PROCEEDINGS OF THE

1ST INTERNATIONAL CONFERENCE ON NEW TRENDS IN CIVIL ENGINEERING (NTCE)

ORGANIZED BY

University of Central Punjab, Pakistan
National Engineering Service, Pakistan
(NESPAK)

In Collaboration with

Ittefaq Construction Associates
Izhar Construction Limited
Union Developers Limited

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- Prof. Dr. Aziz Akbar, UET, Lahore
- Dr. Imran Rasool, NESPAK

Keynote Speakers

Dr. Sergi Saurí Marchán

Dr Sergi Sauri has been the Director of CENIT since 2013 and a part-time lecturer at the Department of Civil and Environmental Engineering of UPC-Barcelona University. He is also the President of the University Network RUITEM. He holds a PhD in Civil Engineering, a Bachelor’s Economics, and a Master’s Degree in Shipping Business. Dr. Sauri is a member of the Infrastructure Committee of Infrastructure Financing of the Professional Association of Civil Engineers of Catalonia.

Dr. Tarunjit Singh Butalia

Dr. Tarunjit Singh Butalia is Research Associate Professor at The Ohio State University and serves a Dias OSU Coal Combustion Products Program Director is an Affiliated Faculty with OSU Sustainability Institute.

Dr. Askar Zhussupbekov

Askar Zhussupbekov earned his Diploma of Civil Engineering in 1977 and his PhD 1985 from Saint-Petersburg State Architectural and Civil Engineering University in Russia. He later received his Doctor of Science degree from Karaganda State Technical University in Kazakhstan in 1996.

Zhussupbekov worked at the Department of Civil Engineering of Karaganda State Industrial University and became the Head of the Department of Civil Engineering in 1987. He was also appointed as the First Vice-Rector of the same university in 1999. In 200, he became a professor at the Department of Civil Engineering of Eurasian National University in Astana, Kazakhstan.

Prof. Dr. Salman Azhar

Dr Salman Azhar is an accomplished academic and researcher in civil engineering. He holds a Ph.D. in Engineering from Florida International University, a Master of Engineering in Structural Engineering from the Asian Institute of Technology, and a B.S. in Civil Engineering from the University of Engineering and Technology currently serves as the Chair of the Ph.D. in Building Construction Program and the Master in Building Construction (MBC) program. His research interests include Building Information Modeling, VR/AR/MR technologies, Construction Safety, Risk Management, and International Construction.

Engr.Tatiana Tronda

Tatiana Tronda is a highly qualified engineer with extensive experience in geotechnics and structural mechanics. She is currently serving as a Senior Lecturer at the Department of Geotechnics and Structural Mechanics at the Belarusian National Technical University. She obtained her Bachelor's degree in Industrial and Civil Engineering from the Belarusian National Technical University in 2011, where she also supervised Undergraduate project at the Department of Geotechnics and Ecology. In 2012, she obtained her Master's degree in Civil Engineering from the same university, with her Master's dissertation also focusing on geotechnics and ecology. From 2012 to 2015, she pursued a researcher's program in Bases and Foundations, Underground Structures at the Belarusian National Technical University, further solidifying her expertise in the field.

Preface

We are delighted to present this preface to the Proceedings of the 1st International Conference on "New Trends in Civil Engineering," organized by the University of Central Punjab. This landmark conference brought together professionals, researchers, academicians, and students from across the globe to explore and discuss the latest advancements and emerging trends in the field of civil engineering. Held on [date], this conference served as a catalyst for knowledge exchange and collaboration, propelling the discipline towards new frontiers.

The conference witnessed an impressive gathering of local and international guests and speakers, who brought their expertise and diverse perspectives to the table. Their invaluable contributions enriched the conference and set the stage for engaging discussions, thought-provoking presentations, and fruitful networking opportunities. We express our heartfelt gratitude to all the participants for their active involvement and commitment to advancing the field of civil engineering.

To ensure maximum accessibility and participation, the conference adopted a hybrid format, blending physical and virtual elements. This innovative approach allowed participants from around the world to join the conference remotely, fostering a truly global community of researchers and practitioners. The hybrid nature of the event ensured that geographical boundaries did not hinder the exchange of ideas and facilitated the dissemination of knowledge to a wider audience.

The conference encompassed five distinctive technical sessions, each dedicated to a specific area of civil engineering. These sessions focused on structural engineering, water and environmental engineering, transportation engineering, geotechnical engineering, and construction management. Participants presented their research findings through paper and video presentations, covering a broad range of topics and shedding light on the latest advancements, challenges, and solutions in each field.

The Proceedings of this conference serve as a comprehensive compilation of the research papers and presentations delivered during the event. This collection represents a significant contribution to the field of civil engineering, showcasing the innovative ideas, methodologies, and technologies shared by esteemed researchers and industry experts. We believe that these Proceedings will inspire further exploration and serve as a valuable resource for researchers, practitioners, and students seeking to stay at the forefront of the discipline.

Prof. Dr. Muhammad Rizwan Shad
Chairman
UCP, Lahore

Welcome Address
Pro-Rector

Chairman Prof. Dr. Muhammad Rizwan Shad Chief Guests from NESPAK, Union Developers, Ittefaq Construction Associate, all the deans and honorable speakers from across the world, ladies and gentleman!
Assalam-o-Alaikum.
Firstly, I would like to welcome you all at here at UCP Lahore on this wonderful knowledge-sharing platform on 1^{st} international conference on New trends in Civil Engineering.

It is needless to say that such activities of bringing academia and industry to sit and share experience and innovation should be staged more frequently than ever.

Today, having so many stakeholders from Structural, Water, Environmental, Transportation, Geotechnical Engineering and Construction Management industry and academia under one roof, I would like to briefly talk about the prospects of initiating research and development partnerships between the faculty and the practitioners. I believe, the Engineering industry, like others, often face unique and unprecedented challenges in pursuing projects involving innovative applications to achieve sustainable, eco-friendly, and economical outcomes. As evident by the rapid modernization of West, the full-time dedicated groups of professionals, such as university faculty, are pertinent to understand new problems and devise desirable solutions in a controlled environment that would be implicated to extended scales in the field. For instance, the Department of Civil Engineering at UCP has a significant number of faculty members having high-end PhD degrees and post-doctorate experiences with significant research contributions such as high-quality patents and journal publications. Cutting short, I invite the Engineering industry to liaise with our faculty members through linkage grants, meaningful industrial collaborations, and effective partnerships. Instead of signing meaningless and peripheral MoUs, let's initiate actual investments from field giants like Union Developer's, Ittefaq Construction Associated, Nespak, Wapda, Irrigation, C&W, LDA, ACE, Descon and others.

Besides, I would also like to shed light on UCP Lahore's contributions to the field of Engineering. Being the oldest school of Engineering in Pakistan, we have been effectively contributing to almost all existing venues across country. UCP Lahore produces engineers capable of leading from the front; be it bureaucracy, technocracy, diplomacy, politics, or even armed forces. I am sure, even this very hall is full of UCP alumni, leading and serving humanity and making us proud. Over the decades, we have been producing some of the finest civil engineers here at the campus, who continue to strive and contribute to both state-of-the-art and state-of-the-practice in and out of the country.

I would now like to wrap up quickly by reiterating UCP's firm commitment with the nation to continue to raise our graduate quality through all possible means. I would also urge our industry to extend their helping hands through direct and generous investments in research and education at UCP Lahore. Lastly, I wish this event a great success and hope it would further enhance the knowledge of the Engineering community and enhance International cooperation in this field.

Once again, welcome to UCP Lahore!

Long live Pakistan.

Welcome Address
Prof. Dr. Muhammad Rizwan Shad
Dean Faculty Of Engineering

Chief Guests from NESPAK, Union Developers, Ittefaq Construction Associate, all the deans and honorable speakers from across the world, ladies and gentleman!

Assalam-o-Alaikum.

It is my pleasure to welcome you all to the 1^{th} International Conference on New Trends in Civil Engineering organized by UCP Lahore. We welcome the distinguished speakers, presenters and guests attending the conference.

UCP vision is to become an internationally acclaimed university in teaching and research. Faculty of Engineering also devoted to the pursuance of the university's vision. I would like to appreciate our savant faculty who is always striving for eminence in research by introducing new trends and techniques.

Today, a number of interesting and high-level technical papers will be presented. Our keynote speakers have taken deep interest to either travel all the way for participating in this big event or have chosen to deliver in hybrid mode. We are particularly grateful to Dr. Tarunjit Singh Butalia from U.S.A, Dr. Askar Zhusspbekov from Kazakhstan, Ms. Tatiana Tronda from Belarus, Dr. Salman Azhar from U.S.A, DR. Muhammad Awais Shafique from Barcelona Spain and Dr. Sana from Dubai. Various technical papers will be presented in five technical sessions of this conference, today and tomorrow, which I am sure will provide useful information and add to the current state of knowledge.

Thank you so much for sparing your valuable time to participate in this event. My special thanks to the all the participants attendees, for this utmost cooperation to hold the international conference at their institution. I thank the organizing committee, its chairman Prof. Dr. Muhammad Rizwan Shad, Co-chairman Engr. Sohail Kibria and vice-chairman Prof. Dr. Kafeel Ahmed as well as the staff of UCP, NESPAK, Union Developers and Ittefaq construction Associates who made this event a big success. My special thanks are due to all our Sponsers and exhibitors who have helped us to bring forth this event in a befitting manners.

1ST INTERNATIONAL CONFERENCE ON

NEW TRENDS IN

CIVIL ENGINEERING

University of Central Punjab-NESPAK

Conference Schedule

Conference Day One 20-Mar-2023

A World of New Ideas

8:30 AM – 9:45 AM Registration and Reception

Inaugural Session (Venue: Auditorium Hall)

10:00 – 10:05	Recitation of the Holy Quran and National Anthem
10:05 – 10:15	Welcome Address by Conference Chairman: Prof. Dr. Muhammad Rizwan Shad
10:15 – 10:20	Address by Conference Co-Chairman: Engr. Sohail Kibria
10:20 – 10:25	Address by Conference Vice-Chairman: Prof. Dr. Kafeel Ahmad
10:25 – 10:40	Inaugural Address by Chief Guest: Dr. Tahir Masood, MD NESPAK
10:40 – 10:55	Keynote Speaker: Dr. Sana Amir, University of Wollongong
10:55 – 11:05	Address by Pro-Rector UCP: Prof. Dr. Nassar Ikram, HI(M) SI(M)
11:05– 11:15	Distribution of Shields
11:15– 11:45	**Tea Break and Group Photo**

Technical Session 1 (Venue: Auditorium Hall)

Session Chair:	Prof. Dr. Zahid Ahmad Siddiqi Session Co-chair: Dr. M. Awais Shafique
11:45 – 12:05	Keynote Speaker: Dr. Sergi Saurí Marchán, Director CENIT, Spain
12:05 – 12:20	Paper Presentation: "*Cracks in structures due to Geotechnical reasons identification, causes and mitigation*" by Engr. Sohail Kibria
12:20 – 12:35	Paper Presentation: "*Development, Investigation, and upscaling of Construction Composites incorporating Cement Replacement Material*" by Dr. Irfan ul Hassan.
12:35 – 12:50	Industrial Field Talk: "*Diamer-Bhasha Dam: Game Changer for Pakistan*" by Dr. Tahir Hayat
12:50 – 01:05	Paper Presentation: "*Development of One-Part and Two-Part slag based Geopolymer Brick*" by Dr. Khurram Rashid

01:05 – 01:20	Industrial Field Talk: "*Designers' Prime Focus on the Basics – A casualty of the Explosion of Digital Computational Power*" by Engr. Rizwan Mirza
01:25 – 01:35	Industrial Field Talk: "*Climate Change Impact Assessment-A Case Study of Mohmand Dam Project*" by Engr. Shariq Ahmad
01:35 – 01:50	Question and Answer Session
01:50 – 02:00	Concluding Remarks and Distribution of Shields
02:00 – 03:00	**Lunch and Prayer Break**

Technical Session 2 (Venue: Auditorium Hall)

Session Chair:	Engr. Rizwan Mirza Session Co-chair: Dr. Irfan ul Hassan
03:00 – 03:20	Keynote Speaker: Dr. Tarunjit Singh Butalia, Ohio State University, USA
03:20 – 03:35	Paper Presentation: "Autonomous Personal Pods as a replacement for cars" by Dr. M. Awais Shafique.
03:35 – 03:50	Paper Presentation: "*Effect of Specimen Type and Size on Strength Properties of Recycled Concrete Aggregate*" by Dr. Sana Amir.
03:50– 04:05	Industrial Field Talk: "*Home the Homeless*" by Engr. Hafiz Abdullah Mahmood, CEO, Ittefaq Construction Associates.
04:05 - 04:20	Industrial Field Talk: "*Use 3D Drone mapping and data analytic to plan and solve day-to-day civil construction and earthworks operations*" Paper Presentation by Engr. Khubaib Qasim, Seymour Whyte Constructions, Australia
04:20 – 04:35	Paper Presentation: "*Study of Geo-polymer Concrete Using Locally Available Materials*" by Dr. Zahid Ahmad Siddiqi
04:35 – 04:50	Question and Answer Session
04:50 – 05:00	Concluding Remarks and Distribution of Shields

Technical Session 3 (Venue: Auditorium Hall)

Session Chair:	Engr. Sohail Kibria, NESPAK Session Co-chair: Dr. Muhammad Babur
10:00 – 10:20	Keynote Speaker: Dr. Askar Zhussupbekov, Professor, L.N.Gumilyov Eurasian National University, Kazakhstan
10:20 – 10:35	Paper Presentation: "*Decision Making for Sustainable Construction System through BIM and MCDM Integration*" by Engr. Khadija Mawara.
10:35 – 10:50	Paper Presentation: "*Comparison of Compaction and Consolidation Behavior of Fine Soil Using Treated Wastewater and Tap Water*" by Engr. Irfan Khalid.
10:50– 11:05	Industrial Field Talk: "*Introduction to BIM, standard workflow and implementation challenges in Pakistan*" by Muhammad Zain Mushtaq, Union Developers
11:05 – 11:20	Question and Answer Session
11:20 – 11:30	Concluding Remarks and Distribution of Shields
11:30 – 12:00	**Tea Break**

Technical Session 4 Parallel Session (Venue: Auditorium Hall)

Session Chair:	Dr. Javed Uppal Session Co-chair: Dr. Khurram Rashid
12:00 – 12:15	Keynote Speaker Prof. Dr. Salman Azhar, University of Auburn, USA

12:15 – 12:30 Paper Presentation: "*Evaluation of mechanical behavior of concrete with partial replacement of coarse aggregate by recycled coarse aggregate with and without SBR latex.*" by Engr. Usman Ali

12:30 – 12:45 Industrial Field Talk: "*Modern trends of construction materials in Pakistan*" by Dr. Wajahat Mirza

12:45 – 01:00 Paper Presentation: "*Attribution analysis of runoff change by using SWAT model a case study of Khanpur dam catchment*" by Dr. Muhammad Shahid

01:00 – 01:30 Industrial Field Talk: "*External developers or When different developers have interests in the same area*" by Engr. Olena Alizi, with "*Effect of Early Contractor Involvement in Statens Vegvesen Projects*" by Engr. Syed Hamza Tariq Bukhari with "*Changes in road technology to contribute to sustainability goals*" by Engr. Beenash Shahzadi : Viken County Municipality, Norway

01:30 – 01:45 Question and Answer Session

01:45 – 02:00 Concluding Remarks and Distribution of Shields

02:00 – 03:00 Lunch and Prayer Break

Parallel Session (Venue: Transportation & Highway Lab)

Session Chair: Prof. Dr. Muhammad Saeed Shah Session Co-chair: Engr. Muhammad Arshad

12:00 – 12:10 Paper Presentation: "*Energy Efficiency Potential of Natural Fiber based Composite Building Material.*" by Engr. Khadija Mawara.

12:10 – 12:20 Paper Presentation: "*Investigation of clay-based Geo-polymers with industrial wastes"* by Engr. Noor Yaseen

12:20 – 12:30 Paper Presentation: "*Investigating Performance of Asphalt Concrete Using Waste Material as Bitumen Modifier*" by Engr. Arfa Tariq

12:30 – 12:40 Paper Presentation: "*Sustainable Construction by Using Steel Chips as a Partial Replacement of Cement*" by Engr. Asad ur Rehman

12:40 – 12:50 Paper Presentation: "*Cost-Effective Energy Efficient Practices for an Existing Residential Building*" by Engr. Mahnoor Arif

12:50 – 01:00 Paper Presentation: "*Battling Environmental Pollution in Lahore: The Importance of a Sustainable Transportation System*" by Engr. Muhammad, Momin Amer

01:00 – 01:10 Paper Presentation: "Causes of flood its damages and measures taken by the government: A case study on District Dera Ghazi khan" by Engr. Maria Talib

01:10 – 01:20 Paper Presentation: "*Cost comparison of clay bricks and concrete blocks in the residential house: A case study*" by Engr. Muhammad Usama

01:20 – 01:30 Paper Presentation: "*Design and Cost Comparison of selected long-span structural systems*" by Engr. Tanveer Younas

01:30 – 01:45 Question and Answer Session

01:45 – 02:00 Concluding Remarks and Distribution of Shields

Technical Session 5 (Venue: Auditorium Hall)

Session Chair: Dr. Wajahat Mirza Session Co-chair: Dr. Khawaja Bilal Ahmed

03:00 – 03:20 Keynote Speaker Engr.Tatiana Tronda, Belarus

03:20 – 03:35 Paper Presentation: "*Effect of addition of Waste Engine Oil and Waste Cooking Oil on Engineering properties of a bitumen*" by Engr. Waqas Haroon

03:35 – 03:50	Industrial Field Talk: "*Efficacy of Safe City Project in improving Urban Management*" by Engr. Amir Ashraf
03:50 – 04:05	Paper Presentation: "*Building Energy Analysis of a Typical House with Conventional Masonry Walls and Comparison with Cavity Wall Construction*" by Engr. Sahar Iftikhar
04:05 – 04:20	Industrial Field Talk: "*Smart Construction Solutions*" by Engr. Ali Mukhtar (Sr. Manager Projects) Izhar Construction (Pvt) Limited
04:20 - 04:30	Industrial Field Talk: "*Launching of Grade 80 Steel & Its Benefits in Pakistan*" by Sohaib Afzal Rana, Chief Marketing Officer, FF Steel
04:30 – 04:45	Question and Answer Session
04:45 – 04:55	Concluding Remarks and Distribution of Shields
04:55 – 05:00	Closing Conference Remarks from Conference Vice-Chairman: Prof. Dr. Kafeel Ahmad

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TECHNICAL SESSION I

VENUE; AUDITORIUM HALL

University of Central Punjab
20 March – 21 March 2023

CHAIR PERSON

PROF DR. ZAHID AHMAD SIDDIQI

CO-CHAIR PERSON

DR. M. AWAIS. SHAFIQUE

NEW TRENDS IN CIVIL ENGINEERING

Cracks in Structures Due To Geotechnical Reasons Identification, Causes, and Mitigation

Sohail Kibria
Geotechnical Engineering
Lahore, Pakistan
(sohailkibria18@yahoo.com)

Tahir Masood
(tmasood267@yahoo.com)

Sadaf Saeed
(sadaf_778@hotmail.com)

M. Tayyab Javed
(tayyabjaved66@yahoo.com)

***Abstract* -- The study of cracks in structures has hitherto, received little attention from the civil engineering profession and as such, remains a rather grey area, calling for more systematic research. The manifestation of structural behavior in the form of development of cracks of various types is a strong performance indicator of structures and an important factor to be considered in the performance-based design.**

There are a variety of cracks which have been observed in the structures, from during-construction to serviceability stages, due to a host of reasons. They may be due to structural, geotechnical, environmental etc. factors.

This paper provides a qualitative dossier on the development of cracks in the structures at various stages, mainly on account of geotechnical factors at the back. The prime causative reasons for such behavior have been differential settlement or differential upheaval. The identification of such cracks along with the causative factors and their mitigation strategy as well as some discussion on the selected case histories have been presented in this paper. The importance of location, width and orientation of such cracks has also been duly emphasized.

It is believed that the contents of this paper will provide useful guidelines for the identification, evaluation and mitigation of cracks in structures. Besides, strategies could be formulated at the design stage to prevent such unwanted performance of structures, owing to geotechnical reasons.

- **Head Research and Development, NESPAK, Pakistan**
- **Managing Director, NESPAK, Pakistan**
- **Principal Engineer, NESPAK, Pakistan**
- **Senior Engineer, NESPAK, Pakistan**

I. INTRODUCTION

The structures designed by civil engineers do develop cracks, insignificant or serious, during their construction as well as during their service life. There are a variety of reasons behind the development of such cracks and may be attributed to the type of materials being used, construction methods, structural design related issues, geotechnical related issues including improper appreciation of ground conditions and / or change in the geo-environmental conditions post-construction.

Ascertainment of the right reason(s) behind the development of cracks is a complex problem and often requires a comprehensive study by experts of diverse specialties including structural engineering, geotechnical engineering, earthquake engineering, engineering geology, hydraulics engineering etc. Quite often, the cracking of a structure manifests a number of causative factors. The cracking may be of primary nature due to the main reason / deficiency or it may be a secondary manifestation of the primary reason.

In order to establish that the primary reason behind the crack development in a structure is geotechnical, it is of utmost importance to give a serious thought to the earlier conditions too, before construction, to delineate the causes and then to plan mitigation.

The cracks in structures may vary in width from less than 0.1 mm (insignificant) to more than 25 mm (threatening), depending upon whether they are just hairline, only serviceability is impaired or structural stability is at risk. Table-1 provides the classification of extent of damage based on cracking of structures.

It is the foundation movement owing to geotechnical reasons, which is the basic condition for the development of cracks in structures. This movement may be further classified as follows:

- Settlement
- Upheaval
- Lateral movement in horizontal fashion
- Sliding on / in slope

The above movement patterns are discussed in succession below, along with some practical case histories.

II. SIMPLIFIED CRACKING PATTERN IN STRUCTURES

TABLE I. BRE Classification of Damage (based on ease of repair of damage)

Category of damage	Description of typical damage (Nature of repair in italic type)
0	Hairline cracking which is normally indistinguishable from other causes such as shrinkage and thermal movement. Typical crack widths 0.1 mm. *No action required.*
1	Fine cracks which *can easily be treated using normal decoration.* Damage generally restricted to internal wall finishes; cracks rarely visible in external brickwork. Typical crack widths up to 1 mm.
2	*Cracks easily filled. Recurrent cracks can be masked by suitable linings.* Cracks not necessarily visible externally; *some external repointing may be required to ensure weather-tightness.* Doors and windows may stick slightly and *require easing and adjusting.* Typical crack widths up to 5 mm.
3	Cracks which *require some opening up and can be patched by a mason. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.* Doors and windows sticking. Service pipes may fracture. Weather-tightness often impaired. Typical crack widths are 5 to 15 mm, or several of, say, 3 mm.
4	Extensive damage which *requires breaking-out and replacing sections of walls,* especially over doors and windows. Windows and door frames distorted, floor sloping noticeably[1]. Walls leaning[1] or bulging noticeably; some loss of bearing in beams. Service pipes disrupted. Typical crack widths are 15 to 25 mm, but also depends on number of cracks.
5	Structural damage which *requires a major repair job, involving partial or complete rebuilding.* Beams lose bearing, walls lean badly and require shoring. Windows broken with distortion. Danger of instability. Typical crack widths are greater than 25 mm, but depends on number of cracks.

Crack is a sign of stress relief in all the materials. The tensile cracks indicate the direction of pulling out by tensile stresses, orthogonal to the plane of crack. The shearing cracks do show up due to sliding failure along a shear plane under the action of shear stresses. Shrinkage cracks, on the other hand, are owing to high heat of hydration which in turn depends on the type of cement, ambient temperature, the thickness / size of concrete pour etc.

General cracking pattern in a structure can be understood in a simplified manner by the theory of bending with a beam analogy. On a simply supported beam, the downward pressure in the form of a uniformly distributed load will result in its sagging while the upward pressure will cause its hogging.

Both, sagging and hogging of a simply supported beam (Figure-2), though develop maximum tensile stresses on the outermost fibers yet they have specifically different crack patterns as outlined below:

- Sagging of a beam results into development of maximum tensile stresses on its bottom-most fibers. This would mean that such cracks will have maximum width at the bottom which will reduce while going up. The cracks close to center of the beam will remain close to vertical while at the edges will become diagonal, making acute angles with the horizontal.

Figure 1. Different Patterns of Movement and Cracking Caused by Subsidence and heave

(a)

(b)

Figure 2. a) & (b): Flexural Crack Pattern on Hogging (a) and Sagging (b) in a Simply Supported Beam

- Hogging of a beam, on the other hand, results into development of maximum tensile stresses on its top-most fibers. This would mean that such cracks will have maximum width at the top which will reduce while going down. The cracks close to center of the beam will remain close to vertical while at the edges will become diagonal, making obtuse angles with the horizontal.

The direction and shape of such cracks are shown in Figure-2 (a) and (b). This cracking pattern grossly prevails in the actual structures too, which may undergo sagging or hogging, because of ground movements. In case of higher order settlement, the diagonal cracks are associated with a series of horizontal cracks. Besides, vis-à-vis a simply supported beam, structures would have abutting / connecting wall, slab and beam elements, which modify the distribution and appearance of cracks understood on the basis of simple beam analogy, mainly due to their restraining effects. In addition, the variation in the subsurface characteristics further affect the distribution and size of cracks. Therefore, understanding and interpreting the cracking pattern in a structure due to foundation / ground movements becomes a complex problem requiring thorough studies of the structural details and ground variations as well (Figure-1).

III. SETTLEMENT OF FOUNDATIONS

The settlement of foundations resulting into cracking of structures is a very common scenario in civil engineering. The settlement or vertical movement may be slow or quick, based on various factors. Excessive settlement may damage the structure too, particularly if it is differential. The following settlement types are expected:

- Elastic settlement
- Consolidation settlement
- Settlement upon collapse of soil structure
- Settlement due to erosion / material migration
- Settlement due to cavity collapse

Settlement or vertical movement of structures by any of the above mechanisms may cause development of cracks particularly if the rate of settlement is high, total magnitude of such settlements are excessive, excessive ground variations are there, foundation system is not rigid enough etc. However, excessive differential settlement may result into damage of the whole or a part of the structure.

The elastic or immediate settlement of foundations is generally small, though instantaneous, and is not likely to result into development of cracks in the structure.

Consolidation settlement is a long-term phenomenon and when its magnitude is high, like in fully saturated soft clays, it may result into large amount of differential settlement and hence cracking and / or tilting of the structure will be there (Figure-3). The size, pattern and distribution of cracks is however dependent on the overall sag or hog pattern of deflection of structure or its parts and the abutting structural elements. In case of higher order settlement, the diagonal cracks are associated with a series of horizontal cracks (Figure-4).

Figure 3. Wall movement of an existing structure at Pakpattan

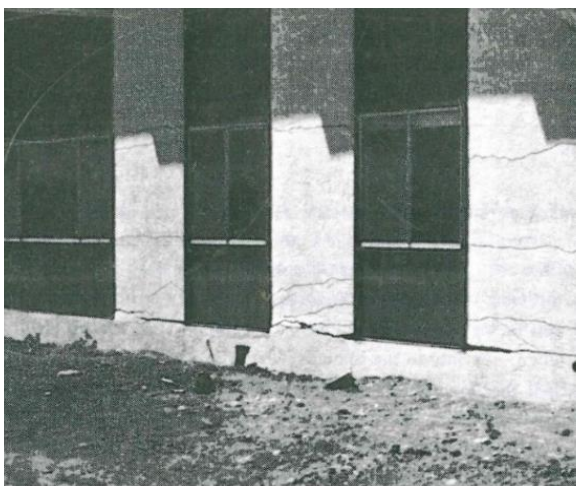
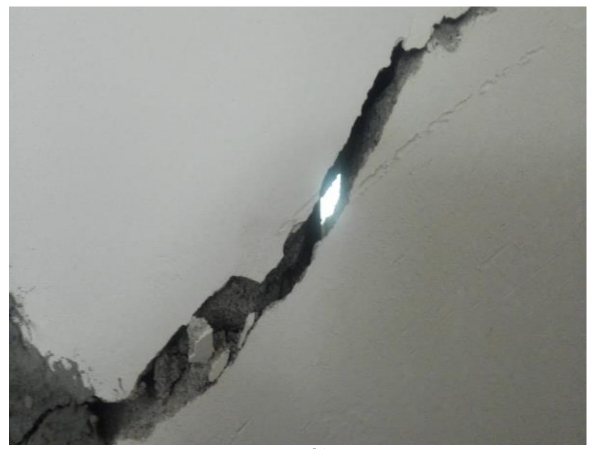


Figure 4.Series of Horizontal Cracks Due to Excessive Settlement

Figure 5. Runway cracks at PAF Base at Bholari

(a)



(b)

Figure 6. Settlement cracks in customs buildings at new Islamabad Airport

A government hospital building located in Said Mitha Bazar in the walled city of Lahore, is sited on thick wet weak cohesive fill. Following its construction in 1997, it was observed to have excessive cracking of various types in the year 2000 due to unequal settlement of mat foundation of unusual geometric shape, based on the clear land area available for construction. The mat rested on weak thick fill in wet condition. Further, cracked abandoned latrines on weak fill were found at Baba Fareed Shrine, Pakpattan (Figure-13)

Customs Building was constructed at New Islamabad International Airport in 2018. Hairline cracks appeared in the structure immediately afterwards. These cracks widened progressively in the coming months and were attributed to the differential settlement of the underlying improperly compacted fill material. This problem was accentuated after wetting of the fill with rain water and some diagonal cracks became as wide as 40 mm (Figure-6).

Settlement upon collapse or breakdown of the structure / skeleton of a soil mass takes place essentially upon wetting, as the temporary bond between the particles at their contact gives way. It is extremely detrimental for structures as it happens suddenly and can be fairly excessive based on the open-ness in the soil structure and the pressure at the instant of wetting. In general, silts and sands having dry density below 1.4 g/cm^3, are particularly considered vulnerable to collapse. The clinker kilns of Lucky Cement Plant located at the foothills of Sulaiman Range in the piedmonts had settled more than a meter more than twenty five years ago, following rainfall in the hills, due to collapse of the soil structure. The excessive foundation movement consisted of vertical settlement and tilting. However, light substation structures at Sahiwal and Galadari Cement Project at Hub were safeguarded against the possible collapse of ground upon wetting by ground improvement, pre-wetting and adopting appropriate foundation types. Settlement due to erosion of soil by piping / underground material migration or

Undercutting along a flow channel may follow crack development in the structure. Sagging / hogging may take place in the structure due to material movement from the ground while the structure on the undercut river bank may be subjected to lateral push or rotational failure of the slope, as well.

Presence of cavities, small or big, in the ground at certain depth is a geologic phenomenon. Any settlement on account of cavity subsidence is sudden and is likely to have catastrophic results ranging from settling excessively, tilting, and cracking or complete destruction of the structure.

IV. MOVEMENT DUE TO UPHEAVAL

The upward movement of parts of a structure takes place on account of differential upheaval, which is mainly due to the presence of expansive soils. Expansive or swelling soils will undergo increase in volume upon wetting by any means, owing to the presence of swelling minerals (like montmorillonite) in soil. The lighter the structure, the more severe will be the uplifting tendency which also increases with the increase in the swell potential of the soil (Figure-7). The cohesive soils having less than 15% natural moisture content, having swelling exceeding 1% and swell pressure more than 1.5 kg/cm^2 are particularly considered vulnerable for the upheaval of 1-2 storey structures.

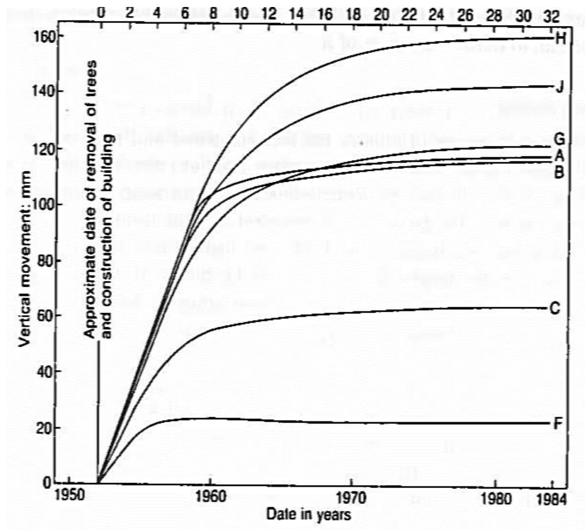


Figure 7. Upheaval in Shrinking Soil / Expansive Soil

In hogging, the pattern of cracks may be a well-defined hog in a part of the structure. The expected cracking thus starts from the upper part of the structure, with cracks maximum open there and gradually closing at the lower levels. However, this pattern is often modified based on the presence of the abutting structural elements and becomes fairly haphazard at times. Upheaval and cracking of the floors and window / door jamming is a common feature in such structures. Depending upon the swelling potential of the underlying soils and the structure loading, the crack width may range from hairline to a few centimeters. The cracks essentially appear diagonal at the edges.

At Gomal University, D.I. Khan (Figure-8), under-construction, Shah Abdul Latif Bhittai University (New Site) and Uch Power Plant, Dera Bugti were found to have undergone severe cracking due to differential upheaval in the swelling ground. The swelling pressures at the three sites were measured as 1.5, 10.0 and 2.0 kg/cm^2, respectively.

Figure 8. Widespread Shrinkage Cracks over the north-eastern part of Tribal Hostel Site, Gomal University D.I.Khan

Mitigation planned at Gomal University consisted of partial replacement of swelling soil with non-swelling soil and transfer of wall load through pad foundations, so as to increase the intensity of imposed pressure. Special care was also taken to keep the area free of wetting in future.

Figure 9. Repaired cracks at PAF base at Bholari

The under-construction campus of Shah Abdul Lateef University was without roof of the first floor yet and it was so badly cracked by high swell pressure of ground, following torrential rains that it was abandoned. New structures at Uch Power Plant consisted of frame structure so that the whole structure responded synergistically against upheaval. Besides, pre-wetting of soil in foundation excavations was also carried out.

Initial construction phase at PAF Base at Bholari was completed in 2017 whereas haphazard cracks (Figure-9 & 5) started appearing in various buildings as well as later in runway in 2018. Initial scrutiny revealed low swelling potential of the onsite soils.

V. LATERAL MOVEMENT IN HORIZONTAL FASHION

Lateral movement of foundations under horizontal or inclined loads may or may not induce cracks in the structures. Such movements can happen only when the passive resistance of ground above the foundation base is less than the imposed lateral / loads.

The induction of cracking and its very pattern will not only depend upon the load magnitude but also on the ground condition, depth of foundation embedment and duration of the load. Such cracking is complex and often gets modified, based on the structural configuration, thus making it difficult to be understood.

VI. SLIDING ON / IN SLOPE

Instability of a slope induces movement in it at slow creep or fast rate, depending on a number of factors. Any structure present on / in it may be subjected to one of the three main conditions:

- Total collapse due to rotation and overturning at a fast rate
- Cracking to a variable degree
- Almost no cracking due to vertical uniform sinking only

Total collapse of many structures on slopes was significantly noted due to large slope movements, during the October 8, 2005 earthquake that hit northern Pakistan.

On the other hand, cracking of structures due to creep of slopes is a common observation in the structures founded on / in slopes in the mountainous terrain. Such cracks widen with time, depending on the rate of slope movement. The large order movements cause bigger cracks. The shape, width and distribution of such cracks is complex and depends on many factors; the most dominant of which is the structural configuration.

There have been situations when the structure sinks / moves down almost uniformly with the sliding event.

There is insignificant cracking of the structure in such a case although the serviceability is seriously impaired. One such movement was noted in the Upper Dewal area in Murree back in 2016 when a whole lot of structures moved down the valley slope on one side of the road, without any significant signs of cracking; About half the road width was eaten up in this mishap.

VII. EFFECT OF STATIC AND TRANSIENT LOADS

The static loads are the ones which remain in place for long duration as the load due to dead weight of the structure, repetitive loads of machinery vibrations, traffic as well as continuous wave action etc. In contrast, the transient loads are short-term loads as due to wind, earthquake, tidal action, bomb blast etc.

The static loads cause generally slow settlement, but the actual rate of settlement would depend on soil type too. Cohesive soils especially with high moisture content tend to settle slowly whereas the non-cohesive ones have a much faster rate of settlement, although the magnitude of total settlement under a given load is of low order compared to that in the cohesive soils.

It is generally the differential settlement of foundations which causes cracking of structures. Such cracks under loads are generally governed by the principle of flexural tensile stresses due to sag at the middle or hog at the edge of a structure and duly modified by the presence of structural elements in a structure. When in the middle, the diagonal cracks are wider at the bottom of the structure while when at the edge, the diagonal cracks are wider at the top.

VIII. EFFECT OF SOIL TYPE

The soil type, whether slow draining or rapid draining, vis-à-vis the rate of applied load, determines the rate of development and severity of cracks. Medium to stiff plastic clays take long time to complete their consolidation settlement and many structures will go on readjusting the consequent revised stress distribution, without the development of any significant cracking. Soft clays however settle excessively and are likely to induce cracking.

Medium-dense to dense sands will settle less than clays under a given load, though at a fast rate but most of the structures will not develop any cracks on such soils. Loose sands, on the other hand, will settle more at high rate and are likely to induce cracks in the structure.

More critical is the condition where a part of the structure rests on strong ground and the remaining part is supported by weak ground or non-engineered fill. This difference in the ground's compressibility potential induces differential settlement, governed by sagging or hogging patterns. The crack patterns happen accordingly in the structure. Good foundation practice is to prevent differential supporting conditions under the structure.

IX. MONITORING OF CRACKS

Once some cracks are noted in a structure or its part due to any reason, the first thing that needs to be established is whether they have become static or are active and widening over a desired period of observation. In the meantime, the causative factors are investigated to find the real causes. The mitigation is to be aimed at arresting the causes, which have resulted into movements and implementation repair rehabilitation plan, once further movements and crack widening become stable.

Table 2. Mitigation Requirements as per degree of damage

Damage classification**	Appropriate action (Relevance of underpinning in italics)
0 to 1	Remedial measures are generally unnecessary as cracks can be repaired as part of routine maintenance. Where cracks recur during periods of dry weather, consider pruning nearby trees and shrubs. Monitoring* is needed to confirm that damage is caused by foundation movement. *Underpinning unlikely to be cost-effective except in very rare circumstances, for example where there is recurrent damage to expensive wall finishes.*
2	Cracks which appear at end of summer and close during subsequent winter can be repaired in spring and steps taken to reduce the risk of damage recurring, such as pruning nearby trees and shrubs. Where cracks are not seasonal, having taken steps to minimise the movement, monitoring* should be used to establish extent, magnitude and rate of foundation movement. *Underpinning is unlikely to be cost-effective, unless foundation movement is progressive or excessive and there is either a likelihood of recurrent damage which will be expensive to repair, or the potential for further movement (e.g. as a result of heave) will create excessive damage (say Category 4)***.
3	Having taken steps to mitigate the cause of the movement, monitoring* should be used to establish extent, magnitude and rate of movement; brick arches and other susceptible features may need propping to prevent deterioration. *Underpinning is likely to be cost-effective, where movement is progressive or excessive and alternatives such as tree removal are impracticable.*
4	Unless there is a risk of instability, monitoring* should be used to establish extent, magnitude and rate of movement. Wherever practicable, steps to remove the cause of the movement should be taken prior to monitoring. *Underpinning is needed to prevent instability where movement is progressive or excessive, unless the cause of the damage is obvious and can be easily removed; for example, if caused by a large tree and there are no impediments to its removal, this may be preferable to underpinning.*
5	Temporary support (e.g. external shoring and/or internal propping) is probably needed to prevent collapse. Monitoring may be needed to give warning of instability, but is unlikely to aid selection of appropriate remedy. *Underpinning or rebuilding on deeper foundations needed to reinstate affected areas†; work should be implemented rapidly to prevent unnecessary deterioration of the structure.*

* Level monitoring should be specified wherever underpinning is being considered as an option.
** As defined in Table III.
† In some circumstances lifting or jacking the structure back to level may provide an economic alternative to rebuilding.

Monitoring with tell-tales (thin glass strips put with epoxy across the crack) to find movement pattern with time is a common and cheap method of crack monitoring. The crack width at the points of monitoring is carefully measured with a linear scale or a crack meter at different intervals of time. Joint meters may also be employed to record the 3-D movements of structures.

When it is desirable to monitor settlement of the ground for the important structure to be constructed anew, rod type / magnetic probe extensometers, settlement markers etc. are installed in the ground or in structure being built.

X. GENERAL MITIGATION POLICY TO AVOID CRACKS / REHABILITATE CRACKED STRUCTURE

There are a host of measures that can be considered to minimize foundation and ground movements, from case to case basis. The main measures for the specific situations are described below. The crack mitigation measures at the designing and planning stages are materially different from those to be adopted to control cracking in an existing structure. Appropriate actions for various level of damages are shown in Table-2.

Improper assessment of ground behavior at the design stage is one of the key factors for the development of cracks. This underlines the requirement of adequate geotechnical investigations with appropriate methods and equipment. The use of appropriate foundations system and / or ground improvement as well as care during construction (particularly water ingress) will pre-empt the development of cracks in the works to be designed and constructed. Besides, water being enemy number one of foundation soils, has to be adequately taken care of during construction as well as performance, to rule out post-construction wetting and development of cracks on account of that. In addition, other root-causes have to be determined from case to case basis and arrested.

After it is ensured that crack movement has stopped, various options are available to repair or to strengthen the foundations and inhibit further cracking by underpinning / additional supporting of the structure.

Repair of cracks can be carried out by a number of standard methods. Use of modern chemicals and flexible crack fillers are commonly used in the good quality repair and rehabilitative works (Figure-10 to Figure-12 & Figure-14 to 16).

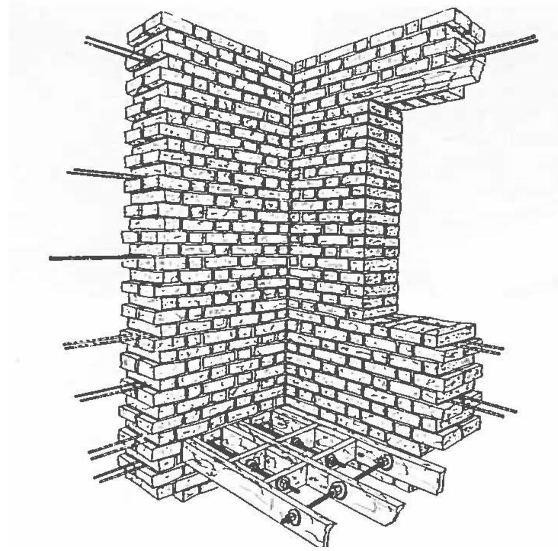


Figure 10. Steel Reinforcement in Masonry Wall

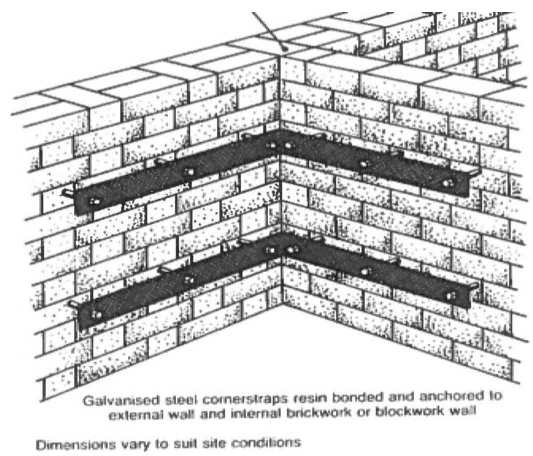


Figure 11. Galvanized Steel Straps Anchored to Masonry Wall

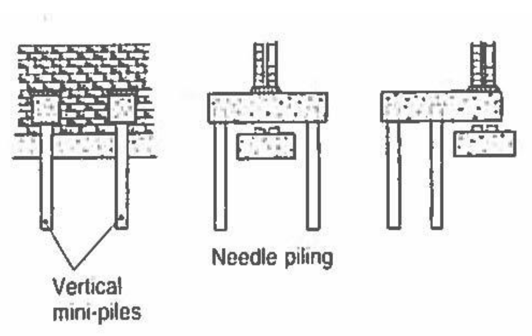


Figure 12. Mini Piles for Underpinning

Figure 13. Cracks Abandoned Latrines located at bottom of the mound, Baba Fareed Shrine

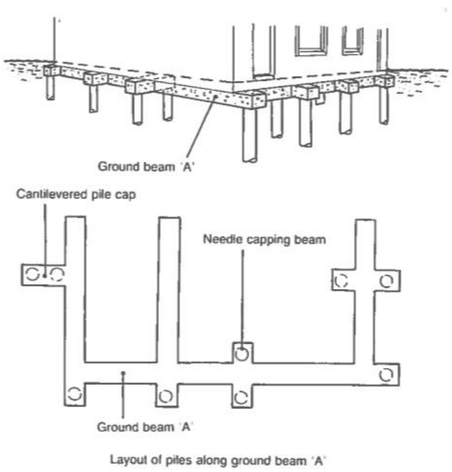


Figure 14. Beam and Pile Underpinning

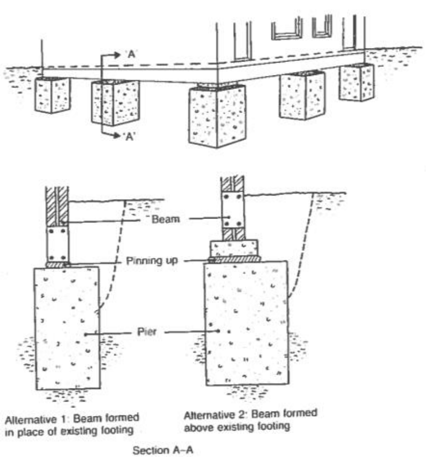


Figure 15. Underpinning with Beams and Piers

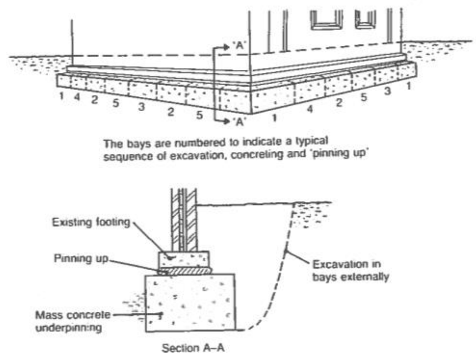


Figure 16. Mass Concrete Underpinning

XI. CONCLUSIONS & RECOMMENDATIONS

The movement of structural foundation / ground may have variable undesirable effect on a structure, ranging from settlement, cracking, tilting to complete damage.

The study of cracking pattern in structures in conjunction with the geotechnical characteristics and structural configuration can lead to delineating the pattern of movements and the causes at the back. Mitigation of cracks in the existing works should be arrived at only after determination of the causes.

While designing new works, detailed geotechnical studies should be conducted to pre-empt crack development in any eventuality arising out of ground, structural or environmental considerations.

Monitoring of cracks is always useful before planning mitigation which should be implemented only after ensuring that the cracks have become dormant.

The size, pattern and orientation of cracks in structures is often modified due to the restraining effects of connecting walls, beams and slabs. A keen study can however, reveal the true nature of movement and the causative factors, to devise suitable measures.

Water ingress being enemy number one in bringing distress to the structures, has the potential to check the foundation movements and hence crack development.

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NESPAK Data of Various Projects

Development of One-Part and Two-Part slag based Geo-polymer Brick

Muhammad Naeem Raoof
Department of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
naeemraoof4@gmail.com

Muhammad Hashim Rafiqi
Department of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
hashim.uet@gmail.com

Dr. Khuram Rashid
Department of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
khuram_ae@uet.edu.pk

***Abstract*—this work was designed to develop a geo-polymer based brick, which is obviously an environment friendly as compared to conventional fired clay or cemented brick. The ground granulated blast furnace slag (GGBS) was used as precursor for the development of geopolymer either by two-part or by one-part methodology. Combination of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solutions were used as alkaline activators for two-part geopolymer, whereas sodium Meta silicate was used as activator for making one-part geopolymer. Total 19 mix design were investigated, and the specimen was prepared by varying (i) molarity of NaOH solution, (ii) alkaline to precursor ratio, (iii) curing condition (iv) sodium meta silicate content and (v) molding pressure. It was observed that GGBS is activated at lower molarity (6M) and give highest compressive strength (30.2 MPa), whereas at higher molarity and lower alkaline to precursor ratio the strength was reduced. At high curing temperature the strength was also increased. 10% sodium Meta silicate was also optimized for developing one-part geopolymer as the strength obtained for the paste was 31.2 MPa. By making mortar the strength was reduced, but by applying molding pressure adequate strength (27.6 MPa) was achieved**.

Keywords*—One part and Two Part Geopolymer, Molarity, Alkaline to Precursor ratio, Curing condition, Molding Pressure, Strength

I. INTRODUCTION

The population of the world is increasing exponentially, so is the need of housing infrastructure. Brick is the basic unit used in this sector. The developing countries lacks the ability to meet the shortage of housing infrastructure due to rapid increase in population, so the need of bricks is going to increase throughout the world. Burnt clay bricks are being manufactured from clay as raw material. The massive production of bricks is depleting the natural resources which causes serious concerns and have adverse effects on the environment. The depletion of clay is affecting the agriculture sector. The production process of clay bricks is energy intensive process because clay bricks are calcined at 900 – 1200oC temperature in the kiln.

Ground granulated blast furnace slag (GGBS) is a byproduct produced from the conversion of iron to steel, which causes huge environmental pollution. The composition of GGBS varies greatly depending on the raw material used and process followed, but in general the percentage of different oxides lies within the range CaO 4560%, SiO_2 10-15%, Al_2O_3 1-5%, Fe_2O_3 3-9%, FeO 7-20%, and MgO 3-13% by mass. The increasing amount of waste material from steel, iron and other various industries is playing a vital role in solid waste management problems across the globe. The waste material is occupying agricultural land for dumping purposes causing wastage of land and has adverse effect on the environment.

Consequently, the alternative of burnt clay bricks is one of the options to control the CO_2 emissions related to the manufacturing of burnt clay bricks in kilns and to reduce the faster depletion of clay level which is natural raw material. In this regard, researchers have developed and investigated geopolymer technology which is considered as potential alternative to the ordinary Portland cement (OPC). Geopolymer (GP) are sustainable material, manufactured by the chemical reaction between aluminosilicate rich materials (precursor) and aqueous alkali solution which are corrosive in nature. Furthermore, GP technology has paved the way for waste management of industrial by-products which are otherwise hazardous in nature and has adverse effects on the environment as well as on human health.

Cement based fly ash (CFA) bricks are being produced on industrial scale but cost effectiveness is an issue. Many researchers have developed the Fly ash (FA) based GP bricks which are proven as a sustainable alternative to the clay bricks. These bricks are not only environment friendly but are meeting the construction requirements as specified by codes. But on industrial scale geopolymer based GGBS bricks are not being developed so far.

Geopolymer are recognized as potential alternative to OPC. Adoption of geopolymer bricks on industrial scale will mitigate the adverse impacts of GGBS on the environment. The main characteristic of GP is their ability to provide an important reduction in CO_2 emissions and less energy requirements for production compared with OPC products. This waste material occupies vast agricultural land for dumping purpose. By the utilization of this waste material for the manufacturing of bricks, wastage of agricultural land will be saved.

GP are the alkali activated materials which are considered as a potential alternative to ordinary Portland cement. In the process of geopolymerization, a reaction takes place between the aluminosilicate rich materials and alkali activators. Alkali activated materials (AAM) are being considered as sustainable green building construction materials [1]. There are two ways present in the literature for the preparation of GP. In one-part GP, only a dry blend is required in addition to water. The dry mixture is composed of solid alkali activator and solid alumina silicate precursor [2]. While in two-part GP, a chemical reaction takes place between concentrated aqueous solutions of alkali hydroxide, carbonate, Sulphate or silicate and solid alumina silicate in addition to water

The content of amorphous silica and alumina present in the precursor plays vital role on the compressive strength of geopolymer. It is important to estimate the reactivity of precursor as it gives the idea about the content of amorphous silica and alumina present in the precursor. There are various other factors that influence the compressive strength of GP. These are alkaline to precursor ratio (A/P), sodium silicate to sodium hydroxide ratio (SS/SH), molarity of sodium hydroxide (SH) and curing temperature

The usage of highly aqueous alkaline solutions in the preparation of two-part GP is major hurdle in the adoption of GP on commercial scale. The most common alkaline solution is SH solution which is highly corrosive and hazardous in nature In this context, one-part GP are gaining attention in the construction industry as the preparation of one-part GP involves the alkali activators in dry form. One-part GP are prepared by dry mixing of alumino-silicate rich materials and solid alkali activators, with or without calcination step. The easier and safer cast in situ applications of one-part GP makes it superior to two-part GP.

II. EXPERMIMENTAL METHODOLOGY

A. Materials

The precursor used in this research work was GGBS in accordance with ASTM C-989. The sieving of GGBS was done and GGBS passed through sieve no. 50 was used for the preparation of one-part GP. While, the GGBS and sand passed through sieve no. 40 were used for the preparation of two-part GP. The GGBS was purchased from Nukshi Star Slag, Mirpur, and AJK. The percentage of main oxides in the precursor was determined through X-ray fluorescence (XRF) is listed in Table 1. The solid alkali activator used in this study was sodium-meta-silicate (SMS). The purity of SMS was 96% and amount of Na_2O was 28.7 %. The SMS was taken from local chemical market in Lahore-Pakistan. The alkaline activators in this research works were sodium silicate solution and sodium hydroxide solution. Combination of sodium silicate (SS) solution and sodium hydroxide (SH) solution was used with SS/SH=2.5. The purity of SH pellets was 99 % and was purchased from local chemical market in Lahore. The sieve analysis of fine aggregate used in this study was done in accordance with ASTM C-136. The source of fine aggregate was Ravi River. The distilled water used for the preparation of SH solution, and it was prepared in laboratory.

TABLE I. Oxides Composition Of Ggbs

Chemical Oxides (%)	GGBS (%)
SiO2	37.42
Al_2O_3	13.25
CaO	40.85
Fe2O3	1.29
MgO	1.63
K_2O	0.01
Na_2O	0.42
SO3	0.64
LOI	2.30

B. Specimen Preparation

In this research study, two different systems were developed and investigated i.e., one-part GP based brick and two-part GP based brick. The varying parameters in the development of two-part GP were alkaline to precursor ratio, molarity of SH solution, and curing condition (ambient curing, hot curing at 70℃). The SH solutions of different molarities (4M, 6M, 8M, 10M, 12M) were prepared and mixed with SS solution in SS/SH=2.5. The cylindrical specimens were casted by pressing the mortar at a pressure of 20 MPa. The pressure of 20 MPa was applied through Universal testing Machine (UTM) for the casting of cylindrical specimens. The casting was done in three series, 1st series consists of GP mortar having GGBS as a precursor (two-part GP), 2nd series consists of GP paste with GGBS used as a precursor for the development of one-part GP, and the third series consists of one-part GP based mortar with precursor to sand ratio as 1:1 and mix design for the series are reported in Table 2 to Table 4. In the preparation of one-part GP, the precursor (GGBS) and alkali activator (SMS) was dry mixed for three minutes with the help of mixer and then 22.5% and 30% water were added in paste and mortar respectively and was mixed again for two minutes. The specimens prepared are shown in Fig. 1. (a, b)

Figure 1. (a, b) Cubical and Cylindrical Specimens

TABLE II. Mix Design For 1st Series

Design	GGBS %	Sand %	SS/SH	A/P	SH Molarity
1	50	50	2.5	0.25	4
2					6
3					8
4					10
5					12
6				0.35	4
7					6
8					8
9					10
10					Figure 12.

TABLE III. Mix Design For 2nd Series

Designs	Sample	GGBS	SMS	W/one part GP
		%	%	%
11	SS-8	92	8	22.5
12	SS-9	91	9	22.5
13	SS-10	90	10	22.5

TABLE IV. Mix Design For 3rd Series

Design	Sample	GGBS %	SS %	Sand %	W/B %	Molding Pressure (MPa)
14	MSS-8	92	8	50	30	0
15	MSS-9	91	9	50	30	0
16	MSS-10	90	10	50	30	0
17	MSS-8	92	8	50	10	20
18	MSS-9	91	9	50	10	20
19	MSS-10	90	10	50	10	20

III. RESULTS AND DISCUSSION

Influence of Molarity on Compressive Strength of Two-part Geopolymer

At alkaline to precursor ratio of 0.35, the compressive strength of GP mortar was investigated by varying the molarity of SH solution from 4M to 12M. The maximum compressive strength was attained at 6M concentration of SH solution as shown in Fig. 11. For 8M, 10M and 12M, the strength was decreased. The decrease in compressive strength is attributed to faster rate of reaction at high molar solution of SH with high calcium precursor. As GGBS is more reactive precursor as compared to FA and other aluminosilicate rich materials, it requires less alkaline environment for its activation.

At A/P=0.35, low molar solutions have given strength much greater than our required strength, which is 10 MPa, as according to ASTM standard for compressive strength of brick 1st class brick should have strength not less than 10 MPa. So, in order to reduce the cost for the manufacturing of brick the A/P was reduced from 0.35 to 0.25 and influence of molarity on the compressive strength was investigated. The mechanical performance of GP at A/P = 0.25 by varying the molarity is shown in Fig. 2. The alkali activator dosage was reduced to 40 % and at all the molarities except for 12M, the compressive strength attained was more than the required.

In the process of geopolymerization, alkali to precursor ratio plays a vital role. The preparation of GP mortar was done at two different alkalis to precursor ratios i.e., 0.25 and 0.35. By decreasing the alkaline to precursor ratio as shown in Fig 3, the strength of geopolymer mortar decreases for the 4M, 6M and 8M molar solutions while for 10M and 12M solution the strength is increased. The considerable decrease in compressive strength was observed for 4M and 6M SH solutions by decreasing the alkaline/precursor ratio from 0.35 to 0.25. For 4M solution, approximately 46% decrease in the compressive strength was observed with the 28% decrease in A/P ratio and for the 6M solution, approximately 40% decrease in compressive strength was observed with the 40% decrease in A/P ratio. After further increase in molarity, there was a slight decrease in compressive strength by decreasing the A/P ratio. The trend was reversed at 10M where increment in strength was observed with the decrease in A/P ratio.

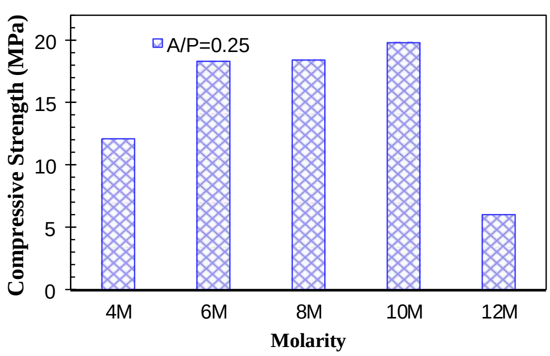

Figure 2. Influence on compressive strength at A/P=0.25

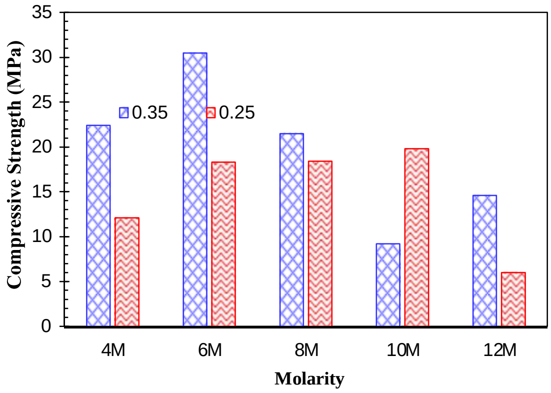

Figure 3. Influence on compressive strength at different A/P

The dosage of alkaline activator affects the Si^+ content and Na^+ content, and the water to binder ratio. These factors play critical role in the process of geopolymerization. At 10M, with the decrease in A/P ratio increase in strength may be attributed to slow rate of reaction due to lower SH content results in an increase in the setting time.

In the first series in which solitary precursor (GGBS) was used, the target strength was achieved at both A/P=0.25 and A/P=0.35. So, A/P=0.25 was optimized for further research work due to lesser cost as compared to A/P=0.35. There is no influence of molarity on the compressive strength of one-part GP paste and mortar as one-part geopolymer was developed by using single alkali activator i.e., SMS which is in powder form.

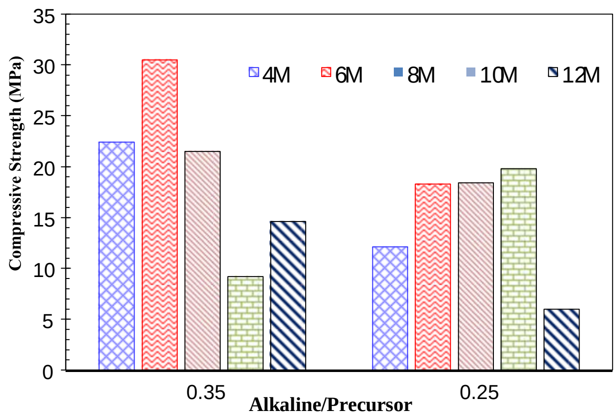

Figure 4. Influence of A/P on compressive strength

C. Influence of Alkaline to Precursor Ratio on Compressive
Strength of Two-Part Geopolymer

The motivation of this research study was to develop geopolymer brick having strength not less than 10 MPa as per ASTM standard for 1st class brick. So, the A/P ratio was decreased from 0.35 to 0.25, in order to reduce the cost. By reducing the A/P to 0.25, the strength was reduced 40% for 6M solution. For 10M, the reduction in strength was negligible when A/P was reduced from 0.35 to 0.25. At A/P ratio of 0.35, the strength at 10M was less than required while, 4M, 6M, 8M, and 12M has given the strength more than the required strength. While at A/P ratio of 0.25, the strength at 12M was less than required while, 4M, 6M, 8M, and 10M has given the strength more than the required strength. The Fig. 4, shows the influence of alkaline to precursor ratio on the compressive strength of GP mortar.

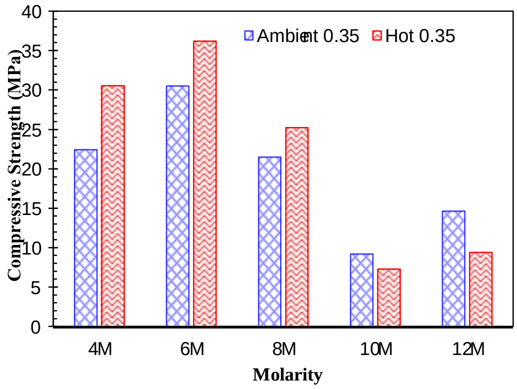

Figure 5. Influence of temperature on compressive strength at A/P=0.35

D. Influence of Temperature on Compressive Strength of
Two-Part Geopolymer

The Fig. 5, shows the influence of curing temperature on the compressive strength at particular molarity of SH solution having A/P=0.35. Hot curing of specimens has increased considerable strength for 4M, 6M, and 8M while for 10M and 12M the strength of ambient cured specimens was more than hot cured specimens. The reason for decrease in strength may be the faster rate of reaction due to high alkaline environment as well as hot curing which ultimately reduces the setting time. Similarly, Fig. 6, shows the influence of temperature on the mechanical performance for different molarities at A/P ratio 0.25. At A/P=0.25, for all the molarities same trend was observed i.e., an increase in strength was observed for hot cured samples. The one-part GP paste and mortar were cured only at ambient temperature as good strength was achieved at ambient curing.

E. Influence of Alkaline to Precursor Ratio on Compressive Strength of One-Part Geopolymer

The GP pastes were prepared using different ratios of SMS/GGBS. The different A/P ratios used were 8/92, 9/91, and 10/90 for specimens SS-8, SS-9, and SS-10 respectively. The Fig. 7, shows the influence of A/P on the compressive strength of one-part GP. By increasing the A/P, the compressive strength of paste increases. For 8/92, 9/91 and 10/90 A/P in the one-part GP, there was almost linear increase in the compressive strength of one-part GP pastes. For each 1% increase in the SMS content (in binder), there was almost 35% increase in the compressive strength up to 10% SMS (in binder).

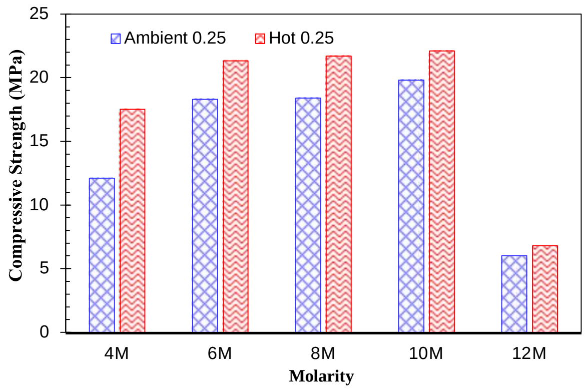

Figure 6. Influence of temperature at A/P=0.25

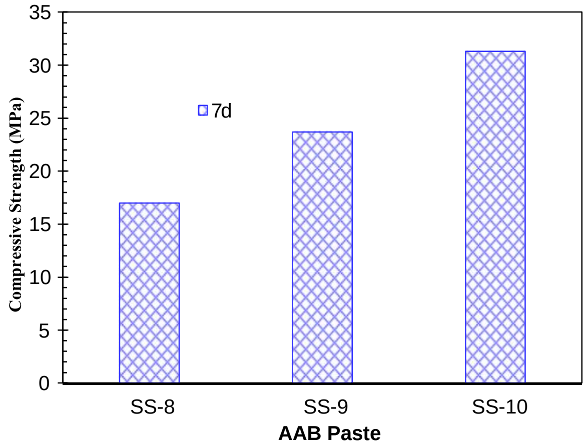

Figure 7. Influence of A/P on Compressive Strength

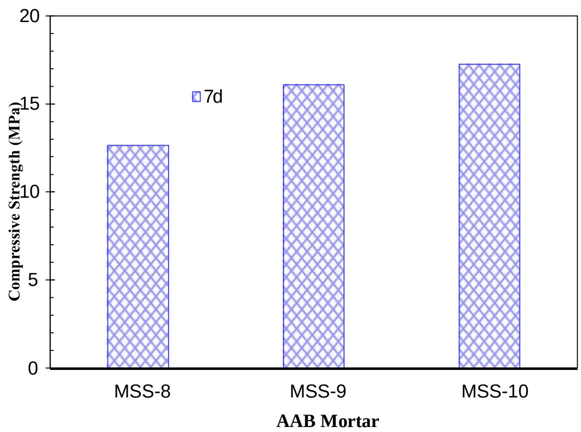

Figure 8. Influence of A/P on Compressive Strength

The modulus of silica (SiO_2/Na_2O) plays very important role in the strength development of geopolymerization process. The commercially available SMS has modulus of silica of 0.9-1.0 which is close to the optimum range [12]. While the modulus of silica for commercially available SS solutions ranges from 2.0 – 3.2, which is not the optimum range [13]. That's why SMS outperforms the sodium silicate solution in one-part GP. The low SiO_2/Na_2O indicates the presence of less polymerized silica and results in the faster dissolution. In SMS based one-part GP denser reaction products are formed which took up less volume. The compressive strength increases up to a certain limit with the increase of SMS content.

In order to reduce the cost of one-part GP brick, the mortars were prepared with one-part GP pastes in ratio 1:1. The compressive results of one-part GP mortars are shown in Fig. 8. By increasing SMS 1% in the one-part GP, an increase of 28% in compressive strength was observed. A marginal increase in strength (7%) was observed when SMS was increased from 9% to 10%. But for all the on-part GP mortars, the compressive strength was more the required strength. The increase in mortar strength by increasing A/P ratio is attributed to increase in binder strength which ultimately cemented the fine aggregate particles strongly. Both mechanical and chemical action plays important role in strength gain mechanism.

F. Influence of Aging on Compressive Strength of One Part Geopolymer Mortar

When 7d compressive strength was compared with 28d compressive strength an increase of 11% in strength was observed for MSS-8, 6% increase in strength was observed for MSS-9, while for MSS-10, an increase of 35% in compressive strength was observed as shown in Fig. 9. The 28d compressive strength of mortar was investigated as all these specimens were ambient cured and unpressurized molding was done. The mechanical action (pressurized molding) and thermal action (hot curing) was absent, so 28d compressive strength was investigated in order to compare it with 7d compressive strength of two-part GP mortar.

G. Influence of Pressure Molding on Compressive Strength of One-Part Geopolymer Mortar

The influence of pressure molding was investigated for one-part GP mortar. The 7d compressive strength of mortars with pressurized and unpressurized was compared. From the Fig. 10, it was observed that almost 50% increase in strength was observed with pressurized molding under pressure 20MPa.

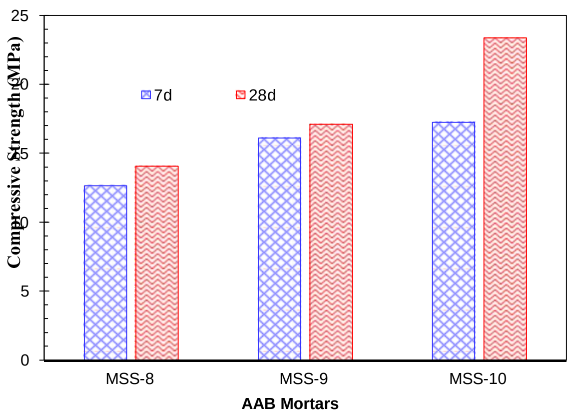

Figure 9. Influence of aging on compressive strength

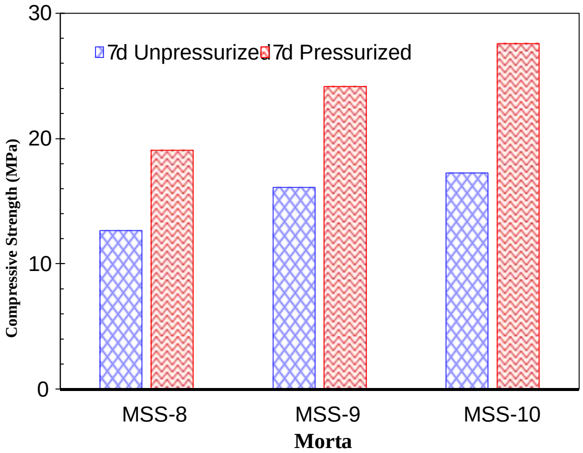

Figure 10. Influence of pressure molding on compressive strength

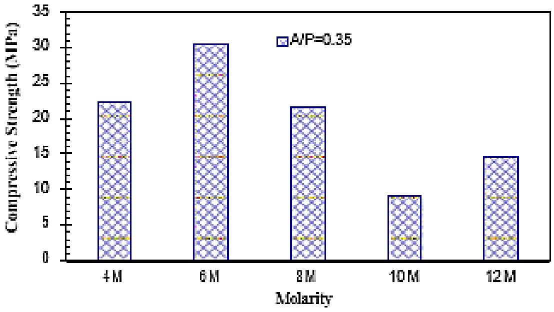

Figure 11. Influence of molarity on compressive strength at A/P= 0.35

IV. CONCLUSIONS

Following are the conclusions drawn from this research work,

For GGBS based GP, when A/P=0.35, the maximum strength of 30.2 MPa was obtained at 6M SH solution. At higher A/P ratio GGBS requires less molarity of SH solution for its activation. When A/P will be reduced GGBS will require high molar SH solution for its activation and gives good compressive strength at higher molarities.

For GGBS based GP, at A/P=0.25, for GGBS as solitary precursor, the maximum strength of 19.8 MPa was achieved at 10M.

The compressive strength for one-part GP paste and their respective mortars increases with the increase in SMS content in the GP cement.

The maximum compressive strength of one-part GP paste was 31.2 MPa having 10% SMS content.

For one-part GP mortar with pressurized molding (20 MPa), the maximum compressive strength attained was 27.58 MPa with GP cement consisting of 10% SMS and 90 % GGBS.

Comparison of all the specimens meeting minimum strength criteria of 10MPa was made.

For one-part GP brick, the minimum compressive strength was 14 MPa and maximum compressive strength was 31.2 MPa.

For two-part GP brick, the minimum compressive strength was 6 MPa and maximum compressive strength was 30.2 MPa.

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Development, Investigation, and Up-scaling of Construction Composites Incorporating Cement Replacement Material

Muhammad Irfan-ul-Hassan
(Corresponding author)
University of Engineering and Technology,
Lahore, Pakistan
irfanulhassan@uet.edu.pk

Muhammd Hasham Zaheer University
of Engineering and Technology
Lahore, Pakistan
hashamzaheer45@gmail.com

Muhammad Burhan Sharif
University of Engineering and
Technology, Lahore.
burhansharif@uet.edu.pk

Abstract— **Determining the separate constituents' roles in construction composites like mortars and concretes has been challenging due to variations in materials chemistry and environmental conditions. In this study, an effort has been made to analyze constructional composites at many scales, starting with a composite made of only one material and progressing to a composite built of multiple materials. Here, cement-based and geopolymer composites are created, and cement is replaced by sustainable cementing ingredients like metakaolin and waste ashes (bagasse ash and fly ash). According to recent innovations for sustainable development goals, this was done to reduce CO2 footprints and utilize the waste material. Here, we describe the different materials in terms of their mechanical and physical characteristics and create composites at a multiscale level. It has been observed that supplementary cementitious materials such as metakaolin, fly ash, and bagasse ash can be very important in the development of strength. The findings at the mono- and multi-level levels show a few intriguing, optimal combinations, demonstrating the advantages of naturally calcined clays and ashes for use in building materials and goods. Energy-intensive techniques are used to create cylindrical specimens, and this time the best mixtures are discovered and scaled up to create a brick or building unit at an industrial level. Results at various scales aided in the optimization of the composite mix design.**

Keywords— *Multiscale, Geopolymer Composites, Supplementary Cementitious Materials, Brick Development*

I. INTRODUCTION

Due to the exponential population growth, cement is now one of the most consumed man-made materials and is widely used in a variety of construction operations worldwide. Due to the rising demand for cement, scarce natural resources are being used up faster than they can be replenished, which causes their exhaustion. If appropriate cement substitutes are not looked into as quickly as feasible, the scarcity of raw resources may worsen to dangerous proportions, resulting in conflicts and price increases. By producing geopolymer-based composites or by adding cementitious materials as a partial replacement for cement, cement can be completely or partially replaced. While different types of locally available materials are abundant and can be used as SCMs. Many researchers used these supplementary cementitious materials and study them briefly. These additional cementitious ingredients included metakaolin, fly ash, bagasse ash, and rice husk ash, among others. The sugar industry produces sugarcane bagasse ash, which is an agricultural waste material. This waste product is often disposed of by combining it with water and depositing it on nearby land. This practice not only wastes potentially useful space but also contributes to environmental degradation (Bahurudeen et al., 2015). V. Amin et al. (2020) found that when compared to other Engineered Cementitious Composite mixes and the control, the Engineered Cementitious Composite mix with 10% ground bagasse ash exhibited a better compressive strength. They demonstrated that cementitious composites can be made from sugarcane bagasse ash and that 10% ground bagasse ash can be substituted for cement to create sustainable Engineered Cementitious Composites with improved compressive, tensile, and flexural strengths, improved deflection resistance, and improved ductility (Amin et al., 2020). Jittin et. al. (2020), In the study, a comparison was made between the physical, chemical, and morphological properties of bagasse ash and rice husk ash. It was observed that the concrete's strength was increased by blending bagasse ash and rice husk ash up to a cement replacement level of 20% and 15%, respectively, in comparison to the control concrete (Jittin et al., 2021). Bagasse ash plays a significant part in the polymerization process used to make a variety of bricks and other goods for the construction sector. In comparison to standard Portland cement (OPC), these materials emit less carbon dioxide (CO_2) during processing: one tonne of geopolymer binder creates 0.19 to 0.24 tonnes of CO_2, whereas one tonne of OPC releases 0.6 to 0.83 tonnes of CO_2 (Zaidi et al., 2017). Another cementitious substance that uses less energy than OPC is metakaolin. One of the highly rich aluminosilicate materials, calcined kaolinite clay, commonly known as metakaolin, has remarkable mechanical and durability qualities among many other precursors (Hodhod et al., 2020; Kuenzel et al., 2013; Ricerche, 1998). China clay, also known as kaolin clay, which is a naturally occurring mineral that can be found in most countries, is calcined to form it. Kaolin clay is found in significant quantities in the Pakistani districts of Shah Dheri (Swat) and Nagar Parkar (Tharparkar), the latter of which has deposits of more than 3.636 and 2.5 million metric tonnes, respectively (Ismail et al., 2015). Another industrial waste is fly ash, which is generated from the combustion of coal in cogeneration chambers of thermal power plants. In an alkaline activator, the silica and alumina in it can dissolve, creating a strong geopolymer binder (Hadi et al., 2018) and With 0.9% of the global total, Pakistan was placed 38th in terms of coal usage (Gollakota et al., 2019).

The investigation of cementitious composites and products at various levels using the multiscale technique. The micro-scale, mesoscale, and macro-scale of the cementitious composites and generated products were explored in this study. Cementitious composites have been the subject of a great deal of research, but no multiscale experiments to enhance composite performance have been carried out. The produced cementitious composites may be employed as a product in the construction sector, and this product could be anything from mortar to concrete to bricks or masonry blocks.

II. MATERIALS AND METHODS

A. *Materials*

Ordinary Portland cement was collected from the industry according to (ASTM C150/C150M, 2019). The bagasse ash (BA) used for this research project was taken from the Pattoki Sugar Factory in Pattoki, Punjab-Pakistan. To remove larger unburnt carbon fibers, the material was dried and sifted using a number 50 sieve, which has a mesh size of 300 microns, as indicated in figure 1(a) (Additional specialized processing of sugarcane bagasse ash was stopped to promote sustainability in the local building industry). Its chemical composition is listed in Table 1. Calcined metakaolin was also used as shown in Figure 1(b). The fly ash used in the study was sourced from Century Paper and Board Mills Limited, located in Lahore, Pakistan as shown in figure 1(c). The fly ash was directly used in the geopolymer blends without undergoing any additional processing. The fly ash chemical composition is given in Table 1. It was classified as Class-F fly ash as per ASTM C618 (Specification, 2014).

(a) (b) (c)

Figure 1. The physical appearance of materials (a) Bagasse ash (b) Metakaolin (c) Fly ash

Table 1. Chemical composition of cement, bagasse ash, fly ash, and metakaolin

Oxides (%)	OPC	Fly ash	Bagasse Ash	Metakaolin
SiO_2	21	62.9	64.4	55.3
Al_2O_3	6	14.5	5.72	28.76
Fe_2O_3	3	3.4	4.22	0.97
CaO	60-63	1.8	1.68	4.77
MgO	1.5	2.5	1.28	0.1
Na_2O	-	-	1.1	-
K_2O	-	-	6.46	-
MnO	-	-	0.08	-
TiO_2	-	-	0.28	-
P2O5	-	-	1.33	-
SO_3	2	0.72	0.2	0.16
LOI	2.0-2.7	4.5	10.36	0.41
SiO_2+ Al_2O_3+ Fe_2O_3	30	-	74.3	-

B. *Experimental Investigation*

Samples were cast using different proportions of cement and other materials at different water-to-binder ratios i.e., at 0.42, 0.45, and 0.50. The multi-scale approach was used and a hierarchy of samples to be cast was created. To measure the compressive strength of the samples, they were cast in cylindrical molds with a diameter of 50mm and a height of 100mm. The mixture that exhibited the highest compressive strength was then scaled up to an industrial level for the production of bricks. The cement-to-mortar ratio was 1:3, here cement was replaced by cementitious material which includes metakaolin, and bagasse ash. Samples were cast with different proportions of cement, metakaolin, and bagasse ash. The samples prepared by incorporation of cement were tested at 7 days, 28 days, and 56 days. Geo-polymer bricks were also formed. To find out the optimum mix proportions the samples were prepared and tested in the laboratory and then they were up scaled to the industrial scale as shown in Figure 3. The solution of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) was prepared 24 hours before the specimens were cast. In this project, tap water supplied by the University of Engineering and Technology in the laboratory was used in all types of mixes.

(a) (b)

Figure 2. (a) Preparation of Molds, (b) curing of samples,

(a) (b)

Figure 3. Brick production at an industrial scale

III. RESULTS AND DISCUSSIONS

A. *Compressive Strength*

Figure 4, there are the compressive strengths of various mortars and found that the tertiary mixes had similar strengths, with the fly ash mix showing the highest strength and the bagasse ash mix showing the lowest. However, the addition of metakaolin to the quaternary mix significantly increased its strength by acting as a binder.

Based on these results, an industrial-scale brick was produced using the quaternary mix along with bagasse ash and sand, achieving a compressive strength of 9.3 MPa at 7 days. In comparison, the geopolymer brick made with a mix of 20% metakaolin and 80% ashes (fly ash and bagasse ash) achieved the maximum compressive strength, reaching a peak value of 35 MPa.

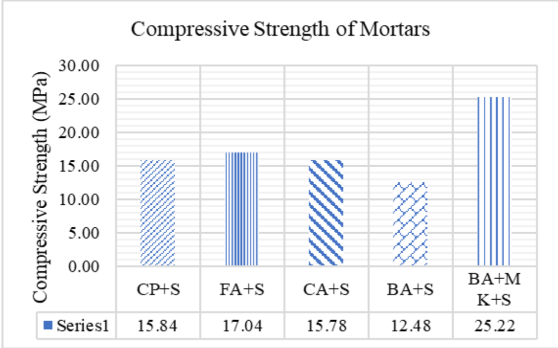

Figure 4. The compressive strength of various mortars that partially replacing cement with different cementitious materials.

B. *Density*

The study compared the density of bricks made with metakaolin, waste ashes, and conventional clay bricks. The bulk density of both types of bricks was compared at different curing intervals, and it was observed that the geopolymer brick made with 20% metakaolin (MK) and 80% waste ashes (FA-BA) had a 16% lower density than the conventional brick after 7 days. The density of the geopolymer brick decreased further at 28 and 56 days, reaching 20% and 22%, respectively. This reduction in density was attributed to the porous nature and lower unit weight of sugarcane bagasse ash. (Agredo, 2014; Jagadesh & Ramachandramurthy, 2015), The mix with 20% metakaolin and 80% waste ashes, where the waste ashes primarily consisted of sugarcane bagasse ash, exhibited a significantly lower density compared to conventional fire burnt bricks. The geopolymer brick made with this mix was 22% lighter than conventional bricks at 56 days of curing, resulting in a lighter-weight construction product.

C. *Water Absorption*

The study also found that the geopolymer bricks made with 20% metakaolin and 80% waste ashes had lower water absorption compared to conventional bricks. This could be attributed to the geopolymer blend of metakaolin and fly ash, which resulted in a lower overall porosity and a more compact structure with fewer voids for water to remain inside the core. Therefore, the geopolymer bricks showed better resistance to water absorption. (Duan et al., 2015). The geopolymer bricks made with 20% metakaolin and 80% waste ashes exhibited a water absorption value of 7.8%, which was significantly lower than the water absorption value of conventional bricks (18.2%). The lower water absorption value indicates good resistance to damage by freezing, as water absorption can lead to the expansion and contraction of bricks during freezing and thawing cycles. Therefore, the geopolymer bricks made with metakaolin and waste ashes have the potential to withstand damage by freezing and can be a suitable alternative to conventional bricks in areas with harsh weather conditions.

D. *Efflorescence*

Efflorescence, which refers to the white salt deposits that appear on the surface of bricks, was observed in both conventional bricks and geopolymer bricks made with metakaolin and waste ashes. However, the extent of efflorescence was significantly lower in the geopolymer bricks. The conventional bricks showed efflorescence in almost 8-9% of the surface area, whereas the geopolymer bricks showed almost negligible efflorescence. This suggests that the incorporation of sugarcane bagasse ash in the geopolymer bricks reduced the efflorescence problem. Efflorescence can be observed in Figure 5.

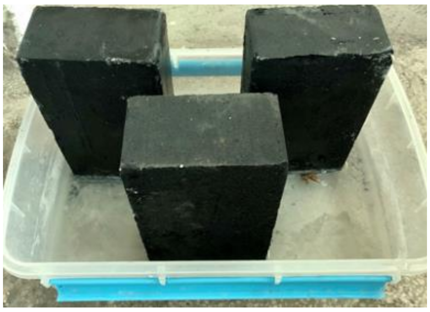

Figure 5. Efflorescence of geopolymer brick

IV. CONCLUSION

This research work focused on studying the mono, binary, and ternary geopolymer mixes to determine the optimal mix for upscaling to the pilot scale at the industrial level. The resulting upgraded bricks were then subjected to mechanical and durability testing, followed by SEM analysis at the micro level. The study showed that waste by-products such as sugarcane bagasse ash and fly ash could be effectively used in the creation of geopolymer blends in conjunction with metakaolin, demonstrating the synergistic use of these materials. The ternary mix containing 20% metakaolin and 80% waste ashes (bagasse ash and fly ash) was identified as the optimal mix for industrial upscaling based on its maximum utilization of sugarcane bagasse ash and optimal compressive strength. The enlarged geopolymer brick can be used successfully in severe weather conditions after 7 days of ambient curing, and after 56 days of curing (Specification, n.d.). The brick made by replacing cement with bagasse ash and metakaolin demonstrated good compressive strength at 7 days, exceeding the minimum limit set by the building code of Pakistan. The geopolymer brick containing 20% metakaolin and 80% waste ashes (bagasse ash and fly ash) exhibited 22.4% less density than the conventional brick, indicating that incorporating sugarcane bagasse ash results in a significantly lighter structure, making it more cost-effective. The research work was further extended and applied to bricks production using clay-based geopolymer bricks [Yasin et. Al. 2021] and geopolymer-based blends by [Azhar et al.] Where the application of multiscale testing was implemented.

V. ACKNOWLEDGEMENT

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NEW TRENDS IN CIVIL ENGINEERING

Autonomous Personal Pods as a Replacement for Cars

Muhammad Awais Shafique
Center for Innovation in Transport (CENIT)
Universitat Politècnica de Catalunya (UPC)
Barcelona, Spain
ashafique@cimne.upc.edu

Sergi Saurí Marchán
Center for Innovation in Transport (CENIT)
Universitat Politècnica de Catalunya (UPC)
Barcelona, Spain
sergi.sauri@upc.edu

***Abstract*— the transportation sector around the globe is looking at autonomous electric vehicles as the next big thing. This paper provides an alternative concept that not only carries the advantages of autonomous electric vehicles but also addresses some of its concerns. Autonomous personal pods moving on tracks underground or elevated aboveground can provide a sustainable, safe, efficient, and feasible replacement for conventional cars running on the roads.**

Keywords*—Active transportation, Autonomous vehicles, Personal pods, Sustainability*

I. INTRODUCTION

Nowadays a lot of research and testing is done in thearea of autonomous and connected vehicles. It is considered the natural evolution of road transport, and a solution to many of the issues faced on roads today. These issues include road crashes, traffic rules violations, inefficient utilization of road capacity, unnecessary delays due to traffic signals causing congestion, and associated problems such as injury and loss of life resulting in a massive increase in healthcare costs, environmental pollution, loss of property, and an increase in passenger depression and anxiety. According to World Health Organization, road accidents result in around 1.3 million deaths annually. Leading causes are speeding, drunk driving, unfocussed driving, faulty vehicles, and risky infrastructure [1]. Autonomous and connected vehicles backed by AI-based traffic management infrastructure would allow safe, efficient, and smooth movement of traffic on the roads as they will tend to eliminate the human factor involved [2-4]. The objective of this innovation is to make traveling secure and streamlined while providing flexibility and comfort to travelers. Essentially, we are adding elements of urban rail transit such as safety, comfort, on-time arrival, and passenger privileges (no driving pressure, no depression dueto congestion, and the ability to do activities like eating, sleeping, etc.) to our vehicles.

However, instead of adding elements of urban rail transitto personal vehicles, another approach can be to add elements of travel by personal vehicles such as personal space, the flexibility of departure, the ability to take the shortest route to the destination, and the ability to reach points not accessed by public transport to a mobility solution on rails. It is essentially redesigning personal vehicles, and how we travel within an urban area. Redesigning travel

Means is not new. This has been achieved before by the introduction of now immensely popular electric scooters. These kick-scooters, assisted by a small electric motor, are part of Personal Mobility Devices (PMDs) as well as the micro-mobility group. Starting in 2017, e-scooters have disrupted the micro-mobility arena so much that they now comprise 57% of the shared micro-mobility fleet in North America [5]. Likewise, this paper describes a reimagined concept of personal transport within cities and discusses its advantages as well as limitations.

II. CONCEPT

Most cities in the world are designed using urban blocks as the central design element. This predominantly results in a grid pattern of roads. Many cities demonstrate a unique traffic circulation pattern where except for a few main roads all the streets in the grid are one-way only. A typical movement pattern is shown in Fig. 1 (a). It can be seen fromthe figure that parallel streets alternate the movement directions in both horizontal and vertical axes. This allows for better traffic circulation and reduced delay time at the intersections since the signalization is 2-phase rather than 4- the phase typically used for 4-legged intersections. This circulation pattern inspires the new concept provided in this paper.

The pods would be similar to the ones used in Personal Rapid Transit (PRT) systems functional in Heathrow Airport,and Masdar City. However, the proposed system is primarily different from the conventional PRT concept in that it is aimed at replacing personal vehicles as opposed to PRTbeing advertised as a feasible alternative to light rail and bustransport.

The huge technological breakthroughs in autonomous and connected vehicles would allow these pods to travel on tracks autonomously and without any risk of crashes. Based on the unique traffic circulation shown inFig. 1 (a), the proposed system would consist of a grid madeup of grade-separated parallel tracks where perpendicular lines will not intersect due to being at different grades. Furthermore, only right turning connections would be provided between perpendicular lines, as demonstrated in Fig. 1 (b).

Fig. 2 shows the right-turn connections. The concept is that the traffic should move without any restrictions. The turning traffic will not restrict the through movement, as their tracks would be separate. With the absence of any smooth and without any delays. The tracks would have switches so that pods can automatically change tracks when required, such as moving on to the right-turning track. Fig. 3 demonstrates the proposed drop-off/pick-up bays at the stations. Pods would be able to enter and exit each bay Separately so that the high efficiency of the network is assured. These stations would be spaced at every two-block distance in the grid. It will not only ensure accessibility and reach throughout the city but would also result in better passenger distribution among the stations.

III. ADVANTAGES

The entire network can be made underground or aboveground via an elevated infrastructure. However, it should not be on the ground since the objective is to eliminate cars from the roads. Hence, the alternative to cars should also be absent from the roads. This will serve a very important purpose i.e. the roads would be redesigned to be used for active transportation with occasional utilization by emergency vehicles. The roads would then become corridorsof public activities boosting social life and public happiness.In such a setting, the response time of emergency vehicles would drastically decrease, saving life and property.

The concept can be easily understood by considering the following scenario. Consider that all personal vehicles on the road are replaced by small smart cars. This would undoubtedly increase the capacity of existing roads since the capacity calculation methodology would change accordingly. It will also result in better equality among passengers. Now consider that all these cars have autonomous driving capabilities at level 5 (fully autonomous). This would decrease crashes due to human errors and would improve the traffic flow. Since roads provide a delimited area for these cars to travel and individual lanes serve as travel paths, we can replace the road with tracks that would allow the flexibility of changing tracks (lanes) when such a need is assessed by the central control system. Next, bring this network underground so that the roads on the ground can be used for active transportation with a considerable area turned into public spaces.

For reference, the standard passenger car dimensions are 5.79 m (L), 2.13 m (W), and 1.30 m (H) [6], whereas the dimensions of Smart EQ For two (one of the many smart cars available in the market) are 2.695 m (L), 1.663 m (W), and 1.555 m (H) [7]. The various values attained after calibration of a free flow model [8] were used to calculate.

The response time and gap for various free flow speed values[9]. The same response time and gap values were used to calculate road capacity using Smart EQ for two dimensions. However, autonomous pods would have different operational characteristics. Since all pods will be centrally controlled, response time would be practically eliminated. Moreover, the gap can also be safely reduced. Therefore, for autonomous pods, the gap was reduced by 75%, and response time was uniformly reduced to 0.5 s (which was still conservative). Using the same dimensions as the smart car, capacities were calculated for autonomous personal pods as well. Fig. 4 provides a comparison of capacities for the three cases discussed. It is evident from the figure that autonomous personal pods would considerably increase the capacity of the same corridor.

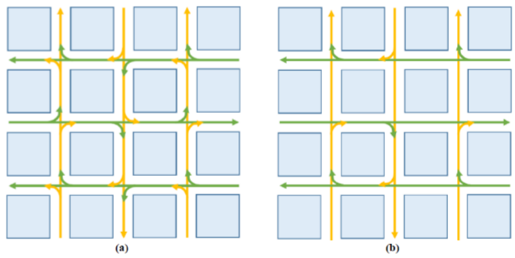

Figure 1. (a) One-way traffic circulation in several cities, (b) Proposed circulation

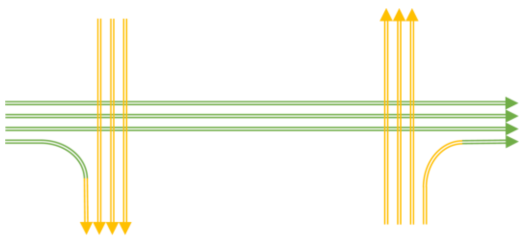

Figure 2. Grade-separated intersections with right-turning movement

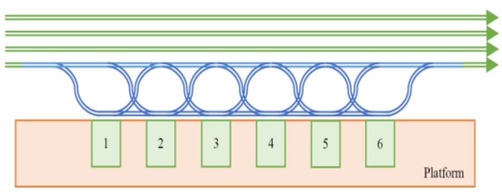

Figure 3. Pick up/ drop off bay

As we are moving towards electric vehicles in addition to making them autonomous, a major obstacle faced is the charging of vehicles. The autonomous personal pods, however, will not have this issue since they would be continuously in contact with the electric grid supporting the system. Moreover, the entire network would depend on electricity that can be generated by renewable sources.

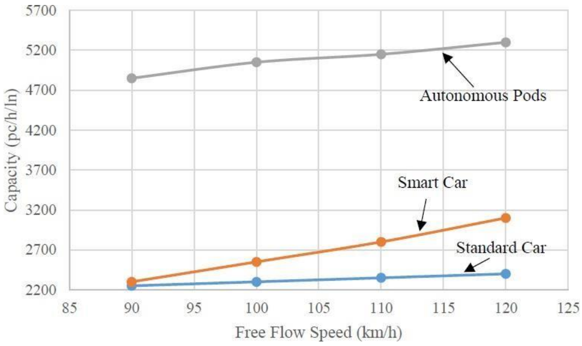

Figure 4. Capacity comparison of the standard car, smart cars, and autonomous pod

On the ground level, there would be no cars meaning no emissions, noise, or crashes. The air quality would improve leading to much-improved life expectancy. Daily commutes would become stress-free. All this will result in considerable savings in the healthcare sector.

There will be no need for car ownership as well as car maintenance. All this expenditure saved could be redirected to achieving other life goals. Since the same transport mode would be available to all the residents, it would improve equality and harmony within the society. For fast traveling within cities, researchers are already working on solutions such as the Hyperloop. So connecting the intercity travel options with the proposed intracity travel concept would make cars completely redundant.

IV. LIMITATIONS

The first and foremost hurdle is the huge investment required to construct, maintain, and manage this system. Associated with it is the research cost to make this system a reality. The algorithms to control the movement of pods within the network must be developed and refined to a foolproof level. This is a huge technological feat to be accomplished. Furthermore, the concept of equality in transportation might not be liked by a certain class within the society. Tough resistance to such a system will be expected. This concept is more suited to densely populated areas with land use designed in a grid pattern. For other areas, this concept with the discussed circulation pattern might not work.

V. CONCLUSION

This paper presents a better alternative to the conventional personal vehicles that we are so used to. The autonomous personal pods would eliminate all the negativecharacteristics associated with driving a car within the city.Like every concept, it has its pros and cons, however, it is a feasible research direction for making travel sustainable and accessible.

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Effect of Specimen Type and Size on Strength Properties of Recycled Aggregate Concrete

Yahya Salah
Faculty of Engineering and Information Sciences
University of Wollongong in Dubai
Dubai, United Arab Emirates
yahyasalah@uowdubai.ac.ae

Dr. Sana Amir
Faculty of Engineering and Information Sciences
University of Wollongong in Dubai
Dubai, United Arab Emirates
sanaamir@uowdubai.ac.ae

***Abstract*— The use of green concrete is on the rise all over the world. The Ministry of Climate Change and Environment in the United Arab Emirates, MoCCAE, has been encouraging the use of recycled aggregates from construction and infrastructure projects which makes it very important to study the strength properties and behavior of recycled aggregate concrete (RAC). While the effect of specimen shape and size on the compressive and flexural strength of normal concrete is a well-established phenomenon, their effecaboutto recycled aggregate concrete (RAC) is yet to be defined. This paper studies the effect of specimen shape and size on the strength properties of RAC by conducting compression tests on cubes and cylinders, and by performing four-point flexural tests on beams. Locally available recycled coarse aggregate, ceramic fine aggregate, and ceramic waste powder were used to develop recycled aggregate concrete. 150mm cubes, and 150 mm×300 mm, and 75mm×150mm cylinders were tested in compression. Beams having sizes of 150mm×150mm×460mm and 75 mm×75 mm×230mm were tested in flexural. Based on the experimental results, a relationship between compressive strength and flexural strength of RAC was developed. It was found that there is a significant effect of specimen shape and size on the strength properties of RAC and the conversion factors are different from normal concrete of the same strength.**

***Keywords*—** *Green Concrete, Ceramic waste material, Size effect, Sustainability, Strength properties*

I. INTRODUCTION

In 1824, cement was invented by Joseph Aspdin and since then, the use of cement and concrete around the world has been tremendously increasing. This increase in production raised concerns about the bad impact of concrete on the environment and natural resources such as increasing CO2 emissions as cement production is responsible for 5-7% of the CO2 global emission, the global shortage of construction sand, and the high usage of clean water and natural aggregate [1]. Moreover, the demolition of concrete structures or the excess concrete waste from construction sites produces waste material and puts more burden on the environment, therefore, the need to use recycled material and reduce the amount of cement in concrete mixes to more sustainable and environ environment-friendly has arisen globally over the past years. Researchers have investigated the use of different types of environment-friendly supplementary cementing material to reduce the amount of cement used in the mix, for instance, the use of Recycled Aggregate (Fig. 1) and ceramic waste material (Fig. 2). However, to use green concrete in the industry, some factors related to the concrete properties need to be reestablished Strength of Concrete

ACI Committee 318-22 (ACI318-22) specifies the compressive strength of concrete as the characteristic compressive strength of a 150×300 mm cylinder sample at 28 days [2], while Standards Association of Australia Committee BD-042, 2014 (AS 3600:2014) allows the use of 100×200 mm cylinders at 28 days [3].

A. *Flexural Strength of Concrete*

Generally, the four-point or three-point bending test is used to determine the flexural strength of concrete. At times, an estimate of the flexural strength is done by using the established relationship between the compressive strength and the flexural strength. The most common form of this relation is:

$$f_{ct.f}{}' = a\, f_c{}'^{b} \tag{1}$$

where $f_{ct.f}'$ is the flexural tensile strength in MPa, f_c' is the compressive strength in MPa, and “a” and “b” are factors and different codes have different values for ‘a’ and ‘b’. For instance, the AS 3600:2018 [4] suggests that a = 0.6 and b = ½ while ACI 318-22 [2] suggests that a = 0.62 and b = ½. However, further investigation is needed to check if this relationship is affected by the change in the type of aggregate or cement.

Figure 1. Recycled Coarse Aggregate

Figure 2. Ceramic Waste Powder

B. *Effect of Size and Shape of Sample on Concrete Strength Properties*

The strength properties of concrete are not unique which means they are affected by the change in some factors including the size and the shape of the sample. In the AS 3600:2018 for instance, a conversion factor of 0.8 was given to convert from the compressive strength of a cube to the compressive strength of a cylinder [5]. However, this is suggested for ordinary concrete reinforced and may not be applied to every type of cement or aggregate as changing these materials result in a change in the way the material behaves.

It is also a known phenomenon that concrete strength properties depend on the size of the sample [6]. When testing samples smaller than the standard size, it is important to establish how size affects the sample strength properties of concrete. Similarly, larger structural components have been known to show a size effect on strength as strength does not increase linearly with the scale [7].

C. *Recycled Aggregate Concrete*

Different studies were conducted to study the effect of the sample size and shape on Recycled Aggregate Concrete (Fig. 1). A cube-to-cylinder conversion factor of 0.78–0.93 for recycled aggregate concrete is reported in some literature [8]. No size effect was observed. In another study, [9], the cube-to-cylinder conversion factor for recycled aggregate concrete using 200 cylinders and cubes was found to be 0.7. Size effect was also studied for recycled aggregate concrete for cubes [10] and cylinders [11] and both of these studies reported a negative side effect (greater strength with larger samples). Nevertheless, none of these studies tested the size effect on flexural strength, and none of the studies utilized 100% recycled aggregate or ceramic waste materials (Fig. 2) in their concrete mixes.

This paper aims to study the effect of the specimen size and shape on the strength properties of recycled aggregate concrete (compressive and flexural strength) while utilizing 100% recycled coarse aggregate and ceramic waste materials.

II. EXPERIMENTAL SETUP

D. *Concrete Mix*

The concrete mix (Table 1) used in this study was originally developed [11] to study the utilization of recycled coarse aggregate and ceramic waste materials and their effect on the strength properties of concrete. In this mix, 100% of the natural coarse aggregate was replaced with recycled aggregate, 20% of the natural fine aggregate was replaced with ceramic fine aggregate, and, 20% of Portland cement was replaced with ceramic waste powder. The water/cement ratio was 0.5. The mix was designed to have a targeted characteristic cylindrical compressive strength of 40 MPa and a mean cylindrical compressive strength of 49.6 MPa.

E. *Sample Type and Size*

Samples with different shapes and sizes were tested; 150×150×150 mm cubes, 150×300 mm, d 75×150 mm cylinders. Nine samples were cast for each size. Three samples of each size were tested for compressive strength on the 7th, 14th, and 28th days. The beams sizes were 150×150×460 mm and 75×75×230 mm. Three samples were cast for each size and they were tested for flexural strength using the four-point bending test on the 28th day. Table 2 shows the summary of specimen and test specifications.

TABLE I. Concrete Mix

Material	Quantity used *Kilogram (kg)*	Material	Quantity used *Liter (L)*
OPC	50	Water	25
Ceramic waste powder	12	Plasticizer	0.75
Recycled coarse aggregate	124	Water/Cement = 0.5 Plasticizer: Poly-carboxylate ether (PC400) Curing: By ponding	
Natural fine aggregate	120		
Ceramic fine aggregate	30		

TABLE II. Specimens and age at the test

Test	Specimen shape and size	No. of specimens	Age
			Days
Compressive Strength	150×150×150mm Cubes 150×300mm Cylinders 75×150 mm Cylinders	9 9 9	7, 14, 28
Flexural Strength	150×150×460 mm Beams 75×75×230 mm Beams	3 3	28

TABLE III. Experimental results

Sample type	Sample size	Mean strength	SD	CoV
	mm	*MPa*	*MPa*	
Cubes[a]	150×150×150	61.6	3.82	6.2
Cylinders[a]	150×300	48.3	1.46	3.73
	75×150	39.9	1.48	3.71
Beams[b]	150×150×460	4	0.75	18.92
	75×75×230	6.4	0.21	3.23

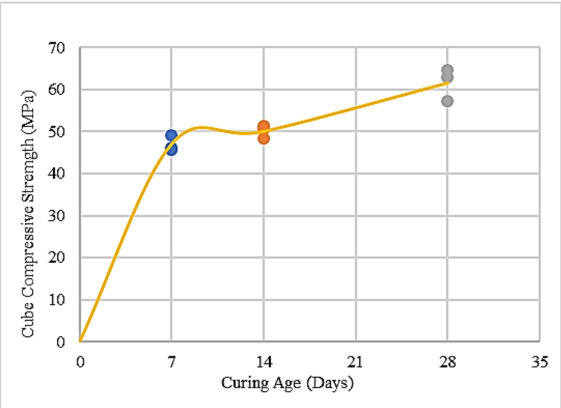

Figure 3. Development of compressive strength of standard cubes with respect to curing age concerning curing age.

III. RESULTS AND DISCUSSION

Table 3 shows the test results for mean compressive strength for all three samples of cubes, cylinders, and beams at 28 days along with the standard deviation (SD) and coefficient of variation (CoV). Fig. 3 shows the development of compressive strength for standard cubes.

F. *Effect of sample shape on compressive strength*

The effect of the shape on the compressive strength is seen in the results as the 150×300 mm cylinder exhibited a lower compressive strength than the 150×150×150 mm cubes. An average conversion factor of approximately 0.78 was found to convert from the standard cube size to the standard cylinder size. This is similar to provisions of AS 3600 [5], and findings in [8] and [9]. Using the cylinder/cube ratio of 0.8 from AS 3600 to convert to a standard-size cylinder, the estimated cylindrical compressive strength is 49.3 MPa which is very close to the experimentally found mean strength of 48.3 MPa.

G. *Effect of size on compressive strength*

Small-scale cylinders 75×150 mm (which is a half-scaled size of the standard size 150×300 mm cylinder) exhibited a higher strength than standard-size cylinders which can be seen in Table 3. The scale factor to convert from full-scale cylinders to small size is 0.5, but the strength size factor is higher i.e. 0.83 (average value in Fig.4), showing the effect of size on compressive strength. The size factor seems to be independent of curing age (in days).

H. *Relationship between Compressive Strength and Flexural Strength*

The small 75×75×230 mm beams exhibited a flexural strength of 6.4 MPa compared to 4 MPa for the 150×150 460 mm beams. Previously, Batikha et al. (2021) report a flexural strength of 4.6 MPa for 100×100×500 mm recycled aggregate concrete beams. A decrease in flexural strength can be observed with an increase in the size of the beam.

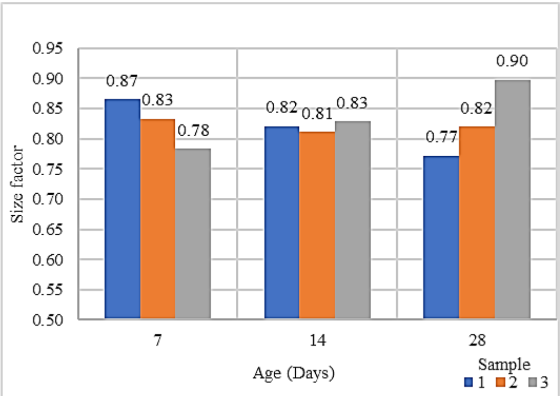

Figure 4. Compressive strength size factor between full-scale and half-scale concrete cylinders.

The experimental mean compressive cylinder strength was found to be 48.3 MPa (Table 3). Substituting 48.3 MPa as the compressive strength into Eq. (1) from the Australian code (AS 3600) where a = 0.6 and b = ½ will give an estimated flexural strength of 4.16 MPa, which is very close to the average flexural strength obtained for the 150×150×460 mm beams. Using ACI code gives a similar result; 4.3 MPa. This validates the results obtained in these experiments.

IV. CONCLUSIONS

This study investigated the effect of the specimen size and shape on the compressive and flexural strength of recycled aggregate concrete. Samples of different shapes and sizes were cast: nine cubes of size 150×150×150 mm, nine cylinders of size 150×300 mm and size 75×150 mm, and three beams of size 75×75×230 mm and size 150×150×460 mm were prepared and water cured. Three cubes and cylinders of each size were tested for compressive strength after 7,14, and 28 days, in addition to beams which were tested for flexural strength after 28 days. The following conclusions can be made:

- The average cylinder/cube ratio was found to be 0.78.
- The effect of the sample size was observed on half and full-scale cylinders. A size factor of 0.83 was developed to convert from small to large cylinders.
- The size effect was present in the flexural strength of the beams as well, though more experiments are needed to conclude a size factor.
- Lastly, the relationship between compressive cylinder strength and flexural strength of concrete beams from AS 3600 and ACI codes or normal strength concrete was found to be reasonably suited for recycled aggregate concrete as well.

V. ACKNOWLEDGMENT

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Comparison of Compaction and Consolidation Behavior of Fine Soil Using Treated Wastewater and Tap Water

Irfan Khalid
Civil Engineering Department
Fast-NUCES
Lahore, Pakistan
Irfan.khalid@nu.edu.pk

Habib-ur-Rehman
Civil Engineering Department
Fast-NUCES
Lahore, Pakistan
habib.rehman@nu.edu.pk

Muhammad Umar
Civil Engineering Department
Fast-NUCES
Lahore, Pakistan
m.umar@nu.edu.pk

***Abstract*--- Moisture content is a major component of soil that has the utmost importance on the consolidation and compaction behavior of the fine soil. The shortage of drinking water is a roaring alarming threat and in such crucial situations, we are required to give an optimistic solution answer. The core objective of this paper is to study the effect of tap water (TW) and treated wastewater (TWW) on the compaction and consolidation characteristics of fine soil. The treated wastewater sample was collected from the wastewater treatment plant located in Bahria Town Rawalpindi. The soil sample was obtained from the Lahore Ring Road Project (LRRP). Parent testing on treated wastewater according to national environmental quality standards (NEQS) and on tap water according to the world health organization (WHO) was carried out. High plastic and low plastic clay samples were collected for this experimental study. The evaluation of Consolidation and compaction properties such as swell index, consolidation index, volume change, maximum dry density, and optimum moisture content was carried out by using TW and TWW. The positive effects of the treated wastewater on these engineering properties were observed. The increase in maximum dry unit weight for both soil and reduction in optimum moisture content of 13% was found in the case of high plastic clayey soils. The pronounced effect in the case of the swelling index and swell pressure was also observed. The reduction of the swell index in the case of high plastic clay was 40% whereas in the case of low plastic clay it was 32% on the use of TWW. The reduction in swelling pressure for both the soils was the same i.e., 15%. The finding of this study emphasized the focus on the use of treated wastewater by elaborating the health effects on the compaction and consolidation characteristics of fine soils.**

Keywords— *compaction, consolidation, treated wastewater*

I. INTRODUCTION

Extensive soils are regarded as a natural hazard because, if improperly handled or accommodated by appropriate protective construction measures, they may result in significant infrastructure damage. The significant net negative charges surrounding them are what cause their volume shifts. The particles that cause a significant number of hydrated cations to be adsorbed also to the adsorption of water molecules when seasonal moisture variations take place. Such harms could seriously disturb a number of structural components in the buildings' foundations and pavements' cracking and crumbling as a result of settlement or heaving linings of canals, railroads, and highway embankments (Chen, 1988; Grim,
1968; Marshall, 1977; Mitchell, 1993; Hillel, 1980).

The three environmental challenges that are currently causing the most worry are the depletion of natural resources, the global water crisis, and greenhouse gas emissions. As a result, sustainable development—which entails satisfying human needs with little harm to the environment—is promoted in every sphere of society. One of the greatest global sectors, the construction sector is also one of the main drivers of greenhouse gas emissions and the depletion of natural resources. Around 25% of the annual global harvest of wood, 40% of the usage of stone, sand, and gravel, 16% of the use of water, and 50% of the emissions of greenhouse gases come from the building industry. (Brito, 2012)

Various soil stabilization techniques are available to improve the geotechnical qualities of fine-grained soils to address the issues posed by such soils. With the use of these techniques, the negative impacts of plastic soils on building construction and afterward can be reduced or eliminated. These techniques include the use of pile foundations, chemical stabilization, soil replacement, moisture and compaction control, rewetting, surcharge loading, mixing with other soils, and soil replacement (Chen, 1988; Koerner, 2005; Nelson & Miller, 1992; Steinberg, 1998; Yong & Ouhadi, 2007). To further enhance the geotechnical and strength characteristics of fine-grained soils, other complex and cutting-edge novel

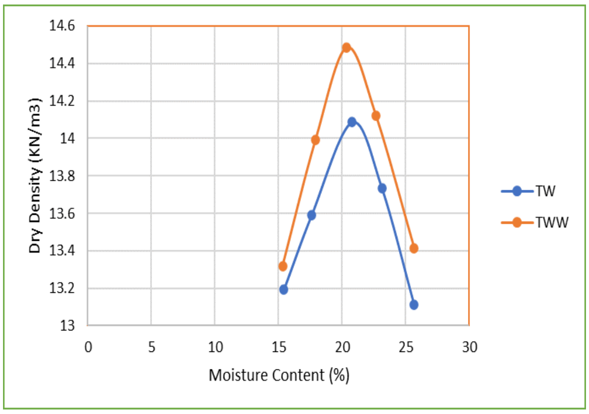
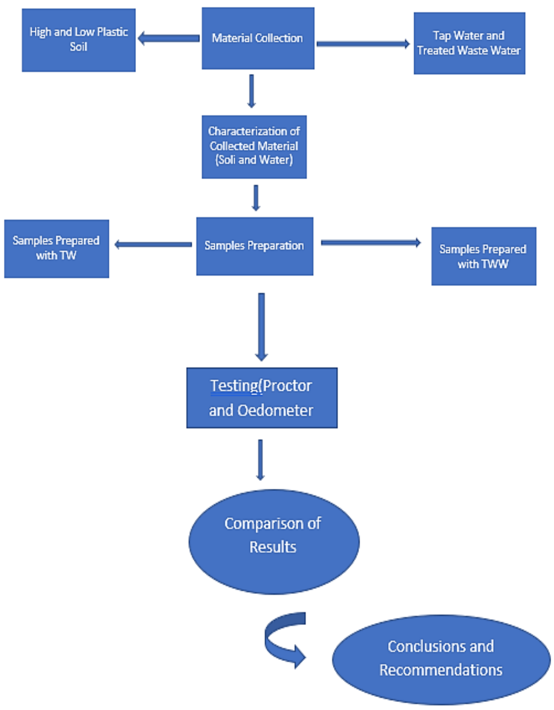


Figure 1. Proctor Compaction Curve for low plastic curve

Techniques are still being investigated (Akbulut, Arasan, & Kalkan, 2007; Moavenian & Yasrobi, 2008; Puppala & Musenda, 2000).

The purpose of this project is to conduct a preliminary investigation into the viability of using treated wastewater as a stabilizing agent to enhance the geotechnical characteristics of high and low plastic soils used in road and foundation systems.

To do this, samples of natural and stabilized fine-grained soil with high and low plasticity were evaluated in a lab setting. The Atterberg's limits, compaction characteristics, and odometer values were utilized to gauge the possible advantages of using sea water mixed with a variety of locally accessible soils to treat wastewater.



Research Methodology

II. PROPERTIES OF SOIL SAMPLE

The two types of soil utilized in the study were subjected to tests, and the findings are provided in Table I along with the gradation, Atterberg's limits, and compaction parameters.

TABLE I. Properties of Soil

	Soil-1	Soil-2
Grain Size Distribution		
Clay (%)	62	40
Silt (%)	26	38
Sand (%)	12	22
Atterberg's Limits		
LL (%)	58	36
PL (%)	20	15
PI (%)	36	19
Compaction		
MDD	13	14
OMC	32	20
Gs	2.65	2.64
Soil Classification (USCS)	CH	CL

Both the tap water and the treated wastewater underwent chemical analysis tests, and the test findings were compared with both the NEQS recommendations for water reuse and the WHO specifications. According to the findings, both forms of water meet the requirements and can be utilized in the construction sector, as shown in Table II.

TABLE II. Chemical Analysis of Water

Sr#	Test	Standard Values			
		Treated Wastewater	Tap Water	NEQS	WHO
1	Temp.	27.4	27.4	25	25
2	PH	7.3	8.1	6 to 10	7.5 to 8.5
3	COD	71	0	150	10
4	BOD	42.6	0	80	10
5	TSS (mg/L)	25.3	15	150	150
6	TDS (mg/L)	1105	652	3500	500
7	Chlorides	171	35	250	250
8	Hardness	186	120		500
9	Alkalinities	180	112	500	500
10	Electrical Conductivity	1201	0		
11	Turbidity	5.86	1.14	NA	NA

III. RESULTS

The two soil types—low plastic soil and highly plastic soil—were subjected to standard Proctor compaction tests utilizing the two water types—tap water and TWW, and the proctor compaction curves produced are depicted in Figs. 1 and 2, for low and high plastic soils, respectively. The test findings revealed that the ideal moisture content for the low plastic soil was somewhat higher when tap water was utilized than when TWW. Additionally, as shown in Fig. 4, the maximum dry unit weight with TWW was marginally higher than with tap water. The ideal moisture level for the highly plastic soil was lower with TWW water than with tap water. The ideal water percentage dropped to just 13.6%. However, as shown in Fig. 5, the maximum dry unit weight for the TWW was larger than for the tap water. The % decreases in moisture content when TWW was used instead of tap water and the percentage increases in the maximum dry unit weight when TWW was used instead of tap water are used to illustrate the variations in the results. Figure 3 displays those findings.

The two water types were used in one-dimensional consolidation testing on both soil types. In Figs. 6 and 7, respectively, the e-log p curves for low and highly plastic soil are displayed. The findings demonstrated that, for the low plastic soil, TWW has a lower compression and swell indices than tap water. Additionally, TWW has a maximum past pressure that is lower than tap water at 1.62 kg/cm2 as opposed to 2 kg/cm2. The findings for very plastic soil are comparable to those for low plastic soil, demonstrating that the consolidation index and swell index are likewise lower when TWW was applied.

TWW also resulted in a reduction in the soil's maximum previous pressure. For TWW water, it dropped from 1.9 kg/cm2 to 1.7 kg/cm2 for tap water. The two soils' swelling pressures have also been assessed. The test findings demonstrated that TWW water had an impact on both swelling pressure and volume change. The volume change fell from 17 percent for tap water to 9 percent for TWW, and the swelling pressure for the low plastic soil decreased from 3.1 kg/cm2 for tap water to 2.6 kg/cm2 for TWW.

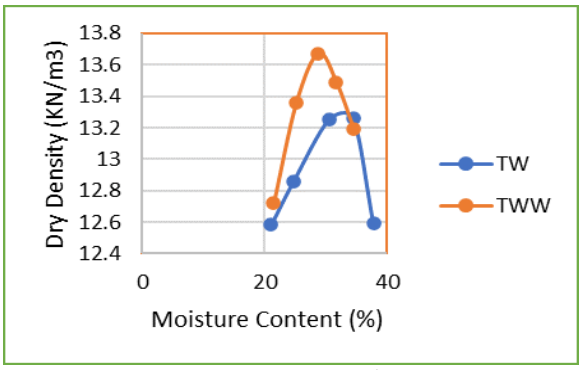


Figure 2. Proctor Compaction Curve for high plastic soil

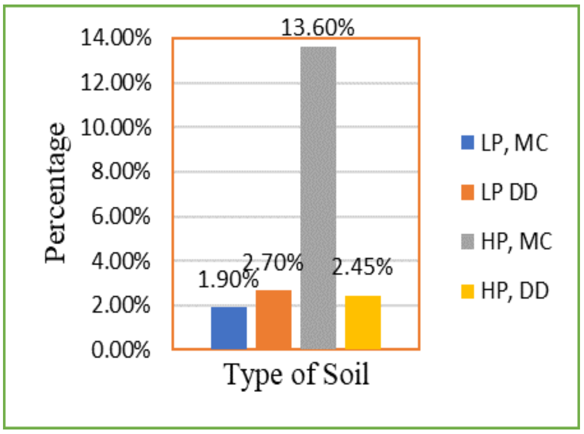


Figure 3. Optimum moisture content and maximum dry unit weight for low plastic soil

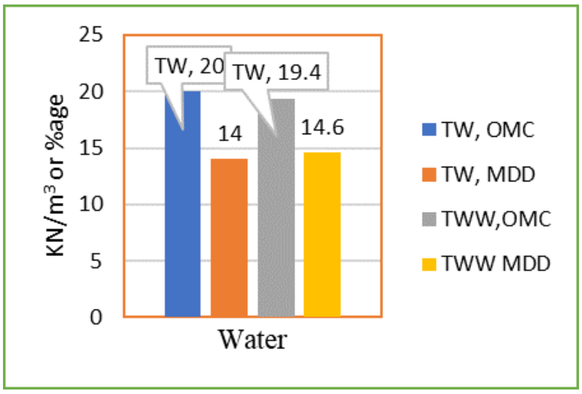


Figure 4. Reduction in moisture contents and increase in maximum dry unit weight due to treated wastewater.

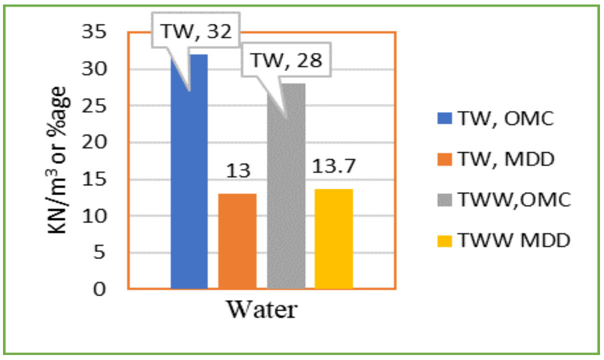


Figure 5. Optimum moisture content and maximum dry unit weight for high plastic soil

The same pattern was seen for the soil that was extremely pliable. The volume change reduced from 30% for tap water to 21% for TWW, and the swelling pressure decreased from 4.3 kg/cm2 to 3.6 kg/cm2 for TWW.

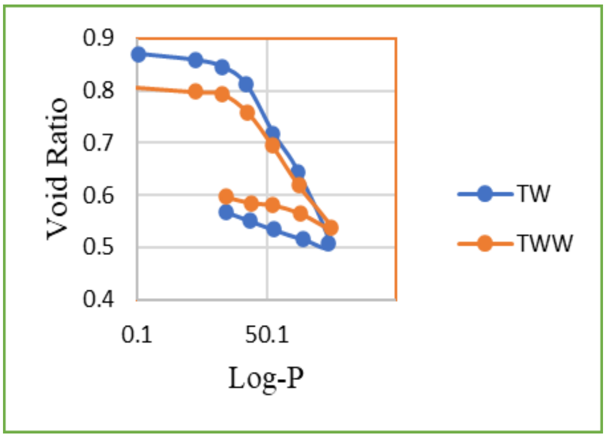


Figure 6. Consolidation Curve for Low Plastic Soil

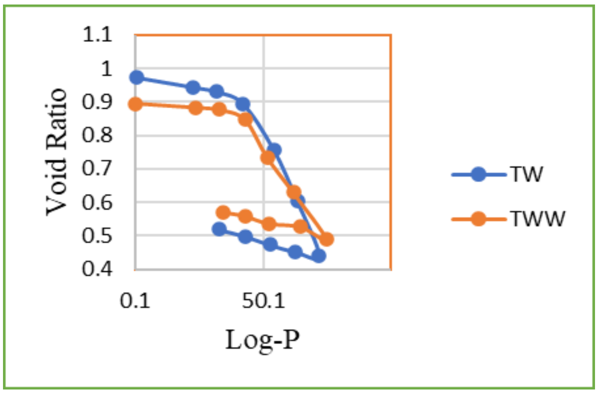


Figure 7. Consolidation Curve for High Plastic Soil

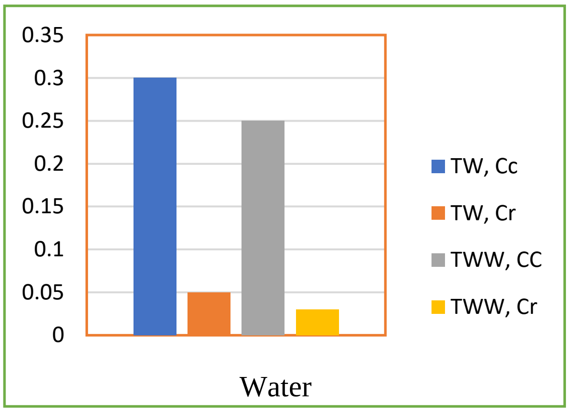


Figure 8. Difference in Consolidation and Swell Indices between tap water and TWW for low plastic soil.

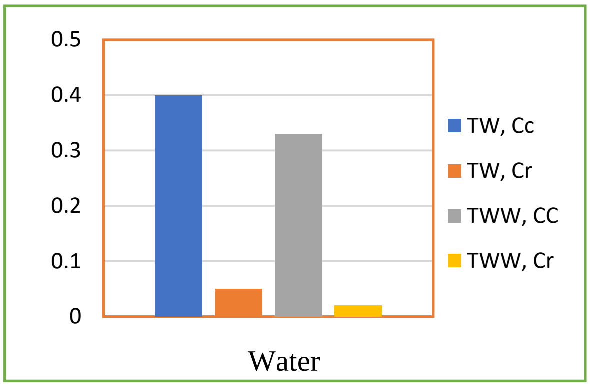


Figure 9. The difference in consolidation and swell indices between tap water and treated wastewater for high plastic soil

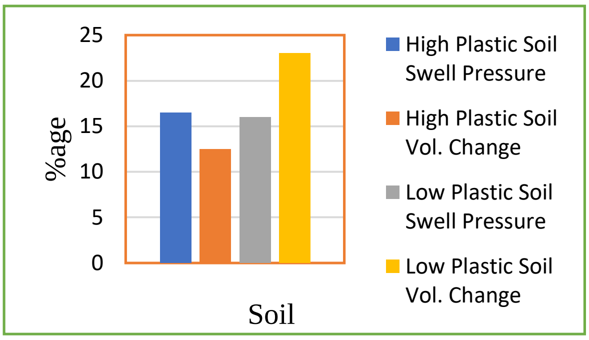


Figure 10. Percentage decrease in swelling pressure and volume change due to treated wastewater.

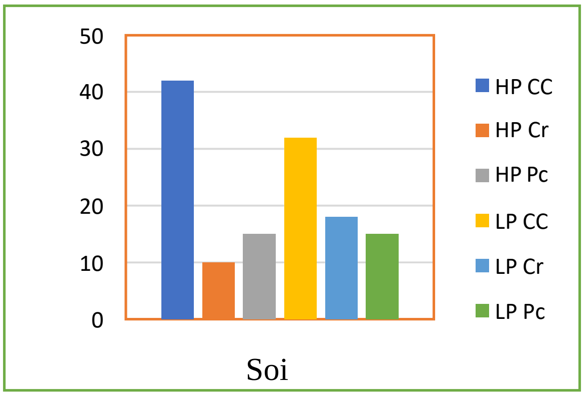


Figure 11. Percentage decrease in consolidation indices, swell indices, and maximum past pressure due to treated wastewater.

IV. CONCLUSION

According to the findings of this study, TWW has an impact on the fine soil's compaction and compressibility qualities. The maximum dry unit went raised. The soil's weight and decreased the ideal moisture level for extremely plastic soil additionally, the compressibility index dropped. And the soil's highest previous pressure as well as the swell index well. Additionally, it was discovered that applying TWW to the soil will reduce the volume change and the swelling pressure. According to a study, TWW should be used instead of tap water in the use of fine soil in engineering practices.

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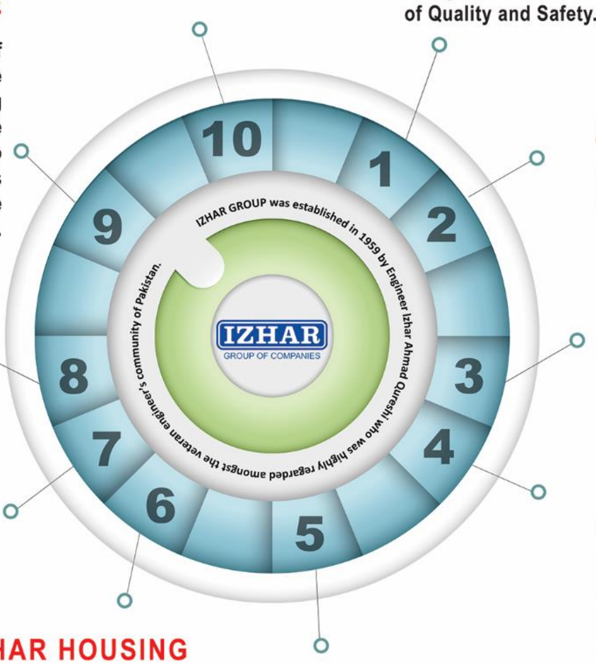

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NEW TRENDS IN CIVIL ENGINEERING

Decision Making For Sustainable Construction System through BIM and MCDM Integration

Khadija Mawra
Dept. of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
khadija@uet.edu.pk

Khuram Rashid
Dept. of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
khuram_ae@uet.edu.pk

Areeba Ashiq
School of Civil and Environmental Engineering
National University of Science and Technology
Islamabad, Pakistan
areebaashiq6@gmail.com

Mushahid Nisar
Dept. of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
untoomushahid66@gmail.com

Hira Naz
Dept. of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
nazhira450@gmail.com

***Abstract*— Sustainability in construction is one of the most vital needs at present giving rise to development of advanced techniques. Modular construction has emerged as one of the popular techniques with glowing time and cost benefits. However, efforts are needed to incorporate all sustainability domains while selecting a particular construction alternative. Therefore, this study was designed to identify a decision matrix, integrating three sustainability pillars: economic, environmental, and social. From the literature review 25 factors were identified, and ranked through a questionnaire-based survey from field experts on a Likert scale. As a result, ten most critical decision-making factors (CDMFs) were identified. Critical economic factors are the cost of, material, labor, transportation, and the project duration. While materialwastage and greenhouse gas emissions are the most critical environmental factors. Availability of skilled labor, safe work process, design adaptability, and the project management expertise were the most critical in social category. The study analyses slab construction systems alternatives; cast in-situ (S1), I-girder slab system (S2) and precast hollow core slab system (S3). Based on three alternatives and nine criteria (from 10 CDMFs), a multi-criteria decision-making method; TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), was adopted to identify the best alternative. The input values for economic and environmental factors were quantifiedthrough 5D Building information modeling (BIM) of amedium rise building with the three slab construction system alternatives. Whereas the social factors inputs were qualitative obtained through questionnaire survey. Results for the project case taken in current study revealed that precast I girder slab system of modular construction turned out to be the best alternative. This method could serve as a decision-making tool in the planning stages of projects for opting best suitable alternative for the construction of a project.**

Keywords — modular construction, decision making factors, decision matrix, BIM, sustainability.

I. INTRODUCTION

Construction industry is one of the key contributors towards economic growth, environmental stability

Emerged to improve the construction methods to achieve sustainability. One of those is the modular construction which has shown better project performance and sustainability potential [1]. For its rapid progress, higher quality control and reduced costs [2], modular construction technique is being promoted worldwide. However, manyfactors tend to effect the positive outcomes of modular construction like availability of skilled labor, organization's competency, design difficulty, site conditions and others [3]. Therefore, it is critical to identify its applicability in early stages of project to maximize expected benefits in all three domains of sustainability. Construction industry is responsible for consumption of 60% of material resources, 40% of energy resources and also a producer of 39% of greenhouse gases and 35% wastage, globally [4]. Modular construction is the industrialized format where schedules can be shrunk by 20 –50% and overall cost savings could be up to 20% [5]. Furthermore, modular construction has a great potential to reduce wastage as modules are manufactured in a controlled factory environment and after detailed designing [6]. Reduction of wastage ultimately saves expenditure and also influences wastage related environmental damages. In environmental perspective modular construction has a strong impact on greenhouse gas (GHG) emissions and a national study quoted that it can reduce GHG emissions by 46% in small scale construction [7]. However, they have mentioned a valid argument that the beneficial nature of modular construction is still dependent on various factors.

Benefits in economic and environmental domain separately and there is a dire need to integrate modular construction with sustainability [8]. This study tends to address this gap by identifying decision factors for adoption of modular construction in three domains of sustainability. The critical decision factors were then integrated through a multi-criteria decision making matrix, validated for slab construction methodologies including two types of modular slabs available in local industry.

II. METHODOLOGY

A. Literature Review

Literature review was conducted to extract important factors that impact the decision-making while opting one of the construction methodologies. The factors were extracted in three categories; economic, environmental and social. Google Scholar, Science Direct and Scopus were used for articles search. The main keywords used were “modular construction”, “offsite construction, “decision-making”, “decision support”, “critical factors” or “success factors”. After gathering articles, firstly quick scan of abstracts and results was carried out. At last the selected articles were reviewed in detail for extraction of factors. A list of total 25 factors were extracted from systematic literature review.

B. Questionnaire Survey

On the basis of factors identified in literature review, a questionnaire was developed to get the factors ranked for their importance in decision making on Likert scale 1 – 5, where “1” indicated “very low (importance)” and “5” indicated “very high (importance)”. Responses were taken from national field experts and academia researchers as the study intends to identify the critical factors as per the construction of a developing country like Pakistan. After collection of responses, factors were ranked and assigned a score – the relative importance index (RII). For this at first, the weighted average (*W.A*) was calculated based on the score assigned by respondents to each factor by the formula given in (1).

$$W.A = \sum S.Si * f / N \qquad 1$$

Where, S.S= score on the Likert scale (i= 1, 2, 3, 4, 5), f= frequency of each score in responses and N is the total number of responses. To priorities factors in the order of their importance, a relative importance index (*RII*) was calculated by using (2)

$$RII = W.Ai / 5 \qquad 2$$

Where, $W.A_i$ is the weighted average for each factor calculated by 1 and 5 being the maximum score on Likert scale. Critical factors are prioritized by considering the factors scoring more than “3” weighted average value as 3 represents medium importance level, so the cut off limit is set at 3 for this study. Similarly on the scale of RII, the score more than 0.6 is considered to filter out critical factors. The scores listed out the most critical factors that influence the decision-making for best option to adopt among modular construction techniques or cast-in-situ construction.

C. Slab Construction Alternatives

The alternatives of slab construction system are used for this study to identify the best alternative in light of the decision making factors. These were selected on availability in the local construction industry. One of the alternatives is conventional cast-in-situ slab system in monolithic concrete construction, while other two alternatives are the precast slab types available in local industry. A triple storey mix usebuilding plan of 530 m^2 was considered for which three types of slab alternatives were incorporated The alternatives details used are as following:

Cast-in-situ – *A typical monolithic frame structure in whichall elements are constructed on site. As per the applying loads 23 slabs of maximum span 7.5m and depth 0.15m were used and named as S1.*

Precast I-girder system – *A hybrid frame structure in whichonly columns are casted on site and I-girder beams and slab modules are precast with sectional detail in Fig. 1(a).I- girders of section “(5x14) inch” and slab panels of “4feet x* 1.5 inch” section are used for 7.5m span, while for shorter span (less than 5.5m) the I-girders of “(5 x 12)inch” with same sized slab panels were selected from the load charts of the local manufacturer (Izhar Concrete (Pvt) Ltd.) and named as S2.

Precast Hollow core slab– *A hybrid frame structure in which only slab is replaced by hollow core precast slab, while rest of the structural elements are casted on site. A typical section of hollow core slab is shown in Fig. 1(b). The selected section size of hollow core slab was “200 HCS with five 3/8inch strands”, also selected as per the loadcharts of Izhar Concrete (Pvt) Ltd and named as S3.*

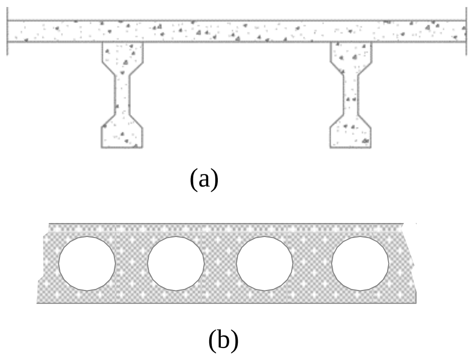

Figure 1. (a) I-girder slab system and (b) Hollow core slab sections

D. 5D BIM Modelling

In order to quantify some critical decision factors for the three alternatives, 5D BIM modelling was used. Through a 5D model, the details of material quantities, labor hours, project schedule and time required for activities were quantified. Therefore, for the factors which could be quantified through a project’s construction details, 5D BIM models were developed for a medium scale project by using the three systems of slab construction in Autodesk Revit (a BIM software). Models were developed for each alternative by selecting slab types from the construction families present in software. For any module if there was no family available, Revit has the feature to create new families according to the type of slab system to be used. The precast systems’ modules were created in Revit according to the details.

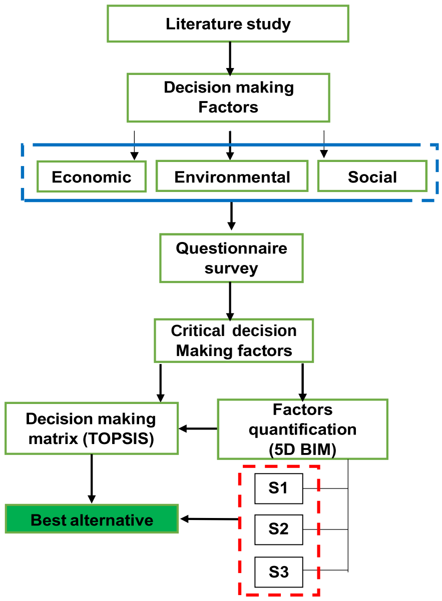

Figure 2. Methodology flow chart for the study

III. RESULTS AND DISCUSSION

A.Critical Decision-Making Factors (CDMFs)

From 25 factors, ten factors were critical based on their weighted average score and relative importance indices. Overall, economic factors play the most important role in suitability of a construction system as shown in Figs. 3, 4 &
5. In economic factors, the costs of material, labor and transportation and project duration are four most critical factors. Project duration has a direct effect on project cost interms of overhead costs. The financial health of the organization seems to be not an important feature as before awarding any project financial competence is alreadychecked during bidding evaluation. In environmental category, wastage and greenhouse gas emissions came were only two critical factors towards construction system selection. Recycling and reusability of construction material was just below the medium importance cut off bar because the local industry at this level is not very common or applied at massive level in Pakistan. In case of social factors, the most critical factor was “availability of skilled labor”, “safe work process”, “and expertise of the project management team”and“design adaptability”.

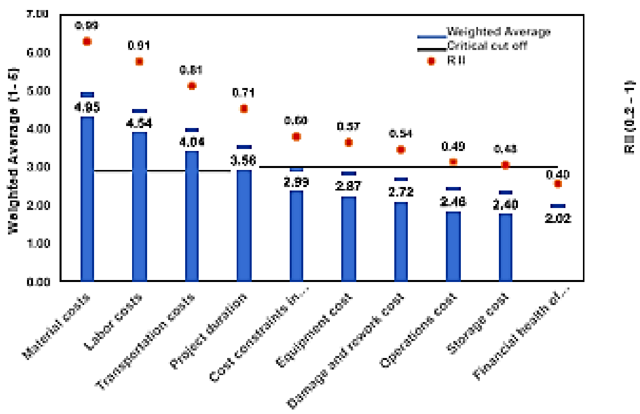

Figure 3. Economic factors ranking as per W.A and RII

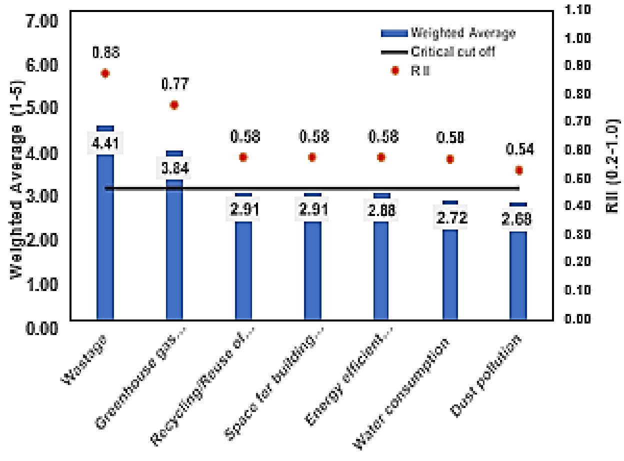

Figure 4. Environmental factor as per W.A and RII

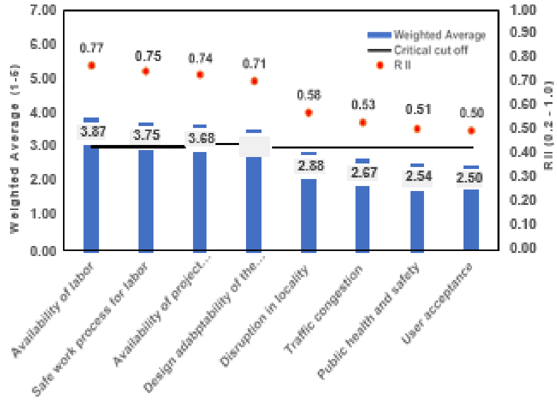

Figure 5. Social factors as per W.A and RII

B. Economic Factors

Material Cost – Material cost for each alternative was computed through implementation of 5D BIM models. Schedules of material quantities were generated, and material costs were estimated on the basis of market rates forthe materials to be used in both cast-in-situ and precast options. A comparison of material costs for the three systems is shown in Fig. 6. It is observed that overall hollow core slab(S3) material cost is highest based on its high rates although the material may have been reduced due to hollows compared to I-girder slab system (S2) in the local manufacturing industry.

Labor Cost – As a result of 4D BIM simulation of construction activities, a schedule of labor hours was determined and based on the market rates total labor cost was calculated. A comparison of labor cost between three construction system alternatives is shown in Fig. 6. It is observed that labor requirement is almost similar in cast-in- situ (S1) and hollow core system (S3) as compared to I-girder system (S2) which is lesser. The reason behind labor cost being higher in hollow core system is that specially qualifiedlabor are required for its assembling at site with higher labor rate. Secondly, in S2 two of the building elements are being constructed off-site; beams and slabs, so more part of work isbeing shifted to offsite construction rather than the hollow S2 system is lowest as it requires the least labor work onsite.

Transportation cost – It included the freight charges for transportation of raw material to the site in case of cast-in- situ system and the transportation of modules from the manufacturer units. For this study, maximum distance withina city radius was considered and transportation costs were calculated accordingly from the material sources location. Transportation cost is a variable factor that greatly depends on the availability of local raw material for cast-in- situ system. And in precast systems it depends on availability of local precast manufacturers and the logistics rates as per the module. Based on amount of materials and space taken by them in a specific construction material transportation vehicle, the transportation hauls are decided. Thecomparisons as shown in Fig. 6 depicts that hollow cores labs transportation is the most expensive as per market rates and number of modules transported to site in one haul.

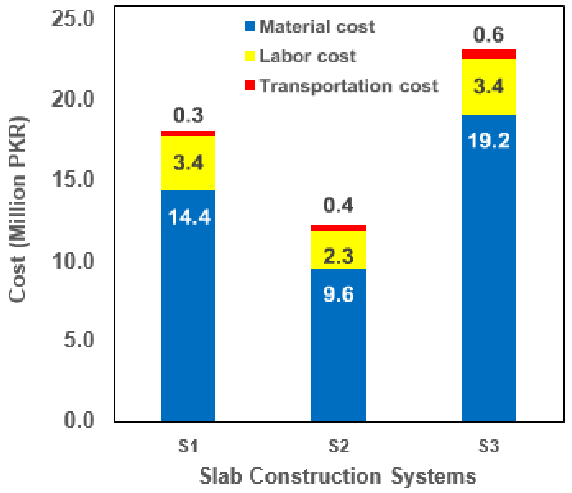

Figure 6. Costs consumption for three slab systems

4D BIM model provided with a detailed project schedule comprising of activities and their respective durations in each construction system's process. Fig. 7 shows the time taken by each system to construct the selected building. It shows that overall precast systems take lesser time than the cast-in-situ case. This is because of the parallel manufacturing of precast modules during the on-site construction for remaining structure. Once the modules are prepared at the time when relevant structure is completed on site, the modules are transported and assembled at the site. However, in two precast systems, a project with the hollow core system (S3) takes the least time to complete (20 weeks). This is because in S3, only one module requires assembling at site and takes less duration than the I-girder slab system which takes slightly higher assembling time because of two module sassembling.

E. Environmental Factors

Wastage – Wastage value for each construction techniquewas calculated by taking a certain percentage of the total quantities of concrete and steel used for any construction system as per standard ranges. For cast in-situ this percentageof wastage was taken as 5–15% of total material, 1.5–2% in case of modular precast construction[7]. The second critical factor was greenhouse gas emissions, however, in this studyit is not considered for being a lengthy explanation and vast scope.

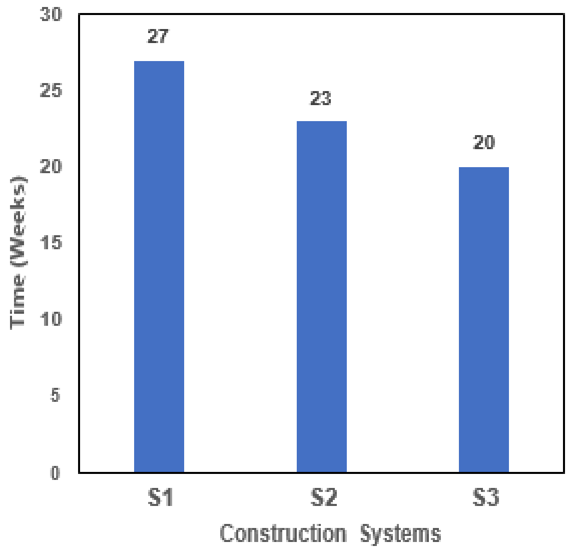

Figure 7. Project duration comparison between construction systems

F. Social Factors

Availability of labor – For each technique expertise of thelabor was recorded on Likert scale 1 to 3 where, 1 means lowavailability of skilled labor, 2 means medium availability of skilled labor and 3 means high availability of skilled labor forany construction system. It was attained from the field experts during questionnaire survey.

Safe work process - Worker's health and safety wasranked on a Likert scale of 1 to 3 on which 1=Low safety, 2=Medium Safety, 3=High Safety. The Likert scale expressed the level of safety that could be achieved during process of any construction alternatives. The safer the method the higher Likert scale value selected by the respondents during questionnaire survey.

Project management expertise – The input value for this factor was on a Likert scale of 1 to 3 where, 1= low expertise required, 2= medium expertise required, 3= highly expert project management team requirement, obtained through questionnaire survey form field experts. The values outlined the level of expertise required to implement a specific construction system type for efficient integration of off-site and on-site.

Design adaptability – Ease of design adaptability was ranked on a Likert scale of 1 to 3 where, 1=low ease and 3= maximum ease.

I. DECISION MATRIX DEVELOPMENT

As there are a set of factors that govern the decision of selection among three alternatives, a multi-criteria; TOPSIS; Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used. The technique is applied in five steps:

Step 1: The decision matrix is created for alternatives (*i*) and criteria (*j*) where x_{ij} is the intersection of *i* and *j*.

Step 2: The weights of the criteria is computed through (1)

Step 3: The normalized decision matrix is computed by using (3), where r_{ij} is the normalized vector

$$r_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{m} x^2_{ij}} \qquad 5$$

Step 4: The weighted normalized decision matrix is computed by multiplying normalized vector with the weighted average (*W.A)* score of each criteria.

Step 5: Positive and negative ideal solutions are computed byusing (4) and (5)

$$Si+ = (rij-xj)^2 = \{(\max vij \mid j \in J), (\min vij \mid j \in J'), i = 1, 2, 3\cdots, m\}$$

$$Si- = (rij-xj)^2 = \{(\min vij \mid j \in J), (\max vij \mid j \in J'), i = 1, 2, 3 \ldots, m\}$$

Step 6: Calculation of separation matrix by using (6) and (7).
Where, "*S+*" is an alternative distance from the positive ideal solution and "S –" is an alternative distance from the negative ideal solution.

$$Si+ = (rij-xj)^2 \qquad 6$$
$$Si- = (rij-xj)^2 \qquad 7$$

Step 7: The Relative Closeness Coefficient RCC_i for eachalternative is computed by

$$RCCi = \frac{Si^-}{Si^+ + Si^-} \qquad 8$$

Step 8: The alternative with the highest closeness coefficient represents the optimal alternative.

TOPSIS Decision Matrix

The critical decision-making factors used as criteria in the decision matrix of best alternative for the considered projectare shown in Table 1 with their quantification units and weight function (W_f). The alternatives used are the three- slab construction systems; Cast-in-situ (S1), I-girder slab system (S-2) and hollow core system (S-3). Decision matrix is shown in Table 2.

TABLE I. CRITERIA OF THE DECISION MATRIX

ID	Factors (Criteria)	Units	(W_f)
C1	Material cost	M. PKR	0.136
C2	Labor cost	M. PKR	0.125
C3	Transportation Cost	M. PKR	0.111
C4	Project Duration	weeks	0.098
C5	Wastage	%	0.121
C6	Labor Availability	Qualitative (1-3)	0.106
C7	Safe work process	Qualitative (1-3)	0.103
C8	Project management Expertise	Qualitative (1-3)	0.101
C9	Design Adaptability	Qualitative (1-3)	0.097

TABLE II. CRITERIA OF THE DECISION MATRIX

Alt	Economic				Env	Social			
	C1	C2	C3	C4	C5	C6	C7	C8	C9
S1	14	3.4	0.3	27	15	3	1	3	1
S2	10	2.3	0.4	23	2	2	2	3	2
S3	19	3.4	0.6	20	2	2	2	3	3

Sustainable Construction System

After implementation of TOPSIS process from equation
(3) – (7), the obtained relative closeness coefficient for the three alternatives are listed in Table 3. Based on the results the alternative of I-girder slab system (S2) is the most sustainable alternative for slab construction among cast-in- situ and precast alternatives.

Alternatives	Relative Closeness Coefficient (RCC)	Priority
S1	0.308	3rd
S2	0.764	1st
S3	0.617	2nd

The conclusions drawn through this study are:
Economic factors are the most significant factors in a sustainability assessment of conventional and precast construction systems, followed by environmental and social, respectively. Material cost plays the mostsignificant role among economic, wastage in environmental and labor availability from social category.
The material costs in case of precast systems are driven by the manufacturing rate which is dependent on the complexity of manufacturing process of a module and availability of manufacturer in locality. Although, precast systems are assumed to reduce cost of construction, but hollow core slab system can be most expensive due to high rates.
Project durations are reduced by 15 –26% from cast-in- situ to I-girder and hollow core system, respectively, with hollow core slab based construction havingshortest duration. However, the labor rates of hollow core are not least due to higher wage rates for special skilled labor required with hollow core system in Pakistan industry, at present.

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Attribution Analysis of Runoff Change by Using SWAT Model a Case Study of Khanpur Dam Catchment

Dr. Muhammad Shahid
Department of Civil Engineering
University of Engineering and Technology
Lahore, Pakistan
m.shahid@uet.edu.pk

Shoaib Salim
NICE, SCEE
NUST H12
Islamabad Pakistan
shoaibkhattak246@gmail.com

Muhammad Waseem
CEWRE
University of Engineering and Technology
Lahore, Pakistan
waseem.jatoi@cewre.edu.pk

***Abstract*—It is important to understand the runoff of a basinand attribute these changes to different factors. Runoff of a basin is sensitive to different factors and climate and land use changes are significant among them. Hydrologists are more interested to evaluate the regional hydrological response and present study is an attempt to understand the hydrological response of Khanpur dam catchment by using Soil and Water Assessment Tool (SWAT). The hydro climatic datasets of the Khanpur dam catchment has been evaluated during 1991-2019. Statistical techniques have been used to evaluate the variables and later simulations have been performed. The results showed that precipitation and temperature data have presented significant changes and based on these changes the study periodhave been divided into Pre-change period (1991-2005) and Post- change period (2006-2019). These changes could be due to land use change and climate changes. The impacts of climate changehave been evaluated by performing simulations in SWAT model. The land use changes have been quantified by using Land use classification in ArcMap. It has been concluded that climate change and land use changes equally contributed to runoff change in Khanpur dam catchment. The results of this study could be useful in understanding the regional hydrologicalcycle. Similar studies can be performed on different sub basins of the Indus basin and collectively these findings could be helpful to understand the overall response of the hydrological cycle.**

Keywords*—*Climate change, Water resources, SWAT, Runoff

I. INTRODUCTION

Water is one of the main component for survival of all living things on this earth. This resource is decreasing day byday and with the increase in population its demand has increased. There are different sectors which are dependent onthe water resources these include domestic, agriculture and industrial sectors. The survival of these sectors is almost impossible without water. The better management and quantification of the water resources could be useful to fulfilthe water demands.

The surface runoff generated from the hydrological cycle is the main source of water and it is mainly used to fulfil maindemands of humans as well as animals. The humans collect and store this surface runoff and animals are dependent on rivers, lakes and open water bodies available on the earth surfaces. Different factors are responsible for the changes in hydrological cycle at global and regional level and researchers are evaluating these factors. These factors includehydrology, geology, topographic features land use and climate of the catchments. It has been concluded that climatechange and land use changes are the main factors which are responsible for changes in the surface runoff. There is no consistent conclusion that among these factors which factor ismainly responsible for these changes. However, different studies are available at global and regional scale. Due tourbanization and development activities the paved surface areahas increased which has reduced the infiltration rates and ultimately increased the surface runoff [1].

Different methods are available to evaluate the impacts of climate change and land use change on surface runoff. These methods include use of conceptual model, mathematical model, lumped model, semi distributed model and fully distributed models. All these models and techniques have beenapplied and tested by researchers all over the world. Each of these models have their own requirements and based on these requirements researchers can decide and select these models. While selection of these models different factors are considered these factors include availability and quality of datasets, length of data sets, availability of resources to perform analysis and simulations. In data scarce regions conceptual models are used and their results have been found good.However, if data availability is not a challenge then use of semi distributed or fully distributed hydrological model is encouraged [2].

Pakistan has diverse and complex topography and it is oneof the water stressed countries in the world. The requirementsof its capital are fulfilled by using water from Rawal dam, Simly dam and Khanpur dam. The Rawal dam has been constructed on the Kurang river basin and it was constructed in 1960, the Simly dam has been constructed on the Soan riverbasin and Khanpur dam is constructed on the Haro river.

Khanpur dam catchment which is constructed on the Haro River has been selected to perform the runoff attribution analysis. The main aim of this study will be to evaluate the trends of different variables and to develop the land use changes maps of the study area. SWAT hydrological model will be used to attribute the changes o climate and land use to surface runoff changes.

II. METHODOLOGY

A. Study area decryption

The Haro River originates in the Abbottabad District of Khyber Pakhtunkhwa in northern Pakistan and flows through sections of Punjab and Khyber Pakhtunkhwa. To supplywater for drinking to cities of Islamabad (the Pakistani capital) and Rawalpindi, the renowned Khanpur Dam was constructed on this river in Khanpur in the Haripur District. Haro River watershed is located from 73.438635E to 34.057708 N and 72.175406 E to 33.737091 N shown Figure 1. The area of the watershed is 3142 Square kilometers.

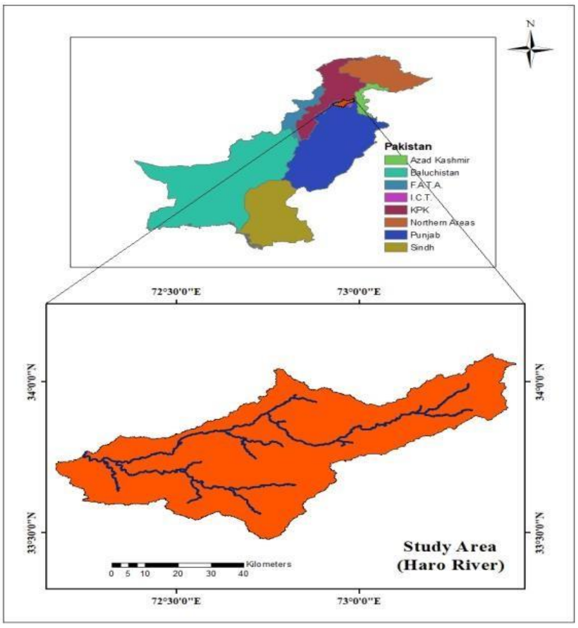

Figure 1. Location map of the study area

B. Datasets

The study of the topography of the surface of the Earth in the study area was required to delineate catchment boundaries of understudy catchment and extraction of terrain informationof the catchments such as streamlines, slope, and elevation bands. This data was gathered using the ALOS PALSAR Digital Elevation Model (DEM), a product of the Alaska Satellite Facility. DEM has a spatial resolution of 12.5 X 12.5m. The DEM of the study area is given in the Figure 2. Hydrological studies require an understanding of the soil conditions of the watershed. It lays the groundwork for determining the relationship between rainfall and runoff. Thisanalysis used a GIS-based soil map from the United Nations 'Food and Agriculture Organization (FAO)'. The FAO 'Digital Soil Map of the World' is a digital representation ofthe FAO UNESCO Soil Map of the World, which was first published in paper print at a scale of 1:5 million. The soil dataof the study are is given in the Figure 3 and its details are presented in the Table 1. The satellite photos of the Sentinel-2A satellite were used to create the land cover. Sentinel-2A isan optical imaging satellite launched by the European Space Agency in 2015. The discharge data has been received fromWater and Power Development Authority (WAPDA) [4].

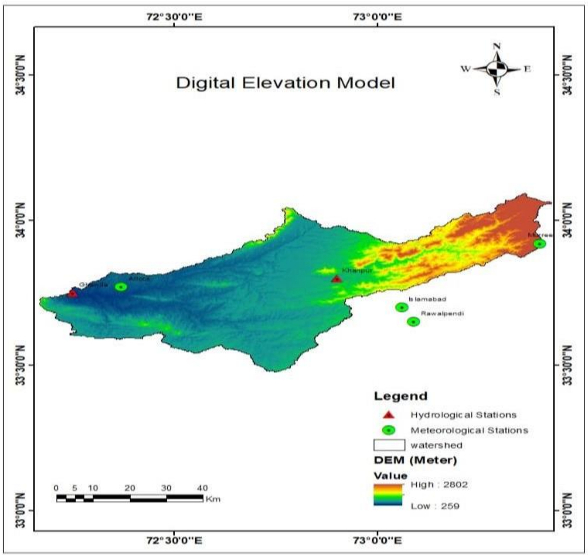

Figure 2. Digital elevation model of the study area.

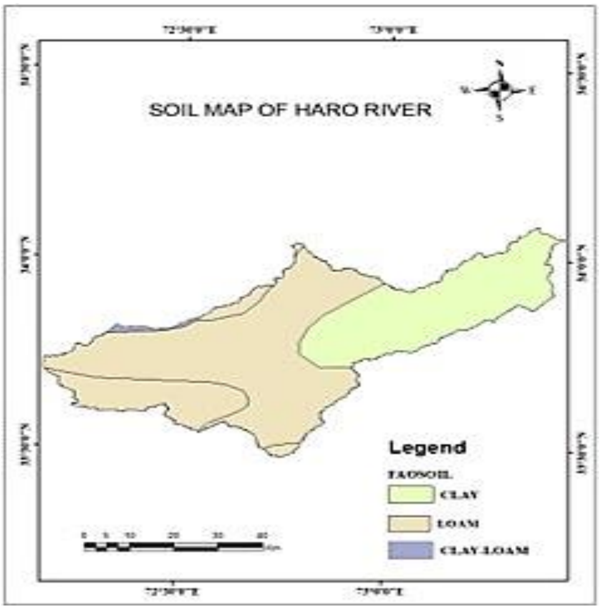

Figure 3. Soil data of the study area.

TABLE I. Soil Data types in detail.

Sr.	*Type*	*Area Percentage*
1	*Be72-3c-3672*	*32.96*
2	*Be73-2c-3673*	*1.89*
3	*I-X-c-3512*	*13.36*
4	*Rc40-2b-3843*	*51.05*
5	*Xh42-2-3a-3871*	*0.75*

III. RESULTS AND DISCUSSION

Two types of tests i.e Mankendal and Pettit test are performed for the trend analysis of hydrological and meteorological variables. The result are shown below for thevariables

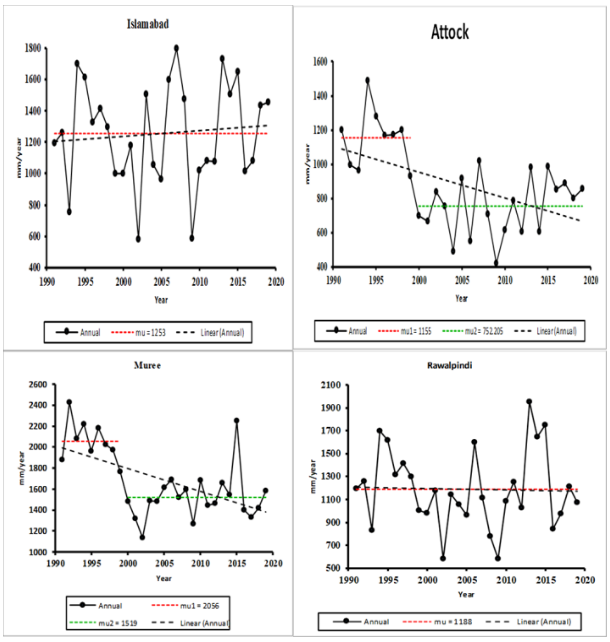

Figure 4. Trend and change point test for precipitation data

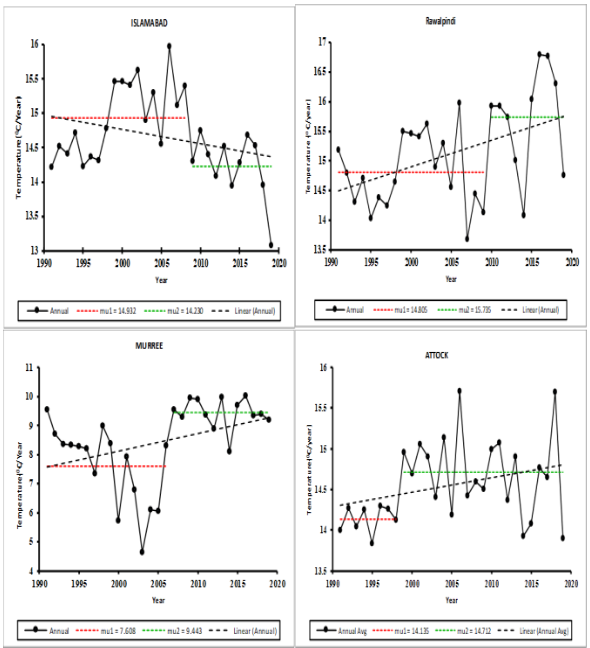

Figure 5. Trend and Chang point test for maximumtemperature data and minimum temperature data

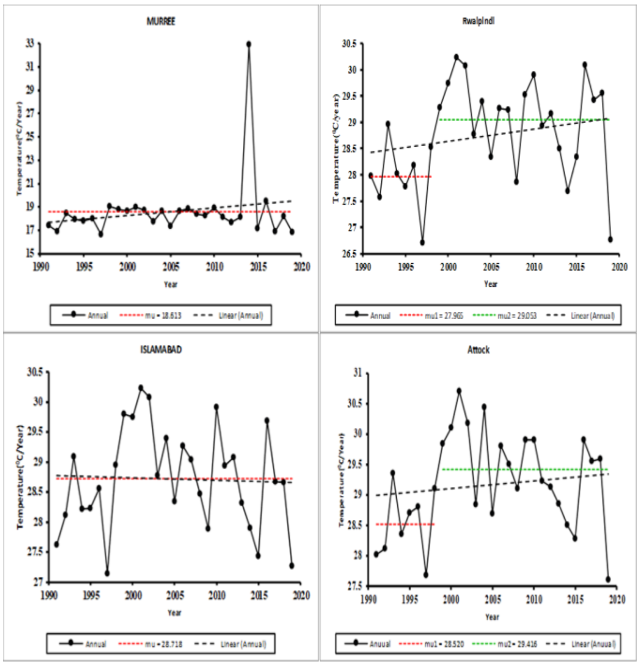

Figure 6. Trend and Chang point test for minimumtemperature data

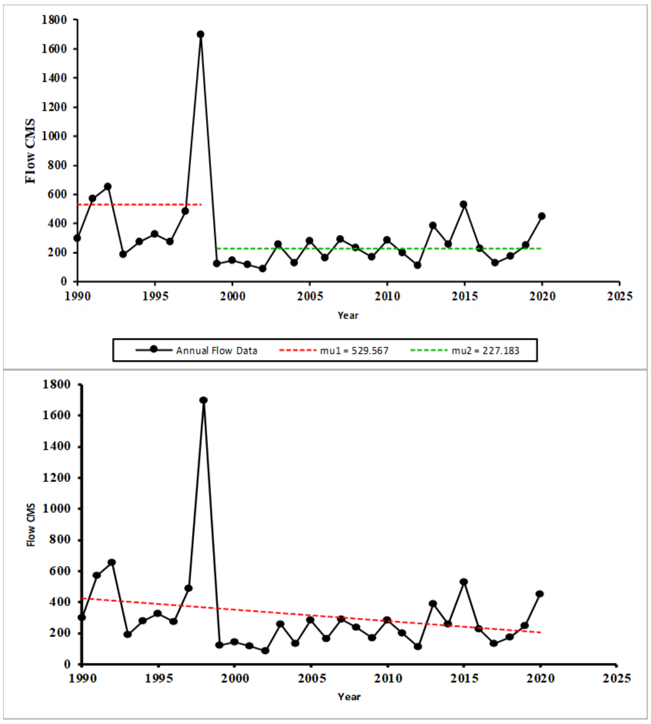

Figure 7. Trend and Chang point test Flow data

Land use changes

The land use and land are changes with the passages of time due the human activities which impact the hydrology ofwater shed badly. Supervised classification of satellite imagery are done to calculate the land use impact on the runoff, for this purpose two satellite imagery were selected one(1996 LULC) before change point and other after change point (2019 LULC). The results of land use classifications arepresented in Table 2

TABLE II. Land use changes.

Classes	1996km^2	2019(km^2)	Change	% Change
Forest	1147.16	689.1003	-458.06	-39.93
Water	11.2716	14.8401	3.5685	31.66
Agriculture	1866.41	2269.432	403.022	21.59
Built-up Area	65.0763	117.5022	52.4259	80.56
Barren	52.5591	51.6024	-0.9567	-1.82

Calibration and validation results

SWATCUP SUFI-2 [5] was used for the "Calibration andvalidation of the model was done on a time period" of sevenyears i.e. from 1994 to 2000 on monthly time scale.

Sensitivity analysis was performed prior to manual calibration. Twenty three parameters come out to be sensitive than the rest of the selected parameters. The results arepresented in Figure 9.

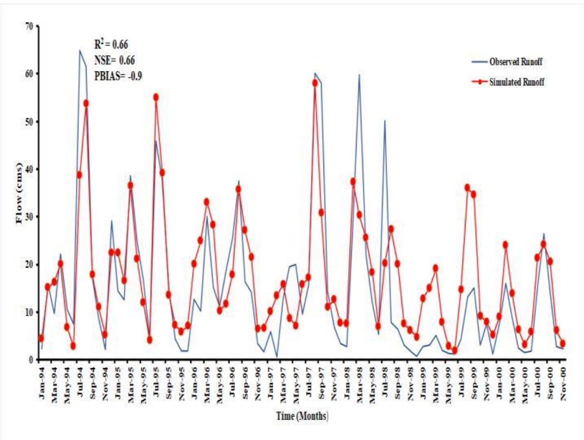

Figure 9. Calibration results

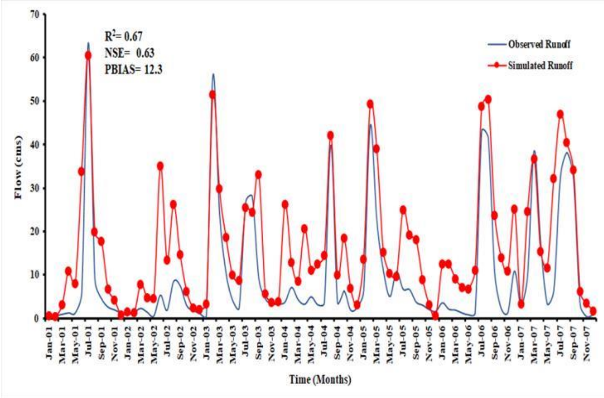

Figure 8. validation results

Similarly, the validation results of the model are presented in Figure 8. Model Arc SWAT was successfully used as an hydrological modeling on Haro River Basin. Calibration and validation of Arc SWAT was carried out for time period of sevenyears from 1994 to 2000 and 2001 to 2007. Both calibration and validation results were in acceptable range for Garialla flow station i.e. R2 for calibration was 0.78 and 0.79 for validation whereas NSE had a value of 0.76 and 0.77, PBIAS 6.1 and 6.8 for calibration and validation respectively.

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Battling Environmental Pollution in Lahore: The Importance of a Sustainable Transportation System

Muhammad Ibrahim
University of Engineering and Technology, Lahore
Department of Transportation Engineering and Management
Lahore, Pakistan
2020te1@student.uet.edu.pk

Muhammad Sohail Jameel
University of Engineering and Technology, Lahore
Department of Transportation Engineering and Management
Lahore, Pakistan
sohail.jameel@uet.edu.pk

Hassan Ali
University of Engineering and Technology, Lahore
Department of Transportation Engineering and Management
Lahore, Pakistan
2020te5@student.uet.edu.pk

Muhammad Momin Amer
University of Engineering and Technology, Lahore
Department of Transportation Engineering and Management
Lahore, Pakistan
2020te10@student.uet.edu.pk

Asna Ahmad
University of Engineering and Technology, Lahore
Department of Transportation Engineering and Management
Lahore, Pakistan
asna.ahmad@uet.edu.pk

Azzan Amir
University of Engineering and Technology, Lahore
Department of Transportation Engineering and Management
Lahore, Pakistan
2020te20@student.uet.edu.pk

***Abstract*- Urbanization and economic development in Pakistan have led to growing concerns about environmental pollution, which threatens people's desire for a high-quality life. This article focuses on the ambient air quality in Lahore, Pakistan, which exceeds the National Environmental Quality Standards (NEQS) for particulate matter. Correlation studies show a positive relationship between particulate matter and other pollutants, such as ozone, nitrogen oxide, and Sulphur dioxide (SO2). High levels of CO/NO suggest that these pollutants are major contributors to air contamination. The article also includes proposed solutions and estimates for improving the air quality in Lahore.**

Key words: *Urbanization, Environmental Quality Standards, high-quality life*

I. INTRODUCTION

A crucial requirement for human longevity on earth is the quality of the air environment. For healthy human growth, an environment that is both clean and acceptable is necessary. However, due to the quick growth of Pakistan's economy and industry as well as the country's ongoing urbanization, the country's air is extremely filthy. People's physical health is impacted by increased air pollution, which also raises their risk of lung cancer, heart disease, and respiratory infections. The government and the general public in Pakistan are particularly concerned about air pollution as a result of regular environmental pollution accidents and severe smog pollution incidents.

A 2016 WHO analysis found that exposure to ambient (outdoor + indoor) air causes 7 million deaths worldwide each year.

II. METHODOLOGY

As the selected site lies within the Lahore. So, the workflow of the whole project process will be as.

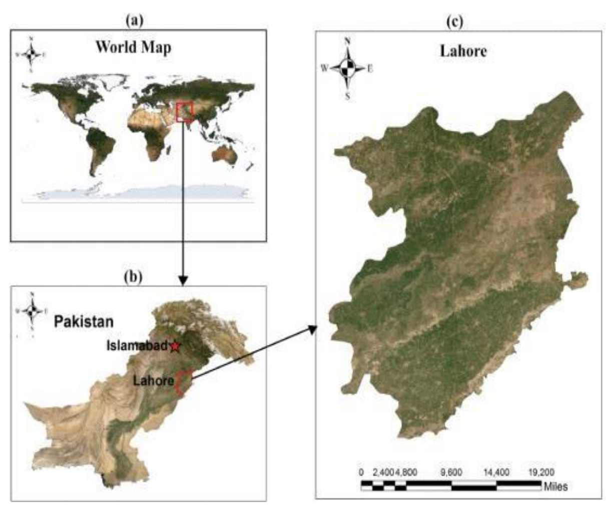

Figure 1. Pakistan Map and Lahore Location

A. Site Description

With an estimated 9.4 million people living in its metropolitan area, Lahore is the second-largest metropolis in Pakistan. It spans 1014 km^2 B and is situated between 31°15′ and 31°45′ N and 74°01′ and 74°39′ E, as shown in the Figure 1.

B. Dataset and Instruments

The automated fixed and mobile air monitoring stations (AMSs) were used by the Federal and Provincial Environmental Protection Agencies to collect data on the atmospheric concentration of six key pollutants as well as meteorological over a six-year period (2014–2019). Due to technical issues with the site instruments, records with the status of SNO (station not operable) and SNA (Station not available) were omitted from the study since their values (2.5% of the data) were not statistically significant. Data has been collected on an hourly basis from several sites (2 static stations and 1 mobile station). The table 1. is showing the List of Pollutants and There Measuring Methods

TABLE I. List of Pollutants and There Measuring Methods in Lahore

Pollutants	Method of Measurements
Sulfur Dioxide (SO_2)	Ultraviolet Fluorescence Method
Oxides of Nitrogen (NO)	Gas Phase Chemiluminescence
Nitrogen Dioxide (NO_2)	Gas Phase Chemiluminescence
Ozone (O_3)	Non-Dispersive UV Absorption
Suspended Particulate Matter (SPM)	High Volume Sampling (flow rate not less than 1.1 m^3/min)
Respirable Particulate Matter (PM_{10})	Preferable β-Ray Absorption Method
Respirable Particulate Matter ($PM_{2.5}$)	Preferable β-Ray Absorption Method
Carbon Mono-oxide (CO)	Non-Dispersive IR Ray Method

Figure 2. Pollution in Lahore

C. Meteorological Factors

Wind speed and direction the destiny of air pollutants is influenced by air movements. Consequently, any investigation into air pollution should include look into regional weather trends (meteorology).

Pollutant concentrations will increase if the air is calm, and they are unable to disperse. On the other hand, when there are strong, turbulent winds, the concentration of pollutants is lower because they scatter more quickly.

Weather information is useful for:

- Inversions and days with high pollutant concentrations are examples of air pollution occurrences that can be predicted.
- Utilizing computer models, simulate and forecast air quality.

The following elements should be measured while researching air quality since they can provide insight into the chemical processes that take place in the atmosphere:

- Wind data records can be used to identify monitoring stations with high pollution concentrations.
- Temperature
- Humidity
- Rain fall
- Solar radiation.

Above figure, Figure 2 shows the Pollution Condition in Lahore.

Wind data recordings help identify the approximate direction and location of the emissions when excessive pollutant concentrations are detected at a monitoring station. Finding the sources allows for the creation of a plan to lessen the effects on air quality.

An anemometer is a device that measures wind speed. We employ sonic anemometers at our monitoring sites instead of other anemometer types.

A sonic anemometer works on the premise that the speed of the wind influences how long it takes sound to travel between two points. It will take less time for sound to move with the wind than against it. Sonic anemometers.

III. IMPACT OF AIR POLLUTION IN LAHORE

Among the many forms of pollution, air pollution is one that is regarded to have an effect on the entire world. According to experts, air pollution may trigger the runaway greenhouse effect, a severe kind of global warming, even in a worst-case scenario if it is not regulated. This scenario has previously occurred on Venus, although being purely fictitious. Air pollution has increased as a result of industrialization and urbanization in both developed and developing countries. Nitrogen, hydrocarbons, local sources like ozone depletion, chlorofluorocarbons, ongoing sources like emission from power plants, municipal waste treatment facilities, and other secondary pollutants have a detrimental impact on population health and play a significant role in the world's ecosystem's rapid decline [1]. According to a World Bank study, transportation is one of the greatest risks to public health in Pakistan and also increases air pollution. Punjab's population has grown by 2.64% to almost 73 million people overall. It is the most populated province in Pakistan, with 358.5 people per square kilometer of population. In addition, only around 31% of its people reside in cities, with the remaining being concentrated in rural regions. Pakistan is the most urbanized country in South Asia, and Lahore, the second-largest city, is considered to have the worst air quality because of its 4% annual growth rate. Haze is a typical issue for metropolitan places in Asia, and Lahore is no exception. Asthma attacks, allergic responses, eye infections, respiratory tract infections, and heart disorders that result in early mortality have increased rapidly in recent years. Smog is to blame for this [2].

According to Pakistan's air quality index, the country's air pollution is at an "unhealthy" level. From 1,600 in 1990 to 5,000 in 2015, the number of deaths in Pakistan attributable to chronic obstructive pulmonary disease (COPD) brought on by ozone exposure. From 82,300 in 1990 to 135,100 in 2015, deaths from PM2.5 exposure rose for all ages and genders. The current study intends to evaluate the air pollutants that lead to haze in Lahore in order to reduce emissions or avoid this dangerous scenario [3].

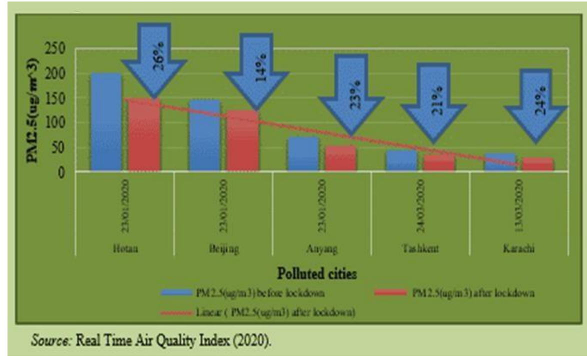

Figure 3. Pollution Trend before and after lockdown

The Figure 3 shows pollution trends before and after lockdown on Global scale in different cities.

The major goals of the research were to gather data on:

I. The primary and secondary air contaminants that were prevalent in the ambient air of Lahore.
II. Examining the seasonal variations in main and secondary toxins.
III. Examine the connection between December's weather and the abundance of smog-causing air contaminants (both primary and secondary).
IV. From March to December, all primary and secondary contaminants are taken into account when calculating theAir Quality Level, shown in the Figure 4.

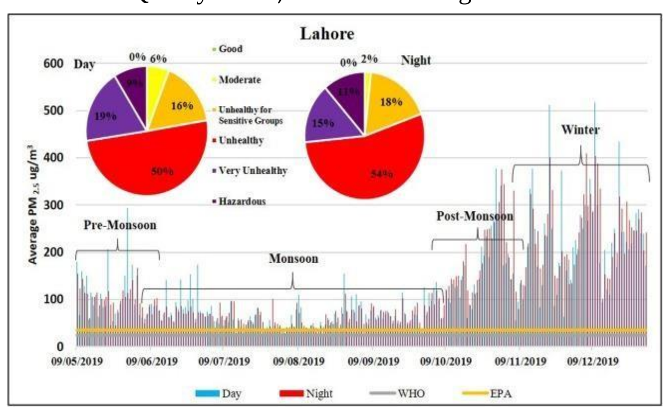

Figure 4. graphical representation of Lahore Pollution

IV. CASE STUDY

Lahore, a historic metropolis, currently has 11.3 million residents and is growing at a 3.35% rate. District Lahore spans 1772 square kilometers [4]. The total number of registered vehicles in Lahore, excluding intercity vehicles, is 85 million [5]. Air pollution from growing numbers of motor vehicles has been a problem in Lahore, formerly known as the "City of Gardens." Unchecked vehicle emissions are terrible for human health, especially in Pakistan's major cities. The maximum acceptable amount of lead in blood is 20µg/dl, and traffic police officers in Lahore had blood lead levels of roughly 35µg/dl (microgram per deciliter) and 38.0µg/dl (microgram per deciliter) in heavily populated areas including malls, circular roads, Yakki Gate, and Shalimar. The table 2 is showing registered vehicles data.

TABLE II. Registered Vehicles Data

VEHICLE TYPE	VEHICULAR COUNT
MOTORBIKES	507374
CARS	237937
JEEPS	6766
PICKUPS	3186
BUSES	9572
AUTO RICKSHAWS	35653
PUBLIC CARRIER	3368
PRIVATE CARRIER	7160
DILIVERY VANS	18987
MINI-BUSES	3685
TAXIES	10535
OTHERS	7150
TOTAL	851373

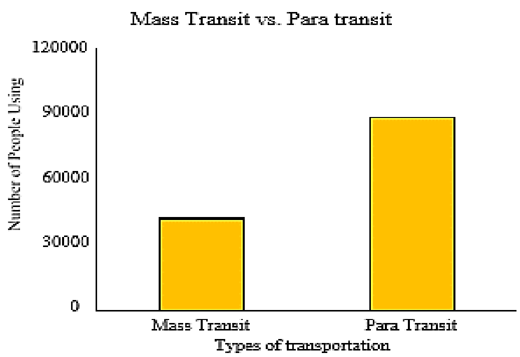

Figure 5. Mass transit vs Para Transit

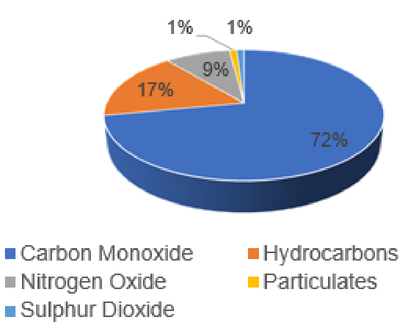

Figure 6. Annual vehicular emission in Lahore

Above graph in Figure 5 shows the comparison between masstransit and para transit system in Lahore.

Above graph in Figure 5 shows the comparison between mass transit and para transit system in Lahore.

Vehicles operating on Lahore's roadways produce a substantial number of different pollutants as shown in fig. 6, each having a different impact. The economy is affected in two ways by rising car acquiring rates and taxes, popular car funding options, and social drifts. They are both increasing the demand on infrastructure facilities and allowing for higher energy use [6].

Pakistan uses 17 million tons of petroleum products annually, with 7.8 million tons going to the transportation sector alone (20% gasoline and 80% diesel). The cost of importing crude oil and other petroleum products into Pakistan amounts to US$2.5 billion annually [7]. Fuel consumption is further described by graphs shown in Figure 7, Figure 8 and Figure 9.

More than 20 million tons of fuel are consumed each year at this time. According to statistics, the transportation industry consumes 46.2% of all fuel, compared to 10.9% for Industry [8].

Vehicles driving on the roads of Lahore emit a lot of different pollutants, each having a different impact. There are two levels of influence on the economy from rising car ownership rates, popular car financing plans, and societal trends. On the one hand, they're adding enormous Energy consumption and vehicle emissions are directly correlated, with higher consumption levels leading to higher emission rates. Lack of parking, altered land use, congested roads, and encroachments are adding gasoline to the fire. As a result, the city's ecology is getting worse, contrary to all international regulations.

A wide gap between WHO criteria and local values is revealed by recent environmental data for six important Lahore locations [9].

The above table 3 shows the annual average concentration of various pollution components in Lahore. Lahore's yearly average PM2.5 concentration is higher than Pakistan's NEQS standard, which is 15 gm^3. From 2014 to 2019, Lahore's yearly average PM2.5 mass concentration was 66.95 47.4, 74.95 51.4, 81.35 39.57, 87.75 46.13, 81.13 47.4, and 60.44 51.34 gm^3, with the highest value recorded in January 2018 at 217 gm^3, followed by February 2018 at 215 gm3, November 2018 at 192.93, 218 μgm^{-3} in December 2017. Black carbons, which are further described in the discussion part, are the cause of the high mass concentration of those particulate materials.

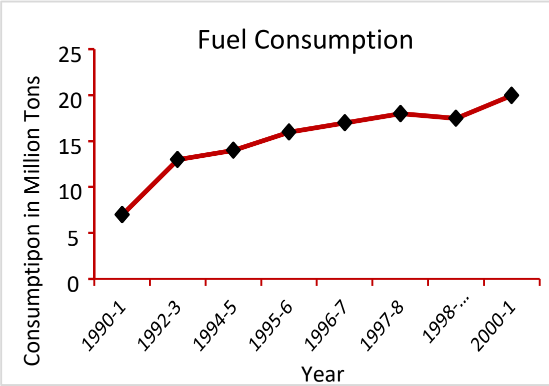

Figure 7. Fuel Consumption

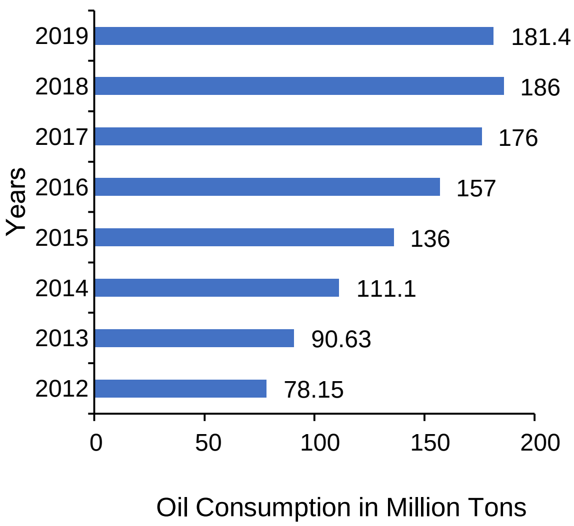

Figure 8. Fuel consumption trends in Pakistan

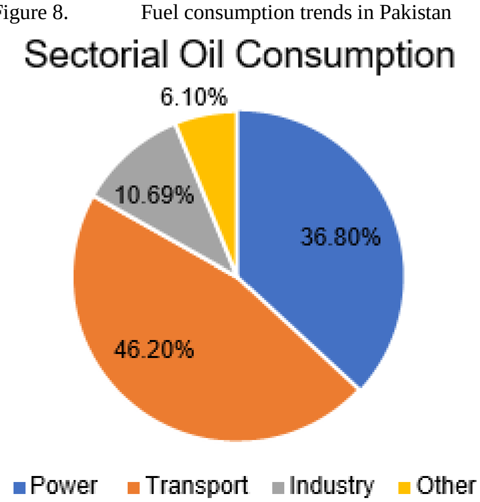

Figure 9. Sectoral oil consumption

TABLE III. Current air pollution table in Lahore.

SITES	PARAMETER	
	NO_x (ppb)	PM10 (µg/m³)
WHO ST.	75	150
Y. KHANA	175	1123
CH CROSS	328	1100
LOHARI GATE	68	1180
BANK SQUARE	208	1050
QURTABA CHK	105	1030
R. STATION	97	900

Unfavorable impacts on human health are linked to high PM2.5. According to the NEQS standard, which is 120µg/m^3 yearly, the average PM10 mass concentration was high from 2014 to 2018, and it was low in 2019. From 2014 to 2019, the annual value of PM10 is 150.15 25.16, 174.69 31.24µg/m^3, 189.38 11.41µg/m^3, 143.29 13.11µg/m^3, and 114.83 16.42µg/m^3, respectively. The highest PM10 value was 411µg/m^3 in January 2018 and 218µg/m^3 in December 2017, respectively. In the years from 2015 to 2019, the yearly average NO concentration is greater than the NEQS value of 40µg/m^3. NO concentrations are 16.88 ± 13.02 µ gm^{-3}, on average. 13.96 x 9.13µg/m^3, 90 x 14.18µg/m^3, 166 x 29.14µg/m^3, 47 x 17.21 gm3, and 43 x 19.82µg/m3, respectively. The highest record levels were 358µg/m^3 in November 2017 and 207µg/m^3 in November 2018, respectively. The SO_2 content is in accordance with the NEQS standard, which is 80µg/m^3. However, the serious scenario is that in Lahore, the concentration of SO_2 is rising annually and could reach in 2020 if essential measures are not implemented. From the years 2014 to 2019, the annual average SO_2 concentration was 16.88 11.42, 30.65 22.12, 39.73 13.45, 48.80 16.71, 40.18 21.12, and 70.18 31.11, respectively. The biggest percentage SO_2 increase from 2017 to 2018 is 43%, which should serve as a serious warning to take appropriate action. Higher quality. The increase in chemical production or mineral processing is caused by SO_2 in the surrounding air. Urbanization in Lahore is significantly growing as a result of the ongoing construction of companies producing clothing and chemicals.

V. SOLUTIONS

Following are solutions to overcome this problem:

A. Driving Restrictions:

Some cities have decided to ban commuters from driving during rush hour on a given day of the week, which often differs for each driver based on the last four digits of their license plate number. This is done in an effort to lessen traffic and air pollution. The type of demand management strategy has been used in several Latin American cities, including Sao Paulo, Mexico City, Santiago, and many others. According to study, vehicle limits in Quito have reduced carbon dioxide (CO) emissions during peak traffic hours by 9–11%. However, the success of this program depends on whether drivers can get around the limits by using other private transportation options. About half of the impacted drivers in Delhi were able to use private transport alternatives like other household vehicles, taxis or rickshaws.

B. Import Regulations on Second-Hand Vehicles:

The great majority of vehicles imported into low-income countries are used automobiles, Lorries, and buses. They frequently date back several years, if not decades, and lack catalytic converters to lessen hazardous gas emissions, which greatly contributes to air pollution. There are numerous approaches developing nations can use to deal with this situation: Tanzania levies an additional excise fee on used cars eight years of age or older, Kenya prohibits the importation of used cars older than eight, and depreciation rates are applied throughout all of East Africa to these imports. The following Table 4 is showing the estimated unit emissions of different vehicles operating in Lahore.

C. Electrification:

It is critical to use the plentiful renewable energy resources present in many emerging nations to reduce reliance on fossil fuels. However, as stated in the GRA, while EVs can be very effective at reducing local air pollution, they are not a panacea for other issues like traffic congestion. Additionally, it's critical to ensure that the electricity used to power EVs originates from sustainable sources in order to optimize environmental benefits.

D. Low Emission Zones (LEZs):

Vehicles that meet the necessary emission standards are not allowed in LEZs. If a vehicle does not fit the criteria, it might have to pay to enter the zone or it might not be let in at all. This idea has gained support from numerous European towns as well as three distinct districts of Hong Kong. However, similar restrictions do not apply to other types of vehicles, such as private cars. In Hong Kong, franchised bus operators are only allowed to operate vehicles that correspond to Euro IV or higher safety regulations.

VI. ESTIMATION OF SOLUTIONS

A. Estimation for Emissions (Vehicular):

- A report from Dunya News states that each motorcycle emits an average of 13.25 kg of CO_2, 1.2 kg of NOx, 3.2 kg of HC, and 13.25 kg of CO per year. Accordingly, Pakistan's total CO_2 emissions from motorcycles are estimated to be around 31 million tons (or almost 16% of Pakistan's overall CO_2 emissions).The following table 5 and fig. 10 showing the number of registered vehicles in Lahore.

TABLE IV. Unit Emissions of different Vehicles Operating in Lahore

Vehicle Type	Unit Emissions μg/m³
Bikes	97.67
Cars	381.68
Jeeps	420
Pickups	396.72
Busses	457.88
Auto Rickshaws	124.59
Taxis	394.72
Public Transit	401.06

TABLE V. TABLE 6. Estimated Number of Vehicles Operating in Lahore / Day

Vehicle Type	Number of Vehicles
Bikes	200000
Cars	100000
Jeeps	30000
Pickups	50000
Busses	35000
Auto Rickshaws	140000
Taxis	20000
Public Transit	30000

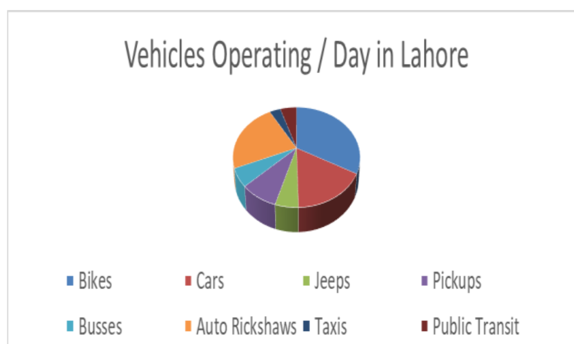

Figure 10. Vehicle Operating/day in Lahore

The emissions from cars are four times more than those from motorcycles. The average motorcycle emits 13 kg of CO, 1.2 kilogram of NOx, 3.2 kg of HC, and 18.25 kg of CO_2 annually, according to a Dunya News report. Accordingly, Pakistan's total CO_2 emissions from motorcycles are estimated to be around 31 million tons (or almost 16% of Pakistan's overall CO_2 emissions

If we consider automobiles, the emissions rise to 4 times to that of a motorcycles. Now according to reports if we calculate the emission of single vehicles on average per day By Multiplying Emissions/Day by Number/Day we will get total emissions done by transportation per day usage as shown by the following table 6.

TABLE VI. By total emission done by transportation per day

Vehicle Type	Emissions mg/m^3
Bikes	19534
Cars	38168
Jeeps	12600
Pickups	19836
Busses	16025.8
Auto Rickshaws	17442.6
Taxis	3947.2
Public Transit	12031.8

- If we compare the estimations by reducing 50% of theprivate transport:
  - Total traffic reduces by 48% which is a bigimprovement.
  - The emissions reduce to 139584.6 mg/m^3 from 267137.4mg/m^3 as shown by the table 7.
  - Keep in Mind that these are 1-day Estimations only moreimproved results will come as an outcome.

TABLE VII. If 50% of the public starts using public Transit that the estimation will drastically change

Vehicle Type	Emissions mg/m^3
Bikes	9767
Cars	19084
Jeeps	6300
Pickups	9918
Busses	8012.9
Auto Rickshaws	8721.3
Taxis	3947.2
Public Transit	12031.8

- If we consider a special case in which 0% privatetransport emissions will drop up to 95.5%

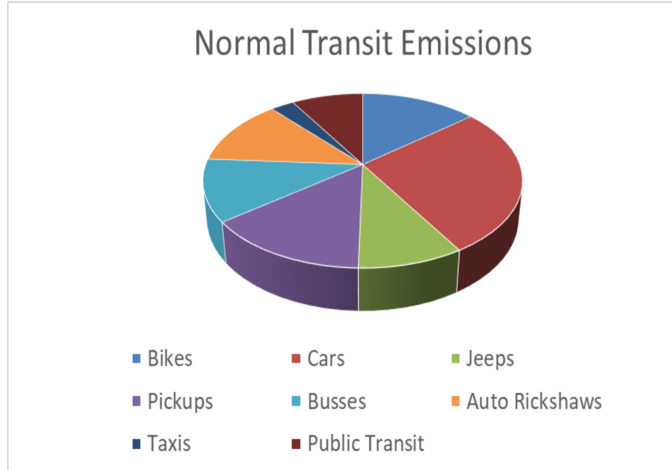

Figure 11. Graphical Representation of Normal Transit Emissions

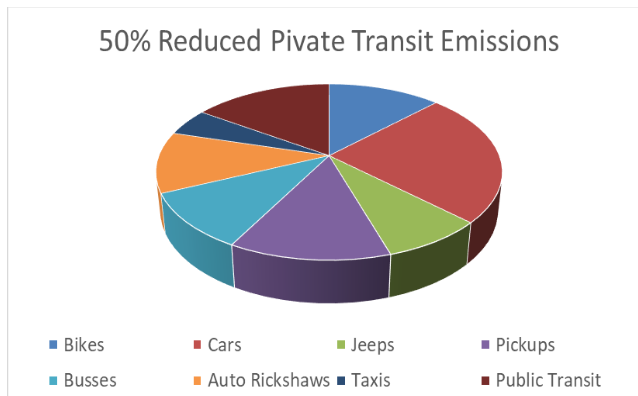

Figure 12. Graphical Representation of Reduced Private Transit Emissions

Above Figure 11 shows Normal transit emissions and Figure 12reduced private transit emissions

A. Estimation of Purification (BY AIR Purifier):

- By looking at the Estimated Vehicular Emissions per Day we get a total of 267137.4 mg/m^3 PM emissions
- A basic normal metropolis Air Purifier can Easily reducethe pollutants by 25% to 30% per day (this is an averagevalue as efficiency varies with area)
- If we install appropriate number of purifiers to cover allthe area of Lahore and keep them well maintained it could give us 10 million cubic meters of clean air everyday once fluent.

- It's not only beneficial for Lahore but also for Punjab
- The only hurdle is that this method is extremely expensive and requires high maintenance.
- But it is capable of resolve all air pollution problems of Lahore.

*C. Estimation of Purification (NEEM PLANTATION***)**

- The production of fresh air by a single neem tree (100m dia - Age: 4 Years) is about 2.2 million on Average.
- If we plant only 5-6 Neem Trees only with good care these will be capable to produce equivalent amount of filtered air to a normal air purifier per day if taken care of and fully grown
- Note that a fully grown neem tree is capable of producing Oxygen 24/7 even at night times and it don't even produce Carbon dioxide emissions at night
- This are drastic results as compared to air purifiers and cost is almost zero.
- Hydrologically this plantation will produce more rainfall increasing GWT and helpful in reducing air pollution.

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CAUSES OF FLOOD its DAMAGES AND MEASURES TAKEN BY THE GOVERNMENT: A CASE STUDY ON DISTRICT DERA GHAZI KHAN

Maria Talib
Water Resources Engineering
University of Engineering and Technology
Lahore, Pakistan
mariatalib832@outlook.com

Muhammad Saleh
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
engrmsaleh502@gmail.com

Hafiz Muhammad Naveed
Department of Environmental Engineering
University of Engineering and Technology
Lahore, Pakistan

ABSTRACT:

Floods are one of the major problems in Pakistan which lead to huge loss of life, infrastructure, etc. In a broader sense, it leads to destruction of land and the environment. It affects the community socially, physically and psychologically. In the current study the past year 2022 floods damages and their liabilities to recover those damages will be analyzed. For the analysis data was collected through site visits and from different organizations. A qualitative research approach has opted for this case study. The true feeling of helplessness and the people suffering during that period is devastating. Hence, as a result, a present study concentrated on the vulnerability and damages caused by floods and measures taken to recover those damages. District Dera Ghazi khan was the most affected area as it is surrounded by mountain Sulaiman. Proper budgeting and management and awareness before flood impacts can minimize the brutal effects of flood disasters in affected communities.

Keywords: Dera Ghazi Khan, Sulaiman Torrents, Punjab irrigation department, Flood protection management, Flood mitigation and management program.

INTRODUCTION:

Evans et al. (2010) District D.G. Khan is a semi-parched area, which is located at a main location that is connecting D.G Khan with four provinces of Pakistan. The community lying in D.G Khan is defenseless to cope with floods as it is in between the Indus River and the Sulaiman Mountains. The Indus River is the main flooding point and the Sulaiman Mountains are ones having huge spate water system network which results in flooding downstream areas. Khwaja & Aslam, (2018) said that cotton, rice and sugarcane are the major crops upon which the community relies and these are being their source of income and means of living. Another element of this area is its population which moved to Gulf countries to earn their living means. The decisions of remote living and earning is a helpful source to cooperate with families. (Do Thi et al., 2014), the government of China conducted a study to measure the severity and zoning of the areas of floods. They established a flood mitigation and management program (FMMP) to aware people of emergency situations and for implementing management strategies. (Benson and Clay, 2004) depicts that since 1950's settlements to vulnerable areas has been continuously increasing. (Tariq and Giesen, 2011) floods contribution towards disaster is 90% more than any other kind of disaster in Pakistan. Pakistan has been a country with natural morphological and climate changes that are prone to natural flood hazard. It is difficult to secure plane-settled areas in Pakistan. (Qaddafi, 2010a) topography and climate of Pakistan are the vulnerable reasons for having floods in Pakistan. (EPA, no date) Glaciers melting in Himalayas are also projected to flooding. (IFRC, 2010) coastal belt is most affected by cyclonic floods. Tariq Ismail, (2022) in express tribune highlights the flood cause and its damages. Rehman and Kamal (2010) Indus River from Tibet glacier in Himalaya reaches Pakistan from North-East side considered as one of the major source of flooding in Pakistan. And Moonsoon rainfall during summer season also contributed a lot in flow to Indus River. Both of the scenarios cause inundation in Indus plains (Gaurav et al, 2011; NDRP 2010). Flood protection management act (2015) was established aimed that the protection of rivers, meet the better flow and quality of water, protecting the environment in the riverine area. This act made to deal with flood liabilities better.

STUDY AREA:

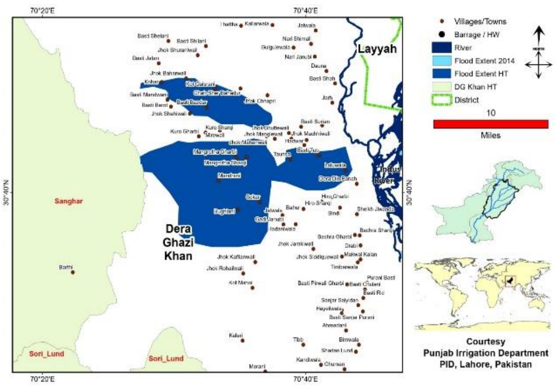

Figure -1 Study Area PID (2022)

Figure-1 shows the study area location which is district Dera Ghazi Khan. The salient features of this area is given below.

SALIENT FEATURES:

Geographically, this range lies between longitude 69°10' E to 70°49' E and serves as a divide line between KPK, Balochistan and Punjab Province. The area from Ramak to Kashmore (Shah Wali) 375 Km in length and Pachad area in width 25 Km to 35 Km lies in this circle. There are 200 hill torrents minor, medium & major. The hill torrents that discharges upto 5000 cusecs are classified as minor, 5000 to 15000 cusecs as medium and hill torrents discharges over 15000 cusecs as major.

Out of 200 hill torrents 13 are classified as major having discharge over 15000 cusecs. Out of 13, seven major hill torrents are in D.G.Khan District and Six are in Rajanpur Districts. These torrents are shown in Figure-2.

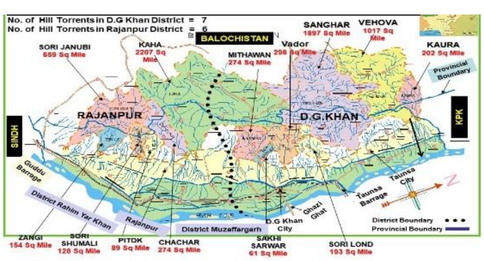

Figure -2 Sulaiman range torrents PID (2022)

PROBLEM STATEMENT:

As, there is no vegetation in that sulaiman range. The Climate is arid and Rainfall amount varies 5-15 inches and is erratic. The Concentration of precipitation is mostly very high during (Monsoon period) in the month of July and August. Due to very Steep slope from Darrah to D.G.Khan Canal is 10 – 15 ft / mile. The velocity of Hill Torrent flood water varies from 6-8 Ft/sec. The sediment or silt content is very fine 20-28%. Hence, there is a need to carry out an investigation on floods impacts and proper remedial measures to minimize the effects of floods in that areas.

CAUSES OF FLOOD AND MEASURES TAKEN TO REDUCE THE EFFECTS OF FLOODS AFFECTED AREAS:

Table 1 shows the precipitation amounts from 2017 to 2022, the rainfall amount average of 8 months yearly data cross the historic limits in DG Khan 201mm. which is also a reason behind flash flood 2022.

There are rain gauge stations established in DG Khan in catchment of these torrents at Bela, Fort Munro, & Ronghin. The Weather Advisory by DG Metrological Department Lahore (2022) issues rainfalls, flash floods, forecast, nature and intensity of rainfall / flooding & Flood Forecast alerts on PMD website daily.

Punjab irrigation department telegraph Office who send the discharge data through SMS to all concerned Irrigation Officers and Administration. The maximum historical peak discharge is shown in Table 2. To effectively pass the tourant flood channels and structures are built. Nutkani and Sori Lund are the channels that carry flood. 231000 and 22000 cusecs flood discharge can pass through these channels. 16250 acres of agriculture damage occurs during the flood of 2022. Cotton, rice and maze are their cultivated crops of DG Khan which become the victim of flood. Due to flood and heavy rainfall many peoples died and injured. Around 7 persons died due to flood and 2 due to structural collapse. Around 449 peoples injured during that natural disaster. 306 animal lost their lives and 3664 houses fully damaged.

Table 1 Average district rainfall PMD (2022)

Year	RAINFALL in mm				
	D.G. Khan	Kot Chutta	Taunsa	Koh-e-Suleman	District Average Rainfall
2017	114	97	115	181	126.75
2018	65	57	81	152	88.75
2019	193.5	212	237.5	251	223.5
2020	148	158	152.5	254	178.126
2021	73	36.5	69.5	172	87.75
01.01.2022 to 29.08.2022	201	192	295.5	868	389.125

1758 houses partially destroyed. Rescue a relief operation was highly active during this flood scenario. Relief camps, medical, veterinary and rescue camps established in DG Khan and its surrounding affected areas. Tents, Atta Bags, Ration, cooked items, Mats, Mosquito nets and blankets were provided for the relief operation.

Table 2 Comparison of past maximum and 2022 peak discharges

Sr. No	Name of Hill Torrent	Catchment Area (Sq miles)	Historical Peak Discharge	
			Year	Cusecs
1	KAURA	202	2010	128500
			2022	105668
2	VEHOVA	1017	2015	149405
			2022	154362
3	SANGHAR	1897	2010	229000
			2022	268149
4	SORI LOND	193	2013	97710
			2022	152487
5	VIDORE	298	2012	145101
			2022	174360
6	SAKHI SARWAR	61	2010	32643
			2022	32345
7	MITHAWAN	274	2010	61905
			2022	42632

CANAL BREACHES AS A RESULT OF FLOOD 2022:

Total 145 Dajal canal branch Kaha hill torrent wing syphon fully dismantled. DG Khan Division –I, total 20 number of breaches occurred. 11 in DG Khan canal division-II. In DG Khan Construction division number of breaches occurred are 13. Khachi canal, Jampur construction division, Chashma right bank canal, Rajanpur canal division also come under the disaster tree of breach. Hence, a lots of destruction occurred to canals. From the field visit and based on interviews it is depicted that the amount of rainfall was not quite enough to generate flash flood. Warnings are given to the bistable but due to lack of awareness, people attitude towards not leaving their home town, poor constructions and availability of resources are the major reasons that become challenge for government to a huge loss.

CONCLUSION:

After analyzing the consequences of floods and its damages to DG Khan following conclusions have been made. Flood occurrence is somehow at the initial stages in 2010 but in 2020 still the government should not be able to prepare the victims regarding the impact of floods before. Early warnings are given to victims so that they can move to safer places. Repairing process to recover from liabilities of flood by the government needs improvement. Government funds to mitigate post flood renovations is quiet helpful to minimize their sufferings and anxiety of peoples. Flood forecast and early warning systems and implementation of pre-flood strategies in Pakistan is improper and needs a hand on concentration. DG Khan is a city which is prone to flood in monsoon season become a challenging situation for government. After 2015 act government of Pakistan had improved this situation somehow, but due to severe flooding and lack of knowledge and expertise of residents to deal with this situation is another big problem. As, DG Khan is not a developed country their economy is minimal in their city but destruction rate is extremely high.

RECOMMENDATIONS:

In order to minimize and to avoid the hazardous situation following recommendations are made:

Among all the damages, infrastructural damage need perfection in structural reassessment. Structural division needs to emphasize on construction perspectives. Proper trainings and budget for trainers will be allocated for preparation of residents before disaster.

From past floods experience it is depicted that evacuation from flood affected area is not possible. Hence, federal government had to provide proper measure through provincial disaster management authorities and through private means. Governmental department effectiveness in dealing with menace is highly on peak.

Early warning systems need to be upgraded to minimize the consequences. Reservoirs and water collection system need to be increased. Proper management of flood plains protection through structures like dykes is necessary.

A latest research of topmix permeable, a porous concrete roads construction somewhat also helpful in floods as well.

Author Contributions: Conceptualization, M.S., Methodology, M.S., Investigation, M.S., Resources, M.S., writing—original draft preparation, M.S., writing— review and editing, M.S., Supervision, M.S., project administration, M.S.,.

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Acronyms

PID	Punjab Irrigation Department
FPM	Flood Protection Management
C&W	Communication and works Department
MD	DG Meteorological Department

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Cost Comparison of Clay Bricks and Concrete Blocks in Residential House: A Case Study

Muhammad Usama
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
muhammadusama104@outlook.com

Hafiz Aiman Jamshed
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
aiman.jamshaid@ucp.edu.pk

M. Usama Amanat
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
mohammad.usama520@gmail.com

***Abstract*- Clay brick is one of the leading building materials used in construction. Carbon dioxide emissions from the brick-making process have been recognized as a major issue of global warming. Therefore, there is a need to focus on the pursuit of environmental solutions for a green environment. To achieve this goal, various materials can be used for construction. Concrete Block is one of the materials which are used in construction. The use of concrete blocks provides a cost-saving solution in construction. This paper highlights a comparative analysis of the cost-effectiveness of using concrete blocks instead of traditional Clay bricks. The 6 inches (concrete block) and 9 inches (Clay Brick) thickness wall structure was designed using Autodesk Revit software and a cost calculation of the various components of the structure was performed for the 10 Marla residential house building which is located in DHA Lahore. For developing countries, the construction cost is very important. So, it is necessary to complete the project economically. By cost analysis using Revit software, it is found that construction costs can be reduced by using Concrete blocks alternative to clay bricks.**

Keywords- Revit, Clay Brick, Concrete Block, Cost comparison, Residential buildings

I. INTRODUCTION

Bricks are one of the most important building materials in Pakistan. Brick is a material used in construction to create walls, pavements, and other aspects. Brick kilns have expanded to satisfy the need in recent years as urbanization has increased and building materials have become more in demand. Numerous environmental and health issues have been brought on by it, either directly or indirectly. Global warming and climate change are phenomena that are largely attributed to environmental contamination from brick-making processes. As a substitute for clay bricks, other types of blocks can be utilized to lessen environmental pollution and global warming. Many types of clay bricks are used in construction. Class A, Class B, and Class C are the classifications of clay brick. These classifications of clay bricks are used according to their usage in buildings. Different countries have different standard brick sizes. The nominal size of brick in Pakistan is 9 x 4.5x 3 inches, but in actuality, it is approximately equal to 8 × 3 5⁄8 × 2

1⁄4 inches [8]. A concrete block is generally employed in the construction of walls as a building material. It can also be referred to as a concrete masonry unit (CMU). One of the many precast concrete building materials is a concrete block. Although both Clay bricks and cement concrete blocks are durable and used for load bearing. Concrete blocks are also available in different sizes such as 12 x 8 x 8 inches, 12 x 8 x 6 inches, and 12 x 8 x 4 inches. Solid concrete blocks, hollow concrete blocks, and Cellular Light Weight blocks (CLC) concrete blocks are available in Pakistan. We may use concrete blocks in exterior walls, interior walls, partition walls, and boundary walls. Both concrete blocks and clay bricks are used as load-bearing walls. As concrete blocks are lightweight, it reduces the whole weight of the structure and is also used as heat insulation material [9]. At the time of installation, they require extra care, although maintenance comes after so many years. Because of its large size and lightweight, it speeds up the construction process. We use Revit for cost analysis, Revit is software that is used by Architects, Structure engineers, and MEP engineers. We can design and create high 3d impact visualizing models and analysis and manage the whole construction process and material for the building. We can integrate all the steps of construction into one place. Furthermore, we easily create 2D and 3D models and then develop their bill of quantities (BOQ). Revit is the software for building information modeling, which is used for better planning, design, and better visualizing experience through the creation of a 3D model. In Revit, we can easily collaborate with our team members or client through its Autodesk cloud services.

II. METHODOLOGY

The selection of the site and the gathering of data are fundamental needs for BIM approaches. Additionally, working drawings and layout plans were gathered for this cost estimation study. In our research project, we take the 10.5 Marla residential building site for cost comparison by using different materials in Autodesk Revit software, located in DHA Lahore. The adopted methodology to complete this study includes a comparison of cost estimation by a BIM software-based approach to the creation of a 2D plan in AutoCAD, then importing this AutoCAD file in Autodesk Revit and covert the 2D plan into a 3D model. After the creation of the 3D model in Revit, start applying different materials properties. In our case we use two different types of materials one is 9x4.5x3 inch Clay brick and the second is 12x8x6 inch Concrete block material properties in the wall. After applying the properties of the different materials in residential house walls as shown in Figure (1) and Figure (2), for this, first we select any random material then we change its material properties to Clay Brick, and then change its dimensions to 9x4.5x3 inch. After applying the properties and dimensions of clay brick in the wall, insert the cost of these materials and takeoff bill of quantities from Revit software as shown in table (1). In the schedule option of the view tab of the Revit software, sheets of quantities are generated to estimate the cost of structure elements, as illustrated in Figure (3). After taking the bill of quantities, again change the properties and

Dimensions for concrete blocks to 12 x 8 x 6 inches, and then again generate a bill of quantities. After generating a bill of quantities for Clay brick wall as well as Concrete block wall, analysis of their cost difference.

TABLE I. Bill of Quantities by Revit

	Concrete Blocks	Clay Bricks
Wall Length	728 ft and 7 inches	
Wall thickness	6 inches	9 inches
Volume of Wall	3313 CF	4673.437 CF
No. of Bricks	9980	66169

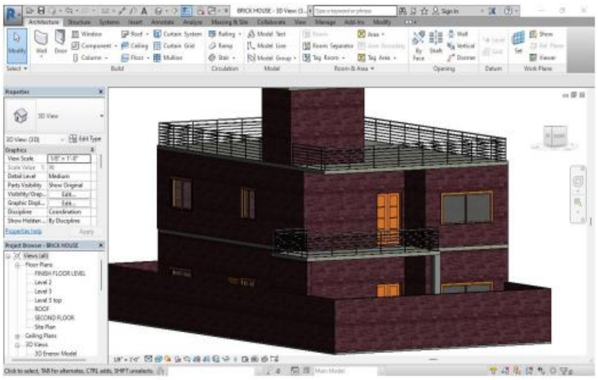

Figure 1. 3D View of Clay Brick House in Revit

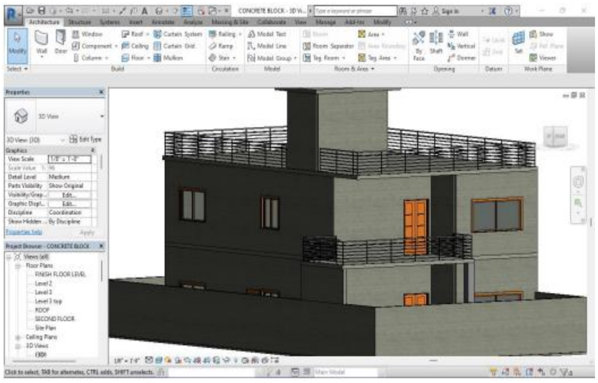

Figure 2. 3D View of Concrete Block House in Revit

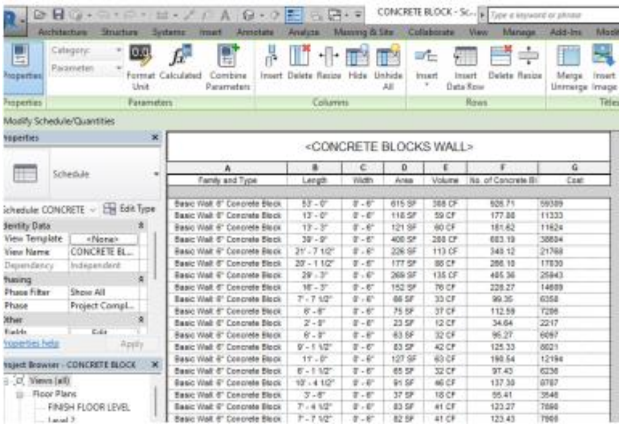

Figure 3. Bill of Quantities from Revit

III. RESULTS

A. Cost Comparison between Clay Brick and Concrete Block

Before construction, the primary goal of cost estimation is to determine the project's exact worth. Quantities calculated by BIM / Revit Software and the Total estimated cost of the project will work using Clay brick is Rs 9,92,535 and using concrete block is Rs 6,98,600 as shown in Table 2. In our case study project, we save Rs 2,93,935. The saving percentage of 29.61 %

in our project by using Concrete block alternative to the Clay bricks as shown in Table 2. In our case, the total carpet area is measured which is shown in Table 3. It is observed that when a Concrete block wall of 6 inches width is used instead of a traditional 9 inches thick Clay brick wall, there is approximately a 4.84 % increase in carpet area per floor of the house. In general, if we use Concrete Block as an alternative to Clay Brick in wall construction, we save cost on the wall up to 1.11 % per cubic meter as shown in Table 4.

TABLE II. Cost Comparison

Sr.	Item	9" Wall	6" Wall	Rate	Cost for 9" thick Wall	Cost for 6" thick Wall	Saving
		Quantities	Quantities	(Rs.)	(Rs.)	(Rs.)	%
1	Concrete Blocks	0	9980	70/Block	0	698600	29.61
2	Clay Bricks	66169	0	15/Brick	992535	0	

TABLE III. Increase in Carpet Area of Residential House

	Clay brick wall (Sq-ft)	Concrete block wall (Sq-ft)	Difference %
Total Carpet Area	1158	1214	4.84

TABLE IV. Savings % per cubic meter

Name	Volume	Qty	Rate	Cost	Cost Saving per m^3
	m^3	-	Rs/-	Rs/m^3	
Clay bricks	1	500	15	7500	1.16
Concrete block	1	105.9	70	7413	

IV. CONCLUSION

The following conclusions on the cost-effectiveness of employing clay bricks and concrete blocks for building construction are taken from the results and discussion above:

The Revit software is quick, simple, effective, automatic, and less likely to make errors.

The overall savings is 29.61% for the 10.5 Marla residential building and the saving per cubic meter is about 1.16% by using concrete block instead of clay brick.

The increase in carpet area for 10.5 Marla residential buildings is 4.84% when we use a 6-inch-thick concrete block wall instead of a 9-inch-thick Clay brick wall.

As the sides of a concrete block wall are flat, less plaster is needed, which reduces the amount of cement and sand needed for the plastering process.

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Cost Effective Energy Efficient Practices For And Existing Residential Building

Tanveer Younas
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
tanveer.younas@ucp.edu.pk

Tehreem Shakoor
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
tehreemshakoor13@gmail.com

Burhan Ahmad
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
burhan.ahmad@ucp.edu.pk

Mahnoor Arif
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
mahnoorarif821@gmail.com

***Abstract*--- World's population is expected to increase in the coming years, leading to an increase in energy demand. This rise in energy demand will eventually cause the depletion of fossil fuel resources. Pakistan is one of the world's most energy-consuming countries, relying mostly on thermal energy sources. The objective of this study is to provide an understanding of ecofriendly methods and to enhance the energy of pre-existing residential buildings. This article will further explain the use of Building Information Modeling (BIM), which digitally represents a building's physical characteristics and materials, and further analysis of the project building (6250 ft2) on Autodesk Revit and Green Building Studio (GBS). Additionally, a photovoltaic analysis is performed to determine the effect of solar panels on energy preservation and cost increment. Presenting the results of a simulation study using measures such as daylight sensors, insulated low-e glazing, window shading and insulation, led to significant energy savings, around 42%. The installation of solar panels resulted in a cost savings of around 50 %. The initial cost to add these energy saving measures is Rs 1.8 million, which is cost effective in the long run, saving around 86% per year. The initial investment cost for applying energy conservation measures is high, but the long-term cost savings justify their incorporation into building design, saving 925K PKR per year. This article serves as a complete guide for anyone interested in conducting energy analysis modeling for a prefabricated residential building.**

Keywords*- Autodesk Revit, Green Building Studios (GBS), Residential Building, Sustainable Buildings, Cost Efficiency, Energy Conservation, Photovoltaic Analysis*

I. INTRODUCTION

The population of the world is expected to increase in coming years, this will directly increase the amount of energy being used. The point of concern is our limited supply of nonrenewable energy fuels such as fossil fuels. This may be a problem because it will lead to a major global energy crisis, and badly impact the environment. Amit Maurya et al. studied that over the years high energy consumption has led to the depletion of non-renewable energy sources [1]. Ahmed Sohail et al. noted that Pakistan is one of the countries with the highest energy consumption for domestic use. Annual energy consumption by the domestic sector is 45.9 % of the total, while the industrial sector consumes about 27.5 %. About half of the total energy consumed is used in buildings and/or heating, ventilation, air conditioning (HVAC), and, lighting appliances [2]. Punjab, being the largest province, according to population, consumes 68% of the total electricity in the country. This creates a severe energy shortfall resulting in a great need for energy efficiency and conservation [3]. The application of energy preservation is crucial to reduce the negative impact it has on the environment. Liu Fang and Zhang Jian Feng add that, to deal with environmental problems globally, ultra-low energy consumption prefabricated buildings have become the main development direction of construction industries [4]. Additionally, Building Information Modelling (BIM) and energy modeling tools are increasingly being utilized to achieve extensive energy efficiency upgrades. Kam-din Wong and Qing Fan examined the use of BIM for sustainable building design such as project delivery (IPD) and design optimization [5]. Abdelazim, A. A. S. et al found that BIM technology can enhance the performance of buildings, promote sustainability in public and housing structures, and ensure a suitable quality of life for residents [6]. Meanwhile, Mushref et al. have identified challenges to the adoption of BIM in promoting sustainable design, such as cultural influences and technology-related issues [7]. The ongoing trend for sustainable construction can also be retrofitted to a prefabricated house on a friendly budget. There has been research done by Joana Fernandes et al. stating retrofitting a prefabricated residential building is about optimizing its basic infrastructure such as heating, ventilation, and air conditioning. The use of passive systems are responsible for 90% of the reduction of energy demand. Passive systems consist of measures that reduce space heating and cooling demands [8]. An article written by Jenan Abu Qadourah et al., explains that energy demand is evaluated and so are the effects of using wall and roof insulation, shading devices, and ventilation. The result proves that it's possible to reduce the annual energy demand by 53, 71, and 78% for cooling, heating, and lighting, respectively, by introducing passive design strategies [9]. First International Conference on New Trends in Civil Engineering© 2023-UCP_NESPAK Improving a building's insulation is a critical factor in reducing energy consumption. The most cost-effective approach to prefabricated wall external insulation finishing systems also known as EIFS is preferred. As Straube, J states, EIFS requires making minimal changes to standard construction practices up to 1 and 1/2 inches of insulation thickness.[10]. This type of insulation makes it easier to be installed into a constructed wall since no changes are required in other properties. Utilizing photovoltaic panels is another significant factor in increasing the energy efficiency of buildings. Albatayneh et al. have found that solar photovoltaic rooftop panels can act as shading devices, reducing heat loss in summer and increasing heat transfer in winter [11]. Chen et al. have found that energy savings can offset the additional cost of construction, which accounts for the largest part of the lifecycle cost [12]. Safeer Abbas et al. examined the effects of various building materials for walls, window panels, and roof construction, and a lifecycle cost analysis was performed. Three-pane glass windows reduced total energy consumption for houses to 14%. Furthermore, wood walls showed comparable energy performance with brick walls without the use of insulation. [13] In Pakistan, numerous studies have been conducted on the use of insulation and other measures before the fabrication of the building. But there is not much research regarding the applications of energy preservative measures in a postconstructed house. This article aims to address this gap and provide an understanding on how to convert a house to a cost-effective sustainable building.

Figure 1. Model of an existing residential building

B. Energy Model

The energy model is an abstraction of a building's overall form and layout into a computational network. This network captures all of the key paths and processes of heat transfer throughout the building. The energy model considers:

- Spaces which are discrete volumes of air that experience heat loss or gain. These heat changes are due to internal processes like occupancy, lighting, equipment, and HVAC.
- Surfaces are the paths of heat transfer to or from each space.
- Zones are groups of spaces used to establish some commonality between those spaces.

II. METHODOLOGY

The methodology involves creating the model of an existing residential building in Autodesk Revit and performing energy analysis on GBS. Different design alternatives will be created on GBS and compared to determine the most cost-effective sustainable design for house.

A. Modeling in Revit

A 3D model will be created in Autodesk Revit as shown in "Fig. 1". The model is a 25 Marla (6,250 ft2) house. It is located in Gujranwala Cant, Pakistan. This is a double story single family house consisting of six bathrooms and five bedrooms.

The construction specifications of the initial model are given in "Table 1". The type is provided along with the R-value. The R-value is known as the Thermal resistance value. This measures the ability of a material to resist heat.

TABLE I. CONSTRUCTION SPECIFICATIONS BEFORE ENERGY CONSERVATION MODIFICATIONS

Model	Construction Type	R-value
Exterior wall	Brick Common (9-inch walls)	1.2
Interior wall	Brick Common (9-inch walls)	1.2
Roof	Concrete Cast in Place (6 inches)	0.83
Floor	Lightweight concrete (12 inches)	9.5
Slab	Concrete Cast in Place (6 inches)	2.1
Glazing	Single pan clear glass (without coating)	1.5
Shade	No shading	-

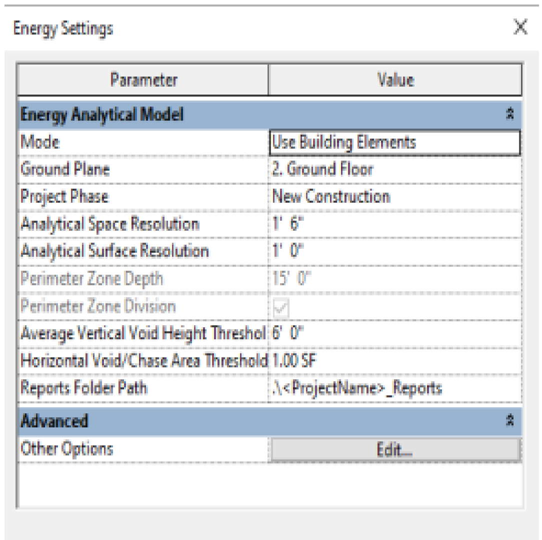


Figure 2. Energy Settings in Revit

Fundamental energy parameters are inputted as shown in "Fig. 2 and 3". Lastly, we change the location of the building to the accurate location as seen in "Fig.4". Then pick the closest weather station, which is stationed in Gujranwala, Punjab.

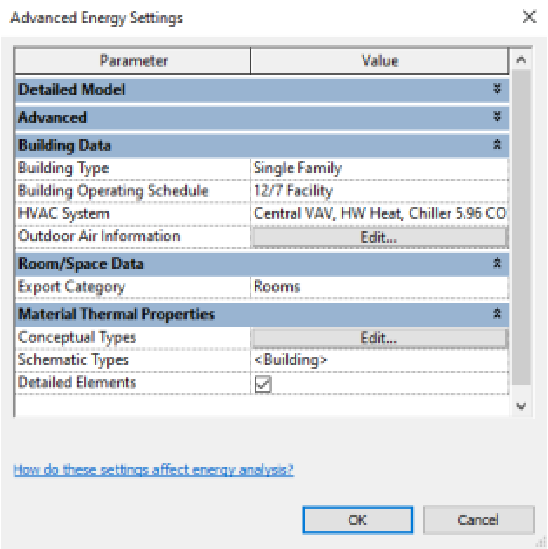


Figure 3. Advanced energy settings in Revit

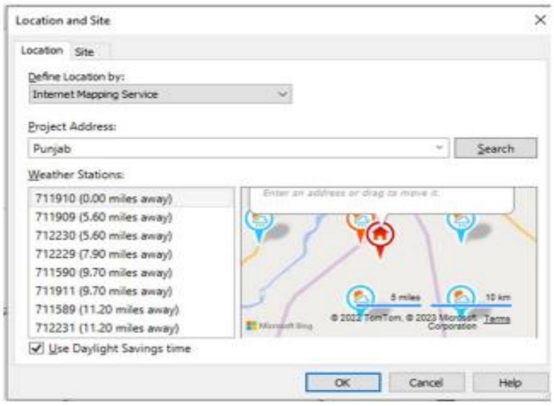


Figure 5. Location and site setting in Revit

After modifying the settings, we are now able to create the energy model in Autodesk Revit as shown in "Fig.5". Creating the energy model allows us to prepare to export this to gbXML format and ultimately to GBS.

C. Exporting from Revit

After creating an analytical model of the house, the file will be exported as gbXML from Revit. The gbXML file will be uploaded in cloud based Green Building Studio to perform energy analysis.

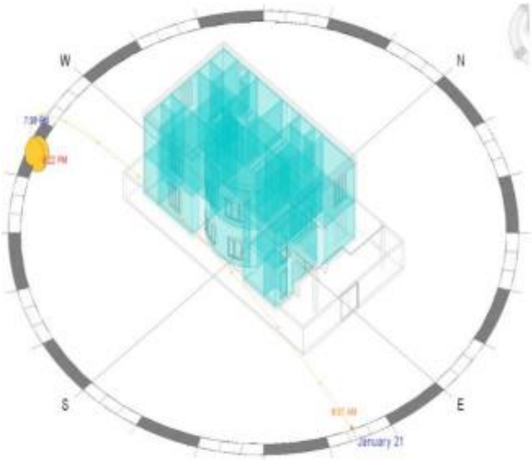


Figure 6. Energy Model

D. Autodesk Green Building Studio (GBS)

GBS helps to design more sustainable buildings that reduce energy consumption, lower environmental impact, and improve indoor environmental quality. It can also help building owners to achieve sustainability goals and cost effectiveness. The initial step in utilizing the GBS is to establish a new project as a test project. After this, setting the currency and other defaults to required specifications is particularly important as GBS default inputs are in American units and currency. Necessary inputs must be added prior to conducting the energy analysis as certain settings cannot be altered once the analysis has begun. The utility rates used for this analysis are PKR.14/kWh for electricity and Rs.40/therm for heating. 1) GBS Base Run In GBS, after setting up the project defaults and energy settings as well as utility rates. The following step is to upload the gbXML file from Revit in order to create a base run. Once the run is completed successfully, it will appear in the Run List tab. The base run is determined by the information obtained from the imported model and the default values inherent in the software. It will give the whole energy analysis.

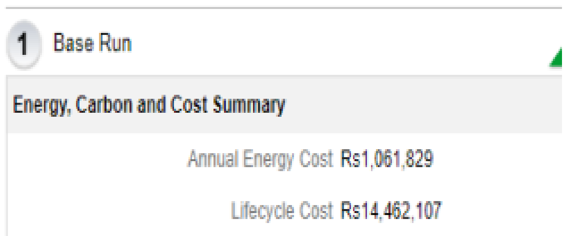
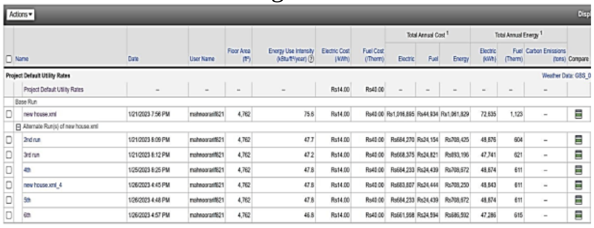


Figure 7. Base Run Model

A Base Run shown in "Fig.6" shows that for our house, 1,061,829 PKR would be consumed yearly on energy prices having conventional construction without insulation. The Life cycle cost is 14,462,107 PKR.

Design Alterations Design alternatives were performed on GBS selecting different available options for the materials and in the last selecting the best modifications that lead to the most efficient sustainable design for a residential building. As seen in "Fig.7", we modified different elements to achieve our most sustainable design.



Name	Date	User Name	Floor Area (ft²)	Energy Use Intensity (kBtu/ft²/year)	Electric Cost (/kWh)	Fuel Cost (/Therm)	Total Annual Cost¹ Electric	Total Annual Cost¹ Fuel	Total Annual Cost¹ Energy	Total Annual Energy¹ Electric (kWh)	Total Annual Energy¹ Fuel (Therm)	Carbon Emissions (tons)	Compare
Project Default Utility Rates													
Project Default Utility Rates	–	–	–	–	Rs14.00	Rs40.00	–	–	–	–	–	–	
Base Run													
new house.xml	1/21/2023 7:56 PM	mahnoorarif621	4,762	75.6	Rs14.00	Rs40.00	Rs1,016,895	Rs44,934	Rs1,061,829	72,635	1,123	–	
Alternate Run(s) of new house.xml													
2nd run	1/21/2023 8:09 PM	mahnoorarif621	4,762	47.7	Rs14.00	Rs40.00	Rs684,270	Rs24,154	Rs708,425	48,876	604	–	
3rd run	1/21/2023 8:12 PM	mahnoorarif621	4,762	47.2	Rs14.00	Rs40.00	Rs668,375	Rs24,821	Rs693,196	47,741	621	–	
4th	1/25/2023 8:25 PM	mahnoorarif621	4,762	47.8	Rs14.00	Rs40.00	Rs684,233	Rs24,439	Rs708,672	48,874	611	–	
new house.xml_4	1/26/2023 4:45 PM	mahnoorarif621	4,762	47.8	Rs14.00	Rs40.00	Rs683,807	Rs24,444	Rs708,250	48,843	611	–	
5th	1/26/2023 4:48 PM	mahnoorarif621	4,762	47.8	Rs14.00	Rs40.00	Rs684,233	Rs24,439	Rs708,672	48,874	611	–	
6th	1/26/2023 4:57 PM	mahnoorarif621	4,762	46.8	Rs14.00	Rs40.00	Rs661,998	Rs24,594	Rs686,592	47,286	615	–	

Figure 8. Design Alternatives in GBS

E. Modifications in Revit Model

1) Insulation Exterior Insulation Finishing System (EIFS) can be defined as an ideal energy-efficient thermal wrapping or facade insulation applied to the exterior surfaces of a building, as shown in "Fig.8", which is then finished with a long-life, decorative and protective wall coating that can be installed on any type of construction. Cellulose is used as an insulation material which is made of newspaper and would help in our sustainability goal. A thickness of 1-inch is provided to the brick wall providing a thermal resistance of 8.67 to the house.

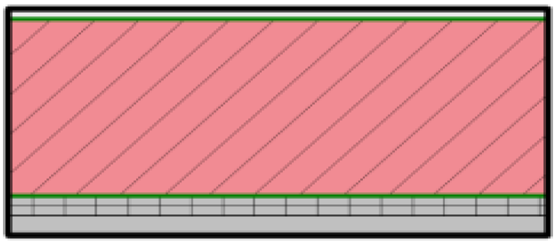


Figure 9. Cross section of 9" wall (1" insulation and 0.5" plaster)

2) LPD Light Source Power Density (LPD) is defined as the number of watts of lighting per square meter of room floor area. This analysis focuses on the economic benefits and energy efficiency improvements of using sunlight instead of artificial lights. As can be seen from the alternative designs, a 10% reduction seems to give the best energy saving results and is reasonable and easy to adjust.

3) Occupancy and Daylight Sensors Occupancy sensors provide automatic on/off switching of lighting loads, improving comfort, security and long-term energy savings. A sensor senses the brightness in room and adjusts the lighting to use sunlight to save power. These sensors will be integrated into the residential building because financial and electrical/mechanical applications are key fact.

4) Cool Roof Cool roofs are designed to reflect more sunlight and absorb less solar energy than traditional roofs. This keeps the building cool. This saves energy and money in air-conditioned buildings. After providing this cool roof thermal resistance boosts to 7.098 from 0.83 as seen in "Fig.9".

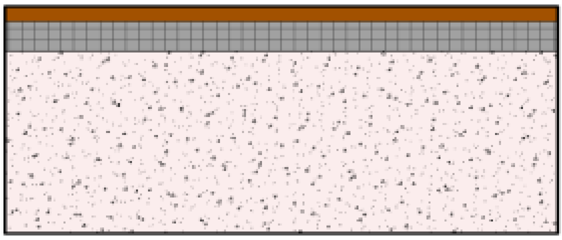


Figure 10. Cross section of 6" roof (1" insulation and 0.5" plaster)

5) Insulated low-e windows Low emissivity glass, also known as Low-E glass, has a coating on the glass that makes windows and doors significantly more energy efficient. In Revit we provided Double Glazing - ¼ in thick low- E (e=0.05) glass windows with a thermal resistance of 2.857, as we can see in "Fig.10"

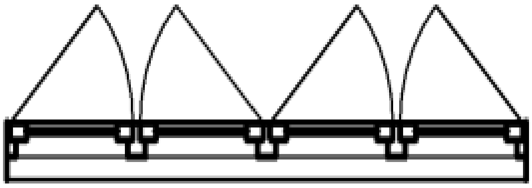


Figure 11. Glazing

6) Monocrystalline Solar panels Monocrystalline solar panels are made from a single silicon crystal that is formed into a cylindrical silicon ingot. The main advantages of monocrystalline panels are that they have higher efficiencies and more importantly their ability to be efficient when there is a change in temperatures. Monocrystalline solar panels have the ability to work more efficiently in low light. Also, the life expectancy of these solar panels is 25 years. The selected solar panel has an efficiency of 13.8% and each solar panel is 5' by 3'.

7) Shading: Shading is provided on the windows of the house. Shading was determined by the sun path in the most economical way. The positioning of this specific residential building allows us to provide ⅔ shading on the left side of the house only. This is because the sun patch is mostly on the left side of the house/ for the front and back around ⅓ shading is provided. Where the sun is not directly facing the house there is no shading provided. This was done to be most economical, and provide protection from the sunrays.

Figure 12. Shading over windows

E. Modified Model in GBS

After installing insulation and window glazing along with shading on the window in Autodesk Revit. The gbXML life is imported to GBS to see the efficiency of the materials. The results shown in "Fig.13", explain the annual energy cost is 693,135PKR, and life cycle cost has been reduced to 9,440,500PKR.

1) Photovoltaic Analysis in GBS

According to the Solar panels available in market one was selected based on efficiency and characteristics of them. The selected solar panels have a 13.8% efficiency and an initial cost of Rs. 120 per watt (including labor). The assumed electricity cost for analysis is Rs. 14 per kilowatt-hour, and the maximum payback period is 6 years. Fig.12. Photovoltaic Analysis This means our application of energy preservation measures are acceptable and are working. We have achieved our goal and have a clear 3D picture.

III. RESULTS AND DISCUSSIONS

The results of multiple simulations on the base and Energy simulation models using GBS are presented. The simulations involved adjustments to construction materials and energy demand to assess

Figure 13. Photovoltaic Analysis

Figure 14. Re-run modified gbXML file in GBS

A. *Retrofitting Results*

Before retrofitting a prefabricated house, the model was uploaded to GBS for an initial analysis. As seen in this analysis in "Fig.", GBS produced charts to compare the annual electric and fuel use, the financial impact and environmental design considerations. The modifications are made to ensure an eco-friendly design outcome. Regarding the GBS results, the software is employed to compare the energy efficiency impact of various energy conservation measures (ECMs) based on simulation results. The DOE 2 engine is used by the software, which presents the data in a user-friendly format. A base run is established by uploading a gbXML file, and 7 design alternatives are generated by modifying different design aspects that influence energy modelling. These design alternatives demonstrate the effect of various factors, such as the insulation we should use or the type of glazing on the windows.

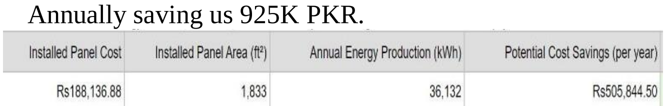
TABLE II. CONSTRUCTION SPECIFICATIONS AFTER ENERGY CONSERVATION

Family and Type	Area (ft²)	Unit Cost (PKR/ft²)	Total Cost (PKR)
Exterior wall insulation	4425	170	752,250
Cool Roof insulation	2244	170	381,410
Solar Panels	2083	102.6	188,137
Windows Double Glazing - ¼ in thick low- E (e=0.05)	864	650	561,600
Total Cost of materials (PKR)	1,883,397		

for the best alternative run that was introduced: wall insulation, cool roof, glazed windows, shading and finally occupancy and daylight sensors. The pie graphs results show several components in the building that require both electrical use and fuel use. These include space cooling, which was improved by 9.6%, and space heating which improved by 40.4%. This shows that after retrofitting we improved the thermal resistance of the building by saving an estimated 368K PKR yearly. This is approximately 35% of the total cost which was reduced. These graphs also show which areas are most affected by the energy conservation measures (ECMs) and which areas in the building have a slight effect on energy consumption. Fig.14. Results before energy efficient practices Fig.15. Results after energy efficient practices

B. *Solar Panels*

The selected solar panel has an efficiency of 13.8 and the installation of the Monocrystalline solar panels on the roof is estimated to produce 36,132 KWh and the installation cost to be around 188K PKR. These panels will save up to 555K PKR per year. This results in around 50% saving of the total annual cost. The energy crisis in Pakistan is severely impacting the nation. Although the initial cost of adding these energy saving measures is 1.8 million PKR, this will be cost effective in the long run since around 86% savings are being made yearly. Annually saving us 925K PKR.



Installed Panel Cost	Installed Panel Area (ft²)	Annual Energy Production (kWh)	Potential Cost Savings (per year)
Rs188,136.88	1,833	36,132	Rs505,844.50

Figure 15. Photovoltaic Analysis

C. Cost Analysis

The most important part of this case study is determining whether these types of buildings are economical for the everyday person. As we can see from “Table II”, Installing both insulation in walls and roof results in the total price of 1.13 million PKR. For installing solar panels, the cost comes to be 188K PKR. Considering retrofitting and solar panels, our total cost comes out to be 1.8 million PKR

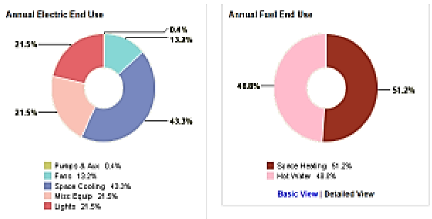


Figure 16. Results before energy efficient practices

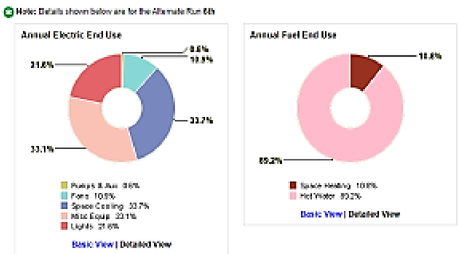


Figure 17. Results after energy efficient practices

IV. CONCLUSION

Most of the energy efficiency measures take place before the construction of the building, but in this article conservation measures were determined after the fabrication of the house. A detailed analysis is performed for this residential building located in Gujranwala, Pakistan. Using Autodesk and GBS as BIM software we are able to visualize and modify the materials of the house. Measures such as insulation, glazing of windows, shading, and photovoltaic panels can significantly reduce energy consumption and costs. After retrofitting the prefabricated house, the annual cost as seen is reduced by an estimated 368K PKR, equivalent to roughly 35% of the total cost. The installation of solar panels on the roof is expected to result in savings of up to 555K PKR per year, which is about 50% of the total annual cost. Although the initial investment for implementing these energy-saving measures is 1.8 million PKR, the long-term cost-effectiveness is apparent, with approximately 86% savings made every year, resulting in an annual saving of 925K PKR. Hence proven, these cost preservative measures allow for the application of energy efficient and cost-effective design.

V. AKNOWLDGMENT

We are sincerely thankful to our advisor for his unwavering support and time invested for this study, and to the Department of Civil Engineering for helping with our research and academic success. I would also like to acknowledge, University of Central Punjab. Last, but not least, I would like to thank my parents for their never-ending support.

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Design and Cost Comparison of Long Span Structural Systems

Engr. Tanveer Younas
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
tanveer.younas@ucp.edu.pk

Muhammad Irfan ul Hassan
Department of Civil Engineering
UET
Lahore, Pakistan
irfanulhassan@uet.edu.pk

Tehreem Shakoor
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
tehreemshakoor133@gmail.com

Mubashar Saeed
Communication and Works Department
(C&W)
Lahore, Pakistan
engr.mubashar177@gmail.com

Burhan Ahmad
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
burhan.ahmad@ucp.edu.pk

Mahnoor Arif
Department of Civil Engineering
University of Central Punjab
Lahore, Pakistan
mahnoorarif821@gmail.com

***Abstract* -- Long-span structures have become a tradition of modern Civil Engineering construction. Depending upon the span and other requirements, it is inevitable to select suitable structural systems which is not only stable but also economically viable. In this study, for a span of 45 m X 120 m, two structural systems are selected and analyzed against structural stability and economy. These include steel trusses (with bracing and without bracing) and non-prismatic steel frames. SAP 2000 is employed for the design of truss and non-prismatic steel frame structural systems. Each of the structural systems is analyzed for similar imposed loading. Their behavior is examined under the application of various loads (dead, live, wind, and earthquake). Cost analysis is performed to have the most economic and efficient system among the selected ones.**

Based on the results, performance, and economy, a truss system without lateral bracing is found to be most viable for long-span structures.

Keywords--long span structures, non-prismatic frame, truss design.

Abbreviations--K_{zt}: topographic factor, K_D: Directionality factor, C_t: time period factor, R: response modification factor, Z: zone factor, C_a, CV: ground response co-efficient, N_a, N_V: near source factors, T: time period, F_t: additional top story force.

I. INTRODUCTION

Structures like industrial buildings, exhibition halls, sports facilities, aircraft hangers etc. require a larger clear span. This draws the attention of structural engineer towards the selection of structural system because the conventional systems such as simple beams are unable to perform the intended use efficiently and economically. This is further pronounced as the dead weight of the structure is the key design parameter in conventional systems. Selection of the structural system is involved at the very beginning stage of the project and is governed by various factors like building codes, cost, and scale of the project and bay sizes as per demand of the program [1]. Khajehpour and Grierson [2] are able to keep the capital and operating cost at minimum while the income is maximum keeping in view safety and profitability [3].

There are various design options for the long span structural systems. Speedway stadium roof structure comprise of 38 girders arranged between the top truss and elliptical external ring. Girder straps are modelled like beam elements while connections with the truss are welded connections [4]. Hybrid structures can also be used as long span structures such as combination of cable and space frame structure or combination of beam-column and space frame structure [5].

II. DESING CONSIDERATIONS

A. *Design of Long Span:*

Structure has to carry its own load whatever the span is under consideration. But the complexity of is pronounced when the factored snow load, wind load and seismic loads are taken into account. Following criteria need to be considered:

B. *Structural Framing:*

Load path, maximization of the efficiency of structural elements, span, size, number of pieces, constructability etc. are to be taken into consideration.

Bracing:

Minimum requirement of bracing is to be ensured in order to have structural demands fulfilled. Later on, this can be made more efficient and interlinked with the architectural fabrication. Connections, structural elements, costs etc.

All should be minimized.

C. Erection:

Sequence of construction (to keep the temporary shoring to minimum and to maximize member size efficiency), location of temporary bracing, change of load path as the construction progresses, structural safety as directed by the structural engineer are the key parameter which are to be taken into account. These synchronize the design decision with the construction considerations and produce possible lowest cost solution.

D. Optimal Design:

Construction can be made efficient if the proper guidance is provided by the structural engineer to the erector keeping in view the sequence of construction. By targeting the constructability, the engineer is capable of achieving a serviceable and economical long span structure for the owner.

E. Spatial Requirements:

These include clear heights, clear spans, imposed limits on structure depth, architecture module etc.

F. Clear Dimensions:

Clear dimensions are larger than then conventional systems due to the long span nature of the structural system. Same is applicable in case of vertical clearances. Vertical clearance may vary along the span. Use of multiple long spans is a good idea in accordance with the architectural layout plan. This is not only good from aesthetic point of view but also is an economical option.

G. Physical Requirements:

Roof systems require physical design criteria regarding load carrying capacity, fire resistance, rigidity and resistance to deterioration which are not covered by the conventional codes of practice. Structural engineer finds himself in a situation where criteria is not available. Following are the physical requirements:

H. Dead Loads:

It is to be observed that dead load is to be defined both in magnitude and distribution for long span structures which is uncommon in ordinary structures. This is because modulus of elasticity for some materials particularly for concrete is dependent upon time as well. Hence, a modification may be required for duct work, lighting, equipment loads and other miscellaneous items. Care must be exercised in negotiating either over or under estimation of their magnitudes and their possible actual distribution must be investigated [7].

I. Live Loads:

Generally ratio of live to dead load is quite high in case of long span structures. Non uniform live load may be the case for long span structures to which the framing elements may be more sensitive. Hence, a careful analysis for the non-uniform live loads may be desired [8].

J. Earthquake Loads:

Designing for horizontal base shear works well for many long span roof structures. However, a long span structure carries a heavy mass supported by long, flexible and weak columns. To be more realistic, a dynamic analysis of such structures is desirable. Because, simplified method of analysis implies more energy as compared to the horizontal acceleration. Same is the case for vertical acceleration caused by the earthquake forces, provided that the roof system is too flexible to respond to vertical accelerations and column displacements [9].

K. Deflections:

In long span structures, deflections are quite larger as compared to those in short spans. Hence, it is inevitable to differentiate between dead load and live load effects. It is observed that deflections in some materials are time dependent. Hence, these are not going to attain maximum values until the long span structure is fully constructed. It must be noted that with increase in span, the accuracy of computing the deflections is not improved.

Various scenarios are to be considered such as deflections caused by infrequent specified design loads and more frequent small deflections under less severe load.

III. DESIGN OF LONG SPAN STRUCTURES

L. Design of long span steel truss system:

SAP 2000 software is used to design the long span steel truss system. Dead loads, superimposed loads, live loads, wind loads and earthquake loads are considered in the software for designing the system. Software has built in various specifications for the design purpose for different loading conditions. It is up to user to choose the desired one. Design wind speed of 90 miles per hour (mph) is selected against an exposure category B. Importance factor (I) is taken as unity. Dead weight of the truss is auto calculated by the software. Live loads are selected against the pitch of the roof. Corresponding windward and leeward co-efficient are taken from ASCE specifications.

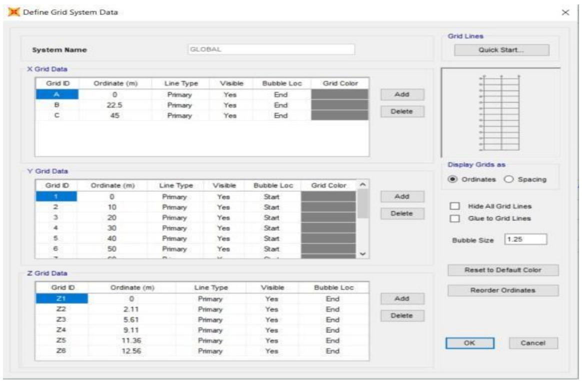

Figure 1. Grid Definition

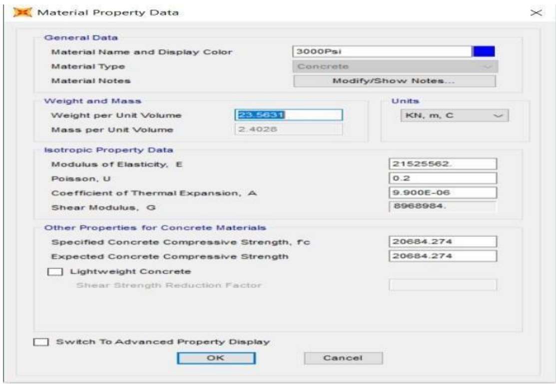

Figure 2. Definition of Steel Sections

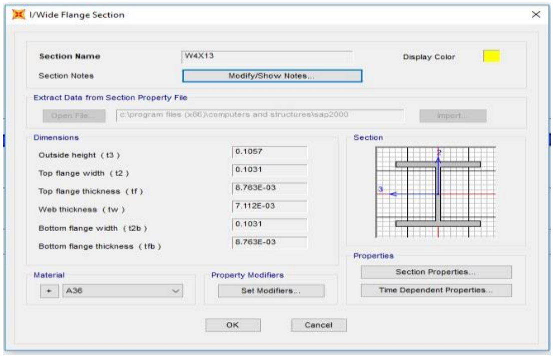

Figure 3. Defining Shell Sections

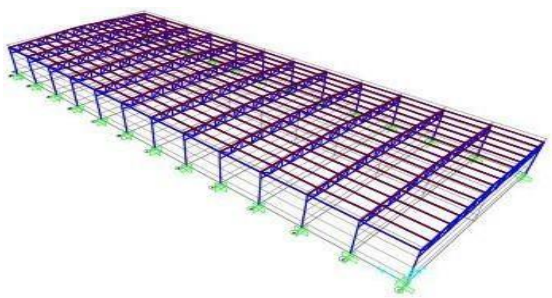

Figure 4. Defining Materials (Concrete 3000 pounds/in^2)

Table I. Wind Load Coefficient

Pattern	Angle Deg	ASCE Case	Exposure	Kzt	Gust factor	Kd
WIND	0	1	B	1	0.85	0.85
WIND-2	90	1	B	1	0.85	0.85
WIND-3	0	2	B	1	0.85	0.85
WIND-4	90	2	B	1	0.85	0.85
WIND-5	0	2	B	1	0.85	0.85
WIND-6	90	2	B	1	0.85	0.85
WIND-7	0	3	B	1	0.85	0.85
WIND-8	90	3	B	1	0.85	0.85

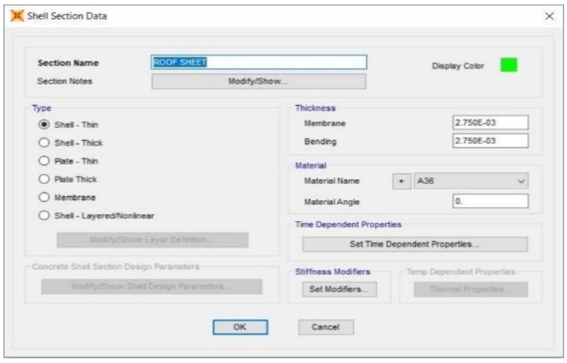

Figure 5. Modelling in SAP 200

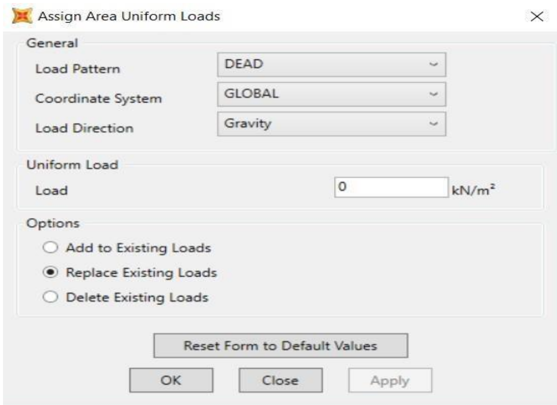

Figure 6. Assigning Super imposed Dead Loads

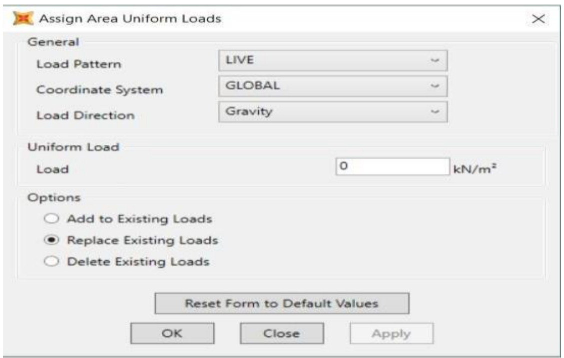

Figure 7. Assigning Live Load

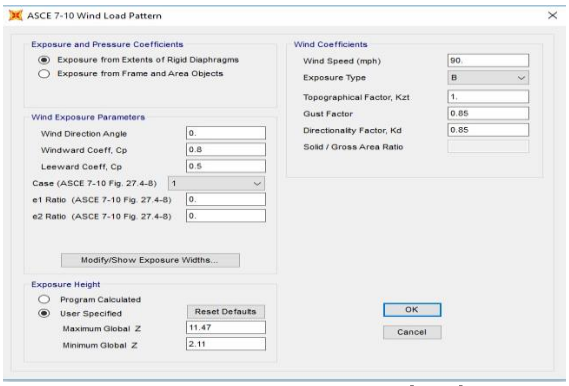

Figure 8. Assigning Wind Load

TABLE III. Seismic Coefficient

Pattern	Ct	R	Soil Type	Z	Ca	Cv
EQ X	0.035	8.5	SD	0.15	0.22	0.32
EQ Y	0.035	8.5	SD	0.15	0.22	0.32
Na	Nv	I	T Sec	Weight KN	Base Shear KN	Ft KN
1.3	1.6	1	0.797	4835.04	228.404	12.742
1.3	1.6	1	0.797	4835.04	228.404	12.742

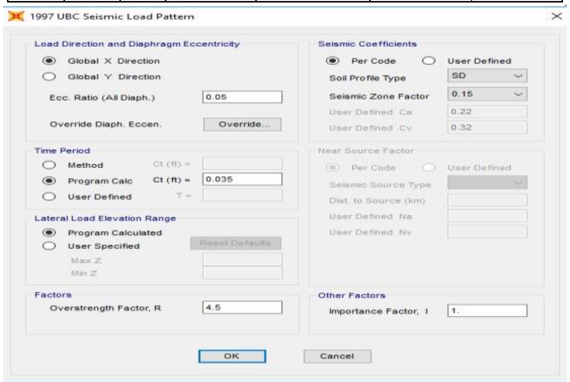

Figure 9. Assigning Earthquake Loads

TABLE IV. Analysis Results for Dead Load

No.	P KN	V2 KN	V3 KN	T KNmm	M2 KN-mm	M3 KNmm
807	-100.2	0.00	0.50	-1.38	-2151.9	0.0
808	-100.3	0.00	0.50	1.39	2152.3	0.0
809	-6.5	-0.13	-0.001	0.01	-0.96	-70.2
810	-5.3	-0.12	-0.001	0.02	-2.05	-55.1
811	-13.2	-0.12	-0.001	0.05	-1.47	-46.4
812	-11.7	-0.14	-0.001	0.03	-1.99	-83.5

After this, design is carried out and software given warnings if a particular sections gets failed. If all sections are passed, "no messages" appears. Ratio for designed sections should be less unity.

TABLE V. Designed Sections

No.	Design Sec	Ratio	Combo	Status
807	2L4X6X5/8	0.919	DSTL47	No Messages
808	2L4X6X5/8	0.387	DSTL47	No Messages
809	2L2.5X2X3/16	0.351	DSTL59	No Messages
810	2L2.5X2X3/16	0.265	DSTL59	No Messages
811	2L2.5X2X3/16	0.551	DSTL57	No Messages
812	2L2.5X2X3/16	0.541	DSTL59	No Messages
813	2L2.5X2X3/16	0.625	DSTL59	No Messages
814	2L2.5X2X3/16	0.583	DSTL59	No Messages
815	2L2.5X2X3/16	0.560	DSTL59	No Messages
816	2L2.5X2X3/16	0.507	DSTL59	No Messages
817	2L2.5X2X3/16	0.508	DSTL59	No Messages
818	2L2.5X2X3/16	0.566	DSTL57	No Messages
819	2L2.5X2X3/16	0.584	DSTL57	No Messages
820	2L2.5X2X3/16	0.626	DSTL57	No Messages
821	2L2.5X2X3/16	0.534	DSTL57	No Messages

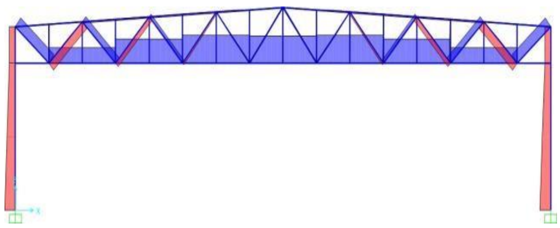

Figure 10. Axial Force Diagram of Steel Truss

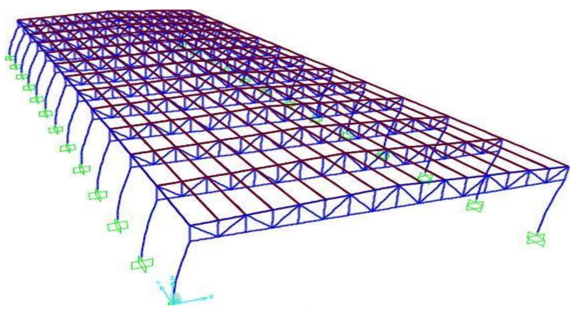

Figure 11. Deflection of Steel Truss against Wind

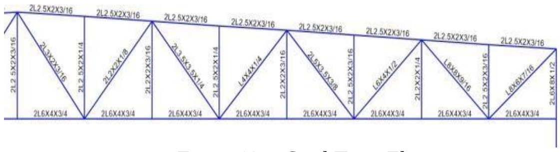

Figure 12. Steel Truss Elements

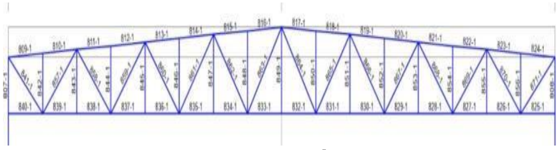

Figure 13. Steel Truss Section

M. Design of non-prismatic frame system:

This non-prismatic frame is designed for four different loadings (dead, live, wind, earthquake) using SAP 2000. Software auto calculates the dead load. Live load is 0.98 KN/m^2 without access to the roof. Wind load co-efficient are taken from ASCE 7-10. Soil type is SD.

TABLE VI. Wind Coefficients

Pattern	Angle Deg.	ASCE Case	Exposure	K_{zt}	Gust Factor	K_d
WIND-1	0	1	B	1	0.85	0.85
WIND-2	90	1	B	1	0.85	0.85
WIND-3	0	2	B	1	0.85	0.85
WIND-4	90	2	B	1	0.85	0.85
WIND-5	0	2	B	1	0.85	0.85
WIND-6	90	2	B	1	0.85	0.85
WIND-7	0	3	B	1	0.85	0.85
WIND-8	90	3	B	1	0.85	0.85

TABLE VII. Seismic Coefficient

Patt -ern	Ct	R	Z	Ca	Cv
EQ X	0.035	4.5	0.15	0.22	0.32
EQ Y	0.035	4.5	0.15	0.22	0.32

Using the values in table VI, base shear and top story forces are calculated.

TABLE VIII. Base shear Calculations

Patt -ern	Ct	R	Z	Ca	Cv
EQ X	0.035	4.5	0.15	0.22	0.32
EQ Y	0.035	4.5	0.15	0.22	0.32

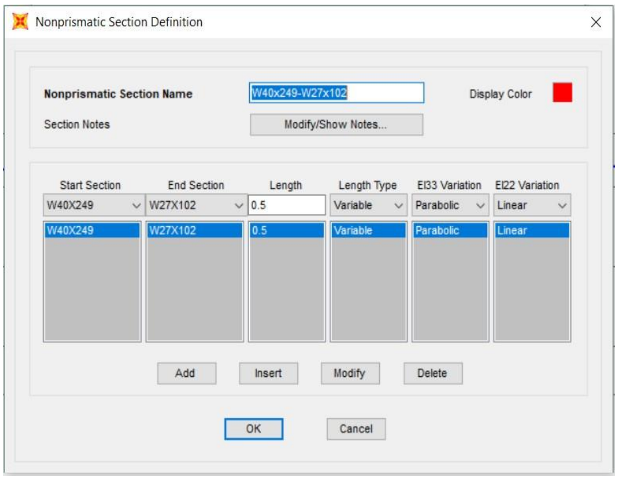

Figure 14. Section Designer for Non Prismatic Sections

Figure 15. Frame Labels

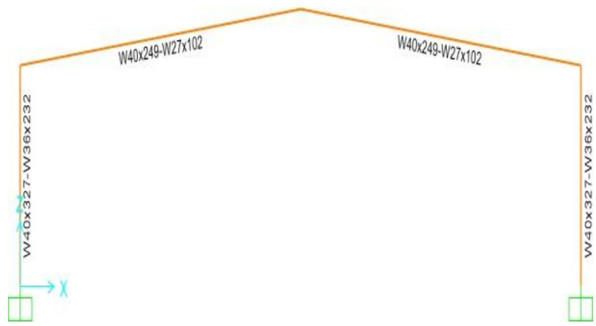

Figure 16. Designed Sections

TABLE IX. Analysis Results for Designed Sections

No.	P KN	V_2 KN	V_3 KN	T KNm	M_2 KNm	M_3 KN-m
554-1	-145.5	-150.3	-0.04	-0.003	-0.07	-1212.8
554-1	-144.5	-140.5	-0.04	-0.003	0.05	-801.8
554-2	-136.0	-125.1	-0.08	-0.002	-0.12	-801.8
554-2	-135.1	-115.1	-0.08	-0.002	0.10	-461.2

554-3	-126.1	-100.7	-0.08	-0.002	-0.13	-461.2
554-3	-125.2	-92.2	-0.08	-0.002	0.11	-188.8

TABLE X. Designed Sections

Frame	Design Section	Ratio	Comb-o	Error Messages
554	W40x249-W27x102	0.993	DSTL 181	No Messages
555	W40x249-W27x102	0.985	DSTL 180	No Messages
580	W40x327-W36x232	0.980	DSTL 171	No Messages
581	W40x327-W36x232	0.973	DSTL 168	No Messages

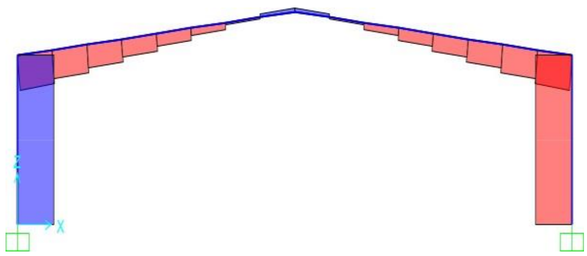

Figure 17. Shear Force Diagram

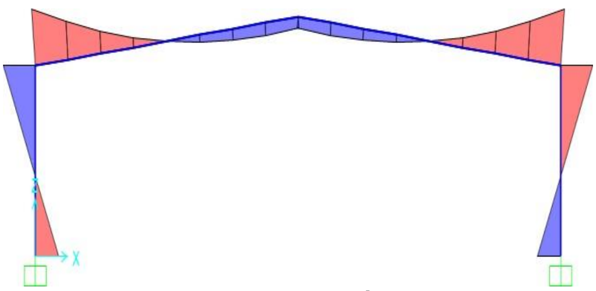

Figure 18. Bending Moment Diagram

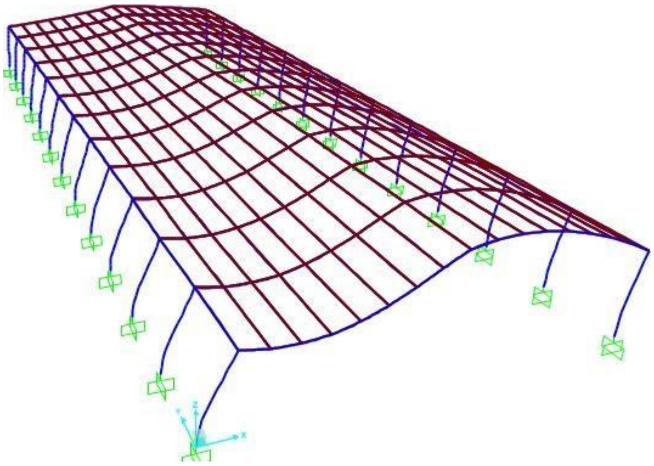

Figure 19. Deflection of Steel Frame against Wind

TABLE XI. Bill of Quantities

Sr. No	Description of Quantities	Unit Quantity	Rate PKR	Value PKR
1	Fabrication of heavy steel work, with angle, tees, flat iron, round iron and sheet iron for making trusses, girders etc., including cutting, drilling, riveting, handling, assembling and fixing, but excluding erection in position.	501998.5 kg	127.492	64000787.3
2	Erecting rolled steel beams or old rails, in roofs, excretion and fixing in position.	501998.5 kg	7.74	3885468.1
3	Providing & Fixing corrugated galvanized iron sheets with G.I. bolts, nuts, limpet and bitumen, washers, wind ties, complete in all respects without valleys and ridges:	5430 m^2	2555.75	13877722.5
Total cost of non-prismatic steel frame structure with bracing (PKR)				**81763977.9**

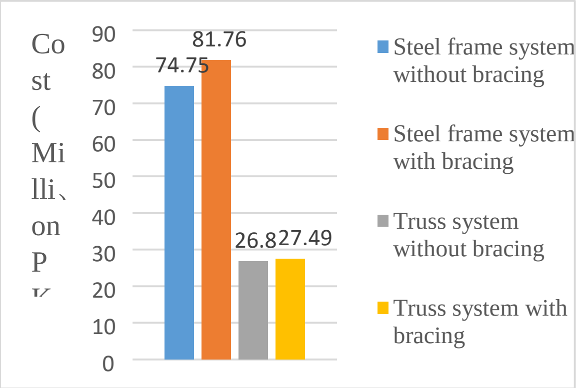

Figure 20. Cost Comparison of Structural System

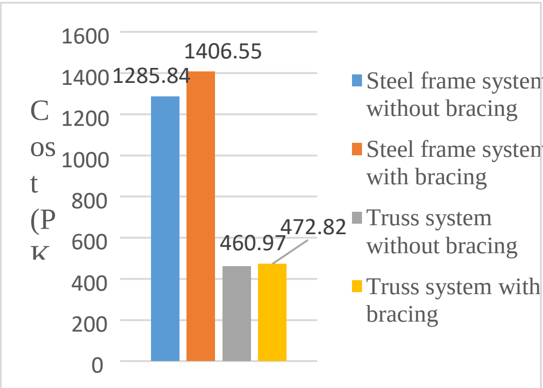

Figure 21. Cost per Square ft. Comparison

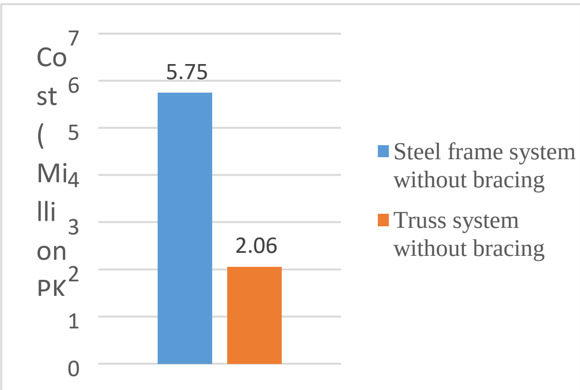

Figure 22. Cost Comparison of Individual Frames

IV. CONCLUSION

Based upon the software results and the cost analysis, it is apprehended that:

Truss system without lateral bracing is the most economical structural system for long span point of view.

Deflection against dead load is minimum for truss system. So, it is the best system from safety point of view.

Drift against wind load is lesser for non-prismatic steel frame as compared to truss system.

Drift against earthquake load is least for steel truss system as compared to non-prismatic frame system.

Time of construction is more in case of truss structural system because a lot of connections are required during erection

V. AKNOWLEDGMENT

We are sincerely thankful to Dr. Muhammad Irfan ul Hassan (Associate Professor, UET, Lahore, Pakistan) for his valuable guidance during this entire study. Engr. Mubashar Saeed played a vital role through his field exposure in design which helped us to carry out a realistic design. Last, but not the least, we are thankful to our parents and friends who are always there for our moral support.

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[11] Uniform Building Code (UBC)-97

[12] Seismic co-efficient, Uniform Building Code.

Energy Efficiency Potential of Natural Fiber-Based Composite Building Material

Khadija Mawra
Dept. of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
khadija@uet.edu.pk

Khurram Rashid
Dept. of Architectural Engineering and Design
University of Engineering and Technology
Lahore, Pakistan
khuram_ae@uet.edu.pk

***Abstract*—The energy crisis has become a major concern globally due to adverse climatic changes and buildings consume 50% of the energy to maintain optimum thermal conditions. Many insulation techniques have evolved to reduce the heating and cooling loads of a building through synthetic coatings or layers of insulating material on the building envelope. However, the use of modified conventional materials (brick and mortar) with enhanced thermal properties through some additives may be a more sustainable approach. Therefore, this study was designed where three natural fibers (bamboo, coconut coir, and jute) were incorporated into the brick-and-mortar. Physico-thermal properties of conventional (reference) materials as well as of fiber-modified composites were assessed by conducting density, water absorption, porosity, and thermal conductivity tests. Results reveal that fiber-modified composites have lighter densities and higher porosities and water absorption due to the porous structure and air-entrapping ability of fibers than reference materials. Furthermore, brick and mortar with coconut coir were the lightest, most porous, and most water absorbent. Noticeable reduction in thermal conductivity was also obtained due to the addition of fibers, as porosity further increases due to the burning of fibers acting acted as a cavity inside the material. The least thermal conductivity values were obtained for brick with coconut coir (0.28 W/mK) and mortar with jute/bamboo fiber (0.35 W/mK). Moreover, both materials were then used in 6D BIM-based energy analysis of a building unit to assess the reduction in heating and cooling loads by modifying reference materials. It was observed that by incorporating the fiber-modified composites the heating and cooling loads were reduced by almost 15%.**

***Keywords* —** *building envelope, natural fibers, brick, mortar, thermal conductivity, BIM, thermal performance.*

I. NTRODUCTION

Commercial and domestic building sectors contribute to 30-60% of energy consumption in developing countries which results in greenhouse gas emissions [1]. This energy consumption is majorly due to the requirement of maintaining thermal comfort for building occupants [2]. Various types of insulation techniques have been introduced in the construction industry like cavity-based, films or coating, insulation layers, or reflective materials [3]. Efforts are also being made to reduce thermal loads by incorporating sustainable alternatives for the building envelope. But specialized material is needed, which obviates the cost. Therefore, investigation is required to modify conventional materials to enhance the energy efficiency of the building.

A conventional system is modified by adding layers of synthetic materials like glass wool, rock wool, or slag wool on floors and roofs. Or advanced insulation materials like vacuum insulated panels on wall claddings, and double or triple-glazed low emissivity glass in windows, are abundantly being studied and utilized. However, the use of inorganic materials is considered dangerous for human health and modern techniques are costlier and difficult to adapt due to their special manufacturing processes [4]. On the other hand, natural insulating materials are cheaper, naturally available, and non-hazardous, therefore, their utilization as admixtures need to be explored in terms of thermal insulation potential [5]. Fibers are porous materials creating a cavity effect when lose water which ultimately enhances the thermal insulation capacity of materials [6]. Since natural fibers are organic naturally occurring plant-based fibers, their use in providing insulation in buildings could be beneficial and needs to be explored. A few studies have investigated the use of natural fibers like; straw, cotton, wheat, and rice husk in bricks and mortar or as an insulation layer between concrete masonry [7]. For quantifying the thermal performance, Building Information Modelling (BIM) analysis has been used to optimize building envelopes for energy retrofits [8].

This study has extended the research by studying the impact of using three natural fibers (bamboo, coconut coir, and jute) in bricks and mortar. A comparison of the role of fibers in altering the physical-thermal properties of brick and mortar is carried out. Results will define the most beneficial alternative in terms of thermal properties. To quantify the benefits of reducing thermal conductivity, a 6D BIM (Building Information Modelling) analysis has been conducted on a small-scale building unit's use of BIM. The energy performance of fiber-modified composites is calculated in terms of variation in heating and cooling loads by creating different combinations of fiber-modified composites in the wall assembly. This may pave the way towards the production and use of fiber-modified materials with lower costs, biodegradation, and environmental burden.

II. METHODOLOGY

b. Materials and Specimen Preparation

For bricks, the soil was obtained from a local brick kiln, and according to the AASHTO soil classification system, it is considered fine sand. It was mixed with water and fiber by an amount of 17% and 1% by weight, respectively. In a mortar, ordinary Portland cement and Chenab sand were used as raw materials along with 1% fibers. Three types of fibers are used in this study; bamboo, coconut coir, and jute, and were selected based on their natural availability in Pakistan. Fibers were cut to lengths of 10 to 15mm and all have different diameters.

The cylindrical plastic molds of both diameter and height of 30 mm were used to cast brick and mortar specimens. For each type, either brick or mortar, four specimens were prepared and narrated as fiber-modified material (FMM) as well as reference materials (reference brick (RB) and reference mortar (RM)). Similarly, modified brick and mortar is defined by MB and MM, respectively, as shown in Fig. 1.

c. Physico-Thermal Testing

In physical properties, the bulk density of all specimens was calculated by taking dry weight (W_{dry}) over volume (V) ratio. W_{dry} for all specimens were obtained by drying the specimens in an oven at 115 ℃ until reaching constant weight and then weighing them. Water absorption was determined by immersing the oven-dried specimens in water at 25 ℃ and their saturated weights (W_{sat}) were measured until got constant. Water absorption was calculated by the ratio of the weight of water absorbed, given by the ratio of W_{sat} - W_{dry}, to the W_{dry}. Whereas, the open porosity of a material can be measured by the ratio of the volume of open pores to the V of the specimen. The open porosity may also be calculated as the ratio of the volume of water absorbed given by the difference of saturated and dry weight of a specimen to the total volume of the specimen (V) as expressed in the following (1) [9].

$$\text{Porosity} = (W_{sat} - W_{dry})/V.\ \rho_w \qquad (1)$$

Thermal conductivity was measured by Heat Conduction Apparatus according to ASTM E1225-13. Nine thermocouples of the apparatus are attached to the hot end, the specimen, and the cold end, three to each. The temperature of all nine thermocouples was noted and plotted. A temperature profile was plotted to obtain the slope dT/dx and thermal conductivity is measured from (2), where; k is thermal conductivity (W/(m. K)), Q is heat flow (watts), and A is area (m^2).

$$k = Q.dx / (A.dT) \qquad (2)$$

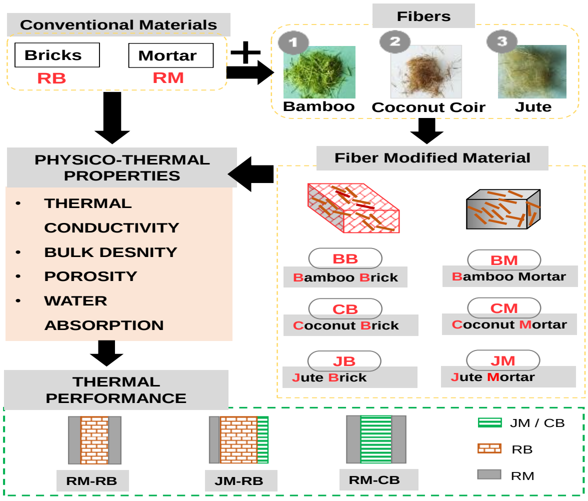

Figure 1. Summary of the entire methodology of the proposed work.

d. Assessment of Thermal Performance

After obtaining the experimental thermal conductivity values, thermal performance by modifying the envelope materials was assessed through an energy analysis carried out in 6D BIM. Firstly, a 3D model for a building unit sized 3m x 3m x 2.5m was developed in Autodesk Revit (a BIM software). Revit has built-in material properties and also allows for modification of the properties. Using this feature, identical materials were created for wall assemblies and only their thermal conductivities were modified as per experimental values of coconut brick (CB) and jute mortar (JM). Once the model was complete, it was converted into a space to compute space volume for which heating and cooling demands are calculated by selecting the weather region of Lahore, Pakistan. Energy analyses were simulated for three different cases based on layers modifications in a standard 230 mm brick wall structure consisting of a bricklayer and outer and inner mortar plaster layer. In the first case, reference materials were used in walls, and is termed an RM-RB case. In the second and third cases, one mortar layer and the bricklayer were replaced with modified materials and are termed JM-RB and RM-CB, respectively. Simulations were made to assess the variations in heating and cooling (H&C) loads before and after applying the fiber-modified brick and mortar. Fig. 1 presents a comprehensive summary of the entire work.

III. EXPERIMENTAL RESULTS AND DISCUSSION

e. Bulk Density

The bulk density of both types of samples, brick and mortar, is mentioned in (Fig. 2). It can be observed that by adding fibers bulk density was reduced and the reduction in the bulk densities of brick is more as compared to the mortar. The reduction in bulk density ranges from 5.5 to 9.9% in bricks and 1.5 – 9.3% in mortar by incorporating fibers. That was due to the burning of fibers during the curing of bricks at 700 ^{C}. Which created empty voids and resulted in lower densities [10]. But in the case of mortar, the reduction is comparatively less but depends upon the fiber, the absorption capability, and the expansion of fibers [6]. Usually, the air is entrapped during the mixing of fibers and thus resulted in lower bulk density. It can be concluded that the addition of coconut coir resulted in the lightest brick (1610 kg/m^3) and also the lightest mortar with 1680 kg/m^3 density.

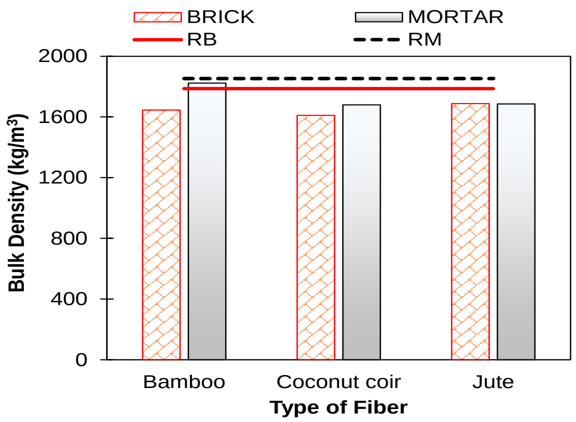

Figure 2. Bulk density of reference and fiber-modified materials.

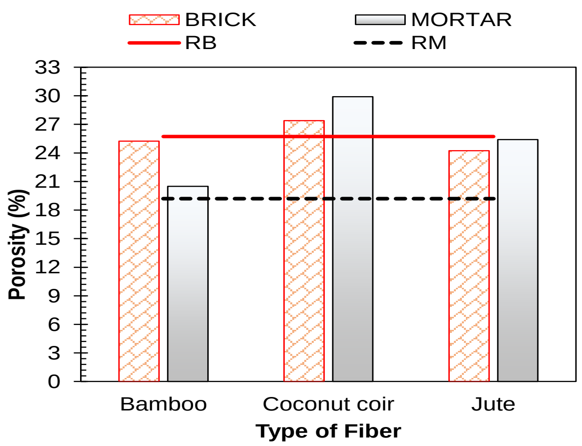

Figure 3. The porosity of reference and fiber-modified materials

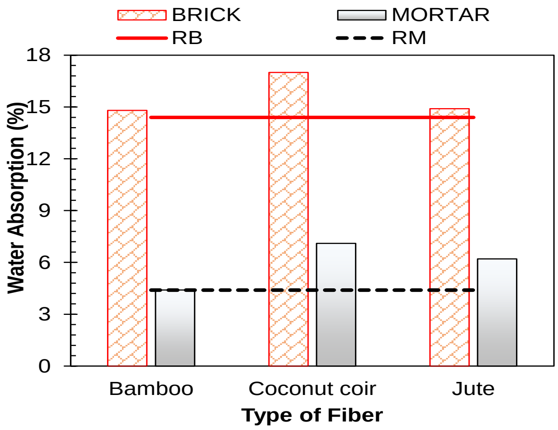

Figure 4. Water absorption of reference and fiber-modified materials.

f. Porosity

Fig. 3 compared the porosities of both types of bricks and mortars. It was observed that porosity generally increases with the addition of fibers in materials, however, the addition of jute and bamboo fibers decreased the porosity in brick only. It is due to the presence of fluxing agents (Fe_2O_3, K_2O, MgO, CaO, and Na_2O) in them, which upon burning at high temperature, convert to a molten material and fill the pores [11]. Only coconut coir resulted in an increase of porosity in brick by 6.5%. In the case of mortar, porosity increased by 6.8 – 55.7%. The addition of coconut coir resulted in the most porous mortar (29.9%), which is 55% more than the reference mortar. Jute and bamboo fibers increased porosity by 32% and 6.8%, respectively. This is due to the presence of air entrapped by porous fibers inside a mortar and varies due to their different diameters.

g. Water Absorption

Water absorption of FMM compared to reference specimens is shown in Fig. 4. Overall, bricks absorb more water than mortar, and it was observed that the addition of fibers increased water absorption. In bricks, the increase ranged from 2.8 – 18% while in mortar the surge was up to 61%. Among all fibers, the coconut coir made the most water-absorbent brick (17%) with an 18% increase from reference, while bamboo gave only a 2.8% increase in water absorption. In a mortar, the addition of coconut coir resulted in a 61% increase of water absorption from reference, then jute with a 41% increase. The addition of bamboo fibers brought no change to the water absorption of mortar because bamboo fibers have the lowest capacity to absorb water as compared to the other two fibers [6].

h. Thermal Conductivity

Fig. 5 presents the results of thermal conductivity before and after the addition of fibers. The impact of fibers overall is to decrease the thermal conductivity of materials. In bricks, the inclusion of fibers contributed to a decrease in the thermal conductivity value by 6 – 18%. Coconut coir brick comes out to be the least thermally conductive brick of all types with a value of 0.286 W/(m. K). On the other hand, in mortar, the range of reduction is 6 – 10%. The reason behind the reduction in thermal conductivity of the bricks being more as compared to mortars was due to the burning of fibers at high temperatures in the baking process of brick. At a high temperature of 700 ºC, all types of fibers are almost 90% burnt and space is created in the place of fibers which act as cavities. The different thermal conductivity value of each fiber is due to their varying sizes and ultimately different size of empty spaces created by their burning also confirmed in a recent study by the author [6].

In the case of mortar, there was no fiber burning due to the moist curing of specimens, but thermal conductivity was reduced. This reduction was due to the porous structure of fibers, and the air entrapped between the interface of fibers and the material mix [6]. Due to the different diameters of fibers and water absorption capability, the surface area for the entrapped air and cavity size varies, and thus the thermal conductivity of the specimens is reduced. In mortars, the least thermally conductive mortar was given by fiber of bamboo and jute with thermal conductivity of 0.35 W/(m. K), which is 10 % lesser than the reference mortar (0.4 W/ (m K).

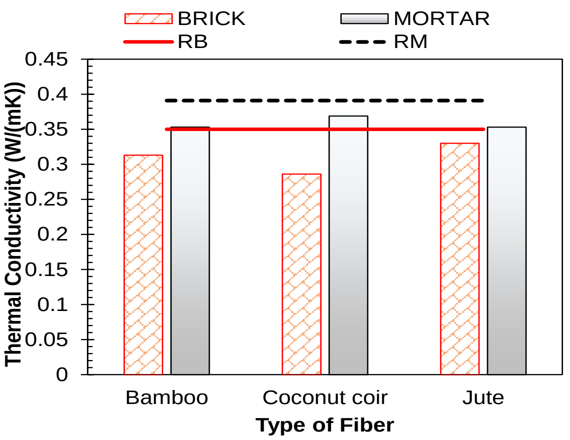

Figure 5. Thermal conductivity of reference and fiber-modified materials.

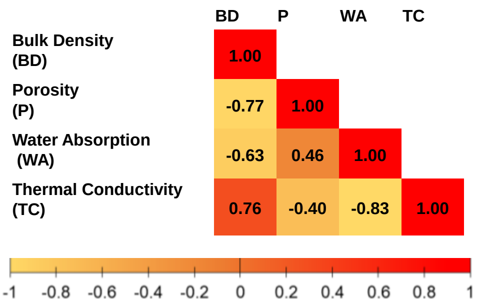

Figure 6. Heat map of the correlation matrix between physio-thermal properties.

i. Physico-Thermal Relationship

The relationship between the physical and thermal properties of the reference and fiber-modified materials is assessed through the Pearson correlation matrix. The correlation coefficients determined the strength and nature of the relationship between the physical-thermal properties shown in Fig. 6. The correlation matrix was developed using the experimental values of physical and thermal properties. The correlation coefficients of the relationships among the physical and thermal properties verify the relationships discussed in Sections 3.1 and 3.2. Bulk density is inversely related to both porosity and water absorption with correlation coefficients of -0.77 and -0.63, respectively, whereas, water absorption and porosity are positively related to each other. It was observed that the water absorption and thermal conductivity were strongly correlated properties with a correlation coefficient value of -0.83. The negative sign indicates the nature of the relationship to be inverse which is consistent with the findings that the enhanced water absorption of bricks and mortars results in a reduction of their thermal conductivity. Thermal conductivity also depicted a strong direct influence of bulk density and a weaker inverse relation with porosity as compared to the other two physical properties.

IV. THERMAL PERFORMANCE

The energy analysis results comprised heating and cooling loads as per defined materials. The results are presented and compared in Fig. 7 and Fig. 8. The first case with all reference materials (RM-RB) in 230 mm brick wall had the highest heating and cooling load for a building unit. Which decreased by 14.5% and 11.3%, respectively, by replacement of reference brick (RB) with coconut brick (CB). It is evident from the results that a major impact on loads is created due to the replacement of reference brick (RB) with fiber-modified brick (CB). Whereas the replacement of mortar with a fiber-modified one does not bring a major change to the loads.

It is pertinent to note that by incorporating only 1% of fibers in brick and mortar, the reduction in thermal loads achieved is reasonable. The results of this study are in good agreement with other similar studies which have also established the reduction in overall energy consumption of buildings in terms of heat gains or heat losses by mixing rice husk into cement mortar [12], insulating walls through straw bale panels [7] and the thermal conductivity of walls being reduced through the use of Ferro-cement sandwich panels filled with coconut fiber [13]. Introducing the hemp wool insulation layer in walls provided a reduction in heating and cooling loads by 60% and 70%, respectively, [14].

V. CONCLUSIONS

The focus of this study was to explore the impact of adding natural fibers (bamboo, coconut coir, and jute) on the physical-thermal properties of brick and mortar. Relations of thermal conductivity with other physical properties of bricks (density, water absorption, and porosity) incorporating fibers were also investigated. Finally, an energy efficiency analysis was conducted through 6D BIM to explore the potential of fiber incorporation toward energy efficiency for a building. Through this experimental and analytical work, the following conclusions were made:

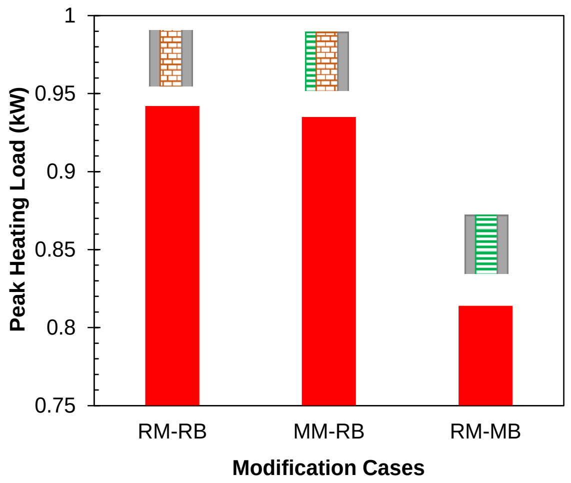

Figure 7. Peak heating loads in wall assemblies

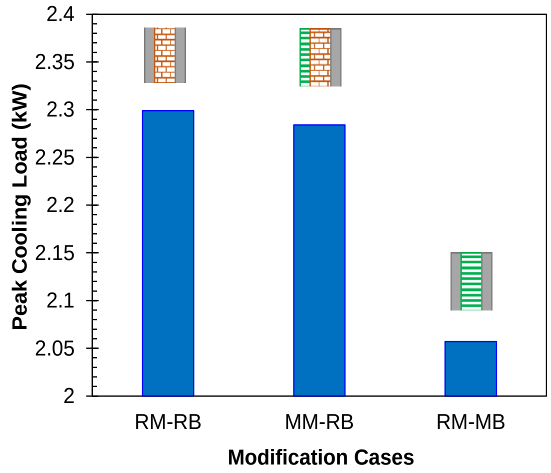

Figure 8. Peak cooling loads in wall assemblies

- Addition of fibers into the conventional materials modified the physical properties and resulted in a decrease in density and an increase in porosity and water absorption. The density value was reduced by about 10% than conventional materials. However, water absorption increased by 18 and 61%, and porosity increased by 6% and 55%, for modified bricks and mortars, respectively.
- Thermal conductivity is reduced by the addition of fibers. Reduction in its value was more for bricks than mortar, quantitatively, it was 18% and 10% reduction, respectively. Coconut brick had the least thermal conductivity (0.28 W/(m. K)), while bamboo and jute fibers in mortar have a thermal conductivity value of 0.35 W/(m, K)
- Thermal conductivity is strongly correlated with the physical properties having the strongest correlation with water absorption. And also fulfill the fundamental laws of materials science.
- Significant reduction in heating and cooling loads (about 15%) was observed by modifying the conventional brick with the brick having coconut coir. However, the influence of fiber-modified mortar was marginal.

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Evaluation of Mechanical Behaviour of Concrete with Partial Replacement of Coarse Aggregate by Recycled Coarse Aggregate with and Without SBR Latex

Usman Ali
University of Engineering and Technology Lahore
Lahore, Pakistan
usmanali.ce14@gmail.com

Sahar Iftikhar
Budapest University of Technology and Economics
Budapest, Hungary
sahariftikhar49@gmail.com

Ali Humza Waris
University of Engineering and Technology Lahore
Lahore, Pakistan
engralihumza99@gmail.com

***Abstract*— these days the modern world is adopting various approaches to use waste materials from the perspective of effective utilization of and preservation of natural resources. The utilization of recycled aggregates is a step forward toward the reuse of materials in the construction industry. A variety of polymers are used to improve the performance of the concrete and it is found that when the polymers are added to a concrete mix, the mechanical response of concrete is improved compared with conventional concrete. This research paper presents the effects of incorporating the Styrene-Butadiene Rubber (SBR) Latex with five different proportions of recycled coarse aggregate (R.A.) on cylindrical compressive strength, flexural strength, and tensile strength. Samples with and without the addition of the SBR Latex are studied with these five proportions. The results obtained by this research study show that virgin aggregate replaced 100 percent with recycled coarse aggregate without the addition of the SBR Latex gives higher compressive, tensile, and flexural strengths provided that the optimum dosage of SBR Latex (i.e., 4%) is adopted. Experimental results show that the SBR-Latex is effective in minimizing the water-to-cement ratio to achieve the same workability in concrete.**

***Keywords*—** *recycled aggregate, modified concrete, SBR Latex, mechanical properties*

I. INTRODUCTION

The concrete is the most usable material on the earth after water [1]. The significance of concrete in the construction industry is notable because of its better durability and strength characteristics. Also, the demolished construction waste has increased considerably in the previous years and utilization of that waste would help in environmental protection.

Construction waste generation and the unsustainable use of depleting natural resources for building materials are linked to the adverse environmental impacts of the construction industry. Globally, it is estimated that approximately 10-30% of waste disposed of in landfills originates from construction and demolition activities [2].

In the last couple of decades, extensive research has been carried out on the properties of the recycled aggregate concrete, durability, and strength of the resulting concrete. The most important mechanical properties of concrete are the tensile strength, flexural strength, and most importantly compressive concrete [3, 4, 11]. The strains produced due to applied stress are very important to be investigated in recycled aggregate concrete.

The addition of polymers in the concrete mix has been carried out to obtain the concrete with higher durability, performance, and improved mechanical properties. The admixtures are frequently added in the concrete and considered as the fifth ingredient of the concrete [5]. The Styrene-Butadiene Rubber Latex is a polymer that has been widely used. SBR Latex is an admixture with adhesive properties and used to improve bonding properties and the mechanical properties (i.e. tensile strength, compressive strength, and flexural strength) in the concrete [12, 14].

In this present research, a combined effect of different proportions of Recycled coarse aggregate and addition of SBR Latex is experimentally investigated and tests are carried out on concrete cylinders and Beams specimens. A split cylinder test is performed to determine the tensile strength and beams are tested under third point loading for the determination of flexural strength of all proportions of recycled aggregate.

II. MATERIAL PROPERTIES

A. Cement

For this experimental research ordinary Portland cement supplied by Maple Leaf is used that complies with ASTM 150 `The initial and final setting time of cement is 238 minutes and 335 minutes respectively using Vicat apparatus. Le Chatelier's soundness is 3mm for the cement. The chemical composition of the cement is Tricalcium silicate 40%, Dicalcium silicate 30%, Tetra calcium Aluminate 11% and Tricalcium Aluminate 11%. Some other impurities like calcium oxide and magnesium oxide are in small percentages.

B. Fine aggregates

The fine aggregate used in concrete is Lawrancepur sand with properties listed in Table 1.

C. Natural coarse aggregate

The natural coarse aggregate used in the concrete is Sargodha Crush that is locally available, and the size of the aggregate is 1/2 inches down. The properties of the aggregate are enlisted in Table 1.

Figure 1. SSD AGGREGATE

D. Recycled coarse aggregate

The recycled aggregate is brought from a local production plant (where the demolished pavement concrete is used for recycling). The recycled aggregate used in concrete is 1/2 inches down. Recycled aggregates have higher water absorption and lesser density compared with virgin aggregates. The properties of the recycled coarse aggregate are enlisted in Table 1.

Figure 2. IMPACT VALUE TEST

TABLE I. Physical Properties of Fine and Coarse Aggregates

Properties	Sand	Natural Aggregate	Recycled Aggregate
Density(kg/m^3):	1547.73	1571.92	1321.39
Bulk specific gravity:	2.65	2.73	2.35
Bulk specific gravity SSD:	2.66	2.76	2.5
Apparent Specific gravity:	2.68	2.81	2.75
Water Absorption (%):	0.49	1.13	6.16
Finesse Modulus:	2.0003	6.6667	6.3054
Impact value:	-	13	17

E. SBR Latex

SBR Latex is used in the form of a thick white liquid. The SBR Latex is obtained from a local supplier (i.e. from Imporient chemicals). The density of the white liquid (SBR Latex) at 25oC is 1.0 Kg/Lit and it is a nontoxic liquid.

III. CONCRETE MIX

Concrete mixes are prepared considering the properties of the aggregates. In total, 10 concrete mixes are prepared in the laboratory including control samples. The prepared concrete mix is varied based on the proportion of the replacement of natural aggregates with recycled aggregates. The percentages replaced are 0%, 25%, 50%, 75% and 100%. These five sets of proportions are prepared twice, once without the addition of SBR Latex and then with the addition of SBR Latex.

The dosage of SBR Latex is decided based on the targeted slump value of the fresh concrete. The targeted concrete slump is fixed 55-60 mm and is achieved with 0.46 w/c with no SBR Latex. The same targeted slump is got with 4 % SBR and 0.35 w/c.

Figure 3. SLUMP TEST

For the experimental purpose, 40 cylinders with dimensions 150 x 300 mm are casted for compression and tensile strength tests. 20 beams of size 100 x 100 x 500 mm are casted for Modulus of rupture test. The workability tests and consistency tests are performed for each mix to ensure the sound concrete. The concrete specimens are dipped in a water container for

28 days for curing. All the tests are performed in 100 tons Computer controlled Shimadzu Universal Testing Machine.

IV. TEST RESULTS:

The tests are performed for all concrete mixes and listed as under

A. Compressive test.

The concrete cylinders are tested to determine the compressive strength in accordance ASTM C39. The cylinders are axially loaded with the uniform rate without any shock.

Results showed that the maximum compressive strength is got when virgin aggregate is completely replaced with recycled aggregate concrete without the addition of SBR. The test results are summarized below in figure 4

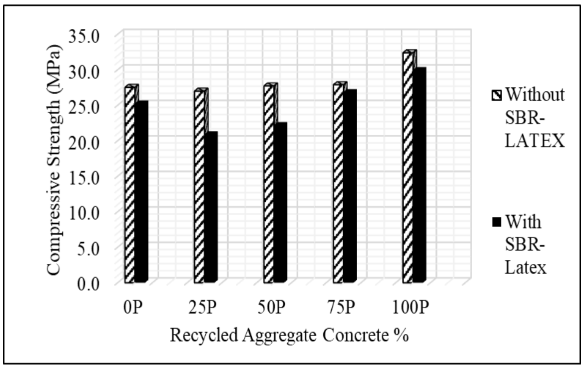


Figure 4. COMPRESSIVE TEST RESULTS

B. Split cylinder test

The tensile strength of the concrete is determined by split cylinder test in accordance ASTM C 496. The tensile strength is used in evaluating the shear resistance of the concrete. Diametrical force is applied along the length of the concrete specimen. Due to the applied compressive forces around the contact point under the action of poison effect tensile stresses are produced in the specimen.

$$f_{ct} = \frac{2P}{\pi DL}$$

Where

f_{ct}: split cylinder strength P: ultimate load at failure
D: Diameter of specimen
L: Length of specimen

C. Modulus of rupture Test

The tests are performed on un-reinforced beam to the flexure failure of beam i.e. measure of the capacity to sustain loading without any deformations in accordance ASTM C 78. The test is performed on the beam specimen using third point loading where tensile stress that causes failure at the utmost fiber.

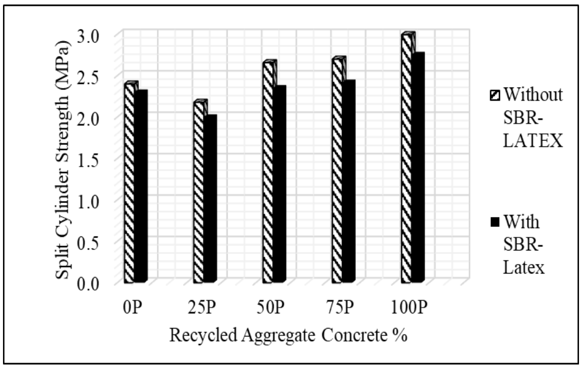


Figure 5. MODULUS OF RUPTURE TEST

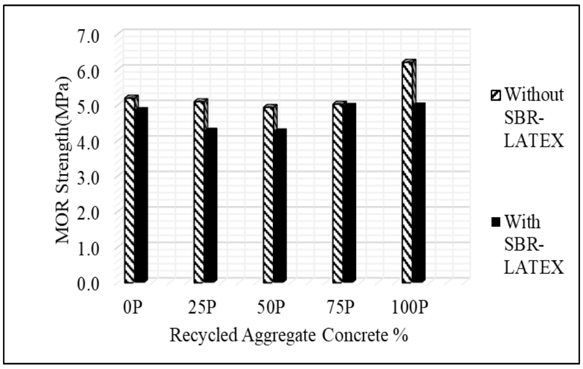
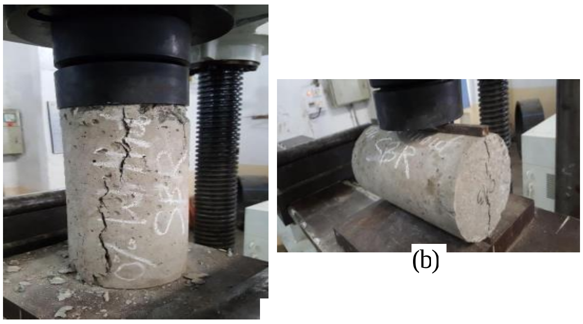


Figure 6. MODULUS OF RUPTURE TEST ARRANGEMENTS



(b)

(a)

Figure 7. COMPRESSIVE TEST ARRANGEMENTS AND TENSILE TEST ARRANGEMENTS

Percentage of RA	Compressive Strength (MPa)		Tensile Strength (MPa)		Modulus of Rupture (MPa)	
%	With SBR	Without SBR	With SBR	Without SBR	With SBR	Without SBR
0 P	25.28	27.53	2.3	2.4	4.87	5.2
25 P	20.94	26.99	2	2.18	4.29	5.1
50 P	22.23	27.73	2.35	2.66	4.27	4.94
75 P	26.88	27.9	2.42	2.7	4.99	5.03
100 P	30	32.4	2.75	3	5	6.21

Figure 8. MECHANICAL PROPERTIES

V. CONCLUSION

In this research paper, experimental results of the mechanical response of SBR Latex modified recycled aggregate concrete are discussed and presented, and the following conclusions can be made based on the results of this study:

- The addition of the SBR Latex has a negative influence on the mechanical response of the concrete (which is prepared from materials with the same properties).
- The addition of SBR Latex increases the workability of the concrete mix.
- The impact value of the recycled aggregate is higher than virgin aggregate because the recycled aggregate is recovered from the high strength concrete. And the results obtained are dependent on the recycled aggregate.
- The improved mechanical properties i.e. higher strengths of the concrete are obtained by replacing all the virgin aggregate with the recycled aggregate concrete.
- Due to the crushing cycles, the flakiness of the recycled aggregate was lesser compared with virgin aggregate

.

VI. RECOMMENDATIONS

Based on the results, the following recommendation can be made

- Experimental research of the mechanical response of the recycled aggregate with more than one cycle of recycled aggregates should be carried.
- Study of the various admixtures with recycled aggregate to increase the durability of the concrete.
- Research to be carried on the varying percentages of SBR Latex on recycled aggregate. concrete to find an optimum percentage of SBR Latex

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Investigating Performance of Asphalt Concrete Using Waste Material as Bitumen Modifier

Arfa Tariq
Civil Engineering Dept.
NFC-IEFR
Faisalabad, Pakistan
(Affiliated with UET-LHR)
muhammadarfatariq@gmail.com

Aiman Sattar
Civil Engineering Dept.
NFC-IEFR
Faisalabad, Pakistan
(Affiliated with UET-LHR)
123aimansattar@gmail.com

Muhamad Nouman Raza
Civil Engineering Dept.
NFC-IEFR
Faisalabad, Pakistan
(Affiliated with UET-LHR)
noumnraza@gmail.com

Muhammad Abdullah
Civil Engineering Dept.
NFC-IEFR
Faisalabad, Pakistan
(Affiliated with UET-LHR)
muhammadabdullah@gmail.com

Muhammad Sohail Saleh
Civil Engineering Dept.
NFC-IEFR
Faisalabad, Pakistan
(Affiliated with UET-LHR)
sohailcivil09@gmail.com

***Abstract*—HMA design represent one of the key components within the life cycle of a road infrastructure but increase in traffic congestion increased the size and load capacity of vehicles. Due to this increase, various pavement defects continue to occur, affecting the characteristics of asphalt pavement. Modified asphalt helps in decreasing the maintenance and improving the construction in terms of improving road quality, durability and reducing the overall cost of road. Here, the science of civil engineering has evolved with the concepts of recycling and sustainability. One of the most important goals of this century is to evaluate the waste of building materials to create sustainable habitats. Recent research related to the waste materials and models both for HMA, made it appropriate to consider addition of polymers. Thus, this study is an attempts to determine the impact of polymers on asphalt concrete performance. ARL bitumen grade & aggregates of Sargodha quarry were used in this research work. Three types of locally available polymers Crumb Rubber (CR), High Density Polyethylene (HDPE), & Low-Density Polyethylene (LDPE) were used. Percentages of polymer varies from 6% to 18% for each type by weight of asphalt cement. Polymers were sieved from 150 mm sieve for the preparation of modified asphalt mixes using dry procedure. Marshall Stability & flow test was performed on specimens and optimum polymer content (OPC) is determined by graphs and calculations. Experimental studies have shown that all polymer modified mixtures are more stable than conventional mixtures. It can be concluded that the addition of (12% CR), (16.24% HDPE) and (14.8% LDPE) to the asphalt mixture gave the best improvement in pavement performance. The percentages mentioned are the optimal concentration percentages for polymer mixtures. From the lab results with addition of polymers it can be concluded that LDPE modified asphaltic binder provides maximum stability on 4% air voids. The increase in stability is 6.8%. (*Abstract*)**

Keywords*—*HMA, polymer, Marshall Stability, flow, OPC, modified HMA, conventional mixtures, HDPE, LDPE, CR

I. INTRODUCTION

T Polymer modification of bitumen is extensively practiced by the asphalt industry for improving the binder properties that affect pavement resistance to thermal cracking, fatigue and rutting [1]. It is commonly acknowledged that the addition of polymer tends to improve the bitumen performance significantly. For instance, polymers enhance elasticity, improve cohesion and reduce the temperature susceptibility, which in turn, improves the performance of asphalt mixtures in terms of durability, flexibility and resistance to deformation at high temperature. It is reported that polymer modification of bitumen improves various properties of bitumen including high stiffness at high temperatures, moisture resistance, fatigue life and the capability of relaxing stresses at lower temperatures [2]. The polymers used as bitumen modifiers are of three categories according to their chemical structure and properties including elastomers, elastomers, and reactive polymers [3]. Though it is a fact that polymer modifiers reduce the thermal susceptibility of bitumen, each type of polymer has a specific effect on the properties of bituminous binders.

Increased traffic loading density and high pressures resulting from heavy vehicles are among the factors that cause cracking leading to premature failure of pavements. Various solutions have been tried to minimize susceptibility of asphalt concrete mixtures to cracking. Among those solutions are trying new materials, new mix design method and additives. In recent years, there is a rapid increase in using additives in asphalt concrete mixtures to improve its properties. Low density polyethylene LDPE has been used to improve the performance characteristics and extend the life of asphalt pavement mixtures by modifying asphalt binders and improving the properties of bitumen mixtures as asphalt modifiers. LDPE is a thermoplastic polymer composed of long chains of ethylene monomers. Produced by polymerization of ethane [4].

Increased traffic density and high pressure from heavy vehicles are one of the factors that cause cracks and premature pavement failure. Various solutions have been tried to minimize the susceptibility of asphalt concrete mixtures to cracking. Among those solutions are trying new materials, new mix design method and additives. In recent years, there is a rapid increase in using additives in asphalt concrete mixtures to improve its properties. LDPE has been widely used to improve the performance and extend the life of asphalt pavement mixtures by modifying asphalt binders and improving the properties of bitumen mixtures as asphalt modifiers. LDPE is a thermoplastic polymer. It is made of long chains of ethylene monomers. It is created through polymerization of ethane [3]. It can be prepared by radical polymerization, anionic addition polymerization, ionic coordination polymerization or cationic addition Polymerization. [5]

All CRM binders generally had good fatigue and shear strength. Wang et al. evaluated the fatigue properties of CRM binders at medium temperatures using them in the Dynamic Shear Remoter test. The concentration of crumb rubber depends on the mass of the bituminous binder. It has been found that the addition of crumb rubber can significantly improve the fatigue life of asphalt binders at medium temperatures. Previous studies in recent years have paid more attention to various crumb rubber modifiers and rubber bituminous additives to improve the fatigue resistance properties [6]. Turkey's manufacturing operations, services and households generate numerous wastes. However, problems arise from the lack of landfill capacity and limited recyclable alternatives. Waste treatment is an attractive alternative to landfill because it reduces or eliminates landfill costs and potential pollution problems while conserving resources. Meanwhile, the cost of highway construction in Turkey has recently risen. It is well known that certain wastes and certain polymers can be added to asphalt binders to improve the performance of asphalt concrete [6] [7]. HDPE material can not only affect the original engineering properties of HMA pavement, but also extend the life of asphalt concrete. However, due to the fact the mixing conditions of bitumen and polymer substantially influence the conduct of polymer changed bitumen, it's far vital to determine the maximum suitable blending situations for bitumen and polymer. For this motive, changed bitumen is received by way of mixing bitumen and modifier at a particular temperature and time. If the bitumen modifier mixture is not provided with a constant mixing time and mixing temperature, the modified bitumen will not perform well in situ, which can lead to premature failure. Therefore, mixing time, mixing temperature and modifier content are recommended for all polymers.

Determine the optimum content of the polymer used. Determine the mixture properties, Marshall Stability and flow analysis, and finally determine the optimal bitumen content. To determine the effect of waste polymer on HMA [8], use as an additive in asphalt concrete. Compared to unmodified asphalt mixture, crumb rubber modified asphalt lowers asphalt life cost, extends pavement lifetime, and decreases noise, CO2 emissions, and tire and road wear & tear. Rubber-modified asphalt also contributes to fuel economy by reducing rolling resistance [9] [9]. HDPE is used to reduce buckling caused by bitumen flooding. [10]. To build a road with a relatively longer lifespan than the existing road. Reduce pavement construction costs by using LDPE, which partially replaces bitumen [11].

II. METHODOLOGY

Different tests are performed for the aggregates and the bitumen. First, the process of sieving is carried out by the gradation curve which we followed in our experimental process. For the characterization of the aggregates, the Abrasion value test, crushing strength of the aggregate test, Impact value of the aggregate, Flakiness test, Elongation test and the specific gravity test has been carried out. For determining the properties of a bitumen used in the hot mix asphalt, The penetration test, softening point along with the flash and fire point tests has been carried out. After that the optimum binder content (OBC) has been finding out by the Marshall Flow and stability test. For the determination of the optimum binder content 21 samples have been prepared of the various percentages (3, 3.5, 4, 4.5, 5, 5.5, and 6) of the bitumen. According to the criterion of the Marshall mix design three different tests has been carried out which includes the bulk specific gravity test (GMB), Marshall flow and stability test and theoretical maximum specific gravity test (GMM) test. Different polymers like crumb rubber (CR) [12], low density polyethylene (LDPE) [13] and high-density Polyethylene (HDPE) [14] is used along with the bitumen. 15 samples of each added polymer are prepared of the various percentages (6%, 9%, 12%, 15%, and 18%).

A. Material Characterization

Aggregate: Crush aggregates were collected from Sargodha stone plant. For this research study gradation 19 (AASHTO, 2013).

TABLE I. NHA Gradation

NHA SPECIFICATION		Wearing Coarse	Base	Subbase
		% Passing	% Passing	% Passing
mm	*inch*	*Class A*	*Class A*	*Class A*
60	2.5	-	-	100
50	2	-	100	90-100
25	1	100	70-95	50-80
19	0.75	90-100	30-65	-
12.5	0.5	-	25-55	-
9.5	0.375	56-70	15-40	-
4.75	#4	35-50	25-55	35-70
2.38	#8	23-35	-	-
2	#10	-	15-40	-
1.18	#16	5-12	-	-
0.425	#40	-	8-20	-
0.075	#200	2-8	2-8	2-8

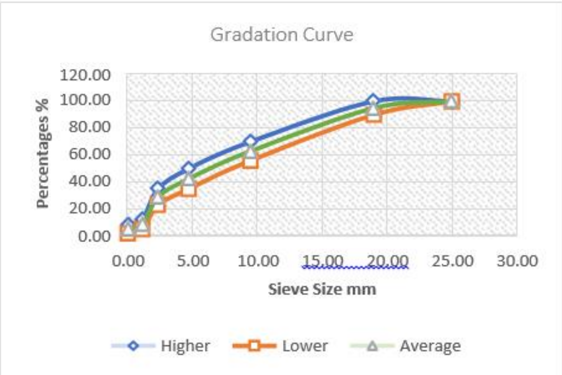


Figure 1. Gradation curve

Bitumen: Taken from Attock oil refinery with a grade 70/80 with different proportions is used. Asphalt was collected by the Civil Laboratory.

Polymers: Crumb rubber [12] is retained through the sieve #100 and passed through sieve #40 is used. LDPE [13] which we used is shopping bags which is one of the waste materials. HDPE [14] which we used is pet plaster is retained through sieve #100 and passed through sieve #40 is used.

B. Experimental Work

Aggregate Testing: Experiments accomplished for aggregate contained within sieve analysis, aggregate gradation, the loss-Angeles abrasion test, aggregate impact value test along with specific gravity of aggregates.

TABLE II. Aggregate Testing & Standards

Test type		AASHTO/ASTM Designation	Standard
Impact value		BS 812 (AASHTO, 2013)	<25%
Los-Angeles Abrasion value [15]		AASHTO-T96, ASTM C-131 (AASHTO, 2013)	<30%
Shape test [16]	Flakiness Index	ASTM d-3398 [16]	<35%
	Elongation Index	ASTM d-3398 [16]	<10%
	Angularity No	ASTM d-5821 [17]	95/90%
Specific gravity (AASHTO, 2013)			
Coarse aggregate		AASHTO t 85-88, ASTM-c 128-84 [18]	
Fine aggregate		AASHTO t 85-88, ASTM-c 128-84 [19]	
Filler		AASHTO t 100-90, ASTM-c 854-83	

Sieve Analysis and Gradation: Aggregate from Sargodha quarry were sieved in the laboratory. Amount retained for each sieve was gathered up in bags individually [20].

Flakiness Index & Elongation Index (AASHTO, 2013)*:* This test is used to determine the shape of aggregate particles, each particle shape being preferred under certain conditions. The aggregate flake index is the weight percent of particles (aggregate) that are less than 3/5 (0.6 times) their average size in thickness [16]. The filler elongation index is the weight percent of particles (agglomerates) whose length exceeds 1 and 4/5 (1.8 times) their average size.

Los Angeles Abrasion Test (AASHTO, 2013): Aggregate in Hot mix Asphalt mixes must be capable to, disintegration, and crushing due to heavy load of traffic. For the purpose (LA) abrasion test is executed to conclude permanency and strength of aggregates. Performance of the test is according to the AASHTO T 96-92. When aggregate go through scratch as per standard procedure with stated number of balls, the resulting material was than sieved from sieve #12. The loss in mass after abrasion was than determined which as per qualifications is to be a lesser amount of than 40% [15].

Aggregate Impact Value Test (AASHTO, 2013)*:* The impact magnitude of an aggregate is a relative measure of the aggregate's resistance to sudden impact or impact, which is different from, for some aggregates, resistance to slow compressive loads. The aggregate passed through a 12.5mm sieve constitutes the test substance. The fill then fills only 1/3 of the graduated cylinder depth with filler. Strike the round end of the tamping rod against the cylinder and make 25 clean strokes to compress the material.

Specific gravity and Absorption (AASHTO, 2013)*:* The gravity of a cloth is the ratio of its mass to the mass of a same amount of distilled water at a particular temperature. The basket and sample waft in water at a temperature of twenty-two° - 32°C. the burden of the suspension in water = W1g is indicated. Get rid of the basket and aggregate from the water and permit it to drain for a couple of minutes before shifting the combination to dry absorbent clothing [18].

Bitumen Testing: Different characterization laboratory tests were performed on bitumen such as penetration test, flash and fire point test, ductility test and softening point test.

TABLE III. Bitumen Testing & Standards

Test type	Method	Standard
Ductility @ 25□C, cm	ASTM D 113 [21] 21]	100
Flash point, COC, □C	ASTM D 92 [22]	≥ 232 ^{0}C
Penetration @ 25□C, mm	ASTM D5 [23]	60-70
Softening Point	ASTM D 36-95 [24]	46-56

Penetration Test of Bitumen (AASHTO, 2013)*:* The bitumen penetration determines the hardness or softness of bitumen with the aid of measuring the depth, in millimeters, that a fashionable antistatic needle penetrates vertically for 5 seconds while keeping the temperature of a bitumen pattern at 25°C. The needle will pierce the sample under its own weight for 5 seconds and then stop automatically. document your readings. degree at least 3 instances. A minimum of two samples must be tested to determine the rating [23].

Softening Point of Bitumen (AASHTO, 2013): This test method covers the determination of the softening point of bitumen in the range of 30-157°C using a ring and ball apparatus immersed in distilled water (30-80°C). The softening temperature is a consistency test and consists in heating the bituminous material until a given consistency is reached [24].

Flash and Fire Point of Bitumen (AASHTO, 2013)*:* In this case, the glass is first filled with softened bitumen up to the filling mark shown on the glass. Now put the lid on and close the cup. Other accessories such as thermometers and flame detection devices are properly secured in their respective positions. Now light the flame and set the flame size to 4mm diameter [22].

Ductility Test of Bitumen (AASHTO, 2013)*:* The ductility of a bituminous material is measured as the space, in centimeters, that both ends of the cloth's fashionable briquettes stretch earlier than breaking whilst torn at a given speed and at a given temperature [21].

The plasticity test of bitumen is carried out in two phases. • Sample Preparation: At this stage, the bitumen sample is melted and poured into the briquette mould. • Sample Test: At this stage, the bitumen sample placed in the mould is tested for plasticity on a plasticity testing machine.

Preparation of Marshall specimens: In order to prepare samples, the total weight we taken 1275gm [25]. In 1275 gm percentages of bitumen and polymers were added while the rest of the weight was aggregate. The aggregate was mixed according to the NHA class a gradation [26].

The aggregates heats up first. Then a proportionate amount of polymers is added and then add the bitumen. Mix the sample at about 160C. After preparing the samples put it in a mould and place it in a marshal mix machine and give 75 blows on both the side of the sample.

Maximum Specific Gravity Test ASTM D-2041: The air voids present in the aggregates were removed by the help of vacuum pump to carry out the GMM test [27]. Crushing of the sample took place by breaking its bond. The specimens were heated at 100-degree centigrade temperature by placing them in oven. The sample weight w1. Weight of sample and desiccator was taken as w2 and the weight of water, weight of sample along with the weight of desiccator was taken as w3. The range for the GMM according to the specification is from
2.2 to 2.6. The formula from which we calculate the GMM,

GMM=w1/w1+w2-w3

MARSHAL Stability and Flow test ASTM D6927-06: A minimum of three specimens of a given mixture shall be tested. Samples must be of the identical kind of aggregation, exceptional, and class [28]. Keep the water bath or oven at 60 °C and leave the samples for at least 30-35 minutes. In order find out the maximum load sustained by the specimen and to measure the vertical deformation, the Marshall Flow and stability test is carried out. The values of flow were recorded in mm and the load measurement was carried out in KN for obtaining the desired proportion. The prepared samples containing the percentages of bitumen as well as the aggregates were tested accordingly. The range for flow according to the specification is from (2-7mm). Experiment time was 30 seconds and the water bath temperature was 60 degree centigrade. For the stability test the equipment range was 50 KN, while the range of stability according to the specification is from 20 to 64 KN. After that stability correction factor was applied to the values of stability. According to the desired conditions the specimen thickness was 63.5 mm. The stability correction factor was 1.157 kg also known as the ring factor or the calibration factor.

Bulk Specific Gravity test ASTM D-2726: To find out the optimum binder content by Marshall Mix design the test carried out was the bulk specific gravity test was carried [29].

GMB= A/B-C

Whereas,

GMB = Bulk specific gravity (compacted sample)

A= Dry weight of the specimen (gram)

B= Surface saturated dry weight of the specimen (gm.)

C= Submerged weight of the specimen in water (gm.)

The voids in mineral combination (VMA) are defined as the voids among the mixture debris of a compacted mixture. VMA is calculated from the overall particular gravity of the mixture and is expressed as a percentage of the total compacted blended extent. VMA calculation formula:

VMA=100− (Gmb*Ps)/ Gsb where:

VMA = voids in mineral aggregate as a % of total volume

Gsb = volumetric specific gravity of aggregate

Gmb = volumetric specific gravity of compacted aggregate mix

Ps = aggregate, % of the total mass of the mixture

Voids Filled with Asphalt (VFA)

Asphalt-filled voids (VFA) of a compact road mix consisting of the corresponding portions of uncompacted asphalt-filled initial aggregate voids (VMA).

The VFA can be determined by the equation:

VFA=100(VMA−Pa)/VMA

Where:

VFA = voids in mineral aggregate, % of bulk volume

Pa = air voids in compacted mixture, % of total volume

C. Experimental Design Matrix for OBC & OPC

TABLE IV. Design Matrix

OBC	
MARSHAL	
Binder Content	***No. Of Samples***
3%	3
3.50%	3
4%	3
4.50%	3
5%	3
5.50%	3
6%	3

OPC					
MARSHAL					
No. Of Samples					
OBC	**3%**	**9%**	**12%**	**15%**	**18%**
LDPE	3	3	3	3	3
HDPE	3	3	3	3	3
CR	3	3	3	3	3
Total	9	9	9	9	9
Grand Total	45				

III. TEST RESULTS & DISCUSSION

A. Aggregate Properties

Crushed aggregate obtained from the Sargodha quarry was used in this study. Gradation was selected according to the requirement of the NHA specification for the wearing course 1998. NHA-An aggregate gradations is adopted to compare the effects of gradation on the mix performance. The properties of Sargodha aggregates are given in table.

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, SC, dc, and rams do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

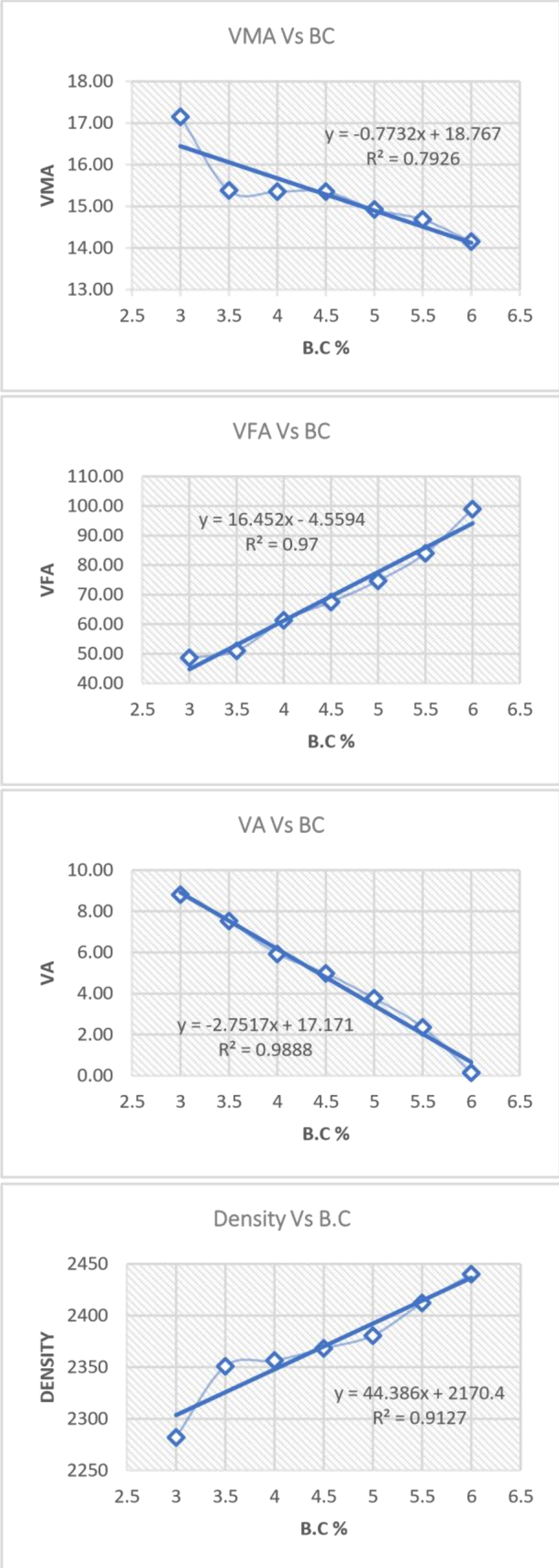


Figure 2 Volumetric properties of Conventional Asphalt

TABLE V. Aggregate Properties

Test Conducted	Test Standard	Result	Specifications
Bulk Specific Gravity Of Course Aggregates	AASHTO T 85-91	2.44	2.5 - 3

Water Absorption Of Course Aggregates	AASHTO T 85-91	1.74%	0.1 – 2 %
Elongation and Flakiness Index of Aggregate	ASTM D 4791- 99	35.50%	<30%
Angularity Number of aggregates	IS: 2386 (Part I) – 1963	8.10%	0 - 11
Loss Angele Abrasion Test Method C	AASHTO T 96-92	15.14%	<30%
Aggregate Impact Value Test (30% Max)	BS 812	10.50%	<30%

B. Bitumen Properties

Asphalt cement with penetration grade 70/80 was used in this work, which was sourced from the Attock oil refinery. Routine tests were performed according to AASHTO and ASTM to determine the physical properties of bitumen. The results are shown in Table 6. All results are within certain limits.

TABLE VI. Bitumen Properties

Test Type	Test Standard	Test Results	Standards
Penetration Test	AASHTO T49-93, ASTM D5	72.43	60-70
Softening Test	AASHTO T53-93, ASTM 36-89	45	46-56
Flash & Fire Point Test	AASHTO T48	262 & 278 °C	≥ 232 °C
Ductility test	ASTM D 113-87	99	100

TABLE VII. Plastic Bottles

Element	Weight%	Atomic%
C K	60.17	67.64
O K	37.58	31.72
Al K	0.55	0.27
Cu L	1.71	0.36
Totals	100	

TABLE VIII. Plastic Bags

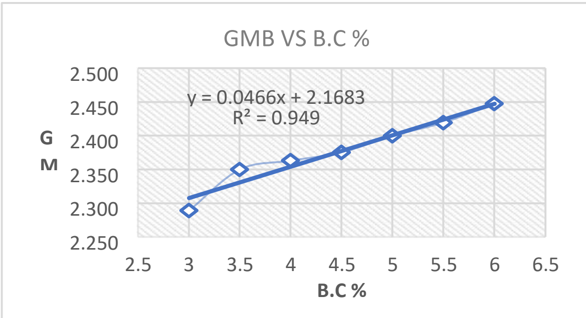
Element	Weight%	Atomic%
C K	97.28	97.94
O K	2.72	2.06
Totals	100	

TABLE IX. Crumb Rubber [30]

Element	Weight%	Atomic%
C	87.2	97.94
O	3.5	1.3
Mg	0.1	0.1
Al	1.2	2.5
Si	1.4	2.2
S	3.5	1.7
Ca	0.1	0.2
Zn	3	3
	100	

D. Volumetric Properties of Conventional Asphalt

The Marshall mix design was used for all mixes. The volume properties of air voids (VP), mineral aggregate voids



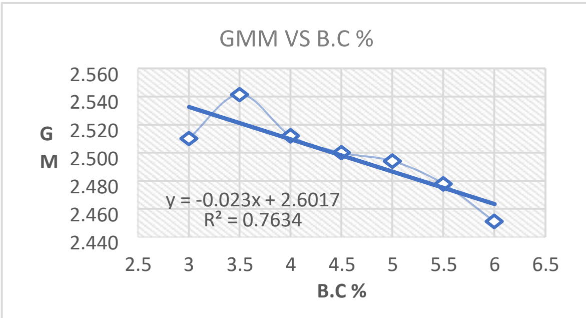


Figure 3 Gmb, Gmm of Conventional Asphalt

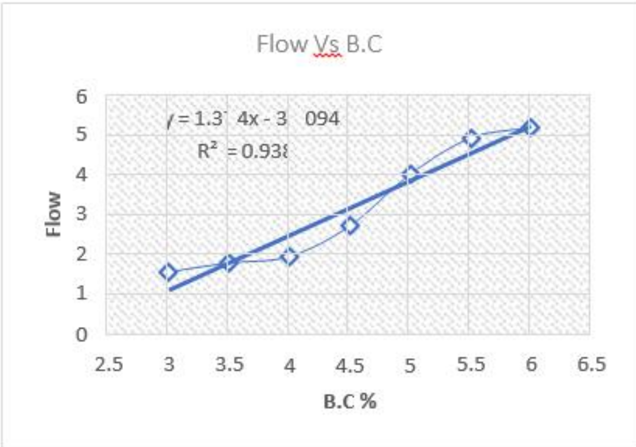


Figure 4 Flow of Conventional Asphalt

(VMA) and asphalt-filled voids (VFA) were evaluated for all modified and conventional mixtures. Fig. 2 shows the conventional asphalt has continuous increase in density, maximum density of 2440.19 kg/m3 achieved when air voids are 0.14%

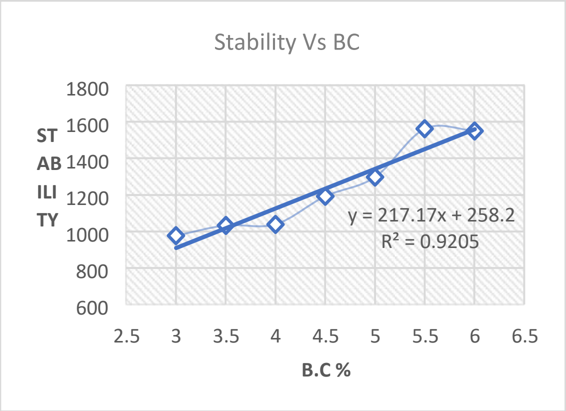


Figure 5 Stability of Conventional Asphalt

E. Specific Gravity Properties of Conventional Asphalt

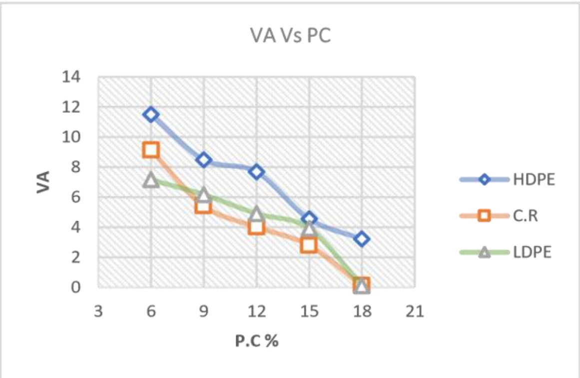


Figure 6 Comparison of Air Voids

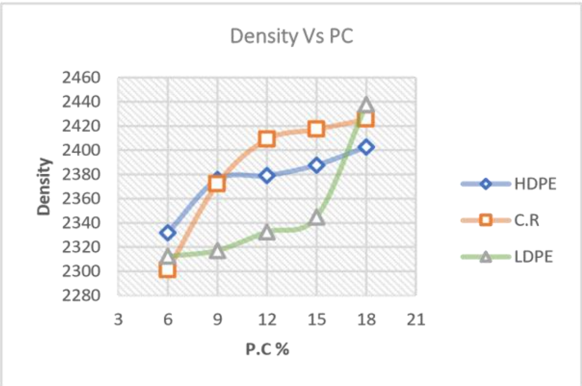


Figure 7 Comparison of Density

Fig. 3 shows the Bulk specific gravity & maximum specific gravity of unmodified mixture. Maximum Gmb (Bulk Specific gravity) of conventional asphalt is 2.41 & Maximum Specific gravity of conventional asphalt is 2.54.

F. Flow Properties of Conventional Asphalt

It is seen from Fig. 4, that flow was increasing with increasing of binder content. Maximum Flow is 5.2 mm for the conventional mixture. So, the deformation or flow value is reasonable in conventional asphalt.

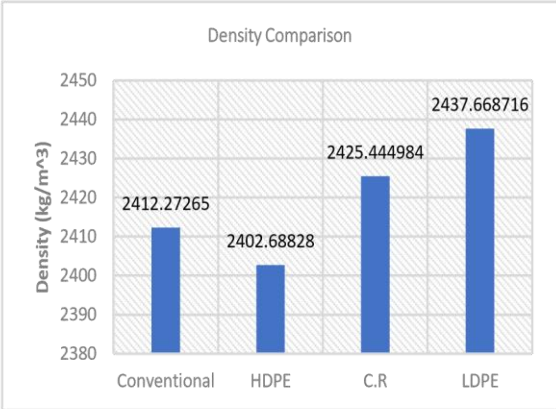


Figure 8 Comparison between Density values

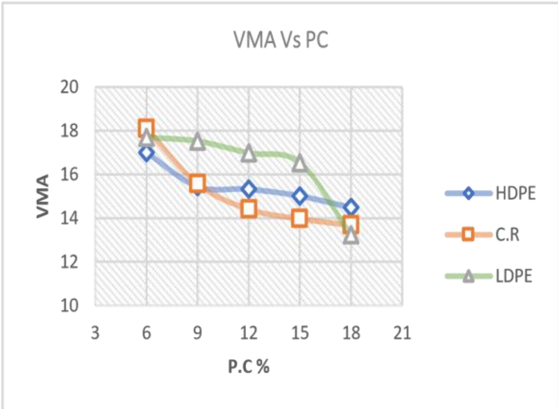


Figure 9 Comparison of Voids in Mineral

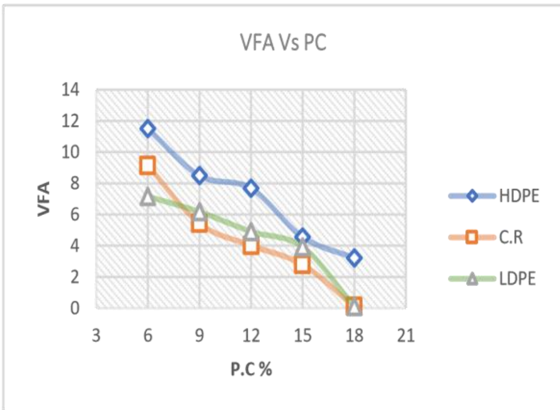


Figure 10 Comparison of Voids filled with Asphalt

I. Variation of Specific Gravities on the Properties of modified HMA.

maximum specific gravity of modified mixtures. with the

G. Stability Variation in Conventional Asphalt

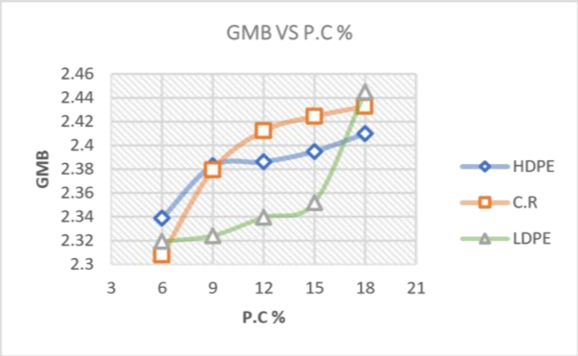


Figure 11 Comparison of Bulk Specific Gravity

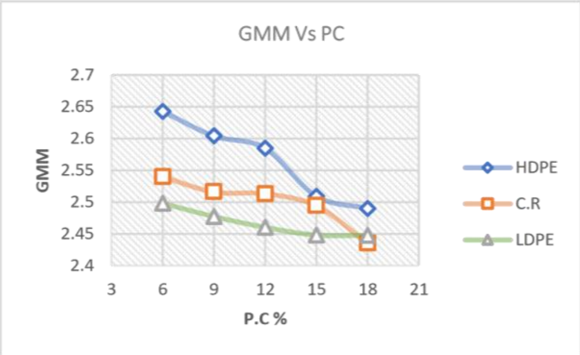


Figure 12 Comparison of Maximum Specific Gravity

J. Variation of Flow on the Properties of Modified HMA

It is seen from Figure 13 that flow increases with increase of polymer content. Maximum Flow. All flow values are higher than the conventional specimen. This could mean that the increase in the amount of polymer affects the internal friction of the mixture.

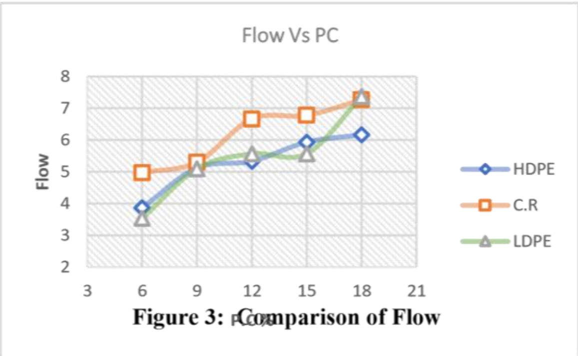


Figure 13 Comparison of Flow

To investigate the effect Marshall Stability for unmodified mixes, Marshall Stability is plotted against the binder content, as shown in figure 8. From these figure we can conclude that Marshall Stability of conventional mix increases on increasing binder content up to 5.5% after that is starts decreasing. Maximum stability of a conventional mix is 1561.57 kg/m^3. Mix design was used for all mixes. The volume properties of air voids (VP), mineral aggregate voids (VMA) and asphaltfilled voids (VFA) were evaluated for all modified and conventional mixtures. Fig. 5 shows the conventional asphalt has continuous increase in stability. increase of polymer, the bulk specific gravity of mixture varies but the maximum bulk specific gravity archived is 2.445 with LDPE. As much as specific gravity goes higher, the higher the strength goes. The high specific gravity increases the compressive strength of the aggregate.

H. Volumetric Properties of Modified Asphalt

Figures 6, 7, 9, and 10 shows the effect of asphalt modification on volumetric properties of mixture. The maximum density of modified mixture decreases with 0.38% (HDPE), 0.15% (C.R), 0.03% (LDPE) w.r.t conventional asphalt. Also, the increase in polymer content decreases the volume of voids the minimum air voids are 3.22% (HDPE), 0.11% (C.R), 0.11% (LDPE), which are 3.08% higher in case of HDPE which directly effects its density value. Figure 11 is a comparison of the maximum density values of modified asphalt and unmodified asphalt. Asphalt mixture with 14.80% (LDPE) addition gives the highest stability among all three polymers, this means that the stiffness of mixture increasing due to the plastic addition. Due to lower melting point, plastic will rapidly stick to the aggregate surface which will increase the adhesion of asphalt and aggregate. The percentage of aggregate voids filled with the plastic waste were also increased along with the percentage of plastic addition to the aggregate, resulting a reduced asphalt absorption of the aggregate.

K. Variation of Stability on the Properties of Modified HMA

The Marshall Stability test result shown in figures 14, 15 the addition of all three selected waste polymers increases the Marshall stability of the asphalt mixture. Asphalt mixture with 14.80% (LDPE) addition gives the highest stability among all three polymers, this means that the stiffness of mixture increasing due to the plastic addition. Due to lower melting point, plastic will rapidly stick to the aggregate surface which will increase the adhesion of asphalt and aggregate. The percentage of aggregate voids filled with the plastic waste were also increased along with the percentage of plastic addition to the aggregate, resulting a reduced asphalt absorption of the aggregate.

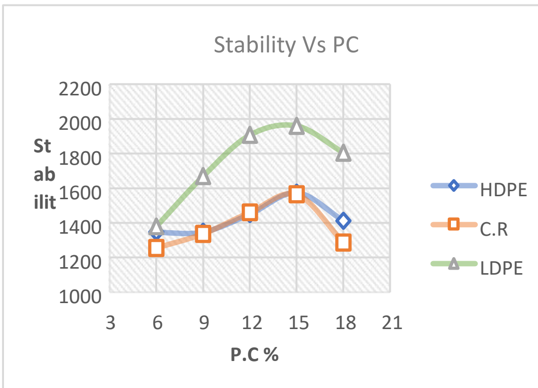


Figure 14 Comparison of Stability

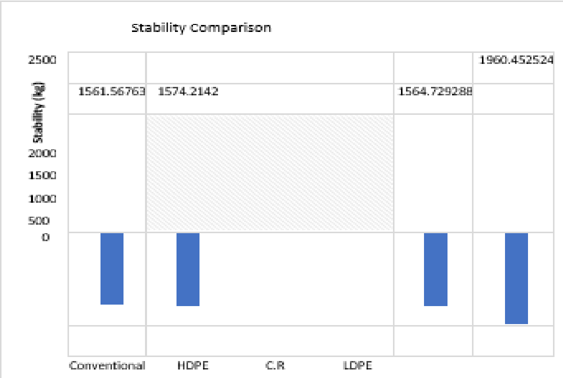


Figure 15 Comparison of Stability Values

IV. CONCLUSIONS

Based on the composition of the mixture and laboratory tests, the following conclusions were drawn:

The modified bitumen & aggregate gradations by the proposed method were acceptable based upon the Marshall mix design criteria. The addition of polymer significantly increased the mixtures stability. The increase in stability indicates that the LDPE-modified blend is much stronger than the control blend. This mix will highly be resistant to permanent deformation in asphalt concrete.

RECOMMENDATIONS

The main purpose of this study is illustrating the rule of polymers in improving the properties of road pavement and hoping to use waste material in the pavement of all new road's construction. We recommend for using waste polymers that will contribute to sustainability and enhance the environment.

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Investigation of Clay-Based Geo-polymers with Fly Ash and Sugarcane Bagasse Ash

Noor Yaseen
UET, Lahore.
Irrigation Department, Khyber Pakhtunkhwa
Peshawar, Pakistan
nooryaseen474@gmail.com

Muhammad Irfan ul Hassan
UET, Lahore.
Lahore, Pakistan
irfanulhassan@uet.edu.pk

***Abstract*— The construction industry produces tremendous amounts of CO2 emissions, be it from the burning of fired bricks or from cement manufacturing. On the other hand, the production of bricks is inevitable owing to the increasing demand for sustainable housing, especially in developing countries such as Pakistan. To cope with such challenges, the present research work was conducted with the aim to produce geopolymer bricks with easily available waste materials namely fly ash (FA) and sugarcane bagasse ash (BA) as precursors (collectively termed as binder) and silty clay (C) as fine aggregate. The research was carried in two phases: the laboratory phase wherein cylindrical specimens were manufactured followed by testing under compression, and the industrial phase wherein based on the optimized results obtained in the laboratory phase, full-size bricks were produced and tested. The bricks were developed by applying a mild forming pressure of 7 MPa and cured under ambient temperature, thereby making the production process of these bricks sustainable and less energy intensive. Mechanical and durability testing of the bricks demonstrated adequate results conforming to different national and international standard codes. Moreover, the scanning electron microscopy (SEM) of the newly developed bricks revealed the dense microstructure thereby increasing the overall performance of the brick structure.**

***Keywords*—** *clay-based geopolymer; brick, forming pressure, durability, sustainability*

I. INTRODUCTION

Traditional fired-clay bricks have been proved inevitable in the field and the production process of such bricks not only consumes excessive fertile land but also results to significant amount of CO_2 emission. By contrast, numerous researchers have proposed alternate manufacturing processes that neither require cement (as binder) nor burning, for attainment of the required mechanical and physical properties. One of such novel solutions is the so called technology, the geopolymerization—the word, geopolymer, was firstly introduced by Joseph Davidovits in 1978, which refers to an inorganic material synthesized at ambient temperature and atmospheric pressure (Davidovitz, 2008). In the literature, the most commonly used alkaline activators in geopolymerization are Sodium- and Potassium-based hydroxides and silicates.

A few research studies have been carried out on sugarcane bagasse ash (BA) as pozzolanic material both in unburnt and fired bricks (Faria et al. 2012; Lima et al. 2012; Madurwar et al. 2014), and as precursor material in geopolymer bricks and other construction products (Deepika et al. 2017; Kazmi et al., 2017; Saleem et al., 2017). Discussing the results so obtained on a broader and general scale, it is revealed that the increasing levels of replacement in high volume of BA with other materials reduced the strength the end product, whereas it increased water absorption owing to the light and porous nature of BA. However, it is pertinent to mention that the construction products with sugarcane bagasse ash has still fulfilled the criteria for the minimum strength as per various standards such as ASTM C1314-14.

As mentioned above, a considerable number of other articles have been published on the use of BA in the production of bricks (Bahurudeen and Santhanam, 2013; Quero et al., 2013; Cordeiro et al., 2009; Corderio et al., 2009b; Cordeiro et al., 2011; Nuntachai et al., 2009). This suggests a considerable potential of BA to be used as a precursor material in geopolymer-based bricks.

II. METHODOLOGY

Clay (C) of silty nature was used as fine aggregate in the preparation of geoploylemrs, Fly Ash (FA) and Sugarcane Bagasse Ash (BA) were used as binder herein the experimental program. The oxide composition of these materials is given in Table 1. The alkaline solution is a mixture of Na_2SiO_3 and a 10 Molar NaOH solution. The alkaline solution was prepared in a ratio of $Na_2SiO_3/NaOH = 1$ and was placed for 24 h prior to using in the manufacturing of bricks.

TABLE I. Chemical composition of clay and binders.

Chemical Composition (%)	Material		
	C	FA	BA
CaO	5.15	6.45	7.79
MgO	1.85	1.53	1.91
SiO2	76.7	51.67	75.15
SO3	2.65	2.15	0.65
AL2O3	4.79	16.54	7.26
Fe2O3	2.05	4.55	1.51
LOI	6.31	4.1	4.01
CI	0.091	0.009	0.01
Others	6.72	17.1	5.72

j. Manufacturing of specimens

- Manufacturing of cylindrical specimens: Laboratory phase

In total, 72 specimens were prepared by varying (1) C/B ratios of 70:30, 50:50 and 30:70 and (2) FA/BA ratios where FA was replaced by BA up to 50% by weight of binder in an interval of 10%.

Figure 1. Set up for casting the cylindrical specimens.

Figure 2. Ambient curing of the prepared specimens.

First, the dry manual mixing of C, FA, and BA was done for 3 to 5 minutes. Secondly, the alkaline activator was added at a fixed liquid solution (L) to binder (B) ratio of 0.55. The mixing procedure was conducted using the equipment shown in Fig. 1. The mold was filled with the obtained composite in four layers by giving 25 number of blows using the compacting bar. After demolding, the resulting specimen was of approximately 100 mm in height. All specimens were cured in ambient conditions as shown in Fig. 2. The samples were tested for compressive strength at 7 day of ambient curing.

- Manufacturing of full-size bricks: Industrial Phase

Owing to the results of the 7 day strength obtained for the cylindrical samples, the mix C50B50 was selected as the optimum one for manufacturing the full-size bricks with size of 225 x 113 x 75 mm . The L/B ratio was retained the same (L/B of 0.55); however, the only variable during the production was the replacement levels of FA by BA from 0 to 100% in an interval of 25% .

- The silty clay and binder were mixed for 3 to 5 minutes tracked by addition of activator and further mixed for 6 to 8 minutes. The mix was then poured in to the mold and the brick was pressed using a compression machine with a forming pressure of 7 MPa. For a certain mix proportion, many specimens were raped in plastic bags, whereas some bricks were kept in open air as shown in Fig. 3. The bricks so produced were then shifted to the laboratory (see Fig. 4) where they were tested for assessing their mechanical and durability performance .

Figure 3. Prepared brick specimens.

Figure 4. Transporting the bricks from industry to the laboratory.

III. RESULTS AND DISCUSSION

A. Laboratory phase

Compressive strength of cylindrical specimens Fig. 5 shows the compressive strength of the cylindrical samples at 7 day after casting. All the specimens were tested The reason for testing such sample after 7 days is ascribed to the fact that in contrast to the ordinary cement, the geopolymerization reaction is a fast chemical reaction

(Hardjito et al., 2004) and a substantial development of the strength can be perceived just after 7 day of curing (Messina et al., 2017). As an example, Islam et al., 2014 found that the strength of geopolymer at 7 day after casting was 90% that of 28 day strength . From Fig. 5, it is obvious that C50B50 displayed the maximum values of compressive strength, predominantly in cases when FA was largely replaced by BA . This accomplishes that comparable proportion of clay and binder are appropriate for producing the geopolymer bricks with silty clay and different proportions of the waste materials being investigated in the current study .

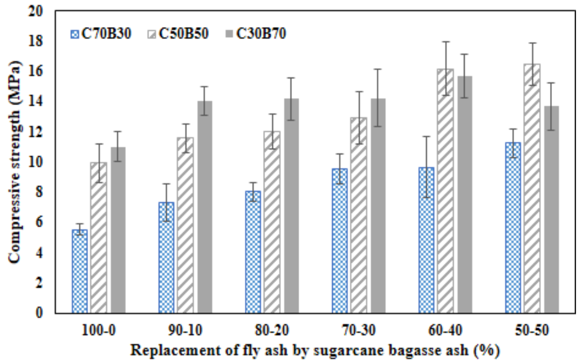

Figure 5. 7 day ambient curing compressive strength of cylindrical specimens.

k. Industrial phase

In view of the results after laboratory investigation, the C50B50 mix (equal proportion of clay and binder) was chosen as the optimum mix for the full-size bricks production .

l. Compressive Strength

The compression test of the brick specimens was performed at 7, 14, 28, and 56 days in order to see the evolution of the compressive strength of the geopolymers so produced, the results of which are shown in Fig. 6–7.

Overall, the air-dried (openly placed) bricks have revealed larger values of compressive strength in comparison with the plastic-sealed bricks . This can be due to the water evaporation in the earlier case, leaving behind discontinuous nano-pores in the geopolymer matrix thus enhancing the performance of the geopolymer (Hardjito and Rangan, 2005). The lower strength achieved in the latter case is also attributable to the lubrication effect as a result of increased moisture content, which provides less resistance against the load applied by the machine.

The effect of increasing the BA content is obvious from Fig. 6-7; in that the compressive strength started increasing up to a maximum value for FA30BA70 followed by a drop for FA0BA100. It is worth mentioning that such rise in the strength as a result of consuming a large amount of BA (up to 70%) is in line with the abundance of BA across the world and especially in Pakistan. The enhanced performance of the FA30BA70 mix is ascribed to the fact that the micro-filling effect of FA in the matrix with large amount of BA to a considerable degree resulting in a compact microstructure. Based on the chemical aspects, BA exhibits high Si/Al ratio with large amount of SiO_2 (75.15% in the present study as can be seen in Table 1), thereby increasing the number of –Si–O–Si– bonds being stronger than –Si–O–Al– and –Al–O–Al– bonds, the latter two otherwise have to be provided by a mix containing larger content of FA . The minimum compressive strength was acquired by FA0BA100 owing to the porous structure of those bricks as a result of larger contents of BA thereof.

Fig. 6-7 also represent the strength development of bricks, whereby the compressive strength gain was higher for the air-dried specimens in comparison with the plastic-sealed specimens, which is more pronounced at the later ages. This is because unlike hydration, the geo polymerization process does not need water, especially at the later ages for strength gain.

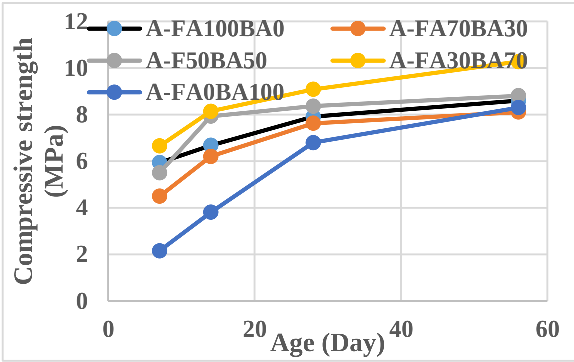

Figure 6. Evolution of compressive strength of the air-dried bricks.

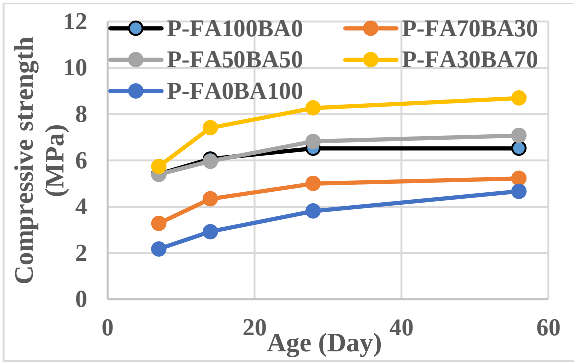

Figure 7. Evolution of compressive strength of the plastic-sealed bricks.

D. Flexure strength

The flexural strength test was performed only for the plastic-sealed specimens due to less availability of the air-dried specimens . The trend for flexural strength with respect to replacement of FA with BA was more or less similar to that of compressive strength (see Fig. 8).

The evolution of the flexural strength of the tested specimens is plotted in Fig. 8., whereby it can be revealed that flexural strength gain was substantially higher in relatively to that of compressive strength of Fig. 7. More specifically, the FA30BA70 mix remarkably demonstrated a linear increase in flexural strength gain. Though the evolution of flexural strength for the traditional bricks is nearly similar to that of their compressive strength, the behavior in case of the present study was different than those reported elsewhere in the literature. This opposing behavior gives rise to an open discussion so as to dig out the reasons behind such trend with a deeper insight.

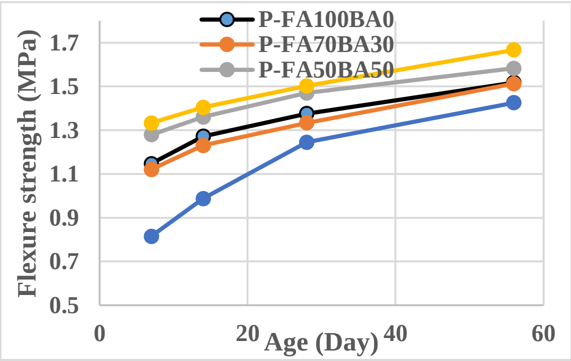

Figure 8. Evolution of flexure strength of the plastic-sealed bricks.

E. Sulfate Resistance

To analyze the effect of sulfate salts, the bricks were placed in a Na_2SO_4 solution after 30 days of casting followed by testing under crushing at 56 day. Fig. 10 shows the effect of sulfate salt on the compressive strength of the bricks demonstrating that the FA30BA70 mix experienced less reduction in compressive strength in comparison to other mixes.

The salts penetrate into the internal micro pores and channels of the brick, resulting in micro cracking as a result of their crystallization (Delali, 2014). With the passage of time, such cracks keep on widening in size and increasing in number that ultimately reduce the strength of the bricks . It is noteworthy that all mixes excluding FA30BA70 resulted in crushing strength fewer than 5 MPa, the least threshold set by Pakistan Building Code.

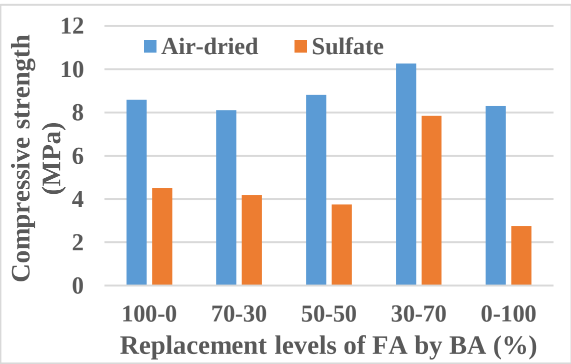

Figure 10. Influence of sulfate salt on the crushing strength of the bricks after 56 days.

F. SEM analysis

The microstructure of the crushed bricks was examined through scanning electron microscopy for which the SEM images are given in Fig. 11-15. The geo polymerization products such as zeolites are not appropriately noticeable in the images. However, the SEM image of FA30BA70 (see Fig. 14) is reasonably different than those of other mixes regarding the precipitation of closely packed needle-like structures. Despite the presence of the same needle-like structures in the case of FA0BA100 (see Fig. 15), the number of such structures is not abundantly available to contribute to increase its compressive strength.

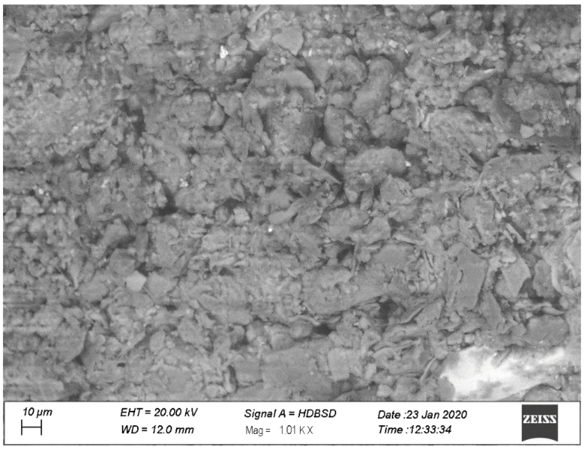

Figure 11. SEM image of P-FA100BA0.

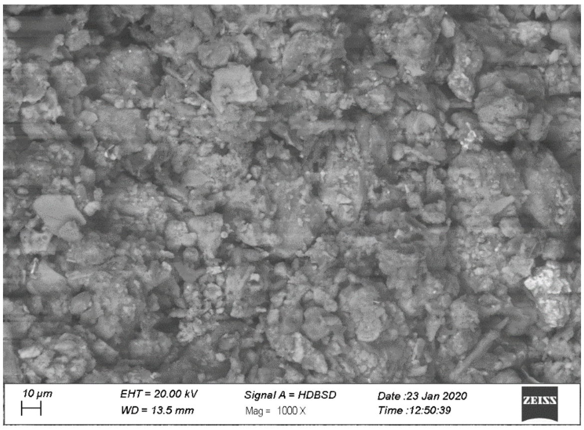

Figure 12. SEM image of P-FA70BA30.

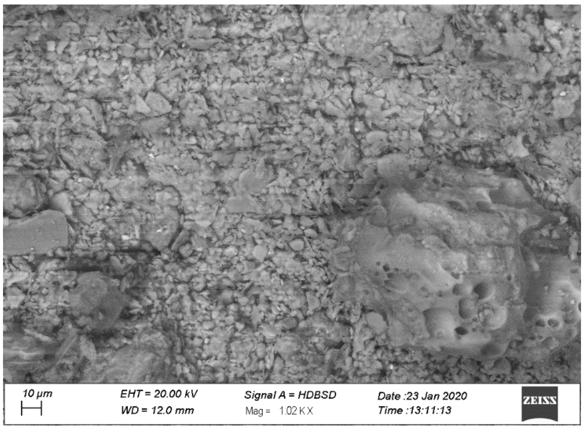

Figure 13. SEM image of P-FA50BA50.

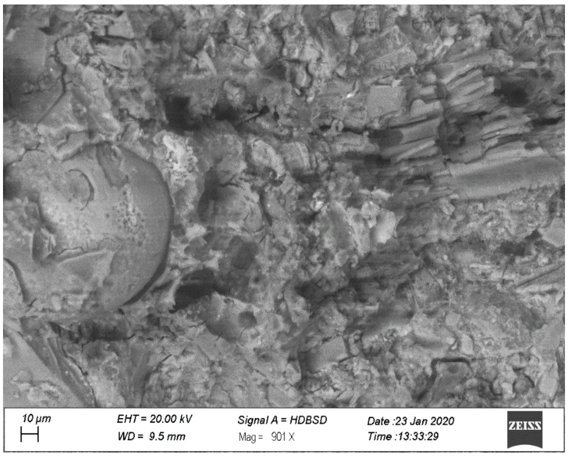

Figure 14. SEM image of P-FA30BA70.

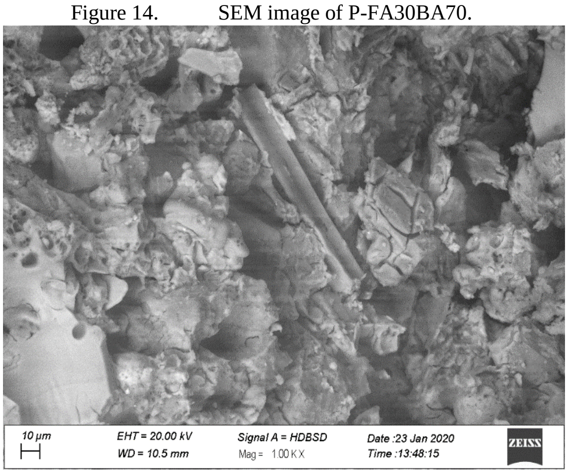

Figure 15. SEM image of P-FA0BA100.

IV. CONCLUSION

All the brick specimens that were air-dried yielded higher compressive strength values than the ones that were plastic-sealed. The reason of decreased compressive strength in plastic-sealed bricks is explained by the presence of entrapped moisture content, resulting in higher lubrication effect.

On the basis of the mechanical properties, the bricks with 30% fly ash and 70% sugarcane bagasse ash are considered optimum. Such large consumption of the bagasse ash is in lines with its large availability in Pakistan .

The flexure strength gain of the newly developed bricks was observed far higher as compared with their compressive strength, a trend quite opposite to the trend commonly found in the traditional bricks .

The newly developed bricks were lighter (the average density of the optimum mix FA30BA70 reported herein is 1670 kg/m^3) as compared to the traditional clay bricks even obtained with the least possible forming pressure of 7 MPa.

This reduction in the weight of individual brick aids in decreasing the whole mass of the structure .

With reference to efflorescence viewpoint, the bricks with 100% BA revealed the minimum amount of efflorescence. The optimum mix FA30BA70 endured the greatest resistance against the Sulphate salt attack.

V. ACKNOWLEDGMENT

The support provided by Mr. Zahid Ullah during the experimental stage of the present study is greatly acknowledged.

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Sustainable Construction by Using Steel Chips as a Partial Replacement of Cement

Asad ur Rahman
Department of Civil Engineering
University of Engineering and Technology
Taxila, Pakistan
18-ce-154@students.uettaxila.edu.pk

Qammar Hayat
Department of Civil Engineering
University of Engineering and Technology
Taxila, Pakistan
18-ce-78@students.uettaxila.edu.pk

Syed Saqib Mehboob
Assistant Professor, Department of Civil Engineering University of Engineering and Technology
Taxila, Pakistan
syed.saqib@uettaxila.edu.pk

Qaiser Uz Zaman Khan
Chairman, Department of Civil Engineering
University of Engineering and Technology
Taxila, Pakistan
dr.qaiser@uettaxila.edu.pk

***Abstract*— Cement industry is very energy consumptive and produces CO2 and also generates greenhouse gases which are the major cause of global warming. The production of cement and the use of concrete are both rising daily. So to protect environment, alternate materials are required. Construction industry have several constructional byproducts and wastes as a variant of traditionally used products. In the process of production and working with steel, steel chips are formed as a waste material. The best way to reduce environmental pollution and improve waste recycling is to partially replace concrete with steel chips. Due to these factors and the abundance of material, steel chips were used as a partial cement replacement at 0.5%, 1%, 1.5%, and 2% by the volume of cement. The properties such as compressive strength, split tensile strength, flexural beam strength, and modulus of elasticity are checked after 7, 14 and 28 days. Comparing these qualities to those of control molds showed that by raising the percentage of steel chips in the concrete up to 1.5%, mechanical characteristics are improved; however, when percentage is increased to 2%, mechanical properties are also affected.**

Keywords— *steel waste, cement pollution, recycling waste, mechanical properties.*

I. INTRODUCTION

The amount of garbage created has expanded due to global development, rapid economic development, and industrial growth, and this volume is often not managed properly. Furthermore, most garbage contains highly hazardous chemicals that are incredibly detrimental to the environment and humans. Traditionally, industries have handled trash by simply releasing waste into the atmosphere without treatment. This exercise significantly increased pollutants and harmed the environment [1]. Around 4 billion tons of Ordinary Portland Cement (OPC) are produced yearly, with output increasing at a 9% annual pace [2]. The emissions

from 1 ton of OPC production are almost 1 kg SO_2, 2 kg NO_x, and 10 kg dust [3]. The cement industry annually emits around 1.5 billion tons of greenhouse emissions worldwide. It accounts for 7-8% of total greenhouse gas emissions [4]. Twenty years ago, the manufacture of OPC had a very high carbon intensity; each ton of OPC generated about 810 kg of CO_2 emissions [5]. Manufacturing cement has a high environmental impact and takes a lot of energy and raw materials. Numerous strategies have been proposed to reduce greenhouse gas emissions, save energy, and reduce the amount of raw materials used in producing OPC. Manufacturing steel scrap cement, and concrete are one of the most incredible possibilities [6]. Metal chips are tiny particles of various metals that are the remnants or waste following machine or similar material removal techniques. They are also known as chips, turnings, filings, or shavings [7]. There are only a few methods for recycling steel chips, including melting and disposal in landfills. The process of melting steel in furnaces is inefficient, polluting, and extremely expensive [6]. Construction materials harm Earth's ecosystems because 50% of all materials used for construction are extracted from Earth [7]. The cement industry is the third largest energy consumer in the whole world, consisting of 7% of all industrial energy use [8]. Since industrial lathes produce a lot of steel waste (3–4 kg per lathe per day), there will be better environmental management of lathe steel waste [7]. Recycling offers a way to reduce that trash and put it to good use.

Study shows, the impact of steel chips on the compressive strength of concrete, which noticeably increases when used as a 25% substitute for the number of coarse particles in any concrete mix. Results show that replacing 5% of the coarse aggregates with steel chips will increase 8% [2]. Additionally, lathe waste concrete beams demonstrate less deformation and fracture propagation than standard beams [8]. The results of the fiber-reinforced concrete show that the porosity of these mixtures increased compared to the base mixture and that the fiber addition did not affect the initial or final setting times [9, 10]. Concrete that has been reinforced with lathe trash performs better than standard concrete [11]. The ability of crack control in the elastic zone is responsible mainly for the increased cracking load of high-strength concrete beams when PET fiber is added to the concrete [3]. The compressive strength rises when lathe waste is added to regular concrete at percentages of 3%, 6%, and 9% by weight of fine aggregate [12]. Additionally, steel fiber increases concrete strength linearly as the proportion of steel fiber is raised, as well as compressive strength, flexural strength, and split tensile strength [13]. Abbas Hadi from the test showed that [7] the mechanical properties of concrete, including compressive strength, split-tensile strength, bending strength, and modulus of elasticity increases by 10.2%, bending strength by 45%, split tensile strength by 30%, and modulus of elasticity increases by 250% [14, 15]. In other instances, the densities rise when the amount of fibers increases. The density rises from 1395.20 kg/m3 for 0% to 1425.57 kg/m3 at 3% fiber content and 28 days [16].

The purpose of the research was to make a contribution in the field of construction industry utilizing the various industrial wastes to protect the environment and obtain more durable concrete. Usage of steel chips in concrete is one of best way to counter the issues, as we can deal with both issues at the same time. According to the literature, steel chips showed outstanding results when used to substitute coarse and fine aggregate in concrete. In this study, we replaced 0.5, 1, 1.5, and 2% of cement with steel chips. The main purpose of this study is:

- Improving the mechanical properties
- Minimizing the usage of cement
- Recycling the waste from steel industry

II. METHODOLOGY

A. *Mix Design*

To determine the impact of steel chips on the properties of concrete, steel chips are employed as a partial replacement for cement in a plain concrete mix of (1:1.5:3) weight given in Table 1, 3000 psi cylindrical strength. Using a standard mixer and a water-to-cement ratio of 0.50, concrete samples were made by ASTM C192M. Table 3 lists the concrete mix proportions. We did not add any admixtures to avoid any potential interference between the steel chips and the admixtures. Concrete is made with steel chips, which substitute cement in weight-based ratios of 0.5, 1.0, 1.5, and 2.0 %.

TABLE I. Mix-Proportion of Concrete

Type	Component	Mix Design (1:1.5:3 ratio)	
	3 Cubes, 3 Cylinders, 1 Beam	Weight (kg)	Properties
Control	Cement	16.36	Normal setting time 30 min
	Water	8.18	Normal tap water
	Fine agg:	24.5	Finess modules: 2.6
	Course agg:	49.09	Finess modules: 3.1
	w/c ratio	0.5	In Consideration of workability
Steel chips	0.5%	0.118	-
	1%	0.236	-
	1.5%	0.354	-
	2%	0.472	-

B. *Casting of Samples*

After the concrete was well mixed, it was cast into various molds (cubes, cylinders, and prisms), with multiple samples being formed for different mix proportions. The number of cast samples is provided in the table; they were demolded and immersed entirely in clean water for curing after almost 24 hours. The concrete specimens were then allowed to cure for 7, 14, and 28 days. Before testing, samples were removed and allowed to dry outside for a day. According to ASTM standards, a total of 27 cubes, 20 cylinders, and 4 beams were cast to test the mechanical properties of concrete at 7, 14, and 28 days.

C. *Curing of Samples*

During curing, the cylinders, cubes and beams are stored at a normal temperature and in an environment that prevents moisture loss for up to 28 Days. Different samples were taken out at 7 days, 14 days and then at 28 days for testing. Curing was done according to ASTM C31.

III. EXPERIMENTAL WORK

The various properties of concrete were investigated in connection to scrap steel chips. The results showed that it outperformed regular concrete regarding workability and compressive strength. Samples were examined after 7, 14, and 28 days. The figure of material and during testing are shown in Figure 1.

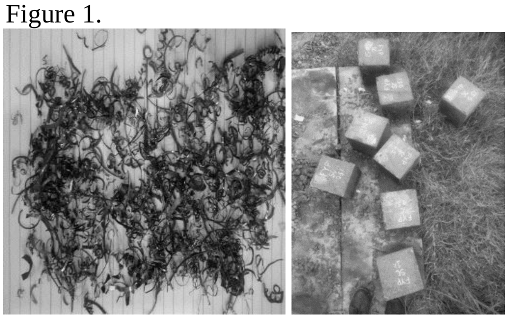

Figure 1. Material and Testing

D. Experimental Results

The control 28 days' cylindrical compressive strength is 20.89 MPa, while by adding 0.5% of steel chips it hiked to 23.53 MPa. Also, for 1% it became 28.89 MPa, and 37.20 MPa, 20.79 MPa for 1.5% and 2% respectively. It can be observed that at 1.5% the strength is max and is about 78% increase in strength. All other tests showed similar results and on average 40-50% increase was noted at 1.5% replacement.

TABLE II. Compression Testing Results for 28 Days (MPa)

Compressive Strength (MPa)						
Steel Chips Ratio %		Control	0.50%	1%	1.50%	2.00 %
Cylinders		20.89	23.53	25.34	30.33	22.59
Cubes	1	15.49	26.22	28.89	37.20	20.79
	2		24.19	30.00	36.25	20.19
	Average	15.49	25.20	29.45	36.72	20.49

Concrete's strength characteristics are improved by the bridging action of discontinuous fibers [17]. As a result, the addition of steel fiber enhances the compressive strength, split tensile strength, flexural beam strength from 0–1.5% replacement. The main strength material in concrete is cement, so by removing more than 1.5% cement affects the strength adversely. We can see in the Table 2, the strength decreases at 2% replacement. Bridging action increases the strength up to 1.5% replacement of steel chips, as it is shown in figure 2.

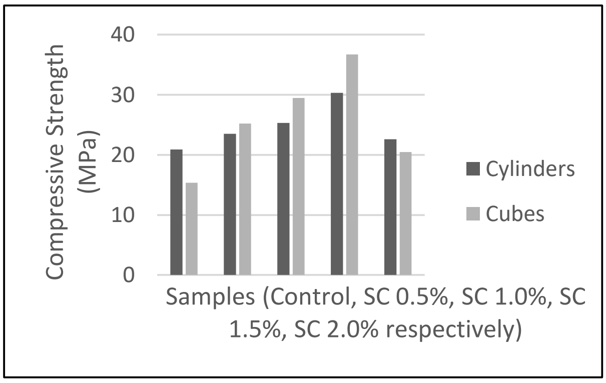

Figure 2. Graph Comparing Compressive Strength with Different Steel Chips Ratio (28 Days)

IV. CONCLUSION

Cement utilization is rising steadily due to the booming building industry. The cement industry is a significant source of pollution and a drain on the environment. Steel industry waste, on the other hand, contributes to landfills. Environmental pollution is a problem in both businesses. These issues may be alleviated by using steel chips to replace cement in specific applications. In addition, the material has superior mechanical characteristics. The best way to ensure concrete maintains its mechanical attributes while preserving the environment is to include steel chips in the mix.

According to our result, the strength of concrete shows rises when steel chips are added. A 10-15% rise is noted at 0.5% SC, 20-25% at 1% SC, and 40-50% at 1.5% SC. Also, the rise in strength for cubes was even higher than this. For every cubic meter of concrete, usage of cement can be decreased by 1.5% or almost 5-6kg. On the other hand, 5-6kg of steel waste will be recycled. The price difference of materials between control specimen and 1.5% replacement is about 220PKR or 1USD per cubic meter. It is recommended to use steel chips as a partial replacement of cement over all other replacements due to their vast availability, high strength. Using this technique on a commercial scale will help both financially and will also be a step toward sustainable construction and a clean environment.

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TECHNICAL SESSION V

VENUE; AUDITORIUM HALL

University of Central Punjab
20 March – 21 March 2023

CHAIR PERSON

DR WAJAHAT MIRZA

CO-CHAIR PERSON

KHUWAJA BILAL AHMED

NEW TRENDS IN CIVIL ENGINEERING

Effect of Addition of Waste Engine Oil and Waste Cooking Oil on Engineering Properties of a Bitumen

Yasir Rafique
Civil Engineering Department,
University of Engineering and Technology, Taxila
Taxila 47050, Pakistan
yasir.rafique272@gmail.com

Dr. Jawad Hussain
Civil Engineering Department,
University of Engineering and Technology, Taxila
Taxila 47050, Pakistan
jawad.hussain@uettaxila.edu.pk

Engr. Waqas Haroon
Civil Engineering Department,
University of Engineering and Technology, Taxila
Taxila 47050, Pakistan
waqas.haroon@iiu.edu.pk

***Abstract*—Waste engine oil (WEO) and waste cooking oil (WCO) have been produced in bulk amounts in current years due to the improvement in the standards of humans and advancements in automobiles. This study focuses on the effect of adding waste engine oil (WEO) and cooking oil (WCO) into the base bitumen. Six blends were prepared using varying three percentages of 7%, 10%, and 13% weight of bitumen of WEO and 3%, 6%, and 9% weight of WCO, respectively. The blends were tested for conventional and thermal susceptibility properties. It was observed that adding WEO and WCO decreased the softening point while increasing the penetration values compared to base bitumen. The WCO improved the flexibility properties while WEO reduced the ductility. The tensile properties and the thermal susceptibility of the WCO-modified bitumen were better compared to WEO modification. The optimum dosage of WCO-3% and WEO-7% was concluded based on the conventional engineering properties of the modified bitumen.**

***Keywords* —** *Waste Engine Oil, Waste Cooking Oil, Penetration, Softening, Ductility, Thermal Susceptibility*

I. INTRODUCTION

With the advancement in the living standard of people around the globe, especially in developed countries like China and Australia, the number of domestic and commercial waste has increased remarkably [1–3]. These wastes are collected from waste cooking oil (WCO) and engine oil (WEO) from the vehicles. China produces almost 7.5 million tons of WCO annually, and 30 million tons of WEO are produced from vehicle maintenance [1].

WCO is typically obtained from various feed sources, e.g., plant vegetable oils and animal fats, and both are used in food and manufacturing sectors. WCO is formed after frying and heating with various diversified sources of edible vegetable and animal oils [4,5]. WCO is generally used in producing soap, paints, and other chemical products, while WEO is customarily discarded or reused in producing new oil [2]. Only 20-30% of WCO is estimated to be recycled or reused from the entire usage [6]. WCO can potentially harm human and environmental health; it is recommended that WCO would be processed and managed appropriately before being disposed of by users in garbage cans, sewers, storm drains, or other similar locations [7,8]. The absence of proper disposal techniques for WCO creates severe environmental concerns because almost 1 ton of WCO can pollute 1 million tons of drinking water [2]. As per a USA study [9], approximately 40% of blockage in the sewerage system results from draining WCO in the kitchen sink, increasing the water treatment costs by up to 25%.

The transportation section relies on the consumption of large quantities of engine oil. The engine oil's properties deteriorated over time or specific usage, and then it was discarded. WEO is discarded oil obtained from the vehicles' engines [10]. The reason for the massive amount of WEO is that millions worldwide use vehicles for routine and commercial matters, producing millions of tons of waste lubricating oils [11]. A substantial quantity of heavy metals in WEO has been carelessly dumped, endangering the water and soil, harming the environment, and damaging human health [12,13]. These oils create severe environmental concerns; it is essential to recollect or recycle them. The Alberta Used Oil Management Association (AUOMA), Canada, recycles WEO as an energy source, like kiln fuels used by asphalt producers [14]. A large quantity of engine oil is typically burned and used as energy or, after refining, is used as engine oil [11]. Modification of the asphalt by different kinds of oils has also been reported, e.g., Mineral-lubricant-based oil, tall oil pitch, and high viscosity oil have improved the low-temperature properties of base bitumen.

The chemical composition of WEO and WCO is similar to that of bitumen because both are byproducts of crude oil [1,10,15]. Recently, the incorporation of waste oils in an asphalt mixture has been given attention to improve the performance of traditional asphalt and reduce environmental and ecological impacts [16]. Thus, it is necessary to study the recycling of waste oils, especially WEO and WCO. Various studies have focused on the blending mechanism of WEO into bitumen [17], and it has been indicated that the WEO could be used by modifying the bitumen [18]. Indeed, using WEO as a bitumen modifier raises its economic value [19].

Pakistan is a developing country, and the country's population increases each year [20]. But this increment has also increased the number of waste produced daily, with almost millions of tons of waste cooking oil (WCO) and waste engine oil (WEO) vehicles produced yearly [21,22]. Both of these wastes create severe environmental problems along with pollution from drinking water and soil pollution. Therefore, it is required to develop waste oil recycled asphalt technology for the sustainable construction of pavements. The main aim of this research is to use or recycle waste engine oil (WEO) and waste cooking oil (WCO) by incorporating them into base bitumen and then determine the effect of these two oils on the performance of asphalt. The other aim is to include a cost-effective modifier in bitumen that may achieve the desired functioning of asphalt. For this purpose, the engineering properties of the modified bitumen were determined by penetrometer, ring, ball apparatus, and Ductilometer, and then the temperature susceptibility of the modified bitumen was evaluated. The roadmap of the study is illustrated in Figure 1.

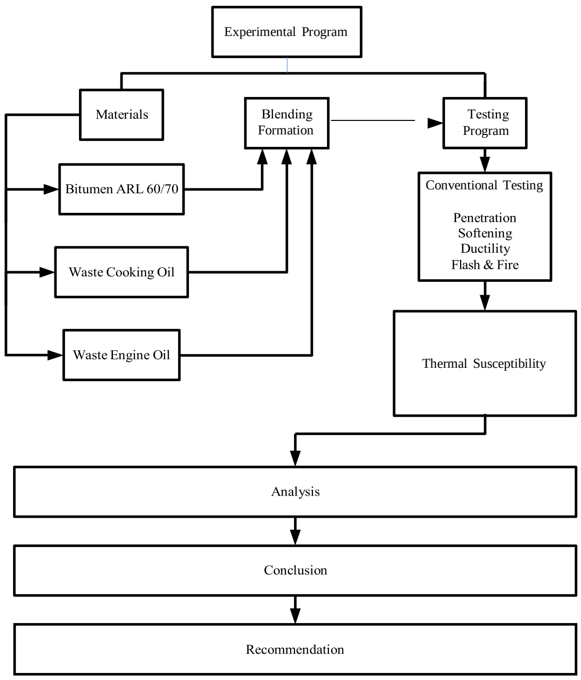

Figure 1. Roadmap of study

II. MATERIALS

a Bitumen

The penetration grade 60/70 bitumen procured from Attock Refinery Limited (ARL), Rawalpindi, Pakistan, was used in this research. This bitumen has extensively been used on major highways and motorways, which carry approximately 75% of Pakistan's road freight.

b Waste Engine Oil

Three different percentages of WEO (7%, 10%, and 13%) based on the previous study were selected, which will include determining the effect of varying levels of WEO in the mixes [11,23]. Waste engine oil used in this study was collected from local auto repair shops in the National market of Chandni-chowk Rawalpindi, Punjab, Pakistan, as illustrated in Figure 2.

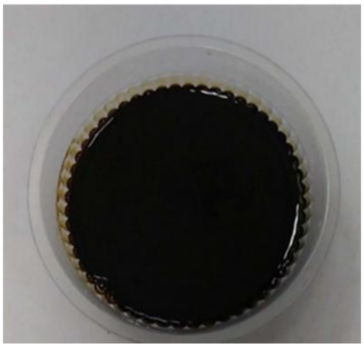

Figure 2. Waste Engine Oil

c Waste Cooking Oil

WCO is "waste cooking oil," a byproduct of several different cooking processes. Its lightweight components are used to revitalize aging asphalt binders since they are similar to the original asphalt binder. [5,24,25]. WCO was tested at 3%, 6%, and 9% in various blends throughout this investigation. The rejuvenator chosen was WCO, obtained from a nearby eatery, as illustrated in Figure 3. Many fried pieces were collected in the oil samples and sorted using a standard physical method. A fine screener filters out larger, unwelcome particles from the oil. After filtration, the oil was so clean and clear that it was used in experiments. The chemical characteristics of waste cooking oil (WCO) are crucial in regulating asphalt behavior. The superiority of a WCO is based on the FFA content of its constituents. In the course of frying, Free Fatty Acid (FFA) is created by the hydrolysis process as the oil is continuously heated to high temperatures with moisture and air content present, resulting in various degradation processes.

Figure 3. Waste Cooking Oil

III. METHODOLOGY

A. Sample Preparation

Untreated bitumen weighing 300g was first heated in an oven at 100 °C, melting it into a fluid state. Physical tests were conducted on base ARL bitumen 60/70 to verify its qualitative properties. Later, dosages of waste cooking oil (3%, 6%, and 9% by weight of bitumen) were blended with bitumen, and three samples were prepared. The blended process was formulated with the help of a homogenizer, as illustrated in Figure 4. The modified samples were heated for 30 minutes at a temperature of 160 °C up to 2000 rpm, as shown in Figure 4. Similarly, waste engine oil (7%, 10%, and 13% by weight of bitumen) was added to bitumen. Each sample was stored in a separate container with a marking on it. Figure 5 (a and b) illustrates the prepared six specimens.

Figure 4. Mixing of WEO in bitumen

(a)

(b)

Figure 5. Prepared Samples of (a) 3%, 6%, and 9% of WCO and (b) 7%, 10%, and 13%

B. Engineering Tests

Penetration tests were performed to determine the effect of WEO and WCO on the stiffness of bitumen, as per ASTM D 5 [26]. Bitumen was heated in an oven until it became fluid. Then it was poured into a container up to its level. Now container was allowed to cool at room temperature for 40 min. The water bath temperature was maintained at 25 °C, and the container was submerged in a water bath for 40 min; then, a needle was attached to a penetrometer, as illustrated in Figure 6. The container was removed from the water bath and placed on a penetrometer. A needle was lowered until its tip touched the container's top surface. Now scale and time were adjusted by setting its value to zero and 5 seconds, respectively. The machine was run and noted down the reading.

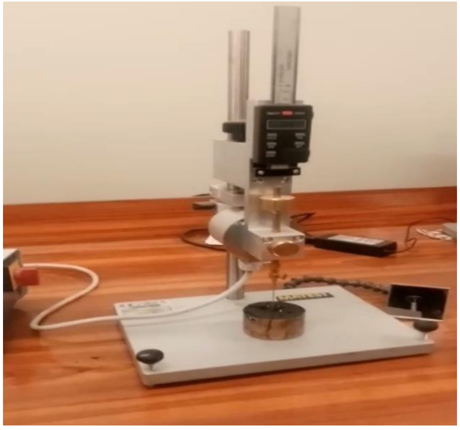

Figure 6. Penetration test Apparatus

As illustrated in Figure 7, the ring and ball apparatus was used to determine the softening point of bitumen as per ASTM D-36 standard [27]. In the first stage, bitumen was heated at 70 to 100 °C around its conditioning point. The blend of glycerin and Dexedrine was set up on a glass plate and apply it to the outer layer of glass to keep bitumen from staying. The ring was placed on the glass surface and covered with bitumen, allowing it to cool for 30 minutes in the air. The excess bitumen from the ring was eliminated from the upper part. The purified water in the measuring container was filled at five °C. The container was filled to such an extent that its surface, around 50 millimeters, was over the sample. The ring and the ball guide were collected and put on the center plate of the metallic casing, leaving them for 15 minutes. The entire unit was placed on the heating plate at a temperature of 50 °C till the bitumen melted and contacted with the lower part of the metal plate. The temperature was noted when the ball alongside bitumen contacted the lower plate.

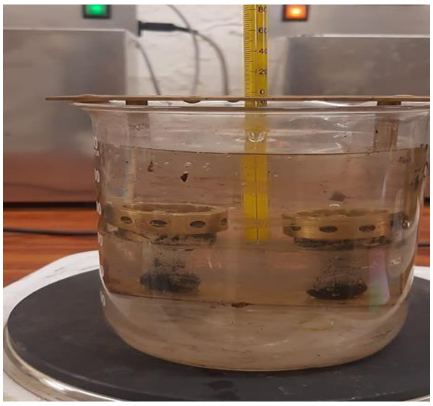

Figure 7. Ring and Ball Apparatus

Ductility tests were performed on Ductilometer, as illustrated in Figure 8, to assess the effect of WEO and ECO on the tensile behavior and flexibility of bitumen, as per ASTM D 113 [28]. The same penetrometer procedure was used to fill and condition the Ductilometer molds. The molds were immersed in a water bath for 40 min (the temperature should be 25 °C). The test was run by keeping its temperature at 25 °C, and the reading was noted when the bitumen thread started to break, or its diameter became thin.

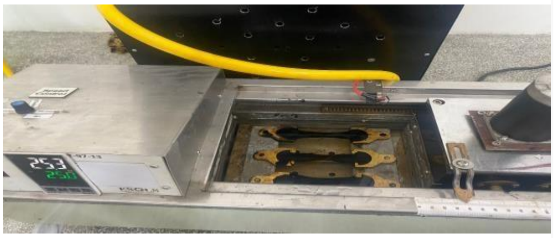

Figure 8. Ductility Tests Performed

C. Thermal Susceptibility

The PI (Penetration index) values were estimated through the usage of equation (1), and this equation represents the effect of penetration as well as softening temperature [29].

$$PI=\frac{20-500A}{1+50A} \quad \text{Where } A=\frac{\log(800)-\log(\text{Pen at T})}{SP-25} \qquad (1)$$

Where 't' indicates the temperature, i.e., 25 °C, at which the penetration test was performed. "Pen at T" is the recorded penetration value at the required temperature. In general, the original bitumen that is more temperature sensitive is more likely to be affected by the rutting distress at higher temperatures. Also, it shows brittle behavior at lower temperatures. The PI typically lies in the range of -2 to +2. The more quantitative value of PI means that the sample is less sensitive to temperatures.

IV. RESULTS AND DISCUSSIONS

A. Effect of WEO and WCO on Penetration values

A penetration test aims to determine the degree of hardness of the base and modified bitumen by WEO and WCO. Figure 9 illustrates the results of penetration tests conducted on base bitumen modified with WEO and WCO. The ARL 60/70 base bitumen's penetration values are 62 mm under standard conditions, whereas the pattern of WCO and WEO has increased in the penetrating values. It can be noted from the bar chart that hardness values of all the modified bitumen by WEO and WCO had reduced with an increase in oil dosages, irrespective of the type. The change in penetrating values is more prominent in the case of WEO compared to WCO.

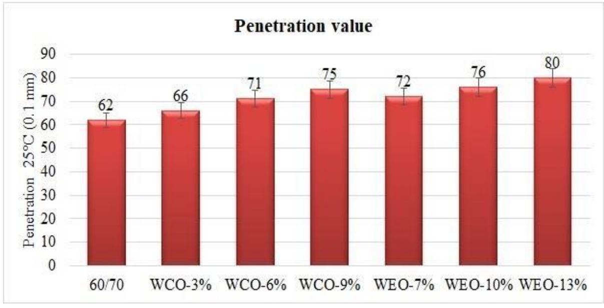

Figure 9. Effect of WEO and WCO on penetration

B. Effect of WEO and WCO on Softening values

Figure 10 illustrates the softening point test results for conventional 60/70 bitumen and modified bitumen for WEO and WCO. The softening point value obtained for base bitumen is 49 °C which is acceptable and within the range. However, the high content of WCO has reduced the softening point values from 49 °C to 43 °C. Similarly, the high dosage of WEO reduced the softening point values from 49 °C to 42 °C. The findings reflect that the penetration results incorporating WEO and WCO tend to soften the bitumen.

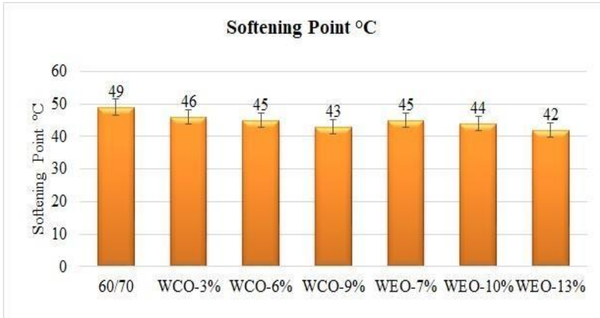

Figure 10. Effect of WEO and WCO on softening

C. Effect of WEO and WCO on Ductility Values

Figure 11 illustrates the ductility test results of the base bitumen ARL 60/70 and WEO and WCO modified-bitumen. It can be seen that the modified bitumen with WEO didn't pass the ductility requirements, i.e., more than 100 cm at 25 °C. The WCO had a more flexible and tensile deformation value of bitumen, i.e., more than 100 cm, which increases with the dosages of WCO up to 6% but less increment was noted at higher dosage due to the non-homogeneity of a blend. The ductility findings of WCO and WEO agree with the previous similar study [5,24,30,31].

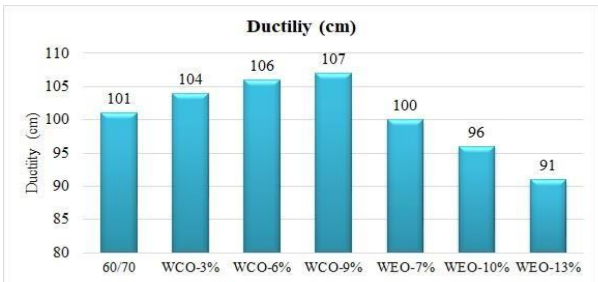

Figure 11. Effect of WEO and WCO on ductility

D. *Effect of WEO and WCO on Thermal Susceptibility*

Figure 12 (a & b) illustrates the thermal susceptibility of base bitumen ARL 60/70 and modified bitumen with waste oils, i.e., WCO and WEO. The results of WCO demonstrate that penetration index (PI) values continuously reduced after incorporating WCO into the base bitumen. It predicts that the effect of WCO has compromised the bitumen's "A" values. Similarly, the WEO reduced the PI values, reducing the bitumen's thermal susceptibility (A). The thermal susceptibility characteristics of WCO show better results compared to WEO modification.

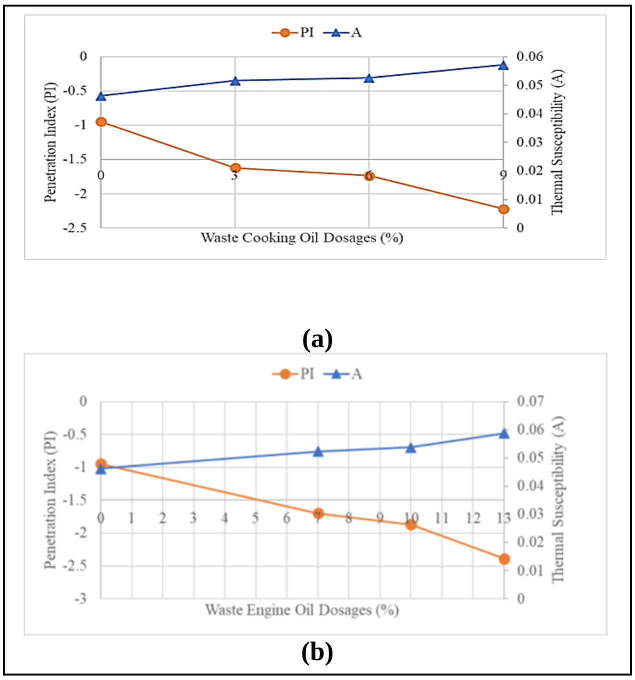

Figure 12. Thermal Susceptiability of (a) Waste Cooking Oil and (b) Waste Engine Oil

V. CONCLUSION AND RECOMMENDATIONS

The conclusions drawn from this study are presented below:

- The WCO and WEO had improved the penetrating values of the modified bitumen compared to the base bitumen. The high concentration of both the wastes oil softens the bitumen. The softness in bitumen is more pronounced in the case of WEO as compared to WCO. The WEO-3% and WCO-7% have shown 16% and 6% fewer stiffness values than base bitumen, respectively. Hence, both waste oils may be feasible for moderate climatic regions. Further, both oils may be a better choice as an antioxidant agent for recycled or reclaimed asphalt pavement (RAP) bitumen to soften the bitumen.

- The lower softening values of the WCO modified-bitumen follow the same trend of penetrating values. The WEO-13% has reported the lowest softening value compared to all the samples. The WEO-7% and WCO-3% have shown 8% and 6% more softness values than the base bitumen. Hence, the higher fluidity indicates its suitability to workable at low temperatures. Further, it may be preferable for the aged bitumen to soften the bitumen.

- Each dosage of WCO bitumen modification passes the ductility requirements of more than 100 cm at 25 °C. In contrast, the higher dosages of WEO modification showed compromise in the tensile behavior of bitumen except at 7% dosage. The WEO-7% has shown 8% less ductile, while WCO-3% is 3% more flexible than the base bitumen.

- The penetration index (PI) of the WEO modified-bitumen was lower than WCO. The WEO-7% and WCO-3% have shown 13% and 11% less thermal susceptibility values than the base bitumen. It predicts that the high-temperature performance of the WCO-modified bitumen is comparatively better compared to WEO.

Overall, it is concluded that WEO-7% and WCO-3% as modifiers of bitumen in asphalt technology can be considered an appropriate dosage and technique to solve the disposal issues of waste oils. In the subsequent studies, it is suggested to check the rheological properties, rutting resistance, and high-performance grade (PG) of the modified and RAP bitumen. Further, it is suggested to check the behavior by adding some additive like polyphosphoric acid in WEO or WCO-modified bitumen that may enhance the stiffness of the bitumen.

VI. ACKNOWLEDGMENT

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Building Energy Analysis of a Typical House with Conventional Masonry Walls and Comparison with Cavity Wall Construction

Sahar Iftikhar

Budapest University of Technology and Economics
Budapest, Hungary
Sahariftikhar49@gmail.com

Usman Ali
University of Engineering and Technology Lahore,
Pakistan
usmanali.ce14@gmail.com

Abstract **Buildings consume a considerable share of energy during operation. In Pakistan typical residential construction is masonry with 9" think brick walls. This type of construction is bad in terms of thermal insulation and leads higher energy demand to provide inside comfort. Higher energy demand leads to higher fuel consumption which is both expensive and environmentally toxic. A detailed energy analysis of a typical house is presented in this study and then a comparison with the cavity wall construction is carried out. It has been noticed that cavity wall construction possesses better insulation as compared to conventional 9" wall. Therefore, energy demand during operational phase is lower and itis a more energy efficient solution than conventional 9"masonry wall.**

Keywords—*Building Energy Modelling, Energy Analysis, Energy Efficient Construction, Design builder Analysis*

I. INTRODUCTION

Buildings consume about 40% of the overall energy consumption and therefore contribute to CO_2 emissions correspondingly. In Pakistan it is the common practice to make residential buildings detached houses. The structure is usually 9" thick burnt brick walls with cement plaster on both sides. In terms of thermal conductivity this wall thickness is relatively lower and since no insulation materialis being used in walls, so the outside temperature effects the inside comfort level. Summer lasts longer than winter in Pakistan and temperature could go to 51°C therefore coolingload is usually very high. In addition to that, usually single glazed windows therefore the installation is negligible.

Of course, the budget constraint is the main reason for this type of construction. Yet there are small measures that can improve the insulating properties of residential structure and is feasible in terms of cost too. In this study a typical detached house located in Lahore-Pakistan is used for building energy analysis. Firstly, detailed analysis of coolingand heating loads, ventilation and infiltration, heat gains andlosses, fuel consumption and CO_2 analysis for the house withtypical 9" walls and single glazed windows has been made by using Design Builder.

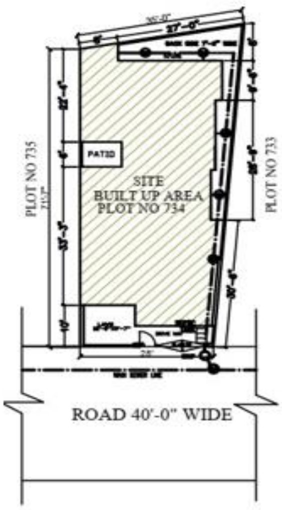


Figure 1. Site plan

Figure 2. Ground Floor Plan

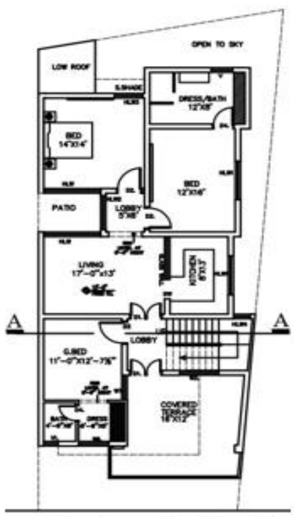


Figure 3. First Floor Plan

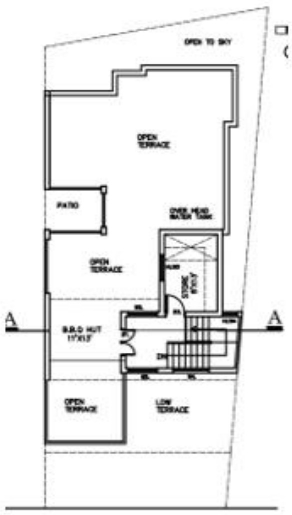


Figure 4. Second Floor Plan

II. LITERATURE REVIEW

Human beings had already urbanized, with more than 50% of the world's population living in cities [1]. The UN predicts that by 2050, when 2.5 billion people will live in cities, this proportion will rise to 68% [2], and by 2060, some
230 billion square meters of new buildings will be built worldwide to house the inhabitants of new cities [3]. Rapid urbanization is occurring because of population growth and alack of economic opportunities in rural areas. It is inevitable and closely linked to climate change. Increased resource usein urban areas will exacerbate and accelerate climate change,which in turn will affect the most vulnerable populations in rural areas. To counteract these negative responses, federal and local governments are increasingly adopting policies andtechnical actions to reduce toxic gas emissions as well as setting carbon reduction targets. At the United Nations Climate Change Conference in September 2019, 77 countries and more than 100 cities pledged to achieve zero CO_2 emissions [4]. The policy and strategic framework recognize that buildings remain a major source of carbon emissions and that there is significant potential to reduce emissions. Worldwide, buildings consume 20-40% of all electricity [5] and are responsible for 40% of direct as well as indirect carbon emissions [6] in developed countries. Carbon reduction strategies generally require the whole building stock, involving new buildings, to be carbon neutral by 2050[7].

A. Zones

The house is divided into several zones depending upon the use of room and position. For instance, living room and dining room are merged into one zone. On first floor two adjacent bedrooms are considered as one zone.

B. Model 1

The house is modelled using Design builder software. The model is shown in Figure 5. Firstly, the model was generatedusing the conventional construction in Lahore-Pakistan, i.e., typical 9" walls and single glazed windows. Figure 6 shows the construction details and Figure 7 gives the wall details ofthe model. In figure 8 opening details of the house are given. The windows are single glazed windows with no external shading. On the internal side normal drapes are being used as shading device. For lighting, general lighting combined with necessary task lighting has been used, as shown in Figure 9

Given the historical trend of carbon emissions from most buildings, which have risen steadily except during global economic crises or pandemics [8], a reduction to zero carbonemissions within 30 years may at first sight seem illusory. Asmore and more zero-energy buildings produce as much renewable energy on-site as they consume in a year, it is becoming increasingly clear that zero-energy buildings are technically feasible, despite the size as well as cost issues [9,10]. According to research by the New Buildings Institute (NBI), subsidies for energy efficiency improvements range from 1 to 12 percent depending on the kind of building, alsofrom 5 to 19 percent for zero-energy buildings [11]. The payback period for energy efficiency investments is very short, however, and can be further reduced through policy measures such as government incentives and tax breaks [11].Our challenge is therefore very similar to the difficult task of eradicating world hunger. We have the technology to produce enough food for all and to produce renewable energy. But we need to use the resources available to us as quickly and efficiently as possible.

In the case of built environment, this means clearer understanding how much energy each building in each region uses, as well as what costs also improvements can be made to decrease energy consumption. It should also enable policy makers, regulators and building owners to develop strategies and plans to promote the most efficient and cost- effective measures. Future building proposals should be integrated together with existing energy supply, distribution, and transmission infrastructure to guarantee long-term stability along with sustainability. To this end, new andefficient decision support systems are needed, especially for buildings in urban areas [12].

III. ENERGY ANALYSIS

The house is modelled using Design builder software. The

C. Model 2

The construction details of second option are shown in Figure 10. The cavity wall details are given in Figure 11, 2" cavity between two layers of 4.5" brick wall is proposed. In this version double glazed windows with internal and external shades have been used Figure 12.

Figure 1. Design Builder Model

Figure 2. Construction Details

Figure 3. 9" Wall Details

Figure 4. Single Glazed Opening Details

Figure 5. Lighting Details

Figure 1. Construction Details (with Cavity Walls)

Figure 2. Cavity WallDetails

Figure 3. Double Glazed Opening Details

IV. RESULTS

Three types of analysis, peak load, typical week, and whole season were conducted for both summer and winter seasons. The results were compared for typical 9” walls and cavity walls.

A. Summer Peak Calculations – 15 July

In Pakistan June and July are hottest months. So peak calculations for 15 July are presented. Figure 13 shows the site data on 15 July. Figure 14 shows comfort data, including operative temperature and humidity. Internal and solar gains including gains through windows, due to occupancy, equipment and lighting are given in figure 15.

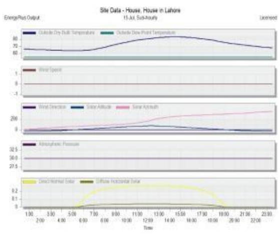


Figure 8. Site Data on 15July

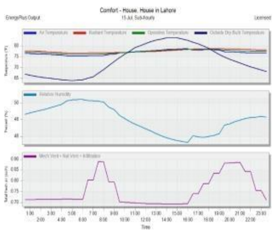


Figure 9. Comfort Data 15July

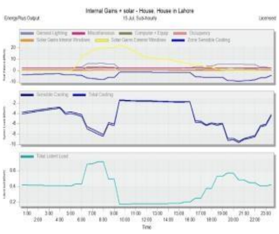


Figure 10. Internal + SolarGains

B. All Summer Analysis

In this section energy analysis for whole summer is given. Figure 16 shows the monthly site data for all summer. Figure 17 gives hourly comfort data for summer. Monthly Internal

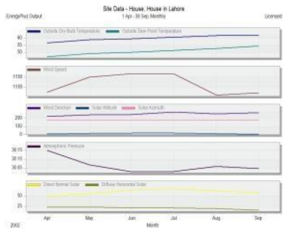


Figure 1. All Summer SiteData

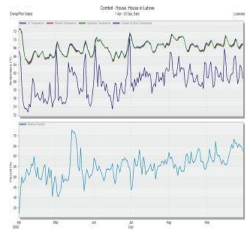


Figure 2. AllSummerComfort Data

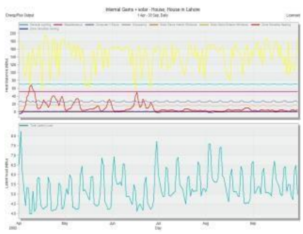


Figure 3. All SummerInternal Plus Solar Gains

Figure 4. All SummerFabric and Ventilation

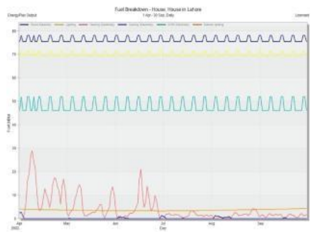


Figure 5. All Summer FuelBreakdown

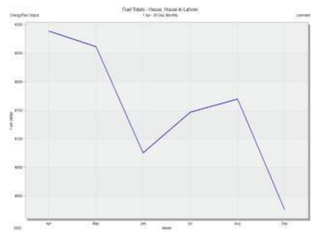


Figure 6. All Summer FuelTotals

Figure 7. All Summer CO2Production

and solar gains are shown in figure 18 and figure 19 shows fabric and ventilation dat.

C. Winter Peak Design

In Lahore – Pakistan peak winter is observed during December and January.

Figure 11. Site Data forWinter Design Week

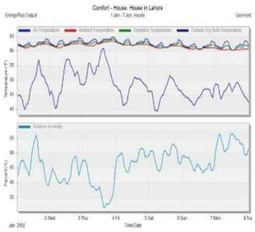


Figure 12. Comfort Data for Winter Design Week

Figure 13. Internal plus Solar Gains for Winter Design Week

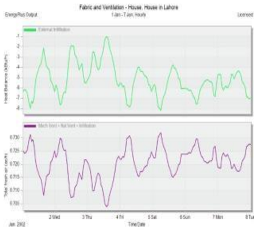


Figure 14. Fabric and Ventilation Loss

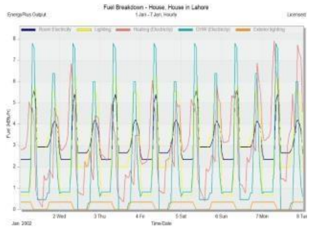


Figure 15. Fuel Breakdownfor Winter Design Week

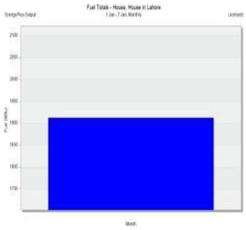


Figure 16. Fuel Totals for Winter Design Week

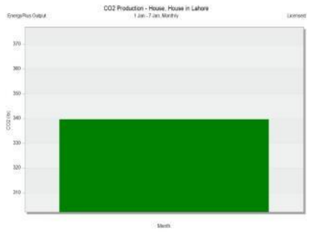


Figure 17. CO_2 Production in Winter Design Week

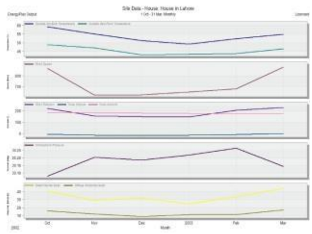


Figure 9. . Site Data for All Winter

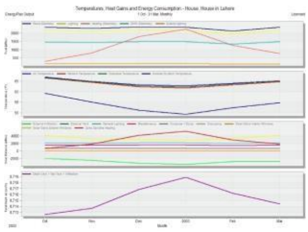


Figure 10. Comfort Datafor All Winter

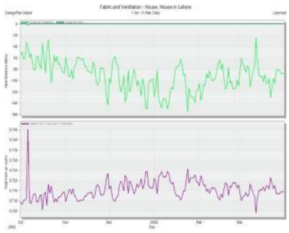


Figure 4. Fabric andVentilation for All Winter

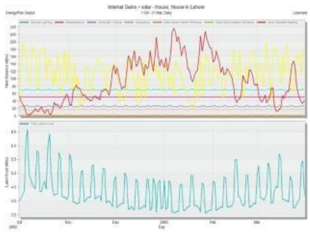


Figure 5. Internal Gains forAll Winter

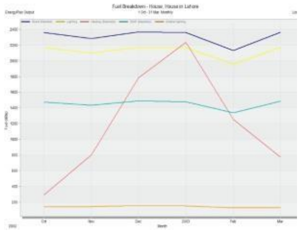


Figure 6. Fuel BreakdownAll Winter

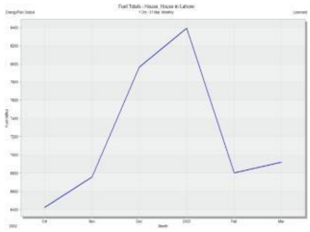


Figure 7. Fuel Totals AllWinter

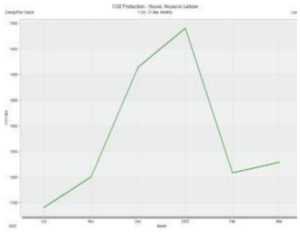


Figure 8. CO2 ProductionAll Winter

October to March time period is used for yearly this section important analysis graphs are presented such as, site data Figure 30, comfort data Figure 3, Fabric and Ventilation Figure 32, Internal Gains Figure 33, Fuel Breakdown Figure 34, Fuel totals Figure 35 and CO_2 Production Figure in 36.

D. Summer Peak Load With Cavity Walls

In the coming sections energy analysis using cavity walls, double glazed windows and external shading is given. This section 4.7 presents the energy analysis for a peak summer load. Figure 37 shows site data, figure 38 comfort data, figure 39 fabric and ventilation, figure 40 internal and solar gains on the hottest summer day.

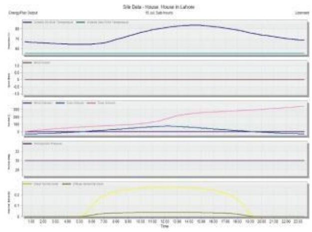


Figure 18. Peak SummerSite Data

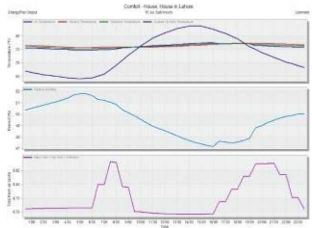


Figure 19. Comfort Data forPeak Summer

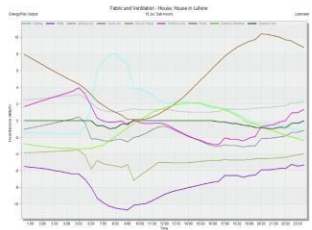


Figure 20. Fabric and Ventilation for Peak Summer (With Cavity Walls)

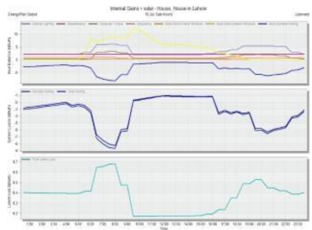


Figure 21. Internal and Solar Gains for PeakSummer (With Cavity Walls)

E. All Summer with Cavity Walls

This section given energy analysis for whole summer period.Figure 41 shows monthly site data, monthly comfort data Figure 42, Fabric and Ventilation Figure 43, Internal plus Solar Gains Figure 44, Fuel Breakdown Figure 45, Fuel Totals Figure 46 and CO_2 Production Figure 47.

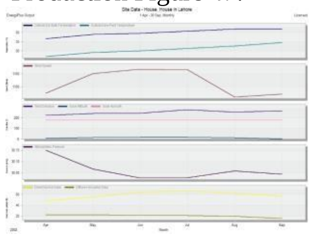
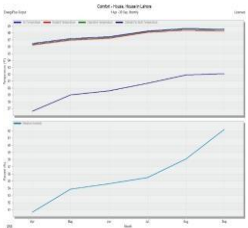


Figure 11. Site Data for All Summer



Comfort Data forAll Summer

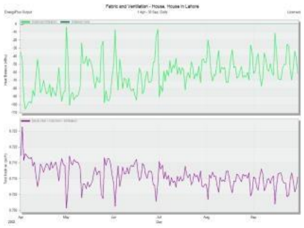


Figure 12. Fabric and Ventilation for All Summer(With Cavity Walls)

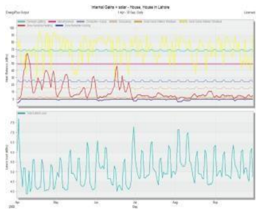


Figure 14. Internal plus Solar Gains for All Summer (With Cavity Walls)

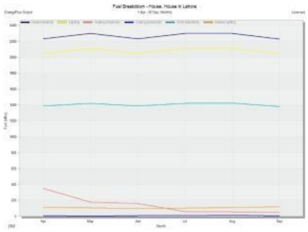


Figure 13. Fuel Breakdownfor All Summer (With CavityWalls)

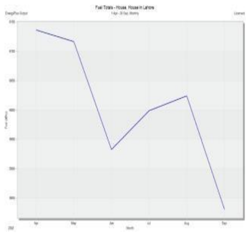


Figure 15. Fuel Totals (With Cavity Walls)

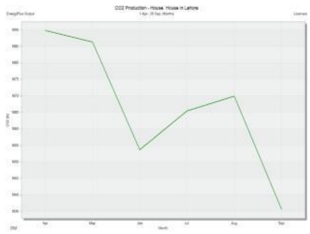


Figure 16. CO2

Production for All Summer(With Cavity Walls)

G. Winter Design Week with Cavity Walls

These trends are observed in case of peak, typicaland whole season.

The detailed analysis of both versions shows that use of cavity walls in residential construction will significantly reduce the energy demand and toxic emissions leading to environmentally friendly construction. Section 4.10 shows winter design week energy analysis. Internal and Solar Gains are shown in Figure 48 and Fuel Totals in Figure 49.

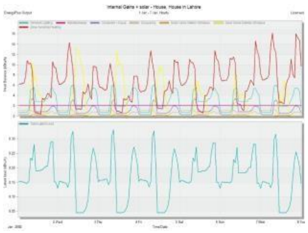


Figure 22. Internal plus Solar Gains for Winter Design Week (With Cavity Walls)

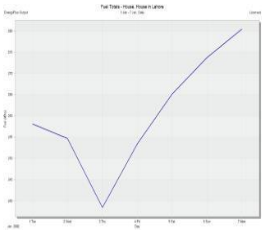


Figure 23. Fuel Totals for Winter Design Week (With Cavity Walls)

H. All Winter with Cavity Walls

Energy analysis for whole winter is presented in this section. Figure 50 shows the site data, figure 51 comfort data, Figure 52 Fabric and Ventilation, Figure 53 Internal plus Solar Gains, Figure 54 Fuel Breakdown, Figure 55 Fuel Totals and Figure 56 gives CO_2 Production.

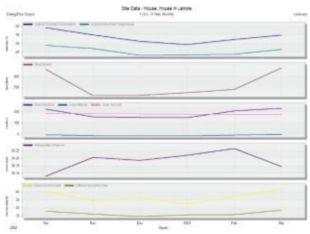


Figure 24. Site Data for All Winter

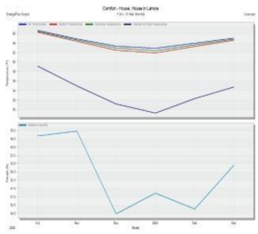


Figure 25. Comfort Data forAll Winter

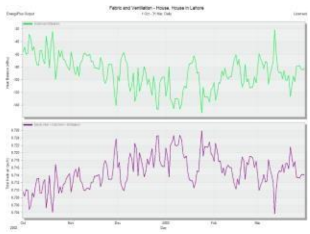


Figure 26. Fabric and Ventilation for All Winter (with Cavity Walls)

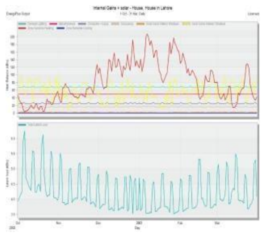


Figure 27. Internal plus Solar Gains for All Winter (with Cavity Walls)

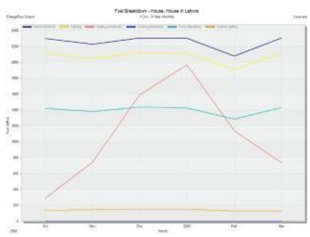


Figure 28. Fuel Breakdown for All Winter (with Cavity Walls)

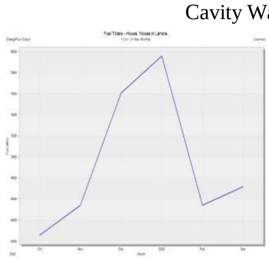


Figure 29. Fuel Totals for All Winter (with Cavity Walls)

V. CONCLUSIONS

Three types of calculation, including peak, typical and whole season was carried out for summer and winter. First option was with conventional 9” walls and single glazed windows with no external shading. The second option was with 9” cavity walls with 2” cavity and double-glazed windows with external shading.

It has been noticed that cavity wall and double- glazed windows significantly reduce the infiltration, internal and solar gains and losses in comparison with the typical walls construction. Fuel usage and CO2 production also lowered in case of cavity walls.

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