To,

Incharge Pakistan Engineering Council Funding Section

Dear sir,
Please find attached to this document a detailed report of our project, whose title is Performance Evaluation Of Interlock Brick Masonry System. For this project, we have won funding of One Hundred Thousand rupees, out of which 40% (forty thousand) is released; therefore, you are requested to release the remaining 60%. (sixty thousand) of the fund details of the group members are given below.;

Muhammad sudais	AUP-19FL-BECE-15496
Asad ibrahim	AUP-19FL-BECE-15419
Numan	AUP-19FL-BECE-16130
Jawad ali khan	AUP-19FL-BECE-15330

Funding details

Total fund	Rs 100,000
Released fund	Rs 40,000
Remaining fund	Rs 60,000

Supervisor ; Dr Tayyaba Bibi
Title : PERFORMANCE EVALUATION OF INTERLOCK BRICKS MASONARY SYSTEM

ABASYN UNIVERSITY PESHAWAR

DEPARTMENT OF CIVIL ENGINEERING

PERFORMANCE EVALUATION OF INTER-LOCK BRICKS MASONRY SYSTEMS

ABSTRACT:

This study looks into the performance evaluation of an interlock brick masonry system. The interlock bricks are supported simply by the interlock between the bricks and do not have motor joints. Because of the lack of mortar and its drying process, construction costs and time are greatly reduced.

This research study's experimental work included compression and flexural tests, as well as tests for water absorption and efflorescence in accordance with ASTM standards.

INTRODUCTION:

Interlocking bricks are an improved form of traditional clay bricks. Each brick is designed to seal itself to other surrounding bricks without the use of mortar. Automatic locking is achieved using the Shear key and the lock mechanism.

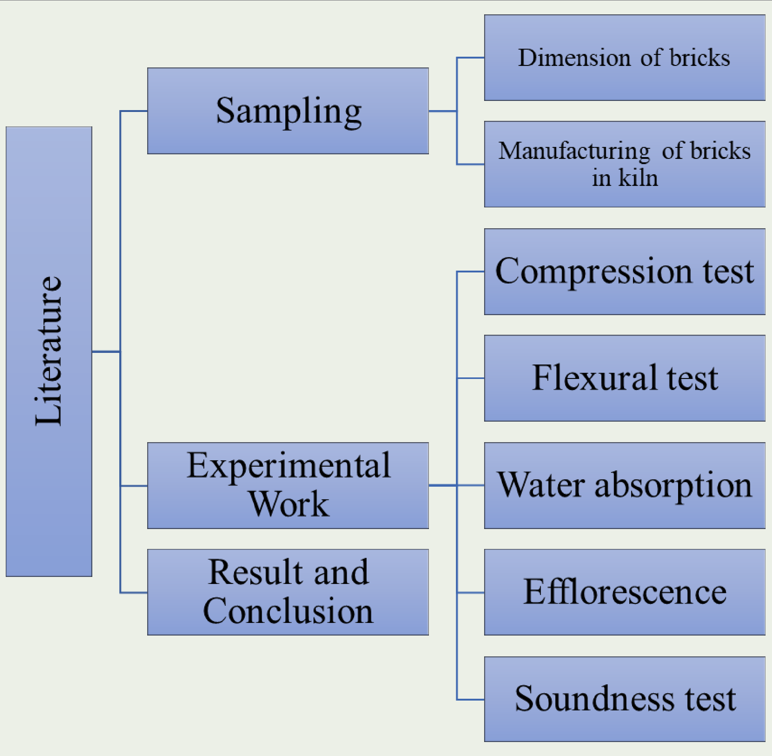
This bricks are 'locked' against each other without the usage of cement mortar, to shape a structurally strong wall that diminishes the half cost and time of construction.

OBJECTIVES:

The following are the main objectives;

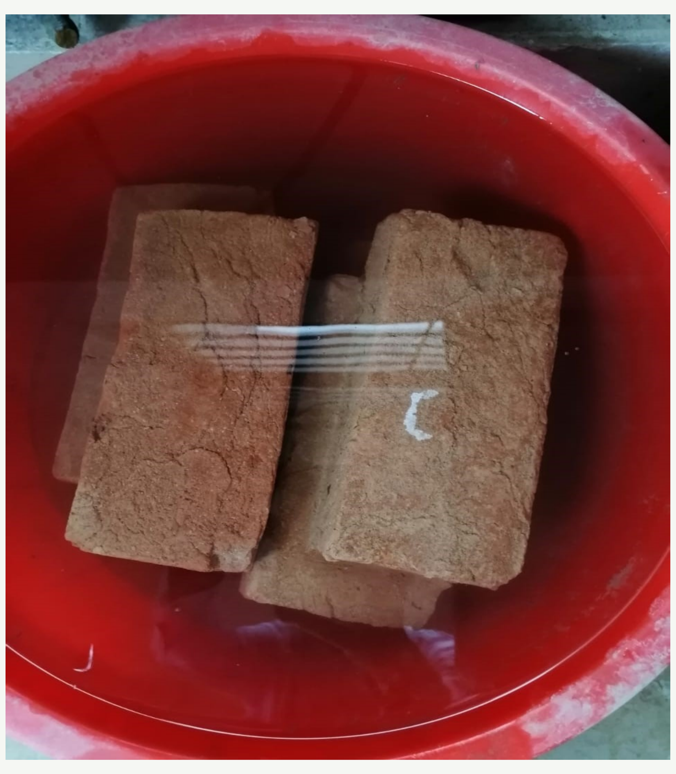
- To evaluate the mechanical properties of self interlocking clay bricks.
- To investigate the durability of self interlocking clay bricks.

METHODOLOGY:



PROGRESS:

Water Absorption C67				
Sample	**Dry Weight (gm.)**	**Saturated Weight (gm)**	**% Absorption**	**Average**
A	4877	5753	17.96	16.61
B	5219	6118	17.23	
C	5283	6050	14.52	
D	4893	5825	19.05	
E	4900	5601	14.31	



Flexural Test C67

Sample	Compressive Strength (Psi)
A	412.5
B	369.457
C	306.896

Prism Testing C1314	
Sample	Max Load (KN)
A	465.2
B	423.09
C	396.11

UPCOMING TASK:

Bricks undergo chemical immersion to assess their durability and chemical resistance, providing confidence in their performance and reliability in demanding environments.

GROUP MEMBERS:

Muhammad Sudais (15496)
Numan (16130)
Jawad Ali Khan (15330)
Asad Ibrahim (15419)

SUPERVISOR:

Dr. Tayyaba Bibi
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Detail of Upcomming Expenditure		
S.No	ITEMS	PRICE (Rs)
1	Hydrochloric Acid (HCL) 100 % pure	2500/ liter = 5000
2	Sodium Sulfate (Na2So4)	2200/liter =4400
3	Plastic Containers	1600 / container =6400
4	Photogramatics Test	800/Test =11200
5	Universial Testing Machine Test Test	300 / Test =5400
6	Poster	2000/poster =4000
7	Thiesis Printing	2000/copy =12000
8	Transportation (Materials to Testing Lab)	Depend on Location

PERFORMANCE EVALUATION OF INTERLOCK BRICKS MASONARY SYSTEM

Final Year Project UG 2022-23

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Department of Civil Engineering

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Session: 2019-2023

PERFORMANCE EVALUATION OF INTERLOCK BRICKS MASONARY SYSTEM

Thesis submitted in partial fulfillment of the requirements for the degree of B.E

Civil Engineering

BY

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Session: 2019-2023

Dedication

This study is devoted to our adored and treasured parents, who stood by us during every difficulty we encountered and selflessly put aside their own comfort for the sake of our bright prospects. It is also a tribute to our mentors who guided us to face life's trials with innovation and bravery, moulding us into the individuals we have become today.

Acknowledgements

We begin by expressing our utmost gratitude and heartfelt thanks to the Almighty Allah for His abundant blessings that have guided and accompanied us throughout our research journey, enabling us to successfully complete our work.

We would like to extend our sincere appreciation to Abasyn University Peshawar, which has provided us with a remarkable platform for learning and growth. The university's commitment to excellence is evident in the exceptional laboratory facilities and equipment made available to us, allowing us to conduct our experiments without any hindrance or limitations.

Our deepest gratitude is reserved for Dr. Tayyaba BiBi, Head of the Department of Civil Engineering at Abasyn University Peshawar. Despite her demanding schedule, she generously offered her invaluable guidance and unwavering support, dedicating her time to mentoring and assisting us in the most affable manner possible. Her expertise and insights have been instrumental in shaping our research work.

We also extend our heartfelt thanks to all the esteemed professors of the Department of Civil Engineering for their profound wisdom and collective knowledge. Their teachings have equipped us with a comprehensive understanding of our field, enabling us to navigate the research process with confidence and competence.

We would be remiss not to acknowledge the unwavering dedication and cooperation of the Lab Engineer and the entire laboratory team. Their consistent assistance and support have been indispensable throughout our research, ensuring the smooth execution of experiments and the collection of reliable data.

Lastly, we owe an immeasurable debt of gratitude to our parents, whose unwavering love, prayers, care, and sacrifices have been the bedrock of our education and preparation for a prosperous future. Their constant support and encouragement have fueled our ambition, and we are forever grateful for their unwavering belief in our abilities.

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Chapter 1

1 Introduction

1.1 General

Bricks within Masonry construction is one of the most common and oldest building materials utilized in industry around the world. Masonry system is used all over the world because of its appealing properties such as fire resistance, durability, workability, economy, and uniform shapes and sizes of masonry units. Despite these benefits, modern masonry construction processes have some drawbacks, such as time consumption, energy inefficiency, non-eco-friendliness, and non-sustainability. An alternative is to manufacture such materials, which can provide sufficient strength, consume less energy (during production), are environmentally friendly, and, most significantly, are cost effective.

Interlock bricks are an improved type of brick that doesn't require mortar to hold them together. They are designed to automatically lock with surrounding bricks through a mechanism called a shear key. The shape of the shear key varies depending on the design of the brick, and it provides a secure lock on the opposite side of the brick. The bricks rely on shear transfer and gravity to transfer the load between them.

Interlock bricks, also known as compressed stabilized earth blocks (CSEBs), are manufactured by compressing a mixture of soil, cement, and water. These bricks feature interlocking mechanisms that eliminate the need for mortar, providing enhanced structural stability and reducing construction time. The interlock brick masonry system offers several advantages, including cost-effectiveness, sustainability, and ease of construction. However, it is essential to evaluate the system's performance to ensure its reliability and adherence to safety standards. The performance evaluation of interlock brick masonry systems encompasses various aspects, including structural behavior, load-bearing capacity, durability, thermal insulation, and resistance to environmental factors. These evaluations aim to determine the system's ability to withstand various loads, including vertical and lateral forces, seismic activity, and temperature fluctuations. Additionally, assessments of water permeability, moisture resistance, and resistance to chemical degradation are conducted to evaluate the system's durability over time. Structural behavior analysis is a fundamental component of the performance evaluation process. It involves assessing the system's response to different loads, such as compressive, tensile, and shear forces. By subjecting representative samples of interlock brick masonry to laboratory tests, such as compression tests, flexural tests, and shear tests, engineers can determine the system's load-bearing capacity and its ability to resist deformations and failures. The evaluation of the system's thermal insulation properties is crucial for optimizing energy efficiency and maintaining comfortable indoor environments. Tests to measure thermal conductivity and heat transfer resistance help assess the system's ability to regulate temperature and minimize energy consumption for heating or cooling purposes.

Figure 1.1 Interlock Bricks

1.2 Significance of interlock brick against traditional bricks

1.2.1 Enhanced Seismic Performance

The interlocking arrangement in interlock masonry systems enhances the structure's resistance to seismic forces. The interlocking units distribute the applied forces throughout the masonry assembly, making it more resilient during earthquakes. Ordinary brick relies on mortar for its support system. If the mortar fails, the entire wall or building will fail.

1.2.2 Speed and Ease of Construction

Interlock masonry systems can be constructed more quickly and efficiently compared to traditional brick masonry. The interlocking units are pre-designed and manufactured, which facilitates faster installation and reduces the need for skilled labor.

1.2.3 Cost-Effective

The interlock masonry system can result in cost savings due to its faster construction process. The reduced labor requirements and shorter construction time can lead to lower overall project costs.

1.2.4 Design Flexibility

Interlock masonry systems offer greater design flexibility than traditional brick masonry. The interlocking units come in various sizes, shapes, and textures, allowing architects and builders to create aesthetically pleasing structures with diverse architectural styles.

1.2.5 Ease of Repair and Maintenance

In the event of damage or deterioration, interlock masonry systems are relatively easier to repair compared to traditional brick masonry. Individual units can be removed and replaced without affecting the entire structure.

1.3 Problem Statement

Traditional brick systems heavily depend on mortar for bonding, which necessitates curing time to ensure proper setting. Unfortunately, this curing process frequently causes delays in construction schedules. Furthermore, unconfined brick masonry, where bricks are laid flat and without adequate bonding, tends to lack the necessary flexural capacity to withstand seismic events, posing structural vulnerabilities and an elevated risk of damage or collapse. Moreover, traditional brick systems often involve significant material and labour costs associated with mortar, which needs to be mixed, applied, and cured.

1.4 Objective

- To Investigate the Mechanical properties of self-Interlocking clay bricks
- To investigate the durability performance of self-Interlocking clay bricks

1.5 Scope of the Project

The project aims to evaluate the mechanical properties and durability performance of self-interlocking clay bricks as an alternative to traditional brick systems. The focus will be on addressing the identified problems associated with traditional brick systems, including reliance on mortar, curing time, lack of flexural capacity, and material and labor costs.The project will involve experimental testing to determine the compressive strength, flexural strength, and tensile strength of self-interlocking clay bricks. These tests will help assess the structural performance and load-bearing capacity of the bricks.

The project will evaluate the durability characteristics of self-interlocking clay bricks, including resistance to weathering, moisture absorption, and freeze-thaw cycles. Various tests and analyses will be conducted to examine the long-term performance and sustainability of the bricks.

By conducting these evaluations, the project aims to provide insights into the feasibility and potential advantages of self-interlocking clay bricks over traditional brick systems.

1.6 Organization of Thesis

The thesis is organized into five sections, each addressing specific aspects of the performance evaluation of interlock brick masonry system. A brief overview of each section is as follows:

1.6.1 Chapter 1: Introduction

This chapter provides an introduction to the project and presents an overview which includes the problem statement, research objectives, the scope of the project and highlighting the significance.

1.6.2 Chapter 2: Literature Review

In this chapter, a comprehensive review of existing research and studies related to the performance evaluation of interlock brick masonry systems is presented.

1.6.3 Chapter 3: Methodology / Experimental Work

This chapter outlines the methodology and experimental approach employed in the project for assessing the performance of interlock brick masonry system. It details the steps involved in data collection, experimental setup, testing procedures, and any specific methodologies used to evaluate the key performance parameters.

1.6.4 Chapter 4: Results and Discussion

In this chapter, the results obtained from the performance evaluation experiments are presented and analysed. The data collected is statistically analysed and presented using graphs, charts, or tables to illustrate the performance characteristics of the interlock brick masonry system.

1.6.5 Chapter 5: Conclusion and Recommendation:

The final chapter concludes the thesis by summarizing the key findings of the performance evaluation of interlock brick masonry system. It discusses the implications of the results and provides recommendations for the practical application and improvement of interlock brick masonry systems based on the performance evaluation.

Chapter 2

2 Literature Review

2.1 General

This chapter gives an overview of the existing research and knowledge about evaluating how well interlock bricks masonry systems perform. The goal is to collect information from different studies and sources to understand the strengths, weaknesses, opportunities, and challenges of using interlock bricks for construction.

Accelerated mortarless masonry constructions have been developed/being used in different countries with limited research studies. This paper first discusses the salient features of interlocking block masonry and then the development of simple interlocking concrete block masonry systems, keeping in view the requirements of shape simplicity and ease of manufacture. Testing of wallettes under axial compression, eccentric compression (e/t ratios of 0, t/6, and t/3) and flexural loading parallel and perpendicular to bed joints were carried out on dry-stacked specimens. Interlocking Block Masonry results in relatively higher efficiency factors in axial compression and eccentric-to-axial capacity ratio as compared to mortar bedded masonry. Unlike conventional masonry, the flexural capacity of interlocking block masonry normal to the bed joint is higher than that parallel to bed joint. Better interlocking mechanism of channel shaped interlocking block as compared to I-shaped block, leads to relatively higher flexural capacity of the former (Anand & Ramamurthy, 2000).

Masonry is a general term encompassing construction methods using hand-placed units of clay, concrete structural clay tile, glass block, natural stones, and similar materials. It refers to both the construction process and the units themselves. Common materials used for masonry units include brick, stone, marble, granite, travertine, limestone, cast stone, concrete block, glass block, stucco, and tile. Masonry units are typically bound with a highly durable construction material.

However, the durability of the overall masonry construction is influenced by factors such as the materials used, mortar quality, workmanship, and assembly pattern. The weakest part of a masonry wall is often the mortar joint, as the substitution of lime for aggregate reduces its overall strength. Skilled masons are required for precise block fitting, which can result in higher labour costs. Additionally, the mortar used for buttering the units can harden within the blocks' openings, hindering insulation or reinforcement insertion.

Figure 2.1 Prism wall samples

To address the issues related to weak mortar joints, the concept of interlocking masonry units/blocks has been introduced. These units allow for mortar-free dry stacking and enable quick and accurate alignment during the stacking process. They eliminate the need for separate stabilizers or reinforcements to prevent structural deflection. The interlocking design of these units produces substantially straight and stable walls while also retarding the flow of air between the faces of the wall. They can be manufactured using a mixture of concrete and lightweight aggregate, offering additional benefits. In terms of compressive strength, interlocking masonry units/blocks demonstrate impressive improvements. They exhibit a 20% increase in strength compared to concrete masonry hollow units and a 40% increase compared to bricks.

Furthermore, the use of interlocking mortar further enhances strength by 30% compared to units without interlocking mortar. Apart from the strength advantages, the ease of construction with interlocking blocks reduces the need for skilled masons and saves on mortar costs. These qualities make interlocking blocks suitable for a wide range of projects, from single-story to multi-story construction (Sajad Ahmad, et al., 2014).

Conventional bricks are the most elementary building materials for houses construction. However, the rapid growth in today's construction industry has obliged the civil engineers in searching for a new building technique that may result in even greater economy, more efficient and durable as an alternative for the conventional brick. Moreover, the high demands for having a speedy and less labour and cost building systems is one of the factors that cause the changes of the masonry conventional systems. These changes have led to improved constructability, performance, and cost as well. Several interlocking bricks has been developed and implemented in building constructions and a few research had studied the manufacturing of interlocking brick and its structural behaviour as load bearing and non-load bearing element.

This technical paper aims to review the development of interlocking brick and its structural behaviour. In conclusion, the concept of interlocking system has been widely used as a replacement of the conventional system where it has been utilized either as load bearing or non-load bearing masonry system (Al-Fakih, Mohammed, Nuruddin, & Nikbakht, 2018).

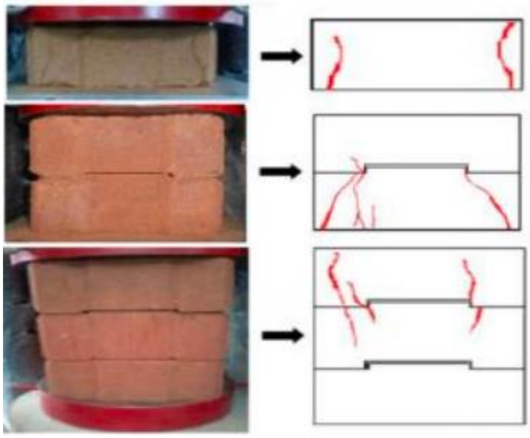


Figure 2.2 Compressive test and cracking pattern

This research paper addresses the urgent need for innovative and sustainable technologies to supplement age-old concrete and brick-and-mortar-based construction in masonry work. It focuses on identifying construction methods that are cost-effective, eco-friendly, and easily adopted in practice, while utilizing locally available resources and reducing transportation requirements. One promising solution is interlocking block masonry, exemplified by Hydra form's system, which has been found to outperform conventional brick masonry in terms of compressive stress.

Although the Indian masonry design standard (IS 1905-1987) does not specifically cover dry interlocking block masonry, it recognizes other types and suggests conducting prism tests to determine appropriate design values.

The paper explores the technical specifications, material options, mix designs, construction procedures, and conformity with building standards of interlocking block masonry. It includes case studies, cost-efficiency analysis, and testing procedures, providing a comprehensive understanding of this sustainable masonry system's viability and potential. In general, this research paper contributes to the quest for innovative masonry solutions that offer increased strength, improved sustainability, and efficient construction practices.

Figure 2.3 Boundary wall with interlocking block

This study presents a laboratory investigation on the properties of interlocking compressed earth brick (ICEB) units. Compressive strength, which is one of the most important properties in masonry structures, is used to determine masonry performance. The compressive strength of the ICEB units was determined by applying a compressive strength test for 340 units from four types of ICEB.

To analyze the strength of the ICEB units, each unit was capped by a steel plate at the top and bottom to create a flat surface, and then ICEB was loaded until failure. The average compressive strength of the corresponding ICEB units are as follows: wall brick, 19.15 N/mm2; beam brick, 16.99 N/mm2; column brick, 13.18 N/mm2; and half brick, 11.79 N/mm2. All the ICEB units had compressive strength of over 5 N/mm2, which is the minimum strength for a load-bearing brick. This study proves that ICEB units may be used as load-bearing bricks. The strength of ICEBs is equal to that of other common bricks and blocks that are currently available in the market (Abu Bakar, Saari, & Surip, 2017).

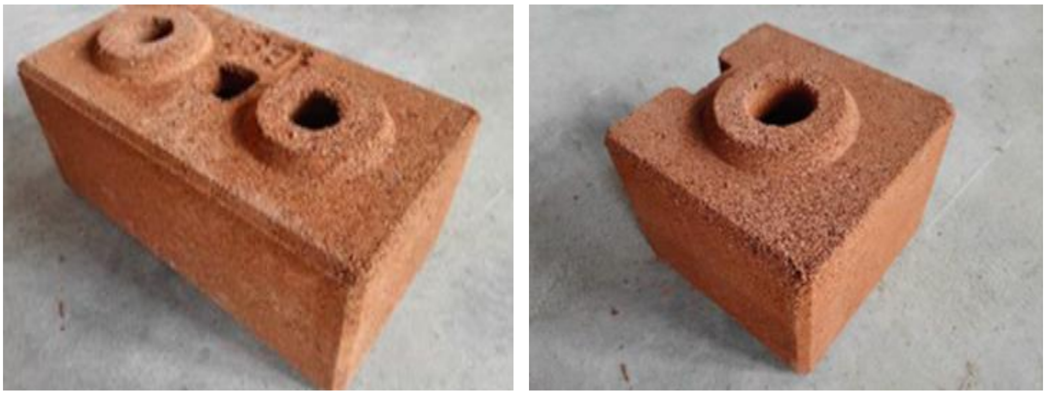


Figure 2.4 Interlock bricks samples for water absorption test

Figures a, b, c and show wall brick, beam brick, column brick and half brick respectively. This study aims to investigate the water absorption characteristic of interlocking compressed earth brick (ICEB) units. Apart from compressive strength, water absorption is an important property in masonry. This property can affect the quality of the brick itself and the bond strength between the brick and mortar in masonry structures and can result in reducing its strength properties. The units were tested for 24 h water absorption and 5 h boiling water absorption. A total of 170 ICEB units from four ICEB types underwent both tests. For the 24 h water absorption, the ICEB units were dried in the oven for 24 h and then cooled before being weighed. Thereafter, each brick was immersed in water for 24 h and weighed (Abu Bakar, Saari, & Surip, 2017).

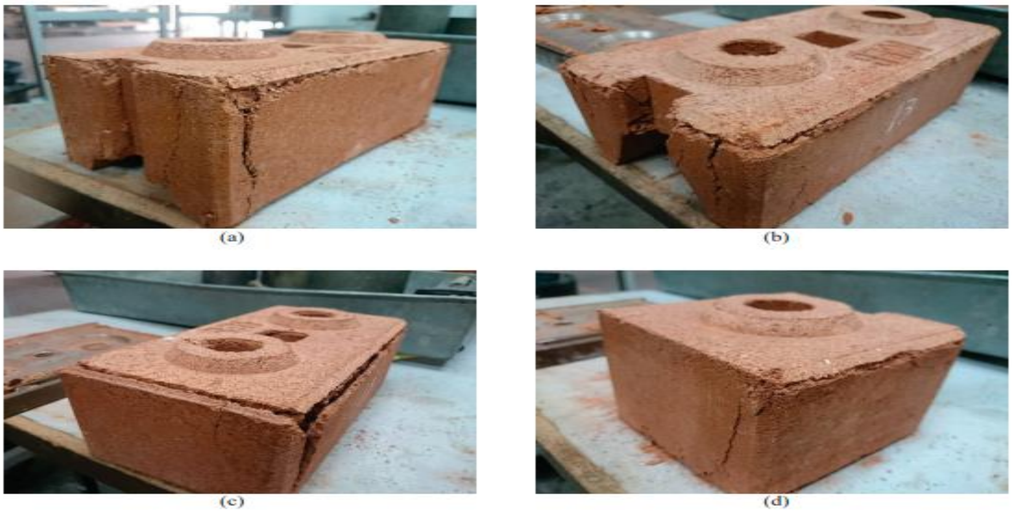
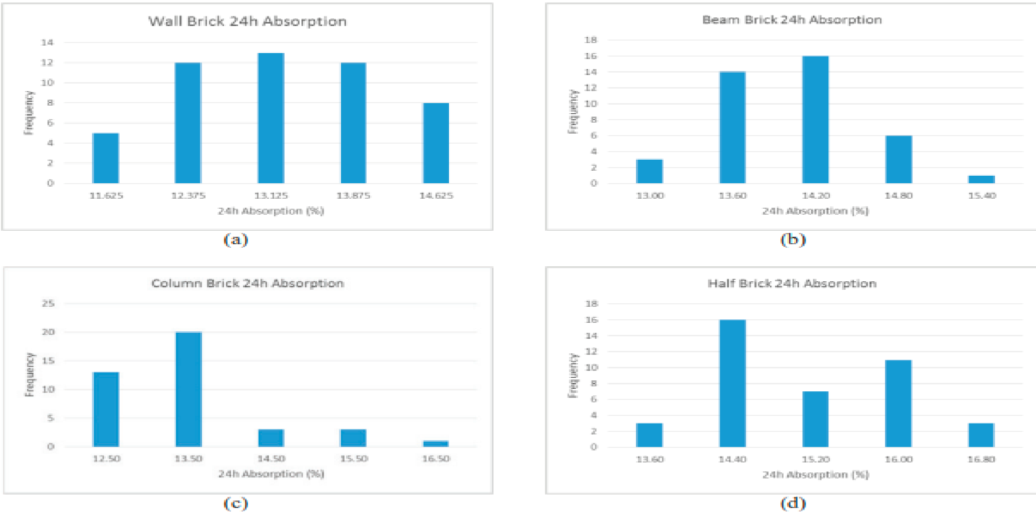


Figure 2.5 water absorption of the selected samples

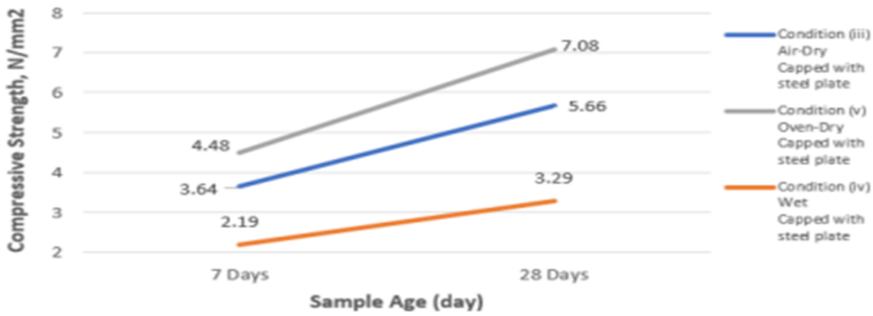
The same specimens used for the 24 h water absorption test was re-used for the 5 h boiling water absorption test. After completing the 24 h water absorption test, the brick was boiled for 5-hours and weighed. The highest water absorption for the ICEBs in the 24-hour water absorption and 5 h boiling water absorption tests are 15.09% and 17.18%, respectively. The half brick has the highest water absorption (15.87%), whereas the beam brick has the lowest (13.20%). The water absorption of an ICEB unit is higher than that of normal bricks, although the water absorption of the former remains below the maximum rate of the brick water absorption (21%) (Abu Bakar, Saari, & Surip, 2017).



Graph 2.1 Graphical representation of each block after 24 h water absorption

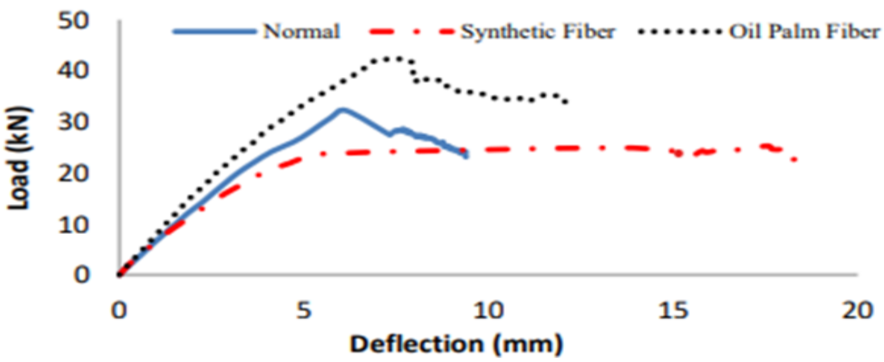
This study presents a compressive strength test of ICEB units with two different methods under five conditions. The first method requires that the tongue be removed by grinding the surface of the samples until the top and bottom surface are parallel with a tolerance of 0.1 mm for every 100 mm and tested with mortar filling (condition I) and without mortar filling (condition ii). The second method used steel plate which capped both the bed surfaces of the samples in order to provide the same parallel planes prior to testing for air-drying (condition iii), wet (condition iv) and oven-drying tests (condition v). The average compressive strength for the five conditions at 28 days is 5.11 N/mm2, 5.14 N/mm2, 5.66 N/mm2, 3.29 N/mm2 and 7.08 N/mm2 respectively.

The ICEB units had compressive strength of more than 5 N/mm2 for all conditions, which is the minimum strength for the load-bearing brick, except for the wet condition. ICEB units tested using steel plate have a higher compressive strength compared to samples with the tongue removed. Whereas the compressive strength of ICEB units with tongue removed tested with mortar filling is 1% higher than that samples without mortar filling. The ICEB units can therefore be used as load-bearing bricks and can be tested using steel plate without the need for tongue removal and mortar filling (Ameer, et al., 2021).



Graph 2.2 Compressive strength curve for condition (i), (ii), (iii)

Interlocking bricks are usually produced by mixing laterite clay, fine sand, and Portland cement. However, the typical problem with this mixture is the formation of cracks due to the brittle behavior of the interlocking materials mixture. Therefore, there is a need to add some fibers that could enhance the strength of the production of interlocking bricks. This paper presents the effects on compressive and flexural strength of interlocking bricks produced by mixing with synthetic polypropylene fiber (SPF) and palm oil fiber (POF). Tests were carried out to compare the relative strength between normal interlocking brick and proposed interlocking brick with fiber. Nine interlocking bricks with various mixture were tested for compression. Three beams specimen were prepared and tested until failure. The results showed that the addition of fiber has significantly increased the strength of interlocking bricks in all tests. POF interlocking bricks showed the highest strength, while SPF interlocking bricks showed higher in compression but lower in flexural strength than normal interlocking brick. It was concluded that the addition of POF in the interlocking mixture could be used as an additive mixture to improve the strength of the interlocking brick system (Awangku Muizz Ag, et al., 2020).



Graph 2.3 Load deflection curve

Masonry in general is the construction of structure by using individual units which are laid, and mortar is used for binding those units. One of the high durable types of construction is masonry. The common masonry materials are burnt clay bricks, stones such as marble, granite, concrete blocks, stabilized earth blocks, etc. The most used masonry units are burnt clay brick (conventional brick) and concrete blocks. Interlocking blocks are the new improved innovative structural components used for construction of buildings which initiates mortar-less construction. These blocks can be produced both by mechanically as well as manually.

These blocks bring about economical production, reduction in cost of labour and utilization of abundantly available materials for construction of structures for both urban and rural development. These blocks have grooves which lead to proper fixing of blocks (blocks will be locked on either side since grooves are provided). The assembling of these blocks does not require skill and can be assembled faster with high efficiency. In temporary structures, the dismantling is very simple, and no part of the wall is destroyed. In this dissertation work, tests like water absorption test, dimensionality test, modulus of elasticity test, compression test on prisms, and shear strength test on wallets are conducted for both interlocking block masonry and conventional brick masonry.

The test results proved that interlocking block masonry gave better results than conventional brick masonry. Also, the design is being done to check the suitability of interlocking blocks in buildings and is found safe for up to G+4 stories, that is interlocking blocks can be used for load bearing walls for up to 5 stories (Rakesh Kumar, Amit Kumar, & Kapil Soni, 2021).

Figure 2.6 Samples during compressive strength test

Interlocking compressed earth brick (ICEB) offers environmentally friendly and cost-effective material compared to conventional building materials such as clay fired brick, cement brick, and concrete block. Earth soil and concrete is a brittle building material with low tensile strength. However, the tensile strength of the ICEB which combination of soil cement and sand has still remained unknown. This paper presents the experimental investigation of the split tensile strength of ICEB units. Split tensile strength is an important parameter in masonry structures to determine the ultimate load which would be able to split the masonry structures.

Several types of ICEB (i.e., wall brick, beam brick, and column brick) was tested under split tensile strength test. In this test, two bearing rods were positioned on the bed and opposite bed surface of the ICEB to provide line load along the bed surface of ICEB unit. From this investigation, wall brick has the highest split tensile strength which is 0.769 N/mm2 followed by column brick, 0.615 N/mm2, and the lowest split tensile strength is beam brick which is 0.479 N/mm2. ICEB units were failed by a tensile crack which parallels to the axis of the loading (B.H. Abu Bakar, S. Saari, & N. A. Surip).

Figure 2.7 Interlock brick during flexural strength test

Plastic bottles are non-biodegradable material made up of Polyethylene Terephthalate (PET) and takes around 450 years to get decomposed. In Malaysia, near 13.2% of plastics contribute to municipal solid waste, where 2.5% is PET. To reduce the waste, interlocking bricks manufacture by waste plastic bottles are used to replace the conventional bricks that use cement and clay.

The purpose of this research is to reuse plastic bottles comprised of Polyethylene Terephthalate and Polyurethane binder, by manufacturing interlocking brick that helps to reduce the waste on landfills and the pollution. The plastic bottles were shredded and grinded to a size of 0.75 mm and mixed with the Polyurethane (PU) and the Polymer. The mixed later casted and compacted in the interlocking brick machine mold. The tests performed on the interlocking bricks were compressive strength, impact, flexural strength and thermal conductivity for obtaining the mechanical and thermal properties. The tests values were then keyed into the Response Surface Methodology (RSM) to obtain the optimal PET and PU to verify reliability. Based on the results it is concluded that PET/PU of 60/40 ratio is suitable as non-load bearing masonry brick and recommended to be used as partition walls (Wesam Salah Alaloul, Vivekka Olivia John, & Muhammad Ali Musarat, 2020).

Figure 2.8 Samples after compressive and split tensile strength test

Interlocking Stabilized Soil Blocks (ISSBs) are an improved version of traditional clay bricks. Each block is specifically designed to interlock with the surrounding blocks without the need for mortar. This self-locking feature is achieved through the use of shear keys and a locking mechanism.

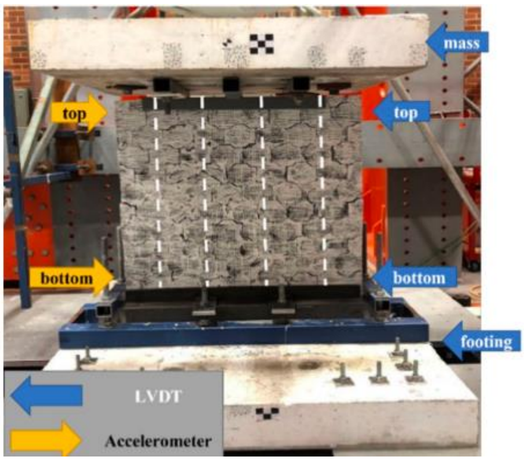
The main raw materials used in making ISSBs are red earth (80%), cement (10%), and either 6mm coarse aggregate (10%) or quarry dust, along with water. These ingredients are mixed and then compressed and moulded using hydraulic pressure. The technology eliminates the need for cement mortar in masonry work, requiring only a small amount of water and cement to join the interlocking blocks. This is one of the main advantages of ISSBs.

Interlocking blocks are considered eco-friendly building materials. The net compressive stress required for the critical section of a single-story wall in a building is determined to be 0.65 MPa (13 tons/meter length). Therefore, ISSBs can be used effectively in load-bearing structures. The primary raw material, red soil, is abundantly available in Ethiopia at a low cost, making the production cost of ISSBs 50% lower than that of cement concrete hollow blocks. This cost-effectiveness makes ISSBs a viable option for construction, leading to overall cost reduction and increased affordability for the society.

This paper aims to promote the use of ISSB technology by sharing successful case studies of ISSB adoption and adaptation to local contexts. It also highlights the challenges faced in developing and promoting the technology, drawing on lessons learned from practical experiences (Dr.A.Paulmakesh & Gizachew Markos Makebo, 2021).

In today's age, concrete stands as one of the most widely consumed materials, second only to water, yet its high costs and significant environmental impact call for alternative solutions in the construction industry. Researchers have delved into exploring innovative ideas, leading to the development of self-interlocking blocks made from a combination of glass fiber reinforced gypsum and fly ash. These blocks feature a unique design comprising male and female portions with specialized projections and grooves that interlock seamlessly. This interlocking mechanism ensures impeccable alignment and stability of the wall while facilitating effortless assembly and disassembly processes. The utilization of fly ash and gypsum as partial replacements for cement brings a sustainable edge to construction practices, reducing costs and minimizing the environmental footprint. Additionally, the incorporation of glass fiber reinforcement in these blocks enhances crack control and improves resistance against alkali attacks, resulting in increased durability. Buildings constructed with these self-interlocking blocks offer rapid construction, cost-effectiveness, and superior strength when compared to conventional walls. Such blocks pave the way for sustainable construction in today's fast-paced civilization, addressing the need for efficiency, economic viability, and reduced environmental impact. Through the adoption of these innovative materials and techniques, the construction industry moves closer to achieving sustainable practices without compromising the demands of modern development (Sisubalan, Naresh Kumar Govindaraj, & Ashokram Subramanian, 2023).

Mortar-less construction using interlocking bricks has gained attention due to its advantages, such as improved construction efficiency and reduced reliance on highly skilled labour. However, there is a lack of understanding regarding the seismic performance of interlocking brick structures. This research paper aims to address this gap by conducting laboratory tests and numerical modelling. In the laboratory, scaled shaking table tests are performed on a reinforced mortar-less interlocking brick wall. The response and damage modes under in-plane seismic loading are investigated. Unlike conventional masonry walls that experience diagonal shear damage, the interlocking brick wall exhibits rocking responses, with damage primarily concentrated at the bottom corners. A detailed numerical model is created and validated using the laboratory testing data.



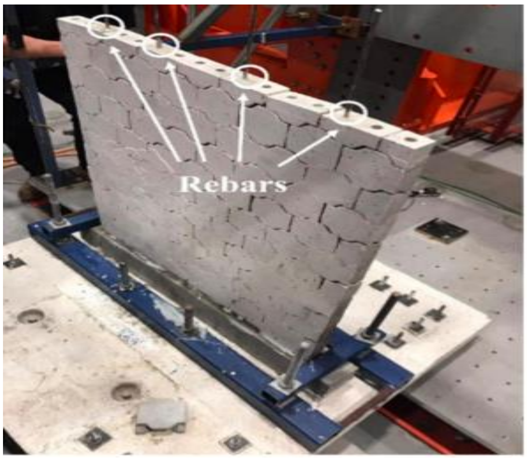


Figure 2.9 Setup of interlocking brick wall for the shaking table test

The study also compares full-scale interlocking brick walls with conventional concrete masonry unit (CMU) walls bonded with mortar. The seismic resistances and damage modes of the two walls are compared, considering factors such as ground motion intensities, vertical components of seismic excitations, and different seismic time histories. The findings demonstrate that the interlocking brick wall has a higher seismic resistance capacity than the CMU wall. Energy dissipation in the interlocking brick wall primarily occurs through inter-brick friction. The vertical component of ground motion significantly influences the damage in interlocking brick walls. Moreover, the interlocking brick walls exhibit less sensitivity to velocity pulses due to their relatively high natural frequency. Through laboratory testing and numerical modelling, this research contributes to a better understanding of the seismic behaviour of interlocking brick structures. The findings suggest that interlocking brick walls offer favourable seismic performance, with higher resistance and effective energy dissipation. These insights can inform the design and construction practices of interlocking brick systems, promoting their use as a viable and sustainable alternative in seismic regions (Guanyu Xie, Xihong Zhang, Hong Hao, Kaiming Bi, & Yuanzheng Lin, 2022).

Chapter 3

3 Methodology / Experimental Work

3.1 General

In this chapter, we will discuss the experiments performed on the brick samples in detail, along with the methodology employed. We will also cover the preparation of the bricks and highlight some of their key characteristics.

In the initial stages of the project, an interlock brick was designed. Following the completion of the design, a brick mold was created. The manufacturing of brick samples was carried out at the Haji M. Anwar Bricks Company in Lundkhwar, Mardan. The samples were then stored in the laboratory for subsequent testing. Several tests were conducted on the brick samples.

3.2 Manufacturing of Interlock Brick

We started by designing an interlock brick and then went to the kiln in Mardan. There, we prepared a specialized kiln mould specifically designed for the interlock brick. Utilizing this mould, we carefully crafted the interlock brick and allowed it to settle for 7 days to attain its desired shape and strength. Following the settling period, the brick was placed in the kiln and subjected to a 30-day firing process, where it was exposed to elevated temperatures. We successfully created the interlock brick with the specified qualities and strength by following the manufacturing process.

Figure 3.1 Manufacturing of interlock bricks

3.3 Sample of Interlock Brick

After preparing and manufacturing we took the following samples of interlock bricks.

Figure 3.2 Samples of interlock bricks before and after heating in kiln

3.4 Experimental Work

To evaluate the performance of interlock bricks masonry system we must perform different test like compression test flexural test etc on interlock bricks.

3.4.1 Water Absorption Test (ASTM C67)

The water absorption test for interlock bricks is done to find out how much water the bricks can soak up. This test helps us determine the percentage of water that the bricks can absorb compared to their weight.

we start water absorption test following ASTM C67 procedure we took random bricks from our sample we dried the specimen in a ventilated oven at a temperature of 105℃ to 115℃ till it achieve considerably constant mass we cooled the specimen to room temperature and took its weight w1. when the specimen was completely dry, we immerse it in the clean water at the room temperature for 24 hours.

After 24 hours we remove the specimen from water and wiped it water with a damp cloth and weigh the specimen. we took the weight w2 of the sample 3 minutes after removing it from water.

Figure 3.3 Interlock bricks sample when immersed in water

We Calculate and report the cold-water absorption of each specimen to the nearest 0.1 % as follows:

Absorption, % = 100(Ws – Wd)/ Wd ………. Equation 3.1

Where:

Wd = dry weight of the sample

Ws = saturated weight of the sample after submersion in cold water.

Equipment's and Materials used in experiment are as follows:

- Samples
- Drying oven
- Weight balance
- Bath filled with water to keep bricks Cloth etc.

3.4.2 Compressive Test (ASTM C67)

The compressive strength of bricks refers to their ability to withstand or resist compression when tested using a machine called a Compression Testing Machine (CTM). By measuring the compressive strength, we can understand the load-carrying capacity of the bricks when subjected to compression forces before it fails by developing cracks or fissures.

We start by capping all the test specimen for the testing of compressive strength. we used gypsum (plaster of Paris) as a capping material. We made it sure that the opposite bearing surfaces so formed were approximately parallel and perpendicular to the vertical axis of the specimen and the thickness of the caps were approximately the same and not exceeding 1⁄8 in. (3.18 mm). Test were performed after 24 hours of capping.

After 24 hours test specimens were ready for testing. Followed ASTM standard for the test and start by placing the specimen in UTM (Universal testing machine). After placing the specimen in UTM (Universal testing machine) we applied the load on it until it bricks.

Figure 3.4 Interlock Brick Sample Before and After Test

We noted the value of failure load and used the following formula to find the compressive strength.

Compressive strength, C = W / A………. Equation 3.2

Where:

C = Compressive strength of the specimen, lb/in2 (or kg/cm2)

W = Maximum load, lbf, (or kgf) (or N), indicated by the testing machine.

A = Average of the gross areas of the upper and lower bearing surfaces of the sample, in2

Equipment’s and Materials used in experiment are as follows:

- Sample
- Drying oven
- Compression testing machine (Universal Testing Machine)
- Weight balance
- Plaster of Paris, water, pan.
- Spatula etc

3.4.2.1 Side Wise Compressive Test for Interlock Brick (ASTM C67)

After keeping the sample for 24 hours test was performed. We followed ASTM standard for the test and start by placed the interlock brick side wise in UTM (Universal testing machine). After placing the sample in UTM (Universal testing machine) we applied the load on it until it bricks.

Figure 3.5 Side Wise Sample of Interlock Brick Before and After Test

3.4.2.2 Vertical Compressive Test for Interlock Brick (ASTM C67)

After the size wise compressive test, we start testing the compressive strength of interlock brick vertically. We followed same ASTM standard for the test and start by placed the interlock brick vertically in UTM (Universal testing machine). After placing the sample in UTM (Universal testing machine) we applied the load on it until it bricks.

Figure 3.6 Vertical Sample of Interlock Brick Before and After Test

We noted the value of failure load for both side wise and vertical sample and used equation 3.2 to find the compressive strength.

3.4.3 Compressive Test for Double Interlock Brick (ASTM C67)

After completion of compressive strength for single brick we also perform the experiment for double interlock bricks. We started by capping all the test samples of interlock brick for the testing of compressive strength. we used gypsum (plaster of Paris) as a capping material. We made it sure that the opposite bearing surfaces so formed were approximately parallel and perpendicular to the vertical axis of the specimen and the thickness of the caps were approximately the same and not exceeding 1⁄8 in. (3.18 mm). Test were performed after 24 hours of capping.

After 24 hours test specimens were ready for testing. Followed ASTM standard for the test and start by placing the specimen in UTM (Universal testing machine). After placing the specimen in UTM (Universal testing machine) we applied the load on it until it bricks.

Figure 3.7 Double Brick Sample Before and After Test

We noted the value of failure load and used the following formula to find the compressive strength.

Compressive strength, C = W / A………. Equation 3.2

Where:

C = Compressive strength of the specimen, lb/in2 (or kg/cm2)

W = Maximum load, lbf, (or kgf) (or N), indicated by the testing machine.

A = Average of the gross areas of the upper and lower bearing surfaces of the sample, in2

Equipment's and Materials used in experiment are as follows:

- Sample
- Drying oven
- Compression testing machine (Universal Testing Machine)
- Weight balance
- Plaster of paris, water, pan.
- Spatula etc

3.4.4 Compressive Test for Triple Interlock Brick (ASTM C67)

After double bricks we also performed the experiment for triple interlock bricks.

We started by capping all the test samples of interlock brick for the testing of compressive strength of triple interlock bricks. we used gypsum (plaster of Paris) as a capping material. We made it sure that the opposite bearing surfaces so formed were approximately parallel and perpendicular to the vertical axis of the specimen and the thickness of the caps were approximately the same and not exceeding 1⁄8 in. (3.18 mm). Test were performed after 24 hours of capping.

After 24 hours test specimens were ready for testing. Followed ASTM standard for the test and start by placing the specimen in UTM (Universal testing machine). After placing the specimen in UTM (Universal testing machine) we applied the load on it until it bricks.

Figure 3.8 Double Brick Sample Before and After Test

We noted the value of failure load and used the following formula to find the compressive strength.

Compressive strength, C = W / A………. Equation 3.2

Where:

C = Compressive strength of the specimen, lb/in2 (or kg/cm2)

W = Maximum load, lbf, (or kgf) (or N), indicated by the testing machine.

A = Average of the gross areas of the upper and lower bearing surfaces of the sample, in2

Equipment's and Materials used in experiment are as follows:

- Sample
- Drying oven
- Compression testing machine (Universal Testing Machine)
- Weight balance
- Plaster of paris, water, pan.
- Spatula etc

3.4.5 Flexure Test (ASTM C67)

The flexure strength test for bricks evaluates their capacity to withstand bending forces without providing specific details on the test procedure. This test assesses the brick's resistance to flexing and bending, providing important insights into its structural integrity and durability. By measuring the flexure strength, we gain a better understanding of the brick's ability to withstand lateral forces and uneven loads.

We start from selecting representative interlock brick specimens for testing and then cleaned the specimens and ensured they are free from any debris or contaminants. We also measured and record the dimensions of each specimen, including length, width, and height. After that we Placed the brick specimen horizontally on two support points, typically positioned at one-third of the specimen's length from each end and ensured the specimen is centred and levelled on the supports. The support points were smooth and not created any localized stress concentrations.

We applied a load at the centre of the interlock brick specimen using a suitable UTM (Universal Testing Machine). The load was applied gradually and continuously until the specimen fractures or reaches its maximum bending capacity. We ensured the loading rate is within the specified range outlined in the ASTM standard.

Figure 3.9 Test Samples Before and After Flexural Failure

After that we calculate the modulus of rupture of each samples using the following formula

$S = 3W (l / 2 - x)\ bd^2$………. Equation 3.3

Where:

S = modulus of rupture of the specimen at the plane of failure, lb. /in^2 (Pa),

W = maximum load indicated by the testing machine, lbf (N),

L= distance between the supports, in. (mm),

B=net width, (face to face minus voids), of the specimen at the plane of failure, in. (mm),

D=depth, (bed surface to bed surface), of the specimen at the plane of failure, in. (mm),

X=average distance from the midspan of the specimen to the plane of failure measured in the direction of the span along the centreline of the bed surface subjected to tension, in. (mm).

3.4.6 Prism Test (ASTM C1314)

The prism test for bricks, conducted in accordance with ASTM standards, is an essential procedure aimed at assessing the compressive strength of masonry units. By subjecting prismatic specimens made from bricks to controlled compression, the test provides valuable information about the bricks' load-bearing capacity and their ability to withstand pressure. This knowledge is crucial for ensuring the structural integrity and safety of masonry structures. The prism test helps in quality control and contributes to the construction industry by promoting the use of durable and reliable bricks, leading to enhanced building longevity and reduced risk of structural failures.

We Select a specific number of interlocking bricks to create a masonry prism and ensured that the bricks are clean, free from any visible defects, and representative of the lot or batch being tested. We Determined the required dimensions and configuration for the masonry prism based on the testing specifications and standards.

We Lay the interlocking bricks horizontally on a flat surface, following ASTM standard. We bond the interlocking bricks together without applying mortar ensuring proper alignment and continued layering and bonding the bricks until the desired prism height was achieved. We carefully transfer the masonry prism to Universal testing machine and aligned the prism so that the load is applied along the longitudinal axis. We ensured that it was stable and cantered on the lower platen of the machine. We applied a compressive load to the prism at a specified rate, typically 0.1 to 0.2 psi per second, until the prism fails.

Figure 3.10 Interlock Brick Sample Before and After Prism Test

We record the maximum load sustained by the prism during the compressive test and calculate the required values using the equation shown below.

Compressive strength, $C = W / A$………. Equation 3.2

Where:

C = Compressive strength of sample

W = Maximum load.

A = Area

Equipment’s and Materials used in experiment are as follows:

- Sample

- Drying oven
- Compression testing machine
- Weight balance.
- Plaster of paris, water, pan
- Spatula etc

3.4.7 Efflorescence Test (ASTM C67-03)

Efflorescence is a common phenomenon in masonry construction, including interlocking bricks, characterized by migration of soluble salts to the surface, resulting in white or greyish deposits. Efflorescence testing is performed to evaluate the presence and severity of these deposits on the surface of interlocking bricks. The primary reason for conducting efflorescence testing is to assess its aesthetic impact on interlocking brick structures. Efflorescence testing helps identify potential moisture and salt-related issues within the masonry system. The presence of efflorescence serves as an indicator of moisture and soluble salts, which, if unaddressed, can lead to long-term durability problems. By conducting efflorescence testing, early detection of these issues becomes possible, enabling timely preventive measures.

We Select representative interlock brick samples from the prepared lot of interlock bricks and ensured that the bricks are clean and free from any visible surface contaminants. We Immersed some brick sample in distilled water some place in a humidity chamber with a relative humidity of 95%. We maintain the wetting conditions for a specific duration of 14 days. After the wetting period, we removed the brick samples from the water and humidity chamber and allows the samples to air dry at room temperature for a specific duration, typically 14 days.

Figure 3.11 Samples for Efflorescence Test

We Inspect the surface of each brick sample for the presence and extent of efflorescence deposits and evaluate the efflorescence based on the observed amount, appearance, and distribution and then we classified the efflorescence severity based on predetermined visual classifications such as "none," "slight," "moderate," or "heavy."

3.4.8 3.4.9 Durability Test for HCl Immersed Interlock Bricks (ASTM C67)

The HCL (Hydrochloric Acid) test for the durability of bricks is a method used to assess the resistance of bricks to acidic conditions. The purpose of the HCL test is to evaluate how well bricks can withstand the corrosive effects of acids or acid fumes, which can cause degradation, disintegration, or weakening of the brick material over time. By immersing the brick samples in the acid solution and observing any changes or deterioration, such as surface erosion, color changes, or physical disintegration, the test helps determine the acid resistance and overall durability of the bricks.

We start by obtaining interlock brick samples that are clean and free from any visible defects or surface coatings and measured and record the dimensions of each sample. We Prepared 2 hydrochloric acid (HCL) solutions by diluting 5% and 10% concentrated hydrochloric acid with water and filled 2 suitable containers with the prepared HCL solution 1 with 5% of HCL and 1 with 10% HCL and immersed the interlock brick samples completely in the acid solutions and ensured that they were fully submerged. We kept the interlock brick samples fully immersed for 48 hours. After 48 hours we removed the interlock brick sample from the acid solution, thoroughly rinsed the interlock brick sample with clean water to remove any residual acid and inspect the specimens for any visible changes or signs of deterioration, such as surface erosion, colour changes, cracking, or physical disintegration.

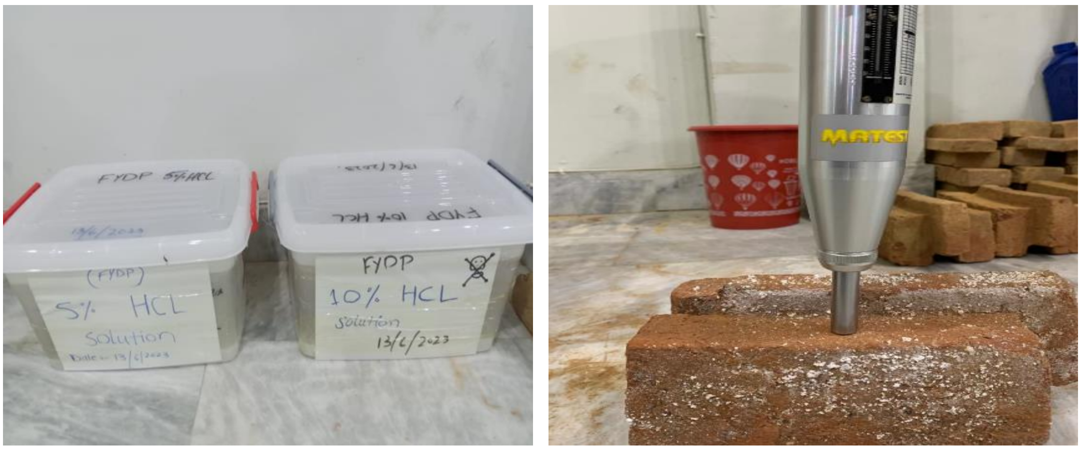


Figure 3.12 Durability Test for HCl Immersed Interlock Bricks

3.4.9 Durability Test for H2SO4 Immersed Interlock Bricks (ASTM C88)

The H2SO4 test is performed to evaluate the soundness or durability of brick, concrete, or aggregate materials in the presence of sodium sulphate. It simulates the potential deleterious effects of sulphate attack, which can cause expansion, cracking, and loss of strength over time. The test involves subjecting the specimens to repeated cycles of wetting and drying with a sodium sulphate solution to assess their resistance to sulphate-induced damage. The purpose of conducting the Na2SO4 test is to determine the potential for sulphate-related deterioration in the tested materials. Sulphates can be present in soils, water sources, or other environments, and can react with certain minerals within the materials, leading to detrimental effects.

We select the interlock brick samples from the available lot and ensured that the specimens are clean and free from any visible defects or surface coatings. We also determine the size of all the selected interlock brick samples. We prepared 2 sodium sulphate (Na2SO4) solution by dissolving 5% and 10% amount of sodium sulphate in water. After that we immersed the interlock brick samples completely in the prepared solutions and ensured that they were fully submerged. We start by wetting and drying the sample every 24 hours. After the 4 times of wetting and drying cycles, we removed the specimens from the sodium sulphate solution and thoroughly rinsed the specimens with clean water to remove any residual solution. At last we inspect each specimen for any visible changes or signs of deterioration, such as expansion, cracking, spalling, or loss of strength.

Figure 3.13 H2SO4 Immersed Interlock Bricks

Chapter 4

4 Results and Discussion

4.1 General

This chapter is all about the results examined from the performed experiments on interlock brick sample like compressive strength test on top, side and vertical of single interlock brick as well as compressive strength test on double and triple brick. This chapter also includes the result from prism test, flexure strength test and the results of effloresce test as well as durability of HCl 5 %, 10% and H2SO4 5%, 10 % immersed on interlock brick samples.

4.2 Results of Compressive Strength for Single Interlock Brick

Compressive Strength test was performed on top, side and vertically on single interlock brick the result from each sample has been discussed below.

4.2.1 Compressive Strength on Top of Interlock Brick

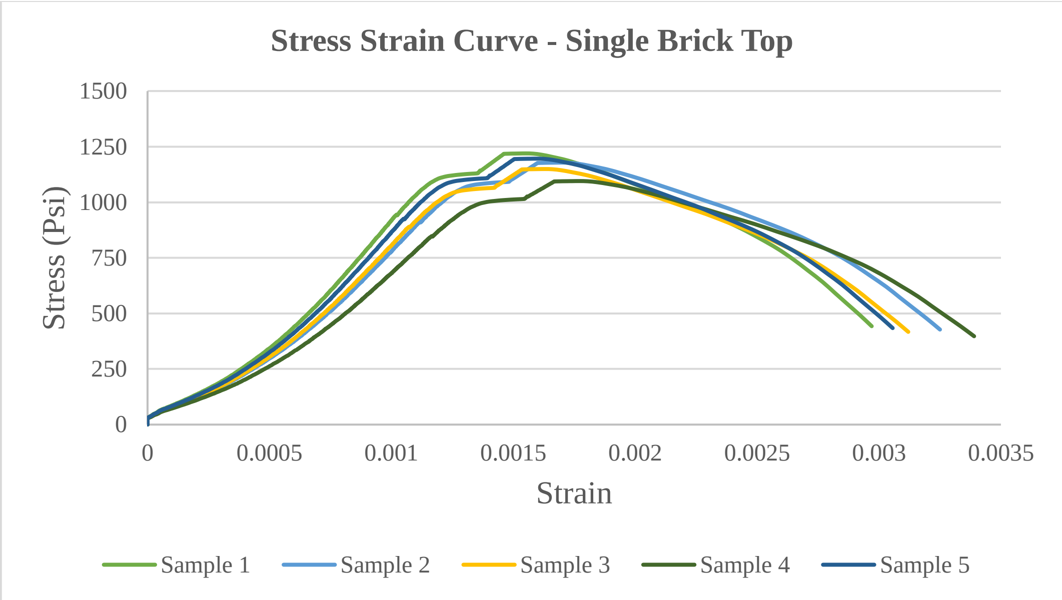
Compressive strength test was performed on top of five single interlocking bricks using ASTM standards. The prepared interlocking bricks which have an area of 34.875 in^2 can bear or withstand a load of up to 42,542.43 lb which means the interlock brick have the maximum compressive strength of 1,219.85 psi. The results revealed that prepared interlocking bricks are suitable for use in load-bearing applications because the average compressive strength of the interlocking bricks is 1,167.94 psi which is above the minimum compressive strength of 1,000 psi required for load-bearing bricks. The maximum compressive strength of 1,219.85 psi is even higher, indicating that the interlocking bricks have a good margin of safety. The overall results obtained from the test are as follows.

Table 4.1 Compressive Strength on Top of Interlock Brick

S. No	Area (in2)	Load (lb)	Compressive Strength (Psi)	Average Compressive Strength (Psi)
Sample 1	34.875	42542.43	1219.8546	1167.94402
Sample 2	34.875	41102.58	1178.56859	

Sample 3	34.875	40091.79	1149.58548	
Sample 4	34.875	38204.06	1095.456845	
Sample 5	34.875	41719.38	1196.254587	

The relationship between compressive strength and strain if we apply load on top of interlock brick is shown below.



Graph 4.1 Stress Strain Curve for Compressive strength of Single Interlock Brick Top

4.2.2 Compressive Strength on Side of Interlock Brick

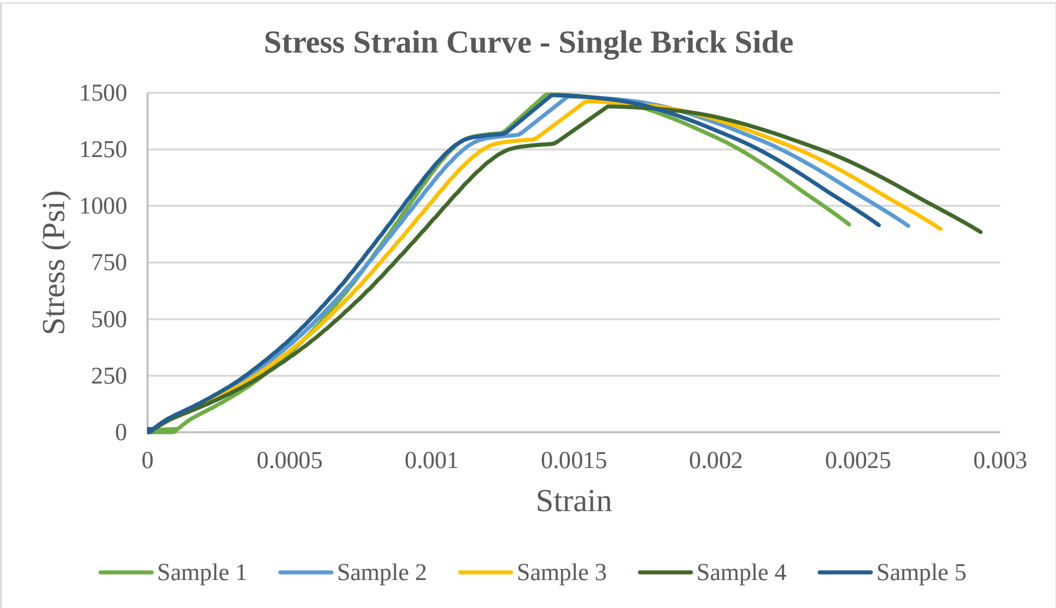
The compressive strength test on the side of five single interlocking bricks using ASTM standards revealed that the bricks can bear or withstand a load of up to 47282.7. The prepared interlocking bricks which have an area of 31.66 in2 can bear or withstand a load of up to 47282.7 lb, which means the interlock brick have the maximum compressive strength of 1493.45 psi. The results revealed that prepared interlocking bricks are suitable for use in load-bearing applications because the average compressive strength of the interlocking bricks is 1473.36 psi which is above the minimum compressive strength of 1,000 psi required for load-bearing bricks. The maximum compressive strength of 1493.45 psi is even higher, indicating exceptional performance of the interlock bricks and reinforce their suitability for load-bearing applications.

The results obtained from the compressive strength test onside of interlock bricks are as follows.

Table 4.2 Compressive Strength on Side of Interlock Brick

S. No	Area (in2)	Load (lb)	Compressive Strength (Psi)	Average Compressive strength (Psi)
Sample 1	31.66	47282.66	1493.451	1473.3605
Sample 2	31.66	46966.59	1483.467913	
Sample 3	31.66	46268.34	1461.413294	
Sample 4	31.66	45571.95	1439.41722	
Sample 5	31.66	47143.42	1489.053071	

The relationship between compressive strength and strain if we apply load on side of interlock brick is shown below.



Graph 4.2 Stress Strain Curve for Compressive Strength of Single Interlock Brick Side

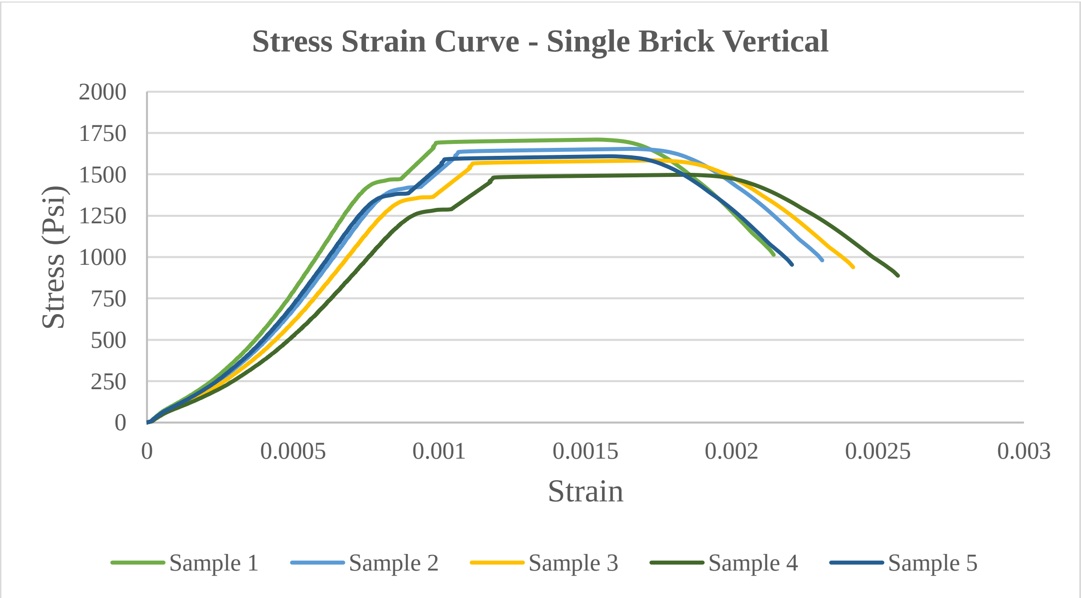
4.2.3 Compressive Strength of Vertical Interlock Brick

The compressive strength test was conducted on five interlocking bricks vertically using ASTM testing standards. These bricks had an area of 5.15 square inches. The results revealed that these interlocking bricks can bear a load of up to 8,807.82 pounds, and Sample 1 demonstrated the highest compressive strength of 1,710.26 pounds per square inch (psi). The average compressive strength across all samples was 1,611.11 psi, which is higher than the minimum requirement of 1,000 psi for load-bearing bricks. This indicates that these interlocking bricks are suitable for various load bearing applications. The results obtained from the compressive strength test on vertical interlock bricks are as follows.

Table 4.3 Compressive Strength on Side of Interlock Brick

S. No	Area (in2)	Load (lb)	Compressive Strength (Psi)	Average Compressive Strength (Psi)
Sample 1	5.15	8807.823	1710.2569	1611.111046
Sample 2	5.15	8519.315	1654.23589	
Sample 3	5.15	8158.81	1584.235	
Sample 4	5.15	7712.587	1497.58964	
Sample 5	5.15	8287.575	1609.2378	

The relationship between compressive strength and strain if we apply load vertically on interlock bricks is shown below.



Graph 4.3 Stress Strain Curve for Compressive Strength of Vertical Interlock Bricks

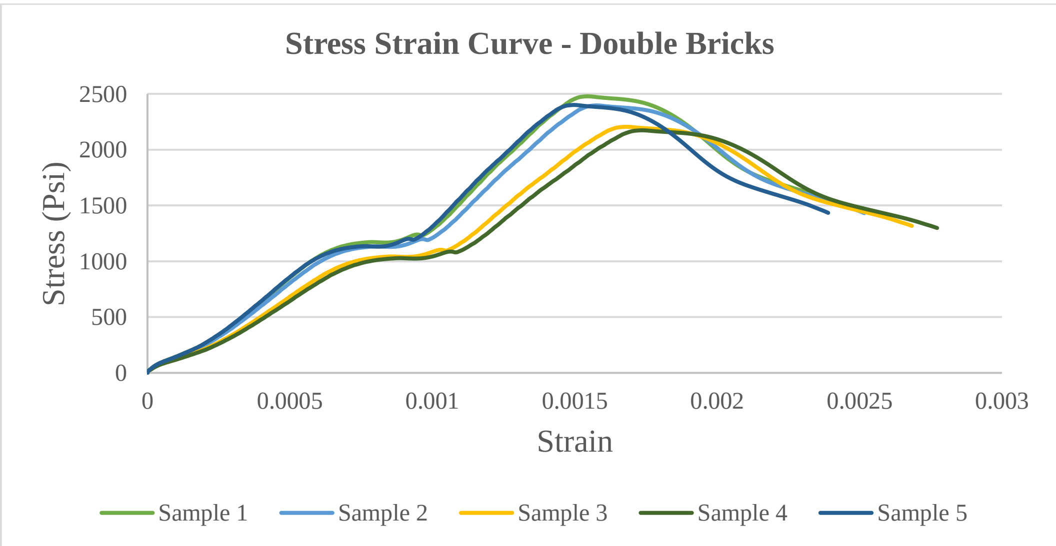
4.3 Results of Compressive Strength for Double Interlock Bricks

A comprehensive compressive strength test was conducted on five double interlock bricks, each having an area of 42.96 square inches. The results sample 1 exhibited outstanding strength, withstanding a significant load of 106,495.9803 pounds, resulting in compressive strength of 2,478.95671 pounds per square inch (psi). The other samples also demonstrated notable compressive strength values, ranging from 2,397.265452 psi to 2,401.356985 psi. The average compressive strength across all samples was about 2,331.5 psi. The results obtained from the compressive strength test on double interlock bricks are as follows.

Table 4.4 Compressive Strength of Double Interlock Bricks

S. No	Area (in2)	Load (lb)	Compressive Strength (Psi)	Average Compressive Strength (Psi)
Sample 1	42.96	106496	2478.95671	2331.499839
Sample 2	42.96	102986.5	2397.265452	
Sample 3	42.96	94754.91	2205.65425	
Sample 4	42.96	93406.46	2174.2658	
Sample 5	42.96	103162.3	2401.356985	

The relationship between compressive strength and strain for double interlock bricks is.



Graph 4.4 Stress Strain Curve for Compressive Strength of Double Interlock Bricks

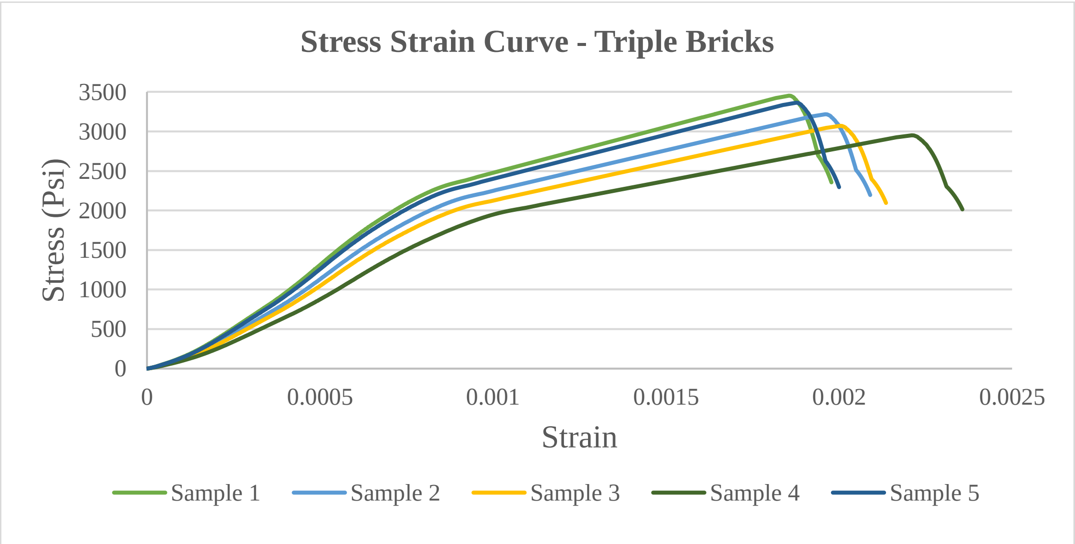
4.4 Results of Compressive Strength for Triple Interlock Bricks

Five triple interlock bricks were tested for their compressive strength. Each brick had an area of 64.44 square inches. The test results. one sample had the highest compressive strength, withstanding a load of 222,483.6 pounds equivalent to a compressive strength of 3,452.6 (psi). The other samples also showed good compressive strength, ranging from 3,217.7 psi to 3,363.6 psi. The average compressive strength across all samples was approximately 3,211.24 psi. This shows that the triple interlock bricks have consistent and dependable strength properties. The results obtained from the compressive strength test on triple interlock bricks are as follows.

Table 4.5 Compressive Strength of Triple Interlock Bricks

S. No	Area (in2)	Load (lb)	Compressive Strength (Psi)	Average Compressive Strength (Psi)
Sample 1	64.44	222483.6	3452.5698	3211.239476
Sample 2	64.44	207339.7	3217.5625	
Sample 3	64.44	197911.7	3071.2548	
Sample 4	64.44	190178.8	2951.25458	
Sample 5	64.44	216747.5	3363.5557	

The relationship between compressive strength and strain for Triple interlock bricks is.



Graph 4.5 Stress Strain Curve for Compressive Strength of Triple Interlock Bricks

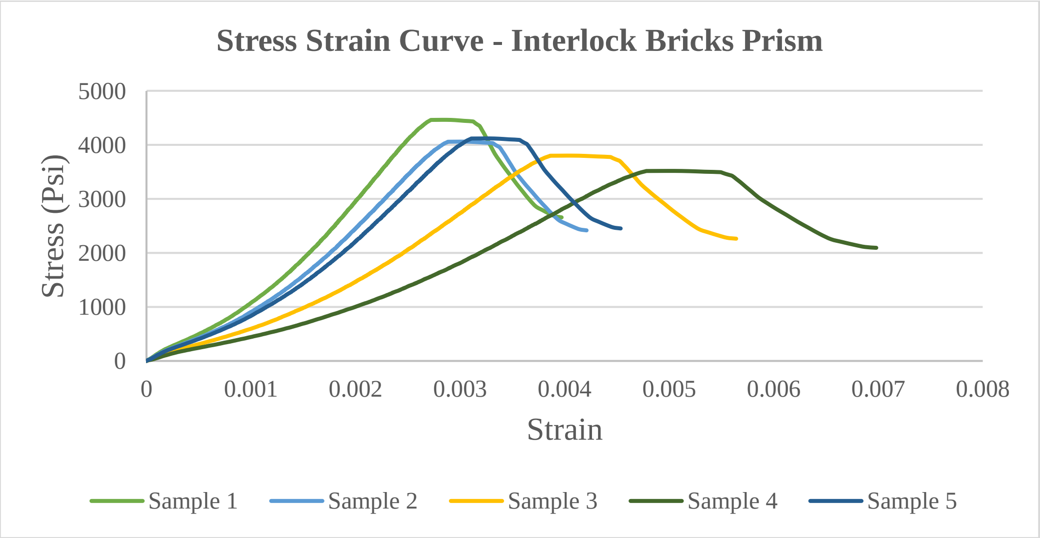
4.5 Results of Compressive Strength for Interlock Brick Prism

We have tested five samples of interlock brick prism for compressive strength. The results showed that the compressive strength of the samples ranged from 3519.26 psi to 4465.41 psi. Each sample had an area of 23.42 in^2, one sample can bear a load of 104579.9608 lb which means the brick have maximum of 4465.4125 psi compressive strength. The average compressive strength across all samples is 3993.8 Psi which indicate the ability of the interlock bricks to withstand compressive forces. The results obtained from the compressive strength test on interlock brick prisms are as follows.

Table 4.6 Compressive Strength of Interlock Brick Prisms

S. No	Area (in2)	Load (lb)	Compressive Strength (Psi)	Average Compressive Strength (Psi)
Sample 1	23.42	104580	4465.4125	3993.775116
Sample 2	23.42	95114.59	4061.2547	
Sample 3	23.42	89048.85	3802.2568	
Sample 4	23.42	82421.07	3519.26	
Sample 5	23.42	96506.6	4120.69158	

Below is the relationship between compressive strength and strain for interlock bricks prism.



Graph 4.6 Stress Strain Curve for Compressive Strength of Interlock Brick Prisms

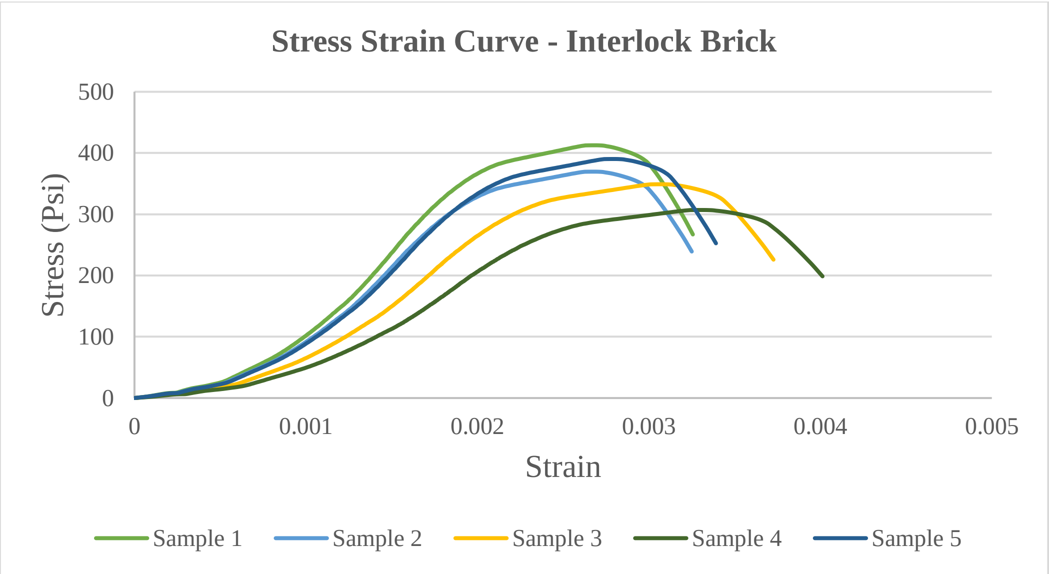
4.6 Results of Flexural Strength for Interlock Brick

We have performed a flexural strength test on five interlock bricks to assess their ability to withstand bending forces. The results highlight the varying flexural strength values among the interlock bricks. One sample exhibited the highest flexural strength with 412.5 Psi, while one sample showed the lowest with 306.896 Psi. The average flexural strength across all samples was calculated to be 365.5748 Psi. The measured flexural strength for each sample are as follows.

Table 4.7 Flexural Strength of Interlock Bricks

S. No	Flexural Strength (Psi)	Average Compressive Strength (Psi)
Sample 1	412.5	365.5748
Sample 2	369.457	
Sample 3	348.8964	
Sample 4	306.896	
Sample 5	390.1246	

Below is the relationship between flexural strength and strain for interlock bricks prism.



Graph 4.7 Stress Strain Curve for Flexural Strength of Interlock Bricks

4.7 Results of Efflorescence Test for Interlock Brick

We have conducted an efflorescence test on five interlock bricks to evaluate the presence of soluble salts on their surface. Among the five interlock brick samples tested, only2 samples exhibited visible efflorescence with 2% each, while other samples displayed no visible efflorescence on their surfaces. The results, expressed as the percentage of efflorescence, along with the average compressive strength, are as follows.

Table 4.8 Efflorescence Test Results for Interlock Brick

S. No	% of Efflorescence	Average Compressive Strength (Psi)
Sample 1	0	0.8
Sample 2	0	
Sample 3	2	
Sample 4	2	
Sample 5	0	

The efflorescence limit for interlock bricks indicates that tendency of bricks for efflorescence is negligible in the test samples as it is way less than the criterion for mild efflorescence (10% for mild efflorescence.

4.8 Results of Durability Test for Acid Immersed Interlock Bricks

Results have been obtained from the Schmidt hammer test for durability of Acid immersed interlocking bricks the results for immersing in interlocking bricks in HCl and H2SO4 are as follows.

4.8.1 Results HCl Immersed Interlock Brick

We conducted a durability test using the Schmidt hammer apparatus on interlock bricks exposed to varying concentrations of hydrochloric acid (HCl). The results demonstrated the impact of HCl immersion on the bricks' durability, measured in Psi. Normal bricks, without HCl exposure, exhibited the highest average durability at 1650 Psi. However, when subjected to 5 percent HCl immersion, the average durability decreased to 1500 Psi, and further immersion in 10 percent HCl resulted in an average durability of 1450 Psi. The overall results for measuring the durability of HCl immersed bricks are as follows.

Table 4.9 Durability of HCl Immersed Interlock Bricks

Brick Sample	Sample 1 Durability (Psi)	Sample 2 Durability (Psi)	Average Durability (Psi)
Normal Bricks	1600	1700	1650
5 Percent HCl	1400	1600	1500
10 Percent HCl	1400	1500	1450

The comparison between normal bricks and HCl immersed brick is shown below.

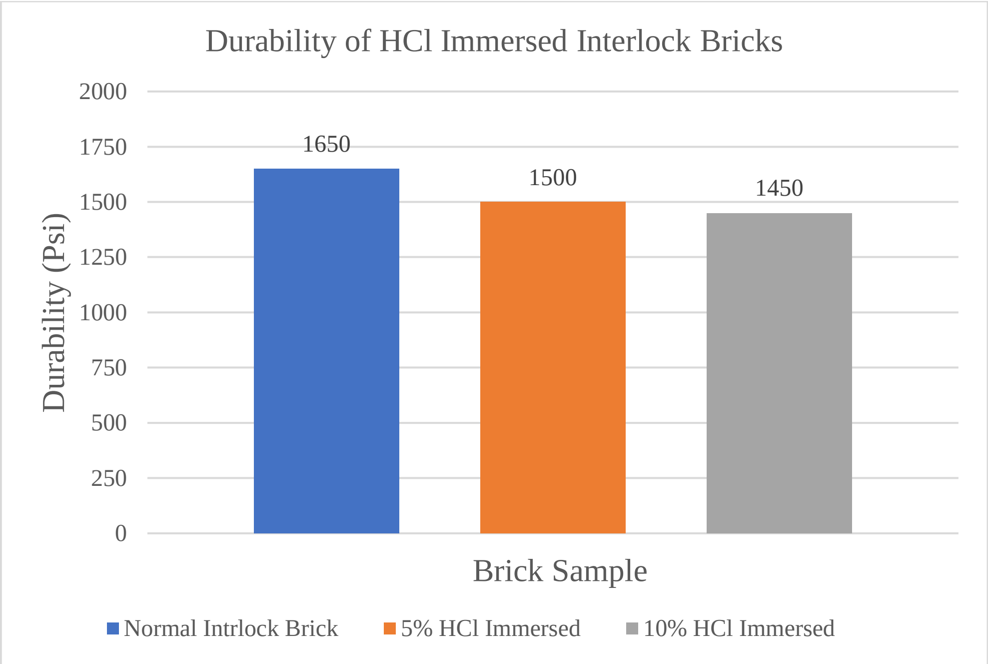


Chart 4.1 Durability Comparison of HCl Immersed Interlock Bricks

4.8.2 Results of H2SO4 Immersed Interlock Brick

Interlock bricks underwent a durability test to assess their response to different concentrations of sulfuric acid (H2SO4) using the Schmidt hammer apparatus. The durability of each sample was measured in Psi. The result revealed that normal Bricks had an average durability of 1650 Psi, while bricks exposed to 5 percent H2SO4 exhibited an average durability of 1450 Psi and interlock bricks immersed in 10 percent H2SO4 demonstrated an average durability of 1400 Psi. The results highlight a significant reduction in durability with increasing sulfuric acid concentration. The overall results for measuring the durability of H2SO4 immersed bricks are as follows.

Table 4.10 Durability of H2SO4 Immersed Interlock Bricks

Brick Sample	Sample 1 Durability (Psi)	Sample 2 Durability (Psi)	Average Durability (Psi)
Normal Bricks	1600	1700	1650
5 Percent H2SO4	1400	1500	1450
10 Percent H2SO4	1300	1500	1400

The comparison between normal bricks and H2SO4 immersed brick is shown below.

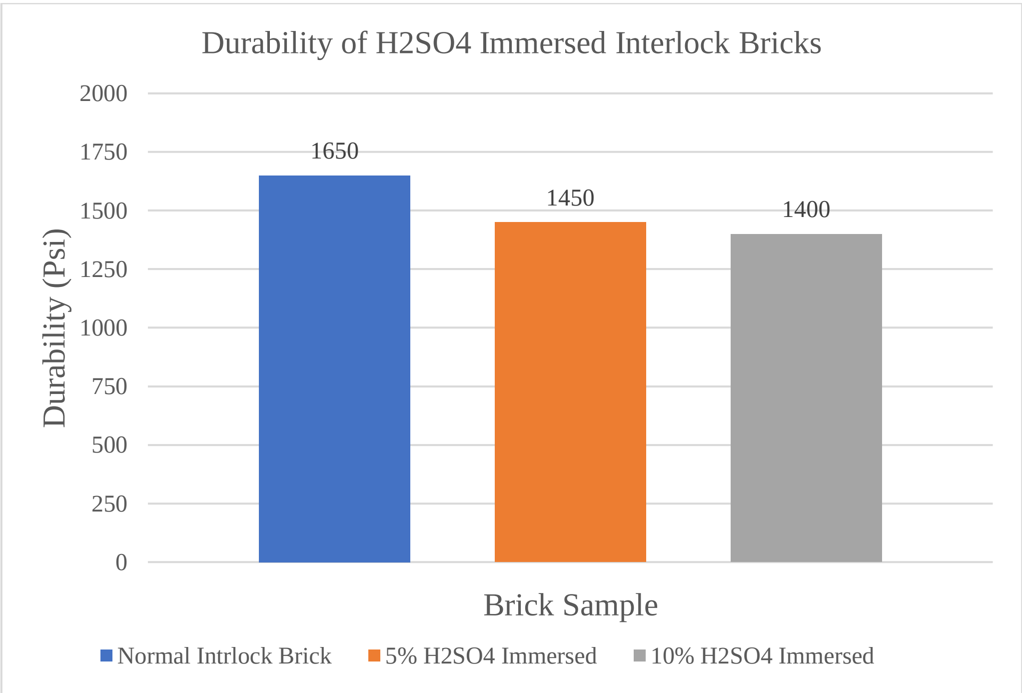


Chart 4.2 Durability Comparison of H2SO4 Immersed Interlock Bricks

Chapter 5

5 Conclusion and Recommendation

- Interlocking clay bricks present an excellent option instead of traditional brick systems, offering cost-effective and structurally reliable construction solutions. Choosing interlock bricks also promotes eco-friendly construction practices, reducing environmental impact while providing durable and efficient building solutions.\.
- Traditional brick systems require a lot of mortar, which leads to delays in construction and longer project schedules while interlock bricks do not rely on mortar, allowing for quicker and more efficient building completion.
- Traditional brick structures, without proper bonding, lack sufficient strength to withstand seismic events, making them vulnerable to potential damage or collapse during earthquakes while self-interlocking clay bricks offer enhanced flexural strength, making them more resistant to seismic forces and significantly improving the overall stability of structures.
- In traditional brick systems, the use of mortar for bonding can result in high material and labor costs due to the need for mixing, applying, and curing. However, interlock bricks offer a cost-effective solution as they eliminate the need for mortar, reducing material usage and labor expenses. This makes interlock bricks a more economical choice for construction projects.
- The average compressive strength of interlock bricks surpassed the minimum requirements for load-bearing applications. This high compressive strength ensures that interlock bricks can withstand heavy loads effectively, thereby enhancing the overall structural integrity of buildings and infrastructure which means interlock bricks is a reliable and durable construction material choice.
- The compressive strength of interlock brick prisms remained consistent and dependable. This reliability makes interlock bricks predictable and ensures they perform uniformly in different construction projects, making them a reliable and trustworthy choice for construction materials.
- The flexural strength of interlock bricks can handle bending forces well, making them more durable and less prone to cracking or bending. The flexural strength of interlock

bricks improves their lifespan, reducing maintenance costs and ensuring longer-lasting structures.

- Interlock bricks have a very low tendency to develop efflorescence, making them suitable for construction in different environmental conditions. Their resistance to efflorescence ensures that structures maintain their aesthetic appeal and appearance over time, without the formation of unsightly white deposits.
- The durability of interlock bricks with exposure to HCl and H2SO4 showed a slight reduction in strength, but interlock bricks remained strong enough for construction use. Even after exposure to harsh chemicals, interlock bricks remain durable for practical applications, ensuring their reliability and performance in tough conditions.

5.1 Recommendations

- Promote the use of interlock masonry in green building rating systems and certifications. Recognize the eco-friendly nature of interlock bricks to motivate their inclusion in environmentally conscious construction projects.
- Conduct additional research to explore the long-term effects of exposure to harsh chemicals on interlock bricks. This will help enhance the understanding of their chemical durability and suitability for specific applications in corrosive environments.
- Investigate potential advancements in interlock brick design to further improve their mechanical properties, such as compressive and flexural strength. This could lead to even more durable and resilient interlock bricks for various construction needs.
- Raise awareness among builders, developers, and consumers about the benefits of interlock masonry. Educate stakeholders about the advantages of using interlock bricks for sustainable and cost-effective construction solutions.
- Monitor the performance of structures built using interlock brick masonry in real-world applications over an extended period. Long-term data on durability and structural performance will provide valuable insights for future improvements and optimizations.

6

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