, minimum time of design and construction, quality assurance, financial management and control, complexity and flexibility of design and techniques to entertain the client requirement, consultancy offered, risk avoidance, available information at project inception, nature of project and client (Babatunde et al., 2010). A research work conducted by Nabil & Osama (2017) in Gaza on the selection of accurate procurement strategy for construction of projects. In this study, it is indicated that the most affected six factors involved in the adoption of accurate procurement methods in the construction of projects are cost competition, degree level of complexity project, time criteria of the project, size of a project, financial capability of client and experienced client in procurement system. Furthermore studies conducted by Osama and Nabil (2013), Oladrin et.al (2013), Shirley.C.J.L et.al (2013), Ogunsanmi.O.E (2013) Akilano et.al (2013), Devis et.al. (2008) also address to the selection of procurement. Based on literature cite above and unstructured interview with industry experts, this study considered forty nine factors which mainly affect the selection of procurement method. The factors were distributed into seven main categories which include: Client characteristics, Time, Cost, Quality, Risk, Project characteristics and External environment for further investigation in context of set objective.

3. Research Methodology and Data Collection

From literature review and published researches, factors affecting the selection criteria of the procurement method have been studied. And at the initial stage, few unstructured interviews were conducted with relevant experts to verify and arrange the factors of literature and past studies in the context of the construction industry of Pakistan. Then a questionnaire was designed and 150 questionnaires were distributed among different professionals involved public sector construction projects. Out of 150, 80 questionnaires were received and considered for further analysis. Table 3.1 shows the frequency and percentage of background of respondents.

Table 3.1: Background of Respondents.

Respondent	Frequency	Percentage
Engineers	28	35
Procurement Specialists	11	13.75
Project Managers	10	12.5
Site Engineers	10	12.5
Management Officers	7	8.75
Teachers/Scholars	6	7.5
Building Inspectors	5	6.25
Assistant Directors	3	3.75
Total	**80**	**100**

Experience of the respondents is portrayed in Figure 3.1

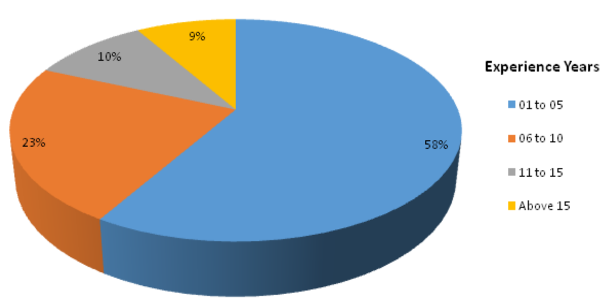

Figure 3.1: Experience of respondents

The rank of the factors was obtained with the help of SPSS and average index method. Rogers (1995) innovation diffusion theory (Adoption of Rogers classification) was then used to clarify the degree of the important factors. The adoption of Rogers classification in Likert scale is shown in Table 3.2 (Rogers.E.M, 2003).

Table 3.2: Interpretation of Adoption of Rogers classification based on 5 pointsLikert scale.

Likert Description	Value Range Allocation	Roger Innovation Adoption Status
Not Effective	0.1-1.0	Laggard
Less Effective	1.1-2.0	Late Majority
Moderately Effective	2.1-3.0	Early Majority
Effective	3.1-4.0	Adopters
Highly Effective	4.1-5.0	Innovators

Source: Alston and Miller (2002); Moohammad et al. (2014); Owusu-Manu (2017)

Based on analysis, the factors considered as effective and highly effective are presented in the table 3.3.

Table 3.3: Identified main factors affecting selection of procurement method

Factors	Mean Value	Relative Importance Index (RII)
Category-1: Client characteristic related factors		
Financial capability of client	4.64	92.75
Client experience in procurement method	4.25	85
Availability of qualified personnel	4.22	84.5
Integrated Design and Construction	4.19	83.75
Catgory-2: Time related factors		
Project completion at estimated time	4.59	91.75
Construction time	4.31	86.25
Delivery time Schedule	4.26	85.25
Catgory-3: Cost related factors:		
Project completion at estimated cost	4.55	91
Level of Price competition in industry	4.23	84.5
Price certainty	4.21	83.75
Catgory-4: Quality related factors		
Quality Certification	4.31	86.25
Experience of project contractor	4.25	85
Required level of quality control	4.24	84.25
Expected performance of project	4.19	83.75
Catgory-5: Risk related factors:		
Complexity in project construction	4.26	85.25
Allocation of responsibility to project stakeholder	4.21	84.25
Economic condition	4.20	84
Catgory-6: Project characteristics related factors		
Nature of Project	4.33	86.5
Size of project	4.26	85.25
Available resources	4.24	84.75
Catgory-7: External Environment related factors		
Procurement policy	4.27	85.5
Material availability	4.25	85
Environment impact	4.23	84.5

4. Results and Discussions

This part consists of results and discussion of factors affecting the selection of procurement method. And the results of this study provide an indication of the relative importance index and rank of the factors. The generated output (mean) of the responses from public sector was taken, and effective y affected factors based on the Rogers innovation classification were selected to determine the status of factors' consideration. These factors were separated into seven groups.

4.1 Client characteristic related factors:

This group contains overall nine factors as shown in figure 4.1. Identified main factors as: financial capability of client with RII (92.75%) and Mean (4.64), client experience in procurement method with RII (85%) and Mean (4.25), availability of qualified personnel with RII (84.5%) and Mean (4.22) and integrated design and construction factor with RII (83.75%) and Mean (4.19). This outcome can be justified since the factors most considered in the choice of procurement are the likelihood of having financially capacity of client which is on first priority and then experienced procurement specialist and qualified manpower, also integrated design and construction is an important factor from the client side

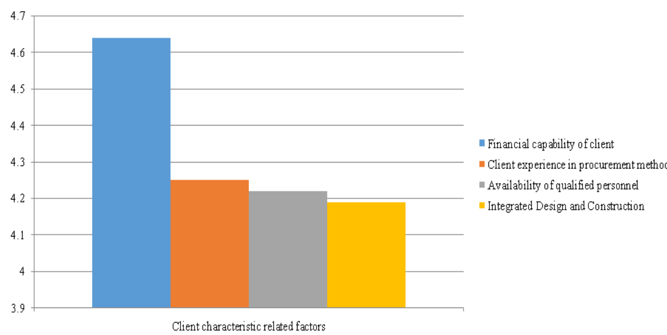

Figure 4.1: Client characteristic related factors

4.2 Time related factors:

This group contains seven factors. Identified important factors include: project completion at estimated time with RII (91.75%) and Mean (4.59), construction time with RII (86.25%) and Mean (4.31) and delivery time schedule with RII (85.25%) and Mean (4.26). This group finding show the factors most considered in the selection of procurement are the likelihood of having no time overrun during project execution, which is on first priority and no any delay during construction at the site and proper maintenance and delivery of material and manpower are prepared activity wise.

4.3 Cost related factors:

This group contains six factors. Identified main factors are: project completion at estimated cost with RII (91%) and Mean (4.55), level of price competition in industry with RII (84.5%) and Mean (4.23) and price certainty with RII (83.75%) and Mean (4.2). This finding can be explained that the factors most considered in the selection of procurement if having no any cost overrun during project construction at the site and. And competition level of price in construction industries, which makes competition between different organization to get projects and certainty of price/cost are also the most important factors.

4.4 Quality related factors:

This group includes seven factors. Identified main factors are: quality certification with RII (86.25%) and Mean (4.31), experience of project contractor with RII (85%) and Mean (4.25), required level of quality control with RII (84.25%) and Mean (4.24) and expected performance of project with RII (83.75%) and Mean (4.19). This finding can be explained as the factors most considered in the selection of procurement if having, ISO certification and project contractor experience to maintain and control quality control at the site are affected factors, also better performance in the project to improve skills are important factors in case of quality.

4.5 Risk related factors:

Project risk group consists of eight factors. As per analysis the main factors are: complexity in project construction with RII (85.25%) and Mean (4.26), allocation of responsibility to project stakeholder with RII (84.25%) and Mean (4.21), economic condition factors with RII (84%) and Mean (4.20) and level of risk responsibilities with RII (75.75%) and Mean (3.79). The output of this can be considered in the adoption of procurement having the complexity of construction project is the important factor, responsibilities of stakeholder and economic condition of the construction project are also the most influential factor for achieving goals.

4.6 Project characteristics related factors:

This group consists of six factors. Identified main factors are: nature of project with RII (86.5%) and Mean (4.33), size of project with RII (85.25%) and Mean (4.26) and available resources with RII (84.75%) and Mean (4.24). This result can be justified as the factors most affected considered in the selection of procurement are having proper nature of the project means what types of the project is. And projects are based on, having proper size of the project because big projects take more time and also it takes to much cost and it must be taken in mind that site will be nearer to recourse as material and manpower are easily access their needs.

4.7 External Environment related factors:

This last group related to external environmental consists of six factors as shown in figure 4.2. Based on analysis, the identified main factors are: procurement policy with RII (85.5%) and Mean (4.27), material availability with RII (85%) and Mean (4.25), environment impact with RII (84.5%) and Mean (4.23). It can be explored as the factor most influenced in the choice of procurement method is procurement policy by government authorities like Public Procurement Regulatory Authority (PPRA), Pakistan. Further material availability at site and the impact of material usage on surrounding environment are the most important factors which influence successful delivery of construction projects.

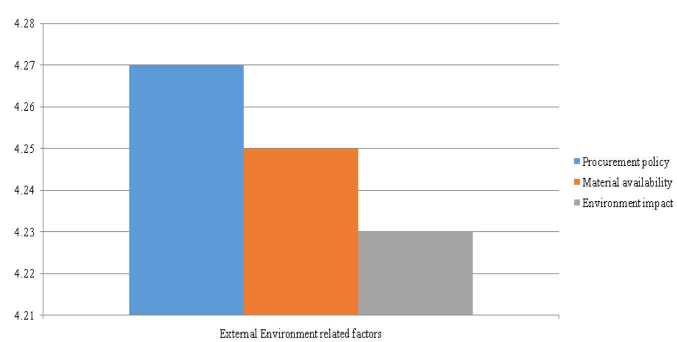

Figure 4.2: External Environment related factors

5. Conclusion

The factors affecting the selection of an appropriate procurement method in public sector construction project is vital to project success. It has been observed that the procurement strategies of the project have not been changed significantly in the last two decades. Successful procurement strategy requires initially proper consideration of relevant factors. To help the clients in choosing the appropriate procurement method, a number of factors are to be considered. An exploratory investigation of factors affecting the selection of procurement method was conducted in this research to determine the level of importance of factors. The results from the survey of this study show that there are some most influential factors affecting the selection of procurement method in public sector construction projects of Pakistan. This study has divided the identified forty nine factors in seven main groups. Rogers innovation diffusion theory for classification of factors was then used to clarify the degree of the importance of identified factors. Some of the most effective factors to be considered in selection of procurement method as identified in this study are: financial capability and experience of the client, project completion at estimated time and cost, level of price competition in industry, quality certification, experience of contractor, construction complexity, allocation of responsibility to project stakeholders, nature, and size of the project, procurement policy, and material availability. Public sector clients usually ponder to adopt suitable method aimed at achieving tangible and sustainable project results. Based on the findings, this study concludes that consideration of identified main factors presented in table 3.3 will help public sector clients in the selection of appropriate procurement method.

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10th International Civil Engineering Conference (ICEC-2019)
"Technological Transformation of Civil Engineering"
February 23-24, 2019, Karachi, Pakistan.

Adoption and Perception of Unmanned Aerial Vehicle in the Construction Industry of Pakistan

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Abstract

The construction sector lags behind the other industries in the rate of adoption of technological advancements. Due to the decreasing prices of technologies and a steady rise in labour costs has inspired in current years of the evolution of new automatization in the construction sector. Technological advancement related to Unmanned Aerial Vehicle (UAV), also called Unmanned Aerial System (UAS), or drones have become more cost-effective and have gone an exponential growth. The use of UAVs and drones is continuously growing in different fields. As a matter of fact, the construction industry can take the edge of such tools and technologies in almost entire scale of practical aspects. The objective of undertaking this research study is to provide insights about role of UAVs in construction industry and to assess the perception of the application of UAVs in the construction industry. The use of UAVs in the construction industry is relatively new in Pakistan. The present research study, therefore, is an endeavour to clear a path for adoption of UAVs in the construction industry of Pakistan. This research study identifies the common applications of UAVs in the construction industry at worldwide by an extensive literature review. Moreover, it explores the relevance of identified applications of UAVs in the construction industry of Pakistan. The results of the study show that UAVs are being used in surveying, 3D Modelling, Project progress and safety monitoring of construction projects. This study will pave the way for smooth adoption of UAVs in the construction industry of Pakistan.

Keywords
Construction industry of Pakistan, Technological advancements, Unmanned Aerial Vehicle

1. Introduction

The Construction industry of a developing country requires harmony between its social, environmental and economic needs in order to achieve goals of sustainable development [1].The construction sector lags behind the other industries in the rate of adoption of technological advancements [2].Due to the decreasing prices of technologies and a steady rise in labour costs has inspired in current years of the evolution of new automatization in the construction sector. Technological advancement related to Unmanned Aerial Vehicle (UAV), also called Unmanned Aerial System (UAS), or drones have become more cost-effective and have gone an exponential growth [3]. An unmanned aerial system or drones is an aircraft working under autonomous /remote control without a human flyer /pilot on board. This unmanned aerial vehicle can fly autonomously and do not carry a pilot. As there is no special word to address a pilot-less airplane or aircraft frequently called as Unmanned Aerial Vehicle (UAS), Unmanned Aerial

System (UAS), and Remotely Piloted Aircraft System (RPAS).Now a days many of UAVs are controlled by tablet or iPhone and provided with camera and sensors like Global Position System (GPS) [4].

The use of UAVs and drones is continuously growing in different fields. [5].The very first use of this device was within the military for border patrol, rescue, damage investigation and monitoring [6].Numerous industries are adopting quickly enhancing scientific tools and introducing solutions to real-world problems [5]. Drones and UAVs have been used in various fields such as forestry, geographical mapping, electrical power, agriculture and environmental monitoring [4].As a matter of fact, the construction industry can take the edge of such tools and technologies in the almost entire scale of practical aspects. Such as UAVs and drones can be used at various phases in a construction project comprising mapping and detailed survey of jobsite, monitoring of construction activities, maintenance of highways and pavements, and monitoring of cracks and damages. Likewise, the drones or UAVs can perform as a real time device for project stakeholders to observe if their project under construction are conforming to their expectations and vision or not [5].

2. Research Overview

The objective of undertaking this research study is to provide insights into role of UAVs in the construction industry and to assess the perception of the application of UAVs in the construction industry of Pakistan.

3. UAVs in Construction Industry

UAVs are being used in different industries in the world. Besides, they are used in the construction projects. With the growth of real-time monitoring tools, UAVs deliver numerous positive utilizations in civil engineering to manage the construction process of the bridge, any infrastructure system and building by capturing images and videos from a project site. Some research studies have contemplated UAVs for inspection of structures in the time of maintenance .Furthermore, they have utilized in different transportation fields, such as traffic monitoring and controlling on roads during severe weather conditions or incidents, maintenance and repair of streets and management of job site to improve the safety of workers [4].

4. Project Lifecycle

In the construction industry, projects go through various phases in their life cycle. These phases include wide surveying of site, designing of 2D /3D maps, architectural designing, resource management, procurement, environmental monitoring, precision and quality and monitoring during execution of the project. In order to understand the use of UAVs or drones, the life cycle of construction project can be divided into three phases [1].

i. Pre-Construction Stage

This stage of construction project comprises of

- Planning and designing
- Survey of the site
- Site mapping
- Estimation of capital

ii. Construction Stage

This phase of construction project comprises of following activities

- Site monitoring
- Execution of project
- 3D modelling
- Inventory management
- Warehouse management

iii. Post-Construction Stage

This stage of construction project comprises of

- Operation and maintenance
- Detection of defects
- Disaster recovery

5. Surveying

The data obtained from surveying aid in planning and designing of a construction project. As a matter of fact, construction and engineering companies expend great effort, money and manpower to gather survey related data. This is a tough job if a project site is situated on tough terrain. Furthermore, the accuracy of data gathered through manual or hand held instrument is questionable. In such cases, drones or UAVs are definitely a good alternate [1].

UAVs can take high-resolution pictures that are then converted into 3D models and be used for showing the project site in 3D form or topographic mapping. At the construction stage drones can be used to prepare a 3D bird's eye view of construction site, making volume or surface measurements attainable. Since UAVs are provided with video cameras, they can help engineer's access videos and images from various locations of the project site [4].

6. 3D Modelling

The data collected through UAVs can be analysed using different software to extract information for making informed decisions[7].The process of making 3D models of an object from the pictures is called 3D reconstruction. In this process, the appearance and 3D shape of a real object is captured .Software such as 3DF Zephyr can be used for 3D reconstruction [5].The quantification of ground data allows the creation of 3D models to provide a realistic image of construction site [1].3D models of large objects or areas can be prepared using UAVs [8].For improved designing and planning, UAV-generated images can serve as a tool for experts to identify discrepancies between the construction and design phase [4].

7. Progress of Construction Project

Monitoring the project progress of a construction site is one of the significant job in the construction project [4].It is also one of the most challenging jobs in the construction, especially of a rail and road infrastructure [1].It is considered one of the critical success factor for the successful completion of a project within the stipulated time and cost [4].Unsatisfactory monitoring will result in poor management of construction project. And poor management results in cost and time overruns [5].

With the advancement of various technologies, UAVs are more helpful than others [7].UAVs are capable of controlling and monitoring the project site as shown in figure 1 below [4].As a result UAVs allow us to have more real-time control over the construction project. Therefore one can keep a record of the progress visually and can create a relationship between pre-construction and construction stages [8]

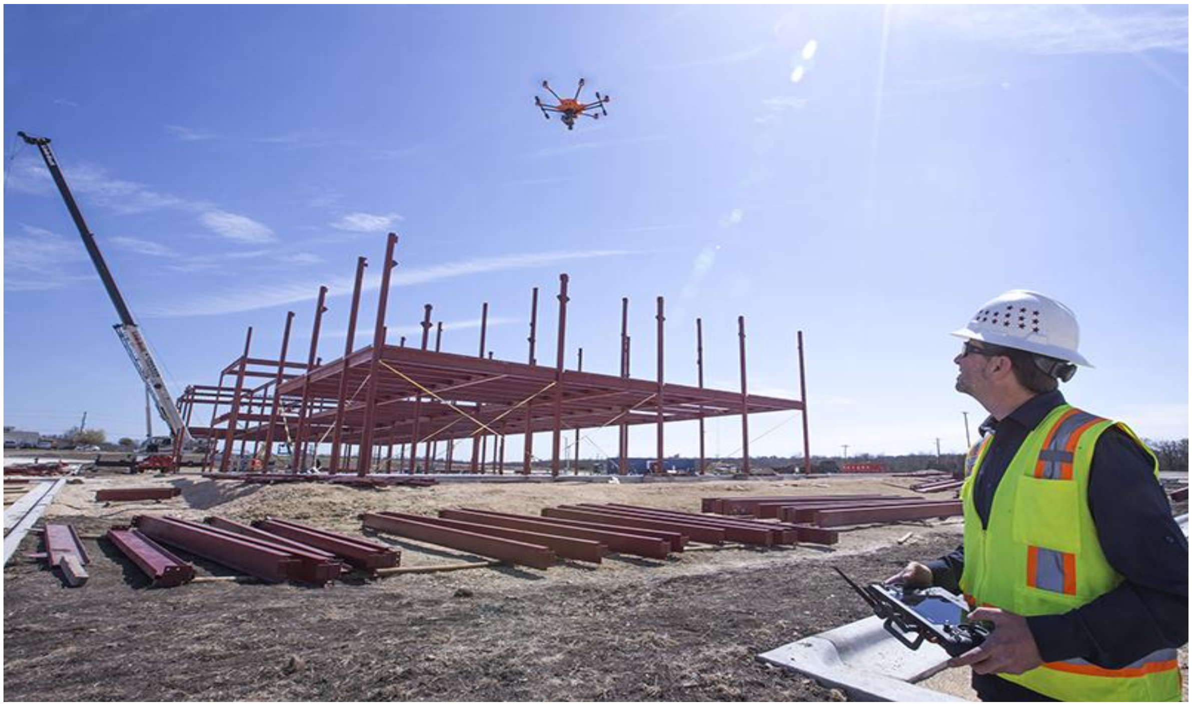

Fig. 1: UAV Camera-Based Monitoring Construction Project [Source. Google images]

8. Safety Monitoring

According to research studies and statistics construction project site is one of the most unsafe workplaces in the world. The major concern in the construction sector is safety [2]. Therefore, systems for safety have been developed in order to prevent the accidents and fatalities [9].Technological advancements in fields such as safety-conscious design, personal protective equipment and safety training have improved the safety of workers. Even with such enhancement, the construction sector continues to be the most dangerous industries in the world [10].

Both practitioners and researchers have addressed unsafe situations in construction workplace and accident prevention [11].The worker's safety and construction site have been monitored through Wireless Network (WN), Ultra-wide Band (UWB), BIM application, as well as Radio Frequency Identification (RFID). Moreover, in the present time, UAVs have been used in construction projects to gather real-time videos and images from blind spots and different views. UAVs are very useful to warn regarding the dangerous situations in construction project from the preparation of site to project completion [8]. Drones can fly over project site collecting real-time data from location of workers and moving equipment's, hazard material as well as blind spots in order to take proactive measures before happening of any accidents [12].

9. Applications of UAV in Construction Industry

A list of applications has been identified which provides insights into the role of UAVs in the construction industry. Based on the review of previous research studies common applications of UAVs in the construction industry are listed in table 1 below.

Table: 1 Common applications of UAV in construction industry

S. No	Application	References																						Frequency
		1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1	Surveying	✓		✓	✓		✓			✓	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓	15
2	3D Modelling	✓			✓	✓	✓	✓		✓	✓		✓				✓			✓	✓	✓	✓	13
3	Project Progress	✓			✓	✓	✓	✓			✓				✓	✓	✓	✓			✓			11
4	Safety Monitoring		✓					✓	✓	✓	✓	✓				✓	✓	✓	✓					10
5	Inspection of structures				✓	✓		✓	✓					✓								✓	✓	7
6	Disaster recovery				✓	✓					✓	✓							✓	✓	✓			7
7	Maintenance Of Highways	✓	✓	✓	✓								✓										✓	6
8	Inventory management	✓	✓		✓	✓																		4
9	Detection of defects	✓			✓	✓																		3
10	Crack Assessment																		✓		✓			2

10. Perception of Applications of UAVs in Construction Industry of Pakistan

Interviews were conducted in order to determine the relevancy of applications of UAVs in the construction industry. For this arbitrarily selected practitioners of the construction sector were interviewed and asked to select the applications of UAVs from above 10 common applications being used worldwide as identified from a review of research studies as in table 1.The demography of the panel participating in interviews is as in table 2. According to Loosemore [24] and Horstman [25] a population of ten to twenty interviews is quite enough for conducting a qualitative research.

Table 2: Demography of Respondents

S. No	Expert	Type of Organization	Experience (years)	Working Position
1	Expert A	Client	21 or above	Executive Engineer
2	Expert B	Client	21 or above	Additional Director
3	Expert C	Client	16 – 20	Executive Engineer
4	Expert D	Consultant	15 – 20	Procurement Manager
5	Expert E	Consultant	06 – 10	Team Leader
6	Expert F	Contractor	15 – 20	Chief Executive

7	Expert G	Contractor	15 – 20	Chief Executive
8	Expert H	Contractor	15 – 20	Chief Executive
9	Expert I	Client	06 – 10	Assistant Director
10	Expert J	Client	06 – 10	Sub Divisional Officer
11	Expert K	Contractor	10-15	Owner & Chief Executive

From table 2 above, it is noticed that all the respondents have remarkable experience of working in the construction industry. They are working in leading positions in their organizations. The participants represented the major stakeholders of the construction industry which include client, contractors and consultant. During interviews, all the participants advocated that all the 10 applications identified in table 1 are relevant to the construction sector. Therefore it was summarized that all 10 applications of UAVs in the construction industry are relevant and can be used in the construction projects.

11. Conclusions & Recommendations

The objective of conducting this study was to provide insights into the role of UAVs in the construction industry and to assess the perception of the application of UAVs in the construction industry of Pakistan**.** In order to facilitate the smooth adoption of UAVs in the construction industry, it is very important to assess the perception of application of UAVs in the construction industry. The main contribution of this research study is to identify the relevant applications of UAVs in the construction industry of Pakistan. The review of the literature revealed 10 common applications of UAVs being used worldwide in the construction projects. Expert opinion of 11 construction practitioners working at leading positions in the construction industry was sought to identify the application of UAVs relevant to the construction industry of Pakistan. It was concluded that surveying, 3D Modelling, Project Progress and safety monitoring were found more relevant applications of UAVs in the construction industry. These applications can further be explored to assess their implementation level in the construction industry of Pakistan.

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Recovering the Lost 'Moment':

How Timber-Laced Masonry May Hold the Secret to Stopping Pancake Collapse of Concrete Moment Frames (PART 2)

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Abstract

In my lecture at the SACEE'19 this week, I focused on the traditional masonry construction that has proven to be remarkably resilient in a number of recent earthquakes. This resilience has been a result of the use of timber as reinforcement in the masonry walls – in Pakistan, both as frames, as in *dhajji-dewari*, or as horizontal ring beams, as in *bhatar.* Also, in that lecture I explored how these premodern, non-engineered, owner-built houses and shops could offer a key for discovering a way to mitigate the risks that are now clearly identified with what is now the almost ubiquitous use of reinforced concrete for new construction in cities, and now also throughout the countryside, in earthquake areas around the world.

Moving on, in this talk for the 10th International Civil Engineering Conference (ICEC), I will focus on the beginning of the modern era in the field of structural engineering of multi-story buildings. First, I will turn to the 1880s & 1890s, when the first of what came to be called "skyscrapers" were constructed in Chicago, and then also in New York City and San Francisco. These were the first of what were tall buildings of full skeleton frame construction. It was during the 1880's that the invention of the Bessemer Converter and then the Siemens–Martin process, more commonly known as the Open Hearth Furnace, enabled the production of steel in large batches sufficient to replace most of the production of wrought iron needed for building construction within a single decade. The comparably higher strength and stiffness of steel made it particularly suitable for tall buildings. The first of these were 10 stories, but within 45 years, the Empire State Building exceeded 100 stories.

By 1906, when the Great San Francisco Earthquake and Fire occurred, there were approximately 27 steel frame mid-to-highrise buildings of 5 to 19 stories in that city. Significantly, none of these buildings collapsed as a result of the earthquake. Indeed, although without exception all of these buildings were burnt out by the subsequent fire, most were still capable of being repaired and put back into service. At least 15 are still in use today, more than 110 years later.

If one looks at the earthquake performance alone, the positive performance of these buildings is worth studying because the steel (and sometimes concrete) framework of every single one of them was infilled and clad with multiple wythes (leafs) of brick masonry, with outer surfaces of stone or terra cotta. The framework itself was often lightweight and lacked wind braces. The paper will explain this development, with references to the common practices of that day and age, making note of the fact that the transition from masonry bearing walls to the predominant use of frames occurred when engineering shifted more and more into reliance on calculations. The paper will document how in the first decades of the 20th century saw the adoption of the moment frame, and the development and broad acceptance of the

contraflexure methodology of moment frame analysis further refined the design of these frames. Masonry infill and cladding conflicted with this analysis method of the engineering design of multistory buildings, because there was no way to include it in the calculations except as dead weight.

As time went on, however, in earthquakes that occurred later in the 20th century, it increasingly became apparent that the steel frame and increasing numbers of reinforced concrete buildings proved to be more vulnerable than what people had been led to believe, particularly after their good performance in the 1906 earthquake in San Francisco. This paper will explain this history, and also how the standard frame analysis method has for decades departed from the reality of these buildings as they have been constructed and occupied. Because it was still needed for partitions and enclosure, the masonry did not disappear, but it became attenuated and weak. Particularly when it comes to earthquakes, the calculations on which the buildings were designed were thus inaccurate in ways that have made the reinforced concrete buildings particularly vulnerable to collapse.

At this point, the paper will return to the question of masonry, but rather than only looking at the steel skeleton frame structures in San Francisco, it will reach further back in time to traditional timber and masonry structures known in Kashmir, India and Pakistan as *dhajji dewari,* in Turkey as *hımış,* and in France and Haiti as *colombage,* and in Portugal after the great earthquake of 1755 as *Gaiola* or *Pombalino* construction. These systems are traditional timber and masonry construction, where the masonry forms a critical component of the lateral resistance of the building walls in ways that have proven to be effective in earthquakes. There is, no doubt, often a large difference in scale. For example, as the paper will then explore, "confined masonry," is a system that was at first not widely embraced as effective by engineers, but which has increasingly been seen to have performed well in earthquakes, especially when the confined panels are not too large (as often they have been in Indonesia).

Then, with examples of concrete from the 1985 Mexico City earthquake and the 1986 San Salvador earthquake, and of steel construction in the Bam, Iran earthquake and also in the 1985 Mexico City earthquake, the paper will describe the potential effectiveness of what the author calls "Armature Crosswalls," as a potentially effective way of modifying standard reinforced concrete construction practice in the present to reduce the vulnerability around the world of the many reinforced concrete multi-story buildings that are poorly constructed and inadequately engineered. In this section, the paper will reach for examples across time from as far back as Ancient Rome, and as close to the present time as the Empire State Building in New York City, but with a focus on how some simple changes in common practice in building construction could have a potentially profoundly beneficial effect.

Keywords
Dhajji Dewari; Bhatar; Taq; Traditional; Masonry; Moment Frame.

1. Introduction

I begin this paper with a personal story of my second trip to Pakistan as part of a UNESCO reconnaissance team. This was not for an earthquake, but for the 2010 Indus River Valley Floods. When I described the 1900 to 2500 BCE Bronze Age urban settlement of Mohenjo-Daro for the UNESCO report after the Indus Valley site visits, I included some of what we found in modern-day agrarian villages surrounding this remarkable archeological site. In addition to farming and growing cattle, some of the villagers took advantage of their location on the alluvial plain of the Indus River to make pottery from the clay – using ancient time-honored design and craftsmanship to produce pots in our current era which have an uncanny resemblance to the prehistoric vessels which had been found in the archeological diggings now housed in the museum (**Figure 1**).

Figure 1: Potter in village near Mohenjo-Daro

For me, this experience brought the archeological site alive in a way that further archeological digging and more displays in the museum could only touch. The people, their tools and their crafts spoke volumes about the site and its past history. They were true representatives of the rural and agricultural population of modern Pakistan, yet they stood there as teachers to us of the ancient world and its civilizations and the continuity of human life away from cars, computers, and the plastic containers that fill grocery stores. Thus I felt it important to include these villages and the effects of the 2010 flooding on them in the UNESCO Report (This report was given to the Government of Pakistan, but has not been published online). This included a description of how their population may contribute to the conservation and interpretation of the larger site around the ruins of Mohenjo-Daro. My notes from the expedition record that the inclusion of this material "was the very thing that got Pir Aftab Hussain Shah Jilani (Minister of Culture) most enthusiastic during our meeting."

Despite this endorsement, when I received what was to be the final draft of the document from UNESCO, I found that all of the references to these closely surrounding communities at Mohenjo-Daro with their traditional crafts and life-style had been deleted from the document. The explanation in an email from the UNESCO head of the mission was the following:

"The proposal to include the villages as part of the experience of Moenjodaro – life like 3000-5000 years ago – is culturally very sensitive and we have to be very cautious about this – UNESCO could be highly critized [sic] making such comparisons."

I mention this because this shows an interpretive boundary between conservation of an artifact of ancient (in this case pre-historic) human culture, and, in the deepest historical sense, the human culture in the present day to which these artifacts are connected.

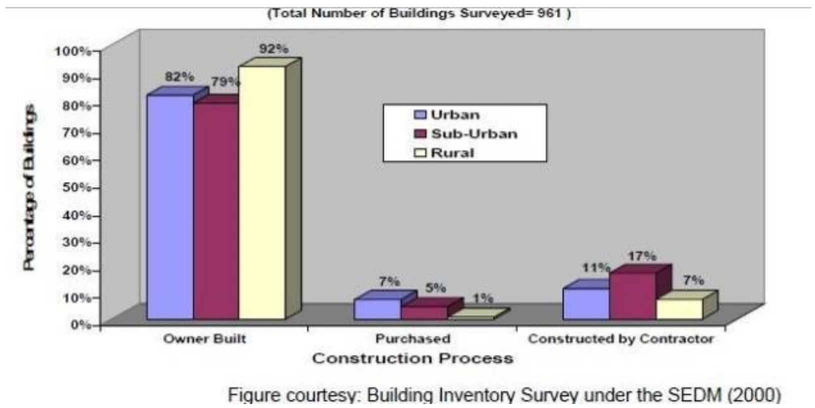


Figure 2: Construction comparison between owner-built and contractor-built (courtesy of Dr Amod Dixit)

2. TRADITIONAL CONSTRUCTION AS CULTURAL HERITAGE

What I describe in the rest of my paper comes from people like those whom I met in Mohenjo-Daro almost a decade ago, here in Pakistan. I did not learn about traditional construction at Harvard University, nor at the Institute of Advanced Architectural Studies in York, England, but rather in Kashmir on both sides of the Line of Control. I found it also in Turkey, Iran, Afghanistan, Nepal, Bhutan, and in Gujarat, India, and in Italy, Portugal, Mexico, Nicaragua, and El Salvador. My teachers were the masons and carpenters in these countries.

When I was invited to give lectures in Srinagar, in Ahmedabad, in Istanbul and in other heritage cities, my talks focused on the local traditional construction that I had found to exist in those very same places, but which I found was either disdained or unrecognized - particularly by the engineers and architects who lived there. In some of these places, for example, in Srinagar, students came up to me afterwards to tell me that I was the first to show them their own traditional construction in a positive light and convince them that it was resilient in earthquakes.

Indeed, when confronted with the evidence laid before me by earthquakes, I have come to realize that it is not enough to know how to design and calculate structures from lessons and codes written on the opposite side of the planet. We must learn from the affected people themselves how they build, before we can then turn around and teach them not only how to make their homes more resilient, but also to convince them to continue do that which they already know and have done well. We must encourage them to carry on those cultural traditions that have proven to be resilient in a recent earthquake, and to give these traditions the respect that they deserve.

This recommendation calls to mind the words written by the leading engineer of the team responsible for the drafting of the Nepal Building Code (DUDBC (2018) over 20 years earlier, Richard Sharpe of BECA in New Zealand. He stated in a Letter to the Editor of Bulletin of the New Zealand Society for Earthquake Engineering (Sharpe, 2016) that *"A year on* [after the Gorkha earthquake of 2015], *there are moves to revise the* [Nepal] *building code - perhaps to "international" levels seismically. A number of those who have called for such a lift appear to be ignorant of the rationale and careful consideration/consultation undertaken in the drafting of the Code. The level of design loads is, obviously, almost irrelevant if there is little compliance with the Code"* Mr. Sharpe's comments were made because he understands the socio-economics of the country and its almost total reliance on owner-builders for almost all rural and much of the urban building construction in the country (**Figure 2**).

3. 2005 KASHMIR 7.6 M_W EARTHQUAKE

The epicentre of October 2005 Kashmir earthquake was close to Muzaffarabad in the Pakistan portion of Kashmir (in Pakistan named *Azad Kashmir* (Free Kashmir)), where eighty thousand people died in both reinforced concrete (RC) buildings (including one modern high-rise residential complex in Islamabad), buildings of mixed concrete slab and block masonry walls, and unreinforced stone masonry buildings. It also affected India across the Line of Control, with approximately 2,000 fatalities (**Figure 3**).

There are two basic types of traditional construction with earthquake resistance capabilities found in Kashmir. One, of solid bearing-wall masonry with timber lacing, is known as taq and the other, a brick-nogged timber frame construction, is known as dhajji-dewari from the Persian words for patch quilt wall. In Pakistan, dhajji dewari is often referred to with only the single word, dhajji, (**Figure 4**) and taq is called bhatar (**Figure 5**). According to the structural engineering professors Durgesh Rai and Challa Murty (Rai and Murty 2005) of the Indian Institute of Technology-Kanpur:

"In Kashmir, traditional timber-brick masonry (dhajji-dewari) construction consists of burnt clay bricks filling in a framework of timber to create a patchwork of masonry, which is confined in small panels by the surrounding timber elements. The resulting masonry is quite different from typical brick masonry and its performance in this earthquake has once again been shown to be superior with no or very little damage."

They cited the fact that "the timber studs … resist progressive destruction of the … wall … and prevent propagation of diagonal shear cracks … and out-of-plane failure." They went on to suggest that: "there is an urgent need to revive these traditional masonry practices which have proven their ability to resist earthquake loads" (Durgesh and Murty, 2005).

My first trip to Pakistan was in 2006, one year following the Kashmir earthquake of 2005. We visited remote rural areas including two agrarian hamlets of Topi and Thub high in the foothills. Then we passed through the earthquake devastated towns of Muzaffarabad and Balakot to the Swat Valley in the Khyber Pakhtunkhwa (KPK). After a visit to the University of Engineering and Technology in Peshawar, we returned to Islamabad where UN-HABITAT had arranged for me to give a talk to Earthquake Reconstruction & Rehabilitation Authority (ERRA) and National Engineering Services Pakistan (NESPAC). ERRA had been established only 16 days after the October 8, 2005 Kashmir earthquake, while NESPAK was established in 1973 as a private limited liability company by the Government of Pakistan.

Figure 3: Collapsed School, Uri, Indian Kashmir. Written on the blackboard before the earthquake, is "*Ramazan Mubarak*" (Blessed Ramadan), which now is all that remains.

Figure 4: *Dhajji* in Pakistan

Figure 5: *Bhatar* in Pakistan

Within a week of this talk in Islamabad, ERRA and NESPAK approved *dhajji* construction as compliant for Government support, and the following year approved *bhatar.* Since those approvals, as reported by the International Federation of Red Cross and Red Crescent Societies, by 2009, at least 150,000 new homes had been constructed using one of these two traditional typologies in this region of northern Pakistan. The credit for the Government's acceptance of these traditional forms of construction belongs to generations of the rural farmers and home builders themselves. They taught both the *dhajji* and *bhatar* construction systems to me and my colleagues when we arrived for the first time after the earthquake. In fact, both of these traditional construction typologies had already been recognized by engineering professors in India by being included in the Indian building code for non-engineered construction as well as the Nepal Building Code, well before I began my own research. Even better than simply knowing these forms of construction was the fact that, in Topi and Thub, as well presumably in many other remote villages, the citizens resurrected these forms of construction from their own past after the 2005 earthquake left such buildings standing, when the newer and more common unreinforced rubble stone buildings had collapsed across the region.

The people themselves had made a decision to rebuild with *dhajji dewari* or *bhatar* walls despite the fact that the Government had told them that they would have to build with RC or reinforced concrete block to get any government assistance, and it was their faces that appeared on the screen in my talk at ERRA. These self-motivated rural citizens provide a modern-day example of the characteristic empirical process that has affected the way building construction has evolved over many millennia, long before complex calculations have come to dominate engineering, which has evolved into a separate and distinct professional field. Teddy Boen, an expert on Non-engineered Buildings, working in Indonesia, wrote in 2008:

“It is not advisable for experts to try to "teach" local people, but instead they must try to absorb and understand the local wisdom regarding why it was done the way it is. Having understood the local way of thinking, experts must try to facilitate locals in among others making their houses earthquake resistant but without introducing abrupt changes or use new alien materials” (UNCRD, 2009).

Back in Pakistan in the rural village of Topi there was only one house of the older *dhajji* construction, but the more recent homes were all simply of unreinforced rubble stone. All of these newer URM homes had collapsed (**Figure 6**), but that one earlier *dhajji* home remained standing. During the year following the earthquake, it had provided a model for all the villagers to follow when setting out to reconstruct their homes.

On the road to the next village, called Thub, is a large 2 ½ story country store building of *dhajji* construction (**Figure 7**). This structure had remained almost completely intact, only losing a few infill panels, but in the village itself, a much more recent three story store structure of reinforced concrete suffered complete collapse of its ground floor (**Figure 8**). From what we observed, it was the only reinforced concrete structure, not only in this village, but in the whole larger area.

Figure 6: New *dhajji* next to ruins of URM house

Figure 7: Large *dhajji* country store block on road to Thub

Figure 8: Collapsed RC country store in Thub

Figure 9: URM wall on left and bhatar wall on right after earthquake

Figures 10: Buildings of *bhatar* construction in Bahrain

After passing through the devastated towns of Muzaffarabad and Balakot towards Besham and then over the mountains to Bahrain in the Swat Valley, we passed a settlement that had examples of *bhatar* construction not far from a partially collapsed building of reinforced concrete. One interconnected wall was particularly interesting in that the unreinforced portion of it was totally collapsed, and a very crudely constructed timber laced section of it with dry laid stonework was entirely intact (**Figure 9**).

Proceeding to Bahrain in the Swat Valley, KPK, there were many structures of *bhatar* construction which had also stood up well in the earthquake (**Figures 10**).

4. Indian Kashmir After The 2005 Earthquake

The trip to the hills of northern Pakistan was almost exactly a year following a trip to Indian Kashmir only two weeks after the 8^{th} of October Kashmir earthquake. It was Srinagar, where I had been so impressed beginning in 1981 with its rich vernacular architecture, that I was stimulated to begin my research on structural aspects of *dhajji dewari* and *taq/bhatar*. The 2005 earthquake and this earlier research led to the publication by UNESCO of my book, *Don't Tear It Down! Preserving the Earthquake Resistant Vernacular Construction of Kashmir* (Langenbach, 2009).

Figure 11: Collapsed School, Uri

Figure 12: *Dhajji dewari* top floor showing ability of *dhajji* to span the wide gap left by collapse of unreinforced brick wall below in Baramulla

By coincidence, I happened to be in Delhi at the time of the earthquake for the "8th Convention on Construction," and thus was able to fly to Srinagar on the 24th of October, only 16 days after the earthquake. Of course the damage was much less than nearer the epicenter in Pakistan, but my reconnaissance of Indian Kashmir took me not only to Srinagar, but also nearer the border with Pakistan, where in Uri there were many collapses (**Figure 11**) and extensive damage in Baramulla (**Figure 12**). Before describing the earthquake damage, it is important to mention how the prehistoric geography has defined the building construction in this region of both India and Pakistan (**Figure 13**). The area around Srinagar is a giant alluvial basin of what had once been a land-locked lake surrounded by the mountains (**Figure 14**). Interestingly, this area is higher in elevation than is the mountain landscape of Pakistan Kashmir (**Figure 15**). At 5,200 ft, Srinagar is more than twice the elevation of Muzaffarabad, which is at 2,400 ft.

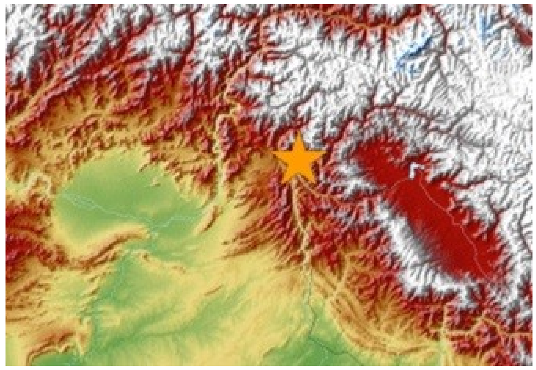


Figure 13: Geography of Indian and Pakistan Kashmir. The large red area between snow covered peaks is the Vale of Kashmir. The star is the EQ epicenter

Figure 14: The setting sun on Dal Lake near Srinagar

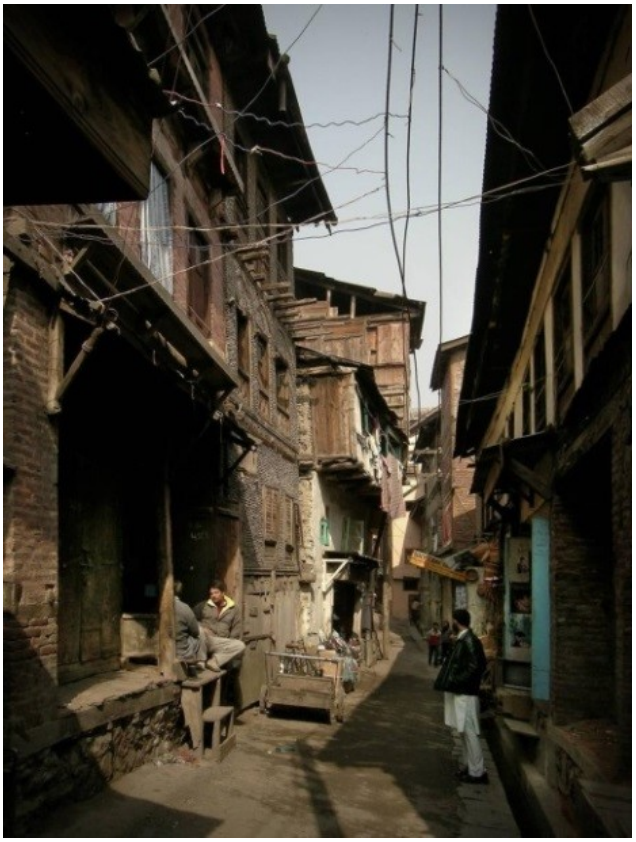
Figure 15: River and mountains of Kashmir near Muzaffarabad

The deep alluvium of the pre-historic lake bed that surrounds Srinagar provides the principle masonry building material in the region around Srinagar - a unique handmade fired brick known as "Maharaja Brick." In the lower elevations of Pakistan Kashmir and in the Swat Valley, the locally available material is stone, which unfortunately is often a rounded river stone rather than freshly quarried rock.

As will be shown, despite this significant difference in masonry materials, there are some remarkable continuities to be found when comparing the traditional construction practices across this geographic region. This is easily explained by the fact that, until the creation of India and Pakistan as separate countries after British withdrawal from India, and the concurrent demise of what had been the princely state of Jammu and Kashmir under the British Empire ruled by a Hindu Rajput prince, this region had been one continuous mountain state without a fortified border. The last prince, Maharaja Hari Singh, attempted to remain independent with friendly relations with both countries, but this noble effort eventually failed with the unfortunate result that this historic and remarkably beautiful mountain kingdom has been plagued by civil conflict that continues to this day.

Almost forty of the eighty years of this divided state's history have now passed since my first arrival in Indian Kashmir in 1981 – a time when Srinagar resembled an historic and picturesque medieval city (**Figures 16** and **17**). My research on the subject of the question of comparative vulnerability and resilience of traditional masonry construction with and without timber lacing began during that first visit to Srinagar. In the decade to follow, it was only written reports by traveling British authors after an earthquake in 1885 that affected Srinagar that provided observations of the resilience of Srinagar's traditional *dhajji dewari* and what is now referred to as *taq* construction. Note that while the term *dhajji dewari* has long been in use to describe timber frame with infill masonry construction, the term *taq* it turned out became used to identify timber laced masonry bearing wall construction after I had been told the term by a young Kashmiri architect – but I later learned that *taq* was an architectural term describing how many window bays such a masonry house had. When I prepared the book *Don't Tear It Down!* (Langenbach, 2009) published by UNESCO in 2009, I was told by my Kashmiri colleagues that the term had now been adopted from my earlier publications, and it was best to keep it because there was no other term for describing its traditional timber-laced masonry construction.

Figure 16: Rainiwari Canal, the only canal not filled in and turned into a road in central Srinagar



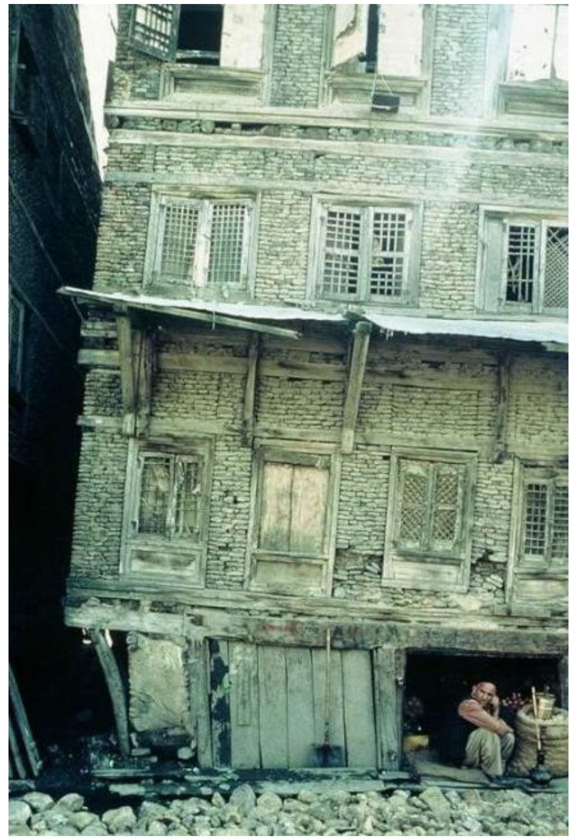


Figure 17: A typical lane in old Srinagar, not yet widened into a motor vehicle road

Figure 18: An old formerly canal-side *taq (bhatar)* building in Srinagar with timber lacing. Notice that the windows do not line up one above the other, a structural feature only possible with the timber ring beams

While the 19th century reports about the earthquake of 1885 give a strong proof of the resilience of the timber-laced bearing wall masonry and timber frame with infill (*dhajji dewari*) construction, they did not provide definitive evidence of the origins of the systems. The origin of these systems is actually most likely not for earthquake resilience, as earthquakes are themselves quite rare, with time between them exceeding the life-span of the people who would carry the memories. It is most likely a product of the location of Srinagar and surrounding villages on the water-laden alluvial soil of the Vale of Kashmir. Absent the ring-beams of timber in *taq* connected together with what has become known as “Kashmiri” scarf joints along the walls and notched timbers at the corners (**Figure 18**, or absent the *dhajji* framework (**Figure 19**), the buildings would simply split apart from differential settlement in much the same way as seen in **Figure 20** taken in Kathmandu Nepal which is also located in an alluvial basin.

One must ask why one can find *dhajji* and *bhatar* construction on the Pakistan side of the Line of Control in the mountain regions where the ground is firm and the masonry building material is stone, not fired or unfired brick? This is a more difficult question to answer definitively. Earthquakes may have had something to do with it just as we have witnessed after the 2005 quake in Topi and Thub, but at the same time, such traditional timber reinforced construction may be a product of the practicality, when trees were plentiful, of using cut timber to reduce the amount of the more time consuming masonry construction work including the lifting of such heavy stones. This is particularly the case with *dhajji* timber frame construction in which the walls are a thin single layer of stone, but also with *bhatar,* the timber ring beams reduce the wall thickness, and thus the weight of masonry that is needed for stability. This is especially true when *dhajji* is used for the upper stories of multi-story buildings, thus providing overburden weight on the masonry walls below, while the *dhajji* itself is well tied together.

Figure 19: A dhajji dewari building in Srinagar

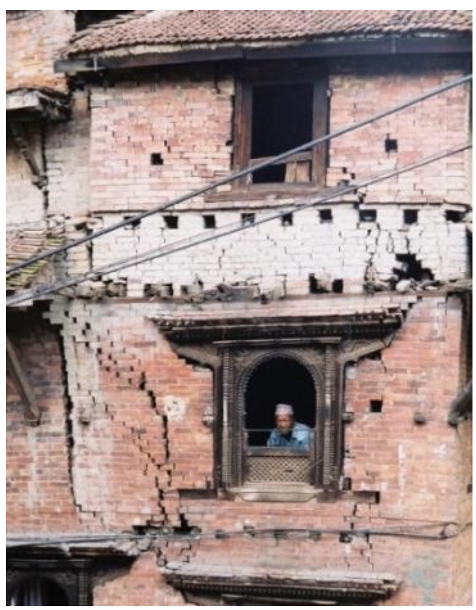


Figure 20: A similar sized building in Kathmandu, Nepal, showing effects of differential settlement without timber lacing causing the building to begin to split apart

Figure 21: the Bhuj branch of the Ahmedabad-based Swaminarayan Temple, the construction is of timber frame with masonry infill which was common in Ahmedabad, but rare in Bhuj, is located in the heart of the walled city of Bhuj, yet it survived almost undamaged, while the modern concrete pavilion seen on the right collapsed

Figure 22: A view within the historic walled city area of Bhuj after the 2001 Gujarat earthquake. Most of the historic buildings were of rubble stone masonry construction and the modern buildings were of reinforced concrete. The earthquake destroyed many of both types of construction

In this way, the system resembles that found in Turkey, and further west in Greece, Hungary, Romania and other Eastern European countries. This also provides cultural evidence that it may have come into Kashmir through the spread of the influence of the Ottoman Empire into the Indian subcontinent during the Mogul Empire (1526-1857) with its connection with the Persian Empire. The Gujarat earthquake of 2001 has reinforced this hypothesis because it revealed a profound difference between the construction heritage found in the Mogul city of Ahmedabad (**Figure 21**) with that of the Hindu princely cities in western Gujarat and Kutch, such as Bhuj (**Figure 22**), where these construction systems were very rare. As a consequence, during the 2001 Gujarat earthquake, the destruction was much more extensive.

5. Timber-Laced Masonry Construction in History

The question of whether timber-laced masonry construction evolved in response to the earthquake risk is difficult to answer, as there were other compelling economic and cultural reasons for the evolution of these systems. In addition to Kashmir's *dhajji dewari*, regional manifestations are called *colombage* in France, *fachwerk* in Germany, *hımış* in Turkey, and *half-timber* in Britain, all of which are in areas of low earthquake risk. Variations that used earthen plaster and sticks or reeds (wattle and daub) include Turkish *Bağdadi* and Peruvian *quincha*. Despite the ephemeral nature of the material, 5,000 year old *quincha* construction has been unearthed at the Peruvian archeological site Caral. A type that is best described as halfway between the masonry version and the wattle and daub version can also be found in Central America, where it is known as *bahareque* or *taquezal*. In the United States, the masonry infill version can be found in New Orleans and other historic French settlements on the Mississippi derived from French *colombage*, and also in parts of Pennsylvania, derived from the German *fachwerk* (Langenbach, 2007).

When archeologists dug up the port town of Herculaneum that had been buried in a hot pyroclastic flow from Mount Vesuvius in 79AD, they found an entire two story half-timber house which was identified as one of the masonry construction typologies described by Vitruvius as "*Craticii*" or "*Opus Craticium*" (**Figure 23**). This example in Herculaneum may provide us with the only surviving example of the form of construction that had been used in ancient Rome for the seven or eight story tenements (*insulae*) that filled that city of a million and a half people. Masonry bearing walls would have been too thick at the base to fit on the known footprints of these ancient buildings with space for rooms left over, so it is likely that the Romans constructed many of these tall buildings with timber frames and infill masonry (Langenbach, 2007).

Laced-bearing wall construction may have had its origins in ancient times as well. This kind of construction can be found in the 5th Century AD Theodosian city walls of Istanbul, where the belts of red brick are an integral part of the architecture (**Figure 24**). Modern restorers reconstructing a portion of the walls mistakenly treated this only as an architectural element by applying a brick band as thin layer on the surface, rather than as a structural layer extending through the masonry. When the 1999 Kocaeli earthquake struck, this newly constructed section collapsed, while the surviving 1600-year-old heavily deteriorated portions of the wall were largely unaffected by the earthquake, despite the pre-existing damage (Langenbach, 2007) (**Figure 25**). It was this system of what I have called "crack-stopper" courses that evolved into the timber-laced system known as *hatil* in Turkey, which is similar to *taq* and *bhatar* described here.

Figure 23: House of the Opus Craticium, Herculaneum, Italy

Figure 24: Unrestored section of the Theodosian City Walls of Constantinople showing brick courses extend into core of the wall

Figure 25: A modern reconstruction of a section of the city walls where the brick courses were only on surface

After the fall of Rome, infill-frame construction became widespread throughout Europe. Timber-with-brick-infill vernacular construction is documented to have first appeared in Turkey as early as the eighth century. Thus, the adoption and continued use of this system until the present time was most likely the successful by-product of a technology developed as much for its economy as for its strength, rather than specifically because of earthquake risk.

6. KOCAELI Earthquake of August 17, 1999

Moving east from Istanbul to those regions affected by the 1999 Kocaeli and Düzce earthquakes, most of the settlements were industrial towns developed mainly in the 20th century. The Kocaeli earthquake of August 17, 1999 killed approximately thirty thousand people. The epicenter was just 200 kilometers east of Istanbul. In some areas of Gölcük and Adapazari, the earthquake destroyed more than a third of all housing units, almost all of them in reinforced concrete buildings (Kandilli Earthquake Research Institute, 2000). While the laced bearing wall type was rare, there were clusters of *hımış* (which is the Turkish word for *dhajji*) buildings in the heart of these districts. The houses were constructed of *hımış* from the ground up. These houses, mostly dating from the early part of the twentieth century, often only pre-dated the ruined reinforced-concrete apartment blocks nearby by a few years. Most of these older *hımış* houses remained intact, with only a few heavily damaged, with damage almost always a result of wood rot, or badly done alterations (Figure 26).

This finding was confirmed by researchers who conducted a detailed statistical study in several areas of the damage district. They found a wide difference in the percentage of modern reinforced concrete buildings that collapsed, compared to those of traditional construction. Gülhan and Güney documented that in one district in the hills above Gölcük, of the 814 reinforced-concrete four-to-seven-story structures, 60 collapsed or were heavily damaged, while only 4 of the 789 two-to-three-story traditional structures collapsed or were heavily damaged. The reinforced-concrete buildings accounted for 287 deaths compared to only 3 in the traditional structures. In the heart of the damage district in Adapazari, where the soil was poorer, research shows that, of the 930 reinforced concrete structures, 257 collapsed or were heavily damaged and 558 were moderately damaged, while none of the 400 traditional structures collapsed or were heavily damaged and 95 were moderately damaged (**Figure 27**) (Gülhan and Güney, 2000).

Figure 26: Formerly 4 story RC building next to dhajji building with very little damage from 1999 earthquake. (reproduced with permission from Adem Doğangün (Doğangün et al., 2006)

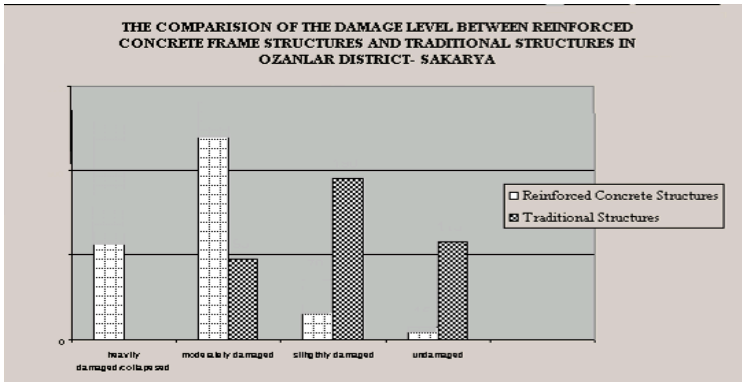


Figure 27: Comparison by Gülhan and Güney of damage to RC buildings with traditional timber and masonry buildings of all types

Figure 28: Margalla Towers, Islamabad (courtesy of Express Tribune)

7. Reinforced Concrete Moment Frames

Returning to Pakistan, while there were a very large number of fatalities in the 2005 earthquake, the effort to distinguish the body count in reinforced concrete buildings is complicated by the fact that so many buildings were of mixed construction with concrete block masonry together with reinforced concrete slabs for floors and roofs. Whereas in Turkey, the 1999 earthquake affected a highly urbanized area with large numbers of multi-story concrete buildings, the one iconic modern multi-story reinforced concrete building complex to experience a pancake collapse in Pakistan was one part of the Margalla Towers complex in Islamabad (**Figure 28**). Both of the small cities of Muzaffarabad and Balakot were almost totally destroyed, with many buildings of reinforced concrete structural frames having collapsed (**Figure 29**).

At the 13th World Conference on Earthquake Engineering in August, 2004, Fouad Bendimerad, Director of the Earthquakes and Megacities Initiative said that roughly 80% of the people at risk of losing their lives in earthquakes in the world today are subjected to risk from collapse of reinforced concrete frame with masonry infill buildings. This is a remarkable statistic because such buildings are entirely of recent origin, and often considered safer than the masonry buildings they replace. As we can see from the statistics in Turkey and other recent earthquakes, there is a pattern emerging where the promised strength and resilience of reinforced concrete has often been found to be less than expected.

Figure 29: This is a remarkable photo taken in Balakot of an open air prayer meeting on the floor slab of the collapsed main Balakot mosque. Every building in the city was reported to have been destroyed, but the strength off this reinforced concrete floor slab to hold this many worshipers is amazing (courtesy IIEES)

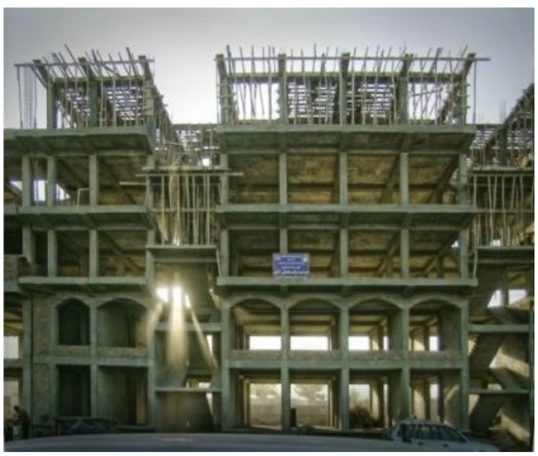


Figure 30: 5+ story RC moment frame building under construction in Kabul, Afghanistan

Figure 31: 10 story moment frame building under construction in Karachi showing infill masonry (cement block) finished up to the 7th floor

There is a discrepancy between the current state of earthquake engineering knowledge and the actual performance of many contemporary buildings. The myth that this construction is earthquake-safe is gradually declining from a promise to that of folklore, yet even after the 2015 Gorkha earthquake in Nepal one hears people saying they wish to have a pillar building by which they mean a building with a concrete frame. In India, the term *pucca* building refers to a 'strong' building. It is used in comparison to a *katcha* building meaning a 'weak' and insubstantial building. *Pucca* is reinforced concrete that is thought to be strong, and *katcha* is weak, which now means timber and masonry or mud brick construction.

In 2011, having found the opposite to be the case in regards to earthquake risks, I entitled my talk at the World Bank in Washington DC: *Katcha* is *Pucca* & *Pucca* is *Katcha.* This was to highlight my findings from the decades of my research that began as an effort to find what I hoped would be at least a minimum level of earthquake safety in the traditional construction so that I could argue in favor of preserving the buildings without that effort being defeated by earthquake safety efforts. Little did I then expect to find the situation now, after several earthquakes in different countries, where these traditional buildings have out-performed what were believed to be the safer and more modern reinforced concrete alternatives. This comes at a time when concrete construction dominates the market throughout most earthquake hazard zones around the entire planet (**Figures 30 and 31),** except where construction quality timber is widely available – which includes the United States and Canada, and parts of Turkey, Eastern Europe and Russia. It also, quite fortunately, includes parts of Indian and Pakistan Kashmir.

The problem with concrete construction is not the concrete, if it is properly mixed, placed and cured correctly. If this were so, then the Pantheon in Rome – a 2,000 year-old-building – would not be standing today. However, had it been reinforced with steel, it would not have lasted for two millennia. The corrosion of steel reinforcing is definitely a problem and in future years it will become more of a problem, as the rusting of the steel reinforcing has proven to shorten the lifespan of buildings to only decades or at most a century in the modern era. This was evident, for example, in Haiti where both the National Palace and the Cathedral collapsed in the 2010 earthquake because the steel reinforcing had largely rusted away.

However, the risk presented by the corrosion of steel reinforcing is a subject for another paper. The other RC building failures in Haiti, in Turkey and in other recent earthquakes around the world, including that in Pakistan, were not from rust, but from structural failure. If one steps back and looks at these collapses as group, rather than individually, a pattern begins to emerge. This pattern brings one to what turns out to be the most significant revolutionary change that has occurred, not only in building construction technology, but also in structural engineering (Langenbach, 2012; 2013).

8. From Walls to Frames

Structural engineering has gone through a revolution over the past century. The 19th century was an era of enormous ferment, producing engineering giants like Brunel and Eiffel, along with William Le Baron Jenney and the other engineers of the first skeleton frame iron and steel highrise buildings in Chicago, New York City, and San Francisco. In the first decades of the 20th century buildings what became known as skyscrapers went from a height of 10 to 20 stories to over 100 stories. This achievement required a shift in engineering practice from a largely empirical process to one of rigorous mathematics.

The teaching and practice of the structural engineering of buildings moved away from the design of solid wall structures with post and beam interiors to the analysis and design of frames. To fully understand the implications of this change, we must first isolate what is meant by the term “frame” in structural engineering in order to distinguish between a framework of columns with simply supported beams and a moment frame where the beams and columns are interconnected sufficiently to allow the frame alone to resist lateral forces as well as to carry loads to the ground. Until the nineteenth century, frame structures and the internal framework of buildings were most often made of timber, with the lateral forces resisted by masonry walls acting in shear and/or by braces within the heavy timber framework.

The advent of steel and steel reinforced concrete has allowed for the creation of moment frames. These no longer need to rely on braces or masonry shear walls. In terms of engineering practice, the linear-elastic portal frame analysis of such structures has come to define most of the day-to-day professional engineering work for multi-story buildings. Moment frames provide lateral resistance by both shear and flexure of the framing members. Their lateral capacity is primarily determined by the strength and ductility of the joints between the beams and the columns. The enclosure and partition walls that turn this open framework into a useable building are routinely ignored in the structural calculations except as dead weight. The advantage of this approach is that it has allowed for a coherent mathematics-based engineering approach to building design by separating the infinite complexity of a finished building with all of its parts from that of the primary structural system – the frame.

An interesting fact about the historical development of the modern skeleton frame construction and portal frame analysis at the late 19th and early 20th centuries is that thick masonry infill and cladding was very much an accepted part of the early iron, and then steel and reinforced concrete buildings, even though it was then, as now, not considered in the engineering calculations for lateral resistance (**Figure 32**). This is made clear by the author of one of the first textbooks on the subject of skeleton frame construction (Freitag, 1901)

“'Skeleton Construction' ... suggests a skeleton or simple framework of beams and columns, dependent largely for its efficiency upon the exterior and interior [masonry] walls and partitions which serve to brace the structure, and which render the skeleton efficient, much as the muscles and covering of the human skeleton…make possible the effective service of the component bones.…While the steel frame is more or less reinforced by the weight and stiffening effects of the [masonry infill], still no definite or even approximate values can be given to such items, except their purely static resistance or weight.”

The 1906 earthquake in San Francisco put skeleton frame buildings – even some done by the same architects as those in Chicago – to the test. As it turned out, they passed that test remarkably well (**Figures 33** and **34)**. Indeed, one must ask why these first generation steel skeleton skyscrapers in San Francisco remained standing with undamaged frames and repairable damage to the masonry walls, when so many frames with infill masonry buildings have been collapsed by earthquakes a century later. Even two of our most distinguished earthquake engineers in practice in California today, Ronald O. Hamburger, and John D. Meyer, both principals and structural engineers at Simpson Gumpertz & Heger, Engineers based in San Francisco, asked the same question in their article on the centennial of the 1906 earthquake in EERI Earthquake Spectra: *“Evaluation of these buildings using modern methods of seismic analysis would not suggest such outstanding performance would occur. This raises the obvious question as to why the performance would be so much better than predicted using modern evaluation techniques* (Hamburger and Meyer, 2006)*.”*

Figure 32: Flatiron Building in New York City under construction in 1902 showing the stone masonry façade resting on the steel frame. The upper walls are constructed separately from the walls below, most probably to ensure their weight is bearing on the steel frame rather than the lower masonry walls.

Figure 33: View of San Francisco after the 1906 earthquake and fire. The three tall buildings in this view were burned out by the fire that followed the earthquake, but all were in good enough condition despite this to be repaired, and they are still extant today.

Figure 34: The Flood Building, San Francisco, constructed in 1904, It is twelve stories with a steel frame and thick infill masonry. (Left) after the Great 1906 earthquake and fire, and (right) its appearance today. It was simply repaired from the earthquake and fire damage after the earthquake. It did not have to be rebuilt.

Hamburger and Meyer go on to examine three contributing factors that may explain the greater than expected resilience of these steel frame buildings during the 1906 earthquake, and their survival of the fire that followed. While their explanations were thoughtful and convincing, together they point out the difficulty that exists with the forensics that generally surrounds the issue of isolating the causes of successes as well as failures after such overwhelming disasters. That is that determining the reasons for successes is usually more difficult than for failures. This is especially conspicuous when one of Hamburger and Meyer's colleagues said that one explanation could be simply that the good performance may not have seemed so remarkable had the fire not happened. Then these buildings would not have been surrounded by burnt out and collapsed ruins. Had the surrounding buildings been only earthquake damaged the difference would have been less apparent.

Figure 35: Collapsed RC Buildings in Gölcük, Turkey after 1999 Kocaeli earthquake

Figure 36: Collapsed steel frame building after 2003 Bam, Iran earthquake

For the purpose of this paper, however, the question is whether there is anything that can be learned from the good performance of these first generation frame skyscrapers which carry the heavy load of masonry infill and stone or terracotta cladding with hollow clay tile interior walls, and which have "soft stories" of open shop fronts and many large windows on all floors. None of these buildings even came close to collapsing even though the earthquake had caused some of the fireproofing of the steel columns to fall away before the fire swept through them. By comparison with the collapse in subsequent earthquakes of hundreds of reinforced concrete (**Figure 35**) (and in Iran, steel (**Figure 36**) frame structures constructed over the last fifty years, the difference is profound.

Figure 37: Hotel Oakland, Oakland, California after 1989 earthquake which caused much of this end façade to fall off

After having experienced a seemingly medieval world in Srinagar, Kashmir, I found that the answer lies where one least expects it – with the infill masonry. This leads to another observation by Ronald Hamburger – who wrote that he is *"not aware of any [structural evaluation] models that incorporated the effects of the [interior masonry] hollow clay tile partitions."* These interior partitions are, of course, in addition to the exterior brick and stone masonry in the engineering assessment of these buildings (Hamburger and Meyer, 2006).

The questions raised by Hamburger and Meyer point to the fact that the masonry in general, and the hollow clay tile interior walls in particular, fall outside of modern seismic analysis models, such that in a seismic retrofit project the typical decision has been simply to replace the hollow clay tile interior walls with lightweight materials. It is worth recalling the quote by Freitag, where he uses the human body as a metaphor for the structural role that the infill masonry must have had in steel frame high-rise buildings, yet "w*hile the steel frame is more or less reinforced by the weight and stiffening effects of the [masonry infill], still no definite or even approximate values can be given to such items, except their purely static resistance or weight* (Freitag, 1901)*."*

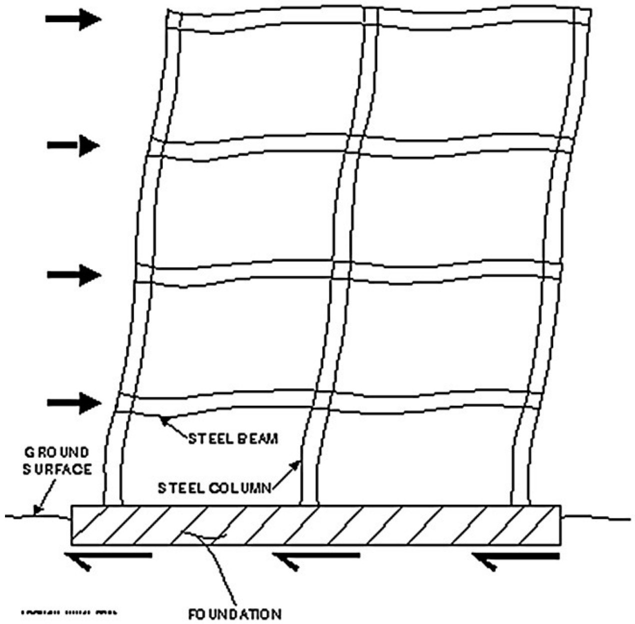
Hamburger and Meyer's comments are particularly interesting in light of what happened during the 1989 Loma Prieta earthquake in Oakland, across the bay from San Francisco. That earthquake affected a number of early 20th-century skeleton-frame mid-rise buildings with masonry curtain walls. None of these buildings came close to collapse during the earthquake, but, as expected, many manifested cracks in their masonry exterior walls, as they did in San Francisco in 1906. However, one such building, the former Hotel Oakland, an eight-story block-sized building recently converted to housing, sustained considerably more damage to its façade than did any of the others. After the earthquake, it was surprising to find out that of all of the buildings of this type, this one building had been the only one that had been seismically upgraded (**Figure 37**). As part of that upgrade, all of the interior hollow clay tile masonry walls had been demolished and replaced with gypsum plasterboard on light weight steel studs.

Thus, this building confirmed that Freitag's instructions in 1901 were as valid as is Hamburger and Meyer's observation that *modern methods of seismic analysis* fail to predict the good performance of the 1906 steel framed buildings in the San Francisco earthquake. It also is another example of how engineers continue to have difficulty finding a way to incorporate infill masonry into their calculations and wish to remove it whenever possible.

Figure 38: Margalla Towers, Islamabad (middle) after debris removal exposes the basement level 'soft story' and (right) base of the section next to that which collapsed showing evidence of onset of short column failure

Returning to the Margalla Towers in Islamabad, together with the thousands of other reinforced concrete moment frame buildings with infill masonry walls which have collapsed in earthquakes, one is forced to ask why for so long these moment frame structures are constructed with masonry infill walls which are largely ignored in their design calculations. Note in the USA and Canada, the use of masonry for infill was banned in the building code more than half a century ago, but in much of the rest of the world, it is still commonly used. In the case of the Margalla Towers as late as 10 years after the earthquake, the Pakistan Express Tribune reported that there was "no answer yet" as to why the Margalla Towers collapsed, but my own photos taken in 2006, a year after the earthquake seem to me to show good evidence that the collapse may have been a soft story failure combined with some short column failures (**Figure 38)** (Usman, 2015).

There are two changes which have taken place, one in engineering and the other in construction. In engineering, most of my historical focus above was on the transition to the use of iron, and then, later, steel and reinforced concrete frames for taller buildings. To accomplish this, engineering practice shifted from a largely empirical process to one of rigorous mathematics. One of the watershed events in this transition is the invention of a way of doing a portal frame analysis using what is called the contraflexure methodology for isolating moments. This method allowed the calculation of the capacity and bending stresses on multi-story frames by mathematically separating a moment frame into parts at each neutral point of bending reversal of the columns and beams. This allows the forces to be calculated using the three equations of equilibrium. Multi-story modern moment-frame steel and concrete buildings as we continue to see them built today in every practical sense date their origin to this change in engineering analysis methodology (Robison, 1989; Langenbach, 2006) (**Figure 39**).



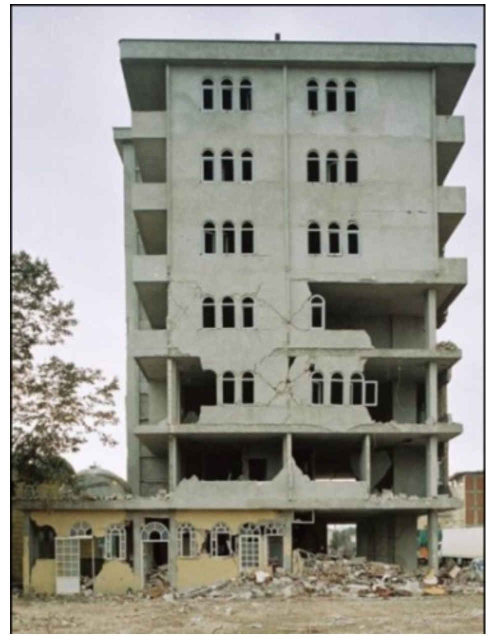


Figure 39: Moment frame under lateral load showing the rigid connections of the beam/column connections which then produce the flexural shapes of the beams and columns. This is an idealized shape of the 'frame action' which engineering calculations are predicated on, whereas the beams are often much deeper, which can more easily lead to rupture of the beam/column connections.

Figure 40: The infill walls can prevent this 'frame action' from happening altogether as can be seen in taken in Gölcük, Turkey after the 1999 earthquake. This photograph shows how the building was brought almost to collapse as the infill walls failed in shear at the lowest levels, causing a soft story condition

While the contraflexure methodology for calculating the forces on a frame for tall buildings allowed for greater accuracy and simplicity, one of the interesting results is that the greater efficiency in the calculations meant the frames were no longer as overdesigned as they had to be prior to the adoption of the contraflexure methodology for moment frames for high-rise buildings, which is reported to have occurred around 1910 to 1915 (Robison, 1989). Thus the sizes of the beams and, particularly, the columns are reduced and a bending 'pin' connection at each floor level is eliminated.

The solution also was to change the construction rather than the mathematics by reducing the amount of masonry used to a single thin layer, while still deliberately leaving the masonry out of the engineering calculations. The seemingly reasonable theory was that by including only the weight of the masonry in the calculations, but not relying on it for lateral strength, the design would be more conservative than if it were included as part of the lateral resistance. Experience has shown that there is a fundamental flaw with this approach. The standard analysis method is based on linear elastic behavior which contradicts the fact that, even under current seismic design regulations, structures are allowed and expected to incur into the nonlinear range. This fact has been recognized in codes through the use of ductility factors which are assigned based on the individual elements that make up a structural frame, but such factors are unresponsive to the conditions that exist when the non-structural infill masonry is added to the system.

The problem is that the masonry is not eliminated, but instead became thin and weak. What had been the strong multiple layers of infill masonry laid in lime mortar that contributed to keeping San Francisco's early skyscrapers standing was in later buildings attenuated into a single layer of brick or hollow clay tile laid in cement mortar that is stiff, yet brittle (**Figure 40**). While these single layer brick infills have proven in recent earthquakes to be strong enough during an earthquake to sometimes rupture the RC moment frames, they then collapse or fall out of the frame, which can cause a pancake collapse of the buildings (**Figure 41**).

Figure 41: Research on the effects of conventional infill walls at Middle East Technical University, Ankara, Turkey. The photos on the right show how the infill can cause the rupture of the surrounding RC frame when pushed laterally parallel to the wall

Figure 42: Buildings in Mingora, Pakistan. On left, what appears to be a very weak RC frame building under construction, and on the right an infill wall building with no visible attempt to give it a cultural or architectural quality

9. From Solid Walls to Frames

Many historians of the early skyscraper era viewed the evolution of skeleton frame building design like a genie waiting to come out of the bottle – true transformation could only come when this traditional masonry envelope was shed, and the open frame itself made the basis for the architectural expression, with flexible floor plans of open spaces and moveable walls. Unfortunately, as can be seen in these illustrations above, the creativity and vision of the first architects such as Le Corbusier, is missing from many of the manifestations of what had been a promising new structural system in the first decades of the 20th century (**Figure 42**).

This transition to the nearly ubiquitous use of reinforced concrete frame construction led to increasing numbers of failures of such buildings in each successive earthquake, presenting a dilemma which only becomes evident when certain disrespected and forgotten examples of traditional timber and masonry construction such as *dhajji* and *hımış* are found to have a better statistical record of collapse prevention in certain large earthquakes than the modern frame structures. While timber lacing and timber frames with infill masonry intuitively are better than plain unreinforced masonry, *how can these, nevertheless, be better than reinforced concrete*? In other words, how can the failure of what is often determined after an earthquake to be bad construction be considered to be an indictment against the RC frame systems themselves? This question is especially difficult to answer, when it can also be seen that better built RC buildings have survived with little or no damage.

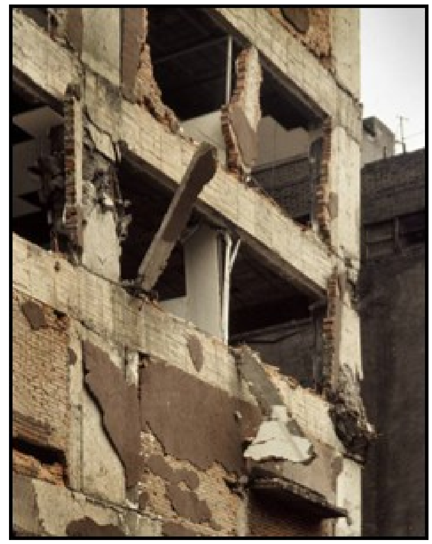


Figure 43: Buildings that were intended to be identical when finished, located near Bhuj, India after the 2001 Gujarat earthquake

Figure 44: Large RC infill wall building after 1985 earthquake in Mexico City showing ruptured columns

In my observations of the behavior of these systems in the Turkey, Kashmir and Gujarat earthquakes, the use of weak rather than strong mortars in combination with the timber framing allows the masonry to shift and slide early in the onset of earthquake shaking, rather than crack through the masonry units and fall out of the framework. The combination of the framework with the masonry thus is interactive, rather than one working against the other. Frame action, the independent working of the frame as a structural system, is neither what exists nor what is important. Although a framework of timbers is constructed, it is imbedded in the masonry wall and “works” in the engineering sense of the term together with the masonry in the wall.

However, with reinforced concrete moment frames, now for more than 100 years, the universally excepted engineering calculations based on frame analysis are based on a fundamentally false premise. Instead, for what is now an entire century, buildings constructed with moment frames, but enclosed and subdivided into rooms with infill masonry walls, and thus cannot actually undergo the “frame action” during earthquakes on which their design calculations are predicated.

I have seen evidence of this many times after a number of earthquakes, but the photograph in **Figure 43** illustrates this in a particularly clear and dramatic way. The two buildings seen were, when finished, intended to be identical, but only the one on the left was finished and occupied, while the bare frame on the right was clearly the only one of the two frames in which the frame action on which all of the structural design calculations were based could occur. Need I say more? The frame is standing, but the finished building has collapsed.

Figure 44 gives a clear view of what the collapse mechanism is for the collapsed building in **Figure 43**. It shows a large infill wall RC building in Mexico City after the 1985 earthquake that was very close to being collapsed by the action of the infill masonry on the frame. The photo shows the rupturing of the corner column on the right in two places in the same story. It is remarkable that it was still standing when photographed.

10. Armature Crosswalls

How can this situation be fixed? For decades, researchers have worked on ways to structurally separate the infill walls from the frames, but still have walls that provide acoustic and fire safety separation between rooms, and a weather separation from the outside. While sophisticated hangers and clips or lightweight materials and composites of different types are all possible, few are as economical or practical as brick or hollow clay tile infill.

The best alternative that I can propose is to do what should have been done over 100 years ago –make the infill masonry an integral part of the engineering of the building. The goal is to make it work, in the engineering sense of the term, together with the frame such that "frame action" will still occur.

I will describe now what I propose, which I have named **Armature Crosswalls**. The term crosswall has been drawn from the terminology used in the Uniform Code for Building Construction (UCBC) Chapter 1 as applied to unreinforced masonry construction. In that code, a "*crosswall decreases the displacement … and will provide damping of the response of the diaphragm to earthquake shaking*." For the purposes of this proposal, a crosswall is an infill wall inserted into the building's structural frame, rather than only connecting floor diaphragms, and thus it is not limited to interior partitions. The word is chosen because of the similar emphasis on its reduction of deflections of the structure and its provision of damping through hysteretic behavior of the crosswalls themselves. Part of the research on the Turkish *hımış* construction has been accomplished with a 2003 EERI Lessons Learned over Time grant. The research and publication of the papers referenced on the last page was supported by this grant). The Armature Crosswall (ACW) technology is founded upon the assumption that (1) vulnerable RC frame structures will continue to be constructed in great numbers, and (2) weak existing RC buildings will continue to be occupied. RC infill construction has become the default form of construction in many countries even though it has proved to be particularly deadly in earthquakes except where engineering design and construction quality control is rigorous. Rapid urbanization and development continues to lead to severe compromises in engineering and construction quality. The technical knowledge and the equipment necessary for construction of acceptable quality simply do not exist in many regions, and proper enforcement and inspection in many locations is simply not possible. The problem with most RC Infill construction in many parts of the world thus is not an engineering problem; it is a socio-economic problem in building delivery (Langenbach, 2003).

The Armature Crosswall concept is focused on the infill walls themselves, rather than the frame. It is based on the idea that the masonry infill walls may hold the key to the prevention of such wide-spread collapses of RC buildings, just as they did for the Chicago Frame buildings in San Francisco in the 1906 earthquake. Previous efforts to reduce the negative effect of the infill walls have included separating them from the frame or reinforcing them, but these approaches do not help to protect against collapse when the RC frames prove to be deficient - especially when supporting the weight imposed when masonry is used for all exterior walls and partitions.

An Armature Crosswall (ACW) is a masonry infill wall that has been constructed or retrofitted with studs and horizontal members (the armature) that subdivide the masonry infill, and surround all openings. The goal is to develop a design for the ACW that is capable of sustaining inelastic deformation with consequential friction over many cycles. To do this, the concept is to make the walls more flexible and less subject to collapse by dividing the masonry into panels, and also by using a mortar that is significantly weaker than the masonry units. The objective is to reduce their elastic stiffness compared to non ACW walls, while making them more stable and robust in their inelastic behavior. The ACW concept is based on the goal of making the infill walls serve both as a secondary means of support and as economical energy dissipaters. The energy dissipation results from the friction from the controlled cracking through only the mortar joints (not the masonry units) and sliding of the masonry within the armature framework. I have also found examples of buildings with a de-facto version of ACWs that have demonstrated their potential resilience in reconnaissance trips to Mexico after the 1985 earthquake, El Salvador after the 1886 earthquake (**Figures 45-47**), and Iran after the 2003 earthquake.

The armature in an ACW consists of a series of studs and cross-beams that divide the infill wall masonry into a series of panels. Although traditionally of timber, the materials to be used for armatures are not critical. It can be timber, steel, precast concrete, or combinations thereof. The ACW is intended to be tightly fitted within the building frame so as to provide sustained friction and energy dissipation over repeated cycles. ACWs will be designed to accommodate doors and windows, and also allow for partitions that are not confined within the frame together with those that are. Since these are crosswalls, rather than shear walls, they do not have to extend unbroken from foundation to roof or have their own foundations or boundary elements.

Figure 45: The brick wall of a power station showing an 'armature' of light steel reinforcement that subdivides the wall into panels. This building suffered no damage in the 1985 Mexico City earthquake while Figure 45 (b) shows RC building under construction just across the street has collaped.

Figure 46: Photos of a soft story collapse of an apartment building in El Salvador in the 1987 earthquake

Figure 47: Upper story walls had been subdivided with an RC 'armature' which prevented the soft story collapse becoming a complete pancake collapse. This kept the occupants of the upper 3 stories from being killed

One important attribute of ACWs is the use of weaker mortar such as lime mortar, rather than stronger, but brittle, cement-based mortar. The objective is that the masonry units be stronger than the mortar, so that any movement within the walls occurs easily within the mortar joints, and between the masonry panels and the armature. The ACW technology can thus avoid the initial stiffness of infill walls in earthquakes by allowing the building frame to deflect uniformly across its entire height. This also will serve to reduce the effect of soft stories at the shop front level, which is now one of the most prevalent reasons for building collapse. The energy dissipation that results reduces the building's resonance with the earthquake. As the story drift of a building with ACWs increases over the course of an earthquake, the individual crosswalls, held up and reinforced by the armature, are squeezed within the deflecting frame of the building, thus serving to brace the frame from collapse.

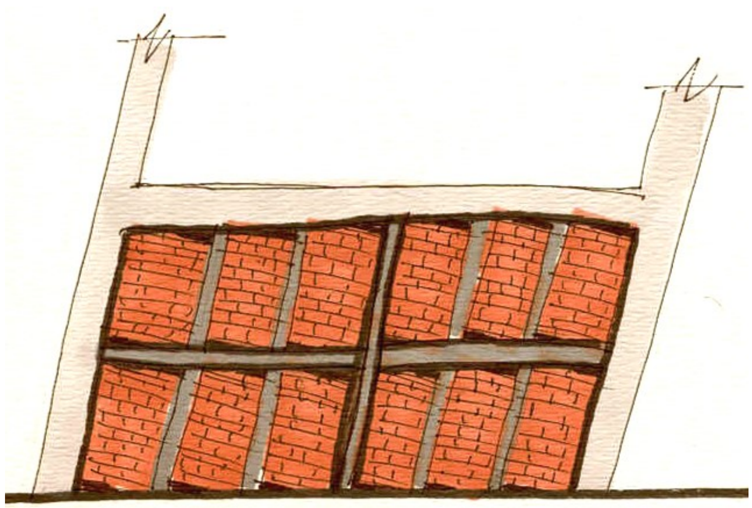


Figure 48: Diagram of the Armature Crosswall in an RC frame

Although the lateral distortion is less than shown, this sketch in **Figure 48** is meant to show the stability of an ACW under shear forces. It contrasts with **Figure 49** where a typical RC frame infill wall of brittle hollow clay tiles has collapsed out of its frame. This view is from inside a building that was partially collapsed by the 1999 Turkey EQ, but was not far from **Figure 50** of a *hımış* wall in a building shaken by the same earthquake forces but which remained undamaged except for the plaster surfaces. The house was immediately adjacent to several RC buildings that had collapsed in Düzce, Turkey.

Figure 49: Photograph taken in an upper story of a partially collapsed RC building in Gölcük

Figure 50: Masonry with timber armature hımış wall in Düzce, Turkey after 1999 Düzce earthquake

In summary, the purpose of the armature is to change the behavior of the wall when subjected to earthquake shaking so that the infill masonry will: (1) remain in place without falling out of the frame from either in-plane or out-of-plane forces, (2) add substantially to the lateral capacity of the building, (3) avoid development of an equivalent diagonal strut that can impose excessive loads onto the beam/column joint, (4) avoid propagation of diagonal tension cracks that can cause the infill wall to fall out of the frame, (5) allow increased flexibility within narrowly defined limits compared to standard infill walls, while resisting extreme excursions that place the stability of the frame at risk, and (6) dissipate substantial amounts of energy over many cycles of severe shaking, and by so doing, reduce the resonance of the structure with the earthquake vibrations (Langenbach, 2008; Langenbach et al., 2006). More information is available at http://www.conservationtech.com/armaturecrosswalls.html

11. Nepal and Gabion Bands

To conclude, I leave the discussion of frame constructions and turn to some of the most remote Himalayan village settlements in Nepal that were affected by the 2015 Gorkha earthquake. The 7.8M_w Gorkha earthquake of 25 April 2015 caused devastation over a wide area in Nepal, including Kathmandu where it devastated the most intact heritage sites of Patan Durbar Square and Bhaktapur. In Sindhupalchok District, it collapsed and destroyed many modern concrete buildings. There were approximately 9,000 fatalities. The 25th of April quake was followed by a Mw 7.3 aftershock on the 12th of May further to the east that killed an additional 200 people and caused damage in additional areas further to the east.

Figure 51: A role of Polypropylene geogrid sufficient for a small house is this easily carried on one's back, making the Gabion Band technology practical for reconstruction of houses remote from the roads high in the Himalayan foothills

Figure 52 (a&b): Construction of this first Gabion Band house with wire mesh bands is shown with the village mason together with the family whose house had fallen down. My instructions to the owner-builders and mason with translation by Nepali volunteers took less than an hour, and the construction of the walls to the roof-line took only 4 days.

Not unlike that which struck Pakistan Kashmir in 2005, the Gorkha earthquake bore the signature characteristic of rural earthquakes everywhere. However, for the reconstruction of the rural residential infrastructure, the situation in northern Nepal was even more extreme because many of the more rural settlements were high in the foothills of the Himalayas, the tallest mountains in the world, and thus many of these settlements were off the road network. This meant that they could not be reached by vehicles capable of carrying the loads of concrete and steel rebars that had been mandated as necessary for safe construction by the more urban-based professional engineers, architects, and building officials. It is for this reason that I have proposed a technology which I have named Gabion Bands (**Figures 51+52+53**).

The idea for Gabion Bands came about after an Australian colleague wrote an essay in which she said that construction-grade timber was in short supply and very costly in Nepal. While there are many trees in the foothills in northern Nepal where the earthquake damage was most extensive, these were often young softwood trees, which are particularly vulnerable to rot and termite attack. Moreover, they would have to be milled after they are cut, so that in many communities the timbers would have to be transported twice, even if grown near to the construction site.

Figure 53: Construction of the 1st Gabion Band house in Mankhu, Nepal showing the laying of the mesh and after it is wrapped around one course. (see also Figure 52)

As I have mentioned above, Nepal had already adopted a building code for non-engineered construction that very closely paralleled the one in India, complete with many of the same graphic images (**Figure 54**). In fact, one of the principal authors of the Indian code, Prof. Anand Arya of IIT-Roorkee had also consulted on the Nepal code. Thus the use of timber ring beams in bearing-wall masonry construction was already an accepted construction typology. When confronted with the problem with having enough affordable timber, I considered what could work as an alternative that would still provide the same or better seismic hazard mitigation provided by the timber ring beams embedded into the walls.

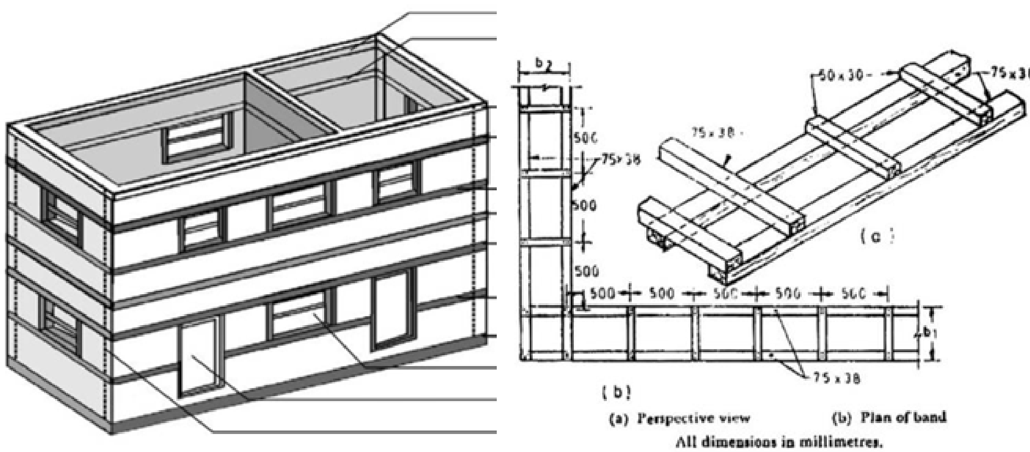


Figure 54: Illustration of timber bands from the Indian and the Nepal Building Codes for non-engineered buildings

Of course, timber would still be needed for the roofs and any floors (should the houses have elevated floors rather than the common simple gravel, dirt and cow dung floor laid on the ground) but the timber for these would most probably be available from the earthquake damaged or collapsed ruins of the previous houses. In addition, the wood to be embedded in the rubble masonry walls had to be more resistant to decay than does the wood (or bamboo) to be used for a roof, as it cannot be replaced or maintained without rebuilding the masonry walls – a strenuous and time consuming project.

The Gabion Bands concept is a simple one. In the same way as does the timber ring beams in the Code, it adds tensile resistance to lateral forces to a one or at most, a two story rubble stone wall by adding a series of ring beams over the height of the wall that are one to three feet apart over the height of the wall. Each of these ring beams consists of a single course (layer) of stones wrapped tightly in the wire or geogrid mesh. At first, I proposed to use a wire mesh (**Figure 52+53**), but after finding the welded wire mesh to be subject to corrosion because of low quality manufacturing, I switched to recommending the use of polypropylene geogrid, which has a long lifespan, especially in a dark environment, and also is very strong with low elasticity.

The idea behind the wrapping of single courses of stone, instead of wrapping the whole wall, is that (1) the polypropylene geogrid is within the wall where it is less subjected to exposure and other causes of breakage or deterioration, and (2) the geogrid forms what is effectively a beam laid into the wall that is flexible enough to remain bearing on the masonry should earthquake vibrations cause some of the stones below it to compress together or fall out.

The geogrid also provides a way of tying and confining the corners of a building with stone walls by being folded back to wrap and tie the corners in a way that is potentially much stronger and more effective than are the notched timbers of the timber ring beams in the code. At the top of the wall, a double layer or more of the wrapped stonework can be used to prevent the tops of the masonry walls from overturning, thus using the parapets or the upper wall courses that are embraced by the eves to provide the overburden weight that can help turn the attic floor into an effective diaphragm without the hazard of masonry falling off from the tops of the walls.

Figure 55: After learning of my Gabion Bands technology when it was featured on the US Public TV science documentary NOVA about the earthquake, a former Peace Corps volunteer John Vavruska of Santa Fe, NM, with Nepali expats from the village of Chupar, Nepal constructed this school building

Gabion Bands have also been proposed for one-story rural schools (**Figure 55**). Unreinforced stone masonry schools have been shown to suffer from two significant problems in addition to the lack of tensile reinforcement. One is that they do not have attics, so the stone walls that surround the classrooms are effectively like garden walls without being securely stabilized at the top, and second, the windows and doors in schools are most often only or mostly on the south sides of the building, resulting in what is in effect is a partial wooden framework on one side of the building which can resonate differently than the rest of the building, throwing the stones around it down.

Figure 56: School building totally collapsed in 2015 Ghorka Earthquake with sheet metal roof.

Figure 57: School building with front and rear walls still standing with a ceramic tile roof. (photos courtesy Nepal School Projects NGO)

In addition to these problems, over the recent years the customary stone slab or clay tile shingle roofs have now most frequently been replaced with galvanized corrugated steel (GCI) sheets which are extremely light. Engineers have frequently embraced this lightening of the tops of the buildings, but in actual fact, masonry must have overburden weight to have any hope of surviving being shaken apart in earthquakes. **Figure 56** shows a school collapsed in 2005 with a GCI sheet metal roof. The front stone wall is entirely destroyed. By contrast, **Figure 57** shows another unreinforced masonry school with both gable ends and all interior crosswalls collapsed, but the roof is a heavier ceramic tile which appears to have helped maintain the front and rear walls from crumbling down.

A report "*GABION BANDS": A Proposed Technology for Reconstructing Rural Rubble Stone Houses after the 2015 Nepal Earthquakes,*" with a more complete description of the Gabion Band technology, can be found on the web by clicking the title, or by going to http://traditional-is-modern.net/Nepal.html and finding it on that webpage.

The story of the Gabion Bands technology is an on-going one because, unlike the Government of Pakistan, through ERRA and NESPAK, which embraced *dhajji dewari* and *bhatar* construction after the wisdom of it became apparent in the remote rural areas of Kashmir, the Government of Nepal has continued to insist on reinforced concrete for bands if stone masonry construction is used, despite the difficulties of delivering such materials needed for it to remote rural locations and its high costs. Engineers connected with the Government of Nepal (Department of Urban Development and Building Construction (DUDBC), the Department of Education, and Nepal Reconstruction Agency (NRA) have been resistant to such technologies by citing the need for calculations when such technologies based on the reinforcement of all sorts of differently configured masonry walls of rubble stone with mud mortar do not lend themselves to being calculated, other than for the statics of dead weight.

Even the principal author of the Nepal Building Code, Richard Sharpe, has expressed opposition to this requirement by simply pointing out that the relevant code is specifically for non-engineered buildings, so requiring calculations for buildings even with what is intended to be a modification to the code, such as Gabion Bands instead of timber bands, is not appropriate. Specifically, the buildings to be reconstructed in rural areas of Nepal, just as they have been in Pakistan Kashmir, are almost all owner-built - which is why it is so important that the applicable code be for non-engineered construction. That is also why its instructions are identified and presented as rules of thumb.

The technology of Gabion Bands harkens back to an earlier age when a more empirical approach to engineering ruled the discipline. It is the approach which lay at the root of the design of the great structures of the world over the centuries of masonry construction and even unreinforced concrete construction, such as the Parthenon in Rome – a 2000 year old structure that would not be there today, had it been reinforced with steel. The need for calculations is an engineering approach that is caught on the fence of time. Mathematics has always existed in engineering, but for the most part it has been the statics of dealing with weight, while the calculations of the modern era are those used to calculate dynamic forces on frames rather than on masonry, including lateral forces on moment frames (The "equivalent diagonal strut" analogy for calculating the potential disruption to a reinforced concrete frame from the infill masonry is a good example of this modern method of using frame theory even for solid walls).

12. Conclusions

The government of Pakistan's endorsement of traditional construction techniques after the 2005 earthquake, described at the beginning of this paper, was not immediate. In May of 2006, only seven months after the earthquake, ERRA published a manual, *"Guidelines For Earthquake Resistant Construction Of Non-Engineered Rural And Suburban Masonry Houses In Cement Sand Mortar In Earthquake Affected Areas,"* in order show that what would be considered "*compliant*" with the government-approved standard for earthquake-resistant construction necessary for financial reimbursement would have to be cement concrete reinforced.

As in Nepal, the affected houses were predominantly rural, with urban housing accounting for only 10 percent of the total. A requirement that government assistance be limited to reinforced masonry with cement mortar would mean that the materials would have to be transported deep into the countryside where, as in Nepal, there are often no roads on which to deliver heavy materials as seen in **Figure 58** below. As described above, many of the families rendered homeless began rebuilding destroyed rubble masonry houses using their own locally grown timbers and stones from the fallen down houses, despite knowing that they would be ineligible for government financial assistance because the transport of required materials was impossible.

One of the difficulties, as reported by UN-HABITAT, was the fact that *dhajji* and *bhatar* construction had not been the subject of engineering research and no generally accepted analytical tools had been developed for it. This explains why many engineers, including those representing the World Bank and other donor agencies have difficulty accepting traditional construction, but it also explains why these traditional masonry-based systems need to be recognized and valued by engineers who have the people's cultural and financial needs at heart. In an effort to provide some professional credibility for the systems, UN-HABITAT prepared a report called *Build Back Better – Bhatar* authored by two structural engineers and an architect, which makes a strong case for the viability of *bhatar* as an earthquake resistant form of construction. It describes the structural characteristics of *bhatar* that give it its resilience. In brief, it says *"The fundamental principle of the bhatar system is dissipation of energy through friction (shear)."* In this report they deal with the argument over the conventional wisdom that calculations are needed by saying:

"Because of the inherent variability and complexity of the individual materials...it is not possible to accurately calculate or model the structural behaviour of the bhatar system. As the bhatar system relies on structural stability and energy dissipation rather than strength characteristics, standard calculation techniques appropriate for dynamic analysis of engineered structures have limited validity when applied to bhatar construction. Of greater value is the vast amount of empirical data available from post-earthquake reconnaissance, and historical evidence."

With the support of Army personnel who could see the practicality of using local vernacular techniques in the mountain areas and the urgency of the need for disaster assistance funding in this historically volatile region, *bhatar* was approved by ERRA in July 2007. While overseeing a program covering the construction of 630,000 new and repaired houses, Waqas Hanif, the ERRA Programme Manager for Rural Housing, came to embrace both *dhajji* and *bhatar* and thus was key in ensuring both were approved as compliant.

Despite the time and effort that it took, architect Tom Schacher observed that "the readiness of the engineering consultants to the government to review their dogmas and approve construction practices hitherto unknown to them, and for which they often didn't have the required scientific evidence, was extraordinary" (Schacher, 2008) (**Figure 59-61**). His finding is certainly confirmed by the contrast between what he observed in Pakistan with that which I have described that is still on-going in Nepal.

PLEASE NOTE that I recommend against the use of diagonals that tightly confined in a box shape in the framework as shown in **Figure 61(a)** because they prevent the masonry from yielding in the way described above, which then allows the movement and energy dissipation that are intended to be features of the Armature Crosswall system. **Figures 4** and **61(b)** illustrates a more traditional, and in my opinion, more effective, arrangement of cross-bracing between the studs.

This history in Pakistan is significant for a number of reasons. Not only has the earthquake made it clear to the government and affected citizens alike that there is a need for more structurally sound and earthquake resistant construction, even in rural areas, it has also served to bring urbanized and university-educated architects and engineers into contact with the culture and indigenous building crafts characteristic of the rural regions.

Figure 58: Hand carrying of cement blocks to a reconstruction site remote from the road in Pakistan after the 2005 earthquake (Photo courtesy of ERRA)

Figure 59: Teaching improved anti-seismic masonry construction to rural masons in Pakistan by SDC and UN-HABITAT with support from ERRA

Most observers had long identified non-engineered traditional masonry construction of all types as archaic and unsuitable for contemporary living, particularly in an earthquake area, but after such a devastating earthquake, they could witness for themselves what survived and what failed. The interaction between the foreign humanitarian technical support teams both with the local engineers and government officials and the local population was crucial in what actually became a creative two-way technology transfer. Before either dhajji or bhatar could be adopted, both the foreign and the Pakistani professionals had to jettison their pre-existing prejudices to accept and improve upon premodern systems that were taught to them by the local people themselves. This stands as a remarkable example of openness, creativity, and acceptance at all levels (Schacher, 2008).

Figure 60: Sample *bhatar* structure for masons training as described for Figure 59

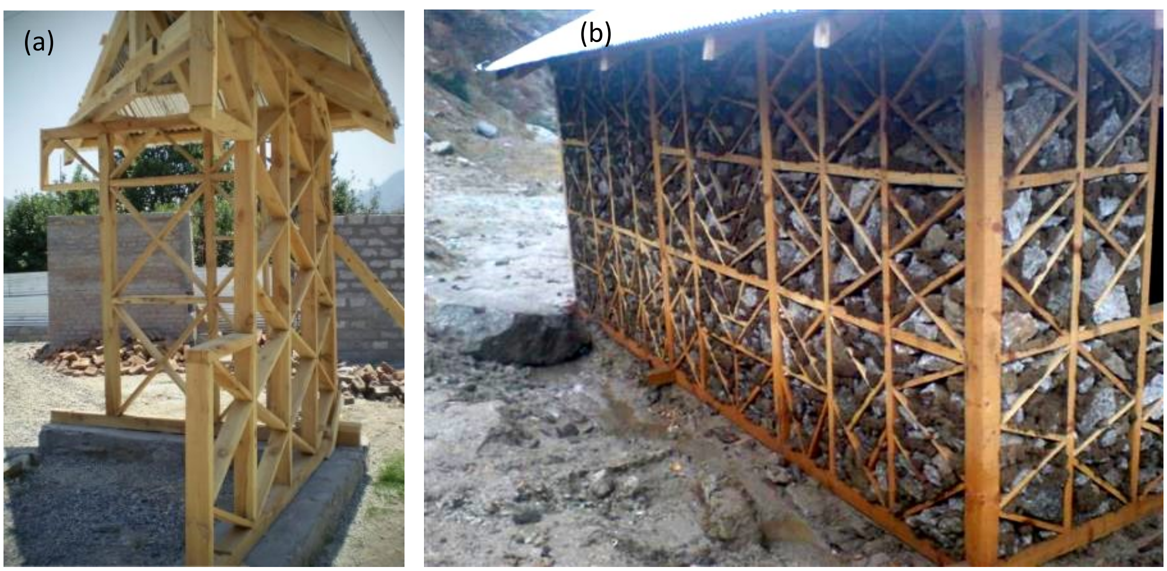


Figure 61: Samples dhajji structure for masons training as described for Figure 59. As mentioned in the paper, I have recommended against the use of such rigidly inserted diagonals as seen in (a), in preference to those which are less likely to jack apart the corners as seen in (b) and also in the traditional construction shown in Figure 4 allows more lateral movement of the masonry infilled frame without breaking apart of the frame

Akcnowledgements

I thank UNESCO, and specifically Minja Yang, Executive Director of UNESCO New Delhi, and Rafique Khan of Srinagar and Los Angeles, for the publication and printing of my book: *Don't Tear It Down! Preserving the Earthquake Resistant Vernacular Construction of Kashmir.* For hosting me in Pakistan and taking me on a reconnaissance through the damage district in Pakistan Kashmir and Khyber Pakhtunkhwa, I thank Architect Tom Schacher of the Swiss Agency for Development and Cooperation (SDC) and Maggie Stephenson of UN-HABITAT. For the opportunity to demonstrate the Gabion Bands, I thank the filmmakers and WGBH Boston, USA for the opportunity to be filmed as a part of the documentary *Himalayan Megaquake* shown on the TV science series *NOVA.*

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