

## EXPERIMENTAL STUDIES ON EFFECT OF STEEL FIBRE, PVC FIBRE AND JUTE FIBRE ON THE ENGINEERING CHARACTERISTICS OF ECO-FRIENDLY INTERLOCKING MUD BRICKS

Gunarani G<sup>1\*</sup>, Karthikeyan B<sup>2</sup>, Deepak Kumaran<sup>3</sup>, Naresh Kanna P G<sup>4</sup>, Praveen G<sup>5</sup>

<sup>1</sup>Assistant Professor, School of Civil Engineering, SASTRA Deemed University, Thirumalaisamudram, Thanjavur, TamilNadu 613401, India.  
[gunarani@civil.sastra.edu](mailto:gunarani@civil.sastra.edu)

<sup>2</sup>Assistant Professor, School of Civil Engineering, SASTRA Deemed University, Thirumalaisamudram, Thanjavur, TamilNadu 613401, India.  
[karthikeyan@civil.sastra.edu](mailto:karthikeyan@civil.sastra.edu)

<sup>3</sup>Former UG Student, School of Civil Engineering, SASTRA Deemed University, Thirumalaisamudram, Thanjavur, TamilNadu 613401, India.  
[deepakkumaran2001@gmail.com](mailto:deepakkumaran2001@gmail.com)

<sup>4</sup>Former UG Student, School of Civil Engineering, SASTRA Deemed University, Thirumalaisamudram, Thanjavur, TamilNadu 613401, India.  
[nareshkannap@gmail.com](mailto:nareshkannap@gmail.com)

<sup>5</sup>Former UG Student, School of Civil Engineering, SASTRA Deemed University, Thirumalaisamudram, Thanjavur, TamilNadu 613401, India.  
[praveenkvs2001@gmail.com](mailto:praveenkvs2001@gmail.com)

\*Corresponding author: [gunarani@civil.sastra.edu](mailto:gunarani@civil.sastra.edu)

### Abstract

The usual method of rising wall in both ancient and modern times are done by filling mortar in between bricks, now cement and M-sand are being used for mortar, which are destructing natural resources, so to avoid this, there comes Interlocking mud bricks, the projection at the top and depression at the bottom are responsible for the interlock mechanism, also good in earthquake-resistant structure, As this is interesting and the product is eco-friendly too, we developed an interest in it. We visited a manufacturing unit and a residential construction entirely done by mud interlock brick, the one major drawback we noticed is that it produces cracks and breaks at edges, which reduces strength, life span, aesthetics and possible threat to infestation. This is the main problem statement of our project. To overcome this, we added fibres during the blending process, namely Steel fibre (0.1%, 0.2%, 0.3%), Jute fibre (0.4%, 0.6%, 0.8%) and PVC fibre (0.6%, 0.8%, 1.0%) which leads to an increase in compressive and flexural strength. The PVC fibre of 0.8% mix ratio produced 39% higher compressive strength when compared to Interlocking mud bricks, which is much higher than all other fibres mainly due to its flexibility and shape factors.

**Keywords:** *Interlocking mud bricks, Steel fibre, Jute fibre, PVC fibre, Compressive and Flexural Strength.*

### 1. INTRODUCTION

#### 1.1 General

Nowadays the building wall materials are largely done by clay bricks which require combustion to produce good quality clay brick, this is then followed by laying mortar in between the bricks, in all these we see greater environmental cause due to high usage of cement, Msand, wood required to burn bricks and finally the carbon gas released due to combustion, all these will soon leads to greater destruction of ecological balance, to eradicate these problems to some extent there comes a great product mud interlocking brick in the market which is made out of mud and very less cement, lime and Msand. Clay bricks are currently the most common material used to construct walls, and combustion is necessary for the drying process. Blocks typically require plaster and accuracy in the field. Materials that are simple to install, sturdy, and environmentally benign are desperately needed to meet these objectives. Advent of interlocking mortarless brickwork has led to a significant increase in field profitability and effectiveness as well as a reduction in the need for extremely specialised work teams. In addition, the use of interlocking blocks as an alternative to conventional blocks for sturdy and long-lasting buildings has gained rapid popularity in many foreign countries. Compared to normal blocks, interlocking blocks are special because there is no need for mortar to be put in between the layers of blocks during building. Interlocking bricks must be created to provide wall materials that are simple to install, durable, and environmentally beneficial. This time, the combustion process is avoided when creating interlocking bricks by adding a cement mixture. The objective is to develop into an interlocking brick that protects the environment and ensures healthy survival for the coming generation. Clay, which must be removed as raw material from brick, is typically a key component in the production of bricks. However, because of environmental harm, these raw materials will eventually become scarce or be subject to excavation limits. Depending on the materials' availability in the area being developed, there are numerous varieties and comparisons of mixed materials used to create an interlocking brick. Cement and compressed soil are combined to create interlocking brick, also known as Interlocking Compressed Earth Block (ICEB). When making interlocking bricks, a mixture of materials consisting of Mud, M-sand, Cement and Water with varying percentages of 40%, 30%, 20%, and 10% respectively, was used to provide the best durability, the desired con-stability, and compressive strength testing of the work's most stable. Here we intend to increase strength, durability, flexibility and other such factors by adding some materials which are durable, strong and mainly flexible. The first material to be blended is crippled steel fibre of size 30 mm, secondly jute fibre of same size and lastly PVC fibre. Here we took three fibres into action based on its make, steel fibre which is machine-cut artificial fibre, next jute is a handmade cut and naturally available fibre and lastly, we extracted PVC fibre from waste electrical wires, this idea was generated out of an interest in reusing the waste materials also comparing its properties like strength, durability to standard fibres.

#### 1.2 LITERATURE REVIEW

**1.2.1 Development of Interlocking Masonry Bricks and its Structural Behavior:** In this technical paper, the authors Amin Al-Fakih, Bashar S Mohammed, Fadhil Nuruddin and Ehsan Nikbakht aimed to analyse the development of interlocking brick and its structural behavior. According to them, the interlocking system concept has been applied widely in place of the traditional system. It may be inferred that the interlocking bricks simple shapes allow for quick and simple production and assembly in masonry systems. Additionally, the locking characteristics of each type of interlocking brick are sufficient to interlock the assembled bricks in various directions. It is possible to draw the conclusion that interlocking block complied with the least criteria and requirements set out by American and British Standards based on study into the structural behaviour of interlocking bricks. Additionally, they demonstrated that interlocking brick may be applied for both load-bearing walls and non-load-bearing building structures.

**1.2.2 Experimental Study of Fibre-reinforced Interlocking mud bricks under Compressive test:** The authors of this paper Muhammad, Muhammad Azhar Saleem et.al, created an interlocking mud brick that could be manually squeezed to analyse its compressive strength. To do this, mud bricks with rice husk and wheat straw (1-4 % of the soil's weight) were created based on 1 to 5 % by weight of soil. Additionally, lime (12%, 15%, and 19 % by weight of soil) and straw husk of 1 to 4 % by weight of soil were tested also a mixture of wheat straw and rice husk were used in the production of mud bricks. The Compressive strength experiment was done to examine the interlocking mud brick's strength and failure pattern. Shrinkage fissures were visible in the control mud bricks, but they weren't visible in the fibre-infused examples (wheat straw, rice husk and straw husk). With increasing fibre concentration in the specimens of mud bricks, a drop in compressive strength was seen. Also, interlocking mud bricks with inclusion of fibres met the nominal strength values of mud-brick standards. When lime was added as a filler, the compressive strength of the mud bricks likewise decreased. However, these bricks containing lime up to 19% met the standards of the nominal strength criterion. As a result, earthen architecture can use Interlocking mud bricks including lime & fibres for sustainable constructions. Shrinkage fissures may be seen in the control mud bricks. However, specimens using fibres showed no evidence of shrinkage cracking. Finally, they concluded that Interlocking mud bricks with addition of lime and fibres can be utilised in earthen buildings as a long-lasting, cost-effective, and eco-friendly material.

**1.2.3 Performance of Steel Fibre Reinforced Interlocking Hollow Block as Load Bearing Wall:** The authors of this paper Sarath P, Pradeep P and Shemy S Babu have proposed to make a hollow concrete block with interlocking joints using M10 mix and the surface is thoroughly

polished as it is the prime concern. The trial-and-error methods were used for control fixing. The hooked end steel fibres were used to strengthen the blocks. a hollow concrete block with interlocking joints. The usage of hollow steel-fibre-reinforced blocks as load-bearing walls is beneficial. The main purpose of this research is to evaluate the load-bearing capacity of the wall with a dimension of 90 cm wide and 90 cm tall and was constructed of hollow blocks. The work is done faster as the interlocking pattern helps with proper alignment. The failure was developed in the joints. The load-bearing capability of a masonry wall made of steel fibre reinforced hollow blocks were higher by 12 and 23% respectively than that of masonry walls made of locally accessible solid and hollow blocks. Face shells coming off hollow block masonry walls caused them to collapse. Detaching of face shells causes hollow block masonry to fail. Compared to locally available solid and hollow blocks, Steel fibre reinforced hollow block reduces the dead load by 28% and 11%. From the result, the authors mentioned that these hollow bricks provide considerable strength to the wall and overall, it reduces the cost of construction.

**1.2.4 Effect of Steel Fibres on the Compressive and Flexural Strength of Concrete:** In this experimental research, Ashfaque Ahmed Jhatial, Samiullah Sohu, et al. used steel fibre as reinforcement in concrete to find the effect on the workability of concrete, flexural strength and compressive strength respectively. According to their findings, the workability was negatively impacted by the reinforcement of steel fibres and as the content of fibre increased, the workability was reduced. On the other hand, the mechanical properties of concrete with the inclusion of steel fibres were significantly improved, obtaining greater strength than the control sample. The compressive strength of concrete is increased by the addition of steel fibres; however, the improvement is comparatively small. The rise was between 9.77% and 18.27%. However, due to an improvement in the ductility behaviour of concrete, the addition of steel fibre to concrete had a substantial impact on the flexural strength. The improvement in flexural strength ranged from 17% to 51.72%. With a 3 percent addition, the highest value of compressive and flexural strength was obtained; as the fibre content increased more, the strength declined. Therefore, it was concluded that 3 percent was the ideal dosage for steel fibres. Despite the 5 percent reinforcement, the compressive and flexural strengths are still higher than in the controlled sample.

**1.2.5 A Study on Compressive Strength Attributes of Jute Fiber Reinforced Cement Concrete Composites:** In this paper, N.Dayananda investigated mechanical properties of jute with cement concrete composites. He chopped jute fibers into 10 mm which are mixed of cement, sand and coarse aggregate with the w/c ratio of 0.45. The mixed specimens are casted for different mixes of 0.2%, 0.4% upto 1.8%) and finally it is cured for 3, 7 and 28 days respectively. The author's objective is to design the mix to attain the strength of 26.6 MPa, at a mix ratio of 1:1.41: 2.83. He observed that the standard concrete specimen's compressive strength increases from 8.8 N/mm<sup>2</sup> upto 44.44 N/mm<sup>2</sup> due to the adding of jute fibres. The compressive strength decreases as the fibre content rises above 0.4 percent. The insufficiency of adequate compaction is demonstrated by poor workability that results from excessive fibre addition. The optimal dose of fibres for concrete to reach its highest compressive strength is determined to be 0.4 percent.

**1.2.6 Characterisation of Jute fiber Reinforced Adobe Brick and Brick masonry :** The authors of this paper Monika H and Sujatha Unnikrishnan proposed research to enhance the performance of adobe bricks by reinforcing with different percentages (1% and 2%) of jute fibres of varying lengths (1cm, 2cm and 3cm) respectively. They conducted comparative research on jute fibre reinforced and unreinforced adobe bricks and brick masonry based on its compressive strength and shear bond strength. As the amount of jute fibre in bricks increases, the compressive strength also increases. It was difficult to obtain a homogeneous mix when the amount of jute fibre was increased to 3 percent, thus the proportion of fibre was limited to 2 percent. They observed that, when the jute fibre of 2 cm length in 1 percent was added, the weight of the jute fibre reinforced brick decreased by 10%. When compared to unreinforced bricks, adobe bricks reinforced with jute fibres have demonstrated better compressive strength. When compared to unreinforced bricks, the compressive strength of bricks reinforced with jute fibres of 2 cm in length and 1 percent (M2) increases by 73%. They concluded that When jute fibre of length 2 cm and 1% was utilised in bricks and by adding jute fibre reinforced mortar, the shear bond strength of an adobe brick triplet increased by 79%. Hence there is an increase in compressive strength of brick and mortar in fibre-reinforced adobe bricks.

**1.2.7 Performance of concrete with PVC fibres:** Both the authors of this paper Senthil Kumar Kalya Vardhan and Tung chai ling have made statements stating that they will introduce a new product of fibre reinforced concrete by mixing PVC cables obtained from E-waste across construction areas, as it would be the best way to dispose way the PVC waste, in his papers performance of PVC fibres with fresh concrete in hardened state are checked, in this it has been suggested that adding PVC fibres at the rate of 0.2 percent of 0.8 percent at the weight of concrete, could greatly enhance concretes performance, hence from the result we could know that with more PVC fibres present concretes workability decline. The incorporation of PVC happens to reduce the fresh and dry density, but the amount reduced is less. PVC fibres are added to concrete to increase their compressive strength, flexural strength, split tensile strength and modulus of elasticity gets increased. The variations in the properties of PVC and FRC are due to its own characteristics such as, shape, alignment, quality, size, orientation, additional method along PVC fibres, by adding 0.2% by adding weight of concrete and 0.8% by weight of cement PVC fibres could increase concretes performance without suffering any appreciable loss.

**1.2.8 Novel Fibrous Concrete Mixture Made from Recycled PVC Fibers from Electronic Waste:** The authors of this paper, Arjun Ramakrishna Kurup and K. Senthil Kumar have proposed fibre-reinforced concrete and silica fibre-reinforced concrete, for this the ideal the amount of adding the e-waste fibres to the concrete was determined to be 0.8% with respect to the weight of cement. As a result, fibre-rcc and silica fibre-rcc made using e-waste fibres were an option to regular concrete since they had improved characteristics and cause less e-waste to be dumped into the environment. It also investigates the percentages of e-waste fibres utilized in concrete at 0.6, 0.8, and 1% of cement weight. These inferences can be made in light of the experimental investigation. In adding 0.6% & 0.8% of e-waste fibres with regard to the weight of cement to the fibre-rcc and silica fibre-rcc result an increasing trend in compressive strength, split tensile strength and flexural strength. The slump values were within the design slump of 50 to 75 mm. The hardened characteristics of both fibre-reinforced concrete and silica fibre-reinforced concrete, however, exhibit a gradually rising as contrasted to when e-waste fibres are added at 1% of the cement.

### 3. MATERIALS AND METHODOLOGY

#### 3.1 MATERIALS:

**3.1.1 SOIL:** Soil is a homogeneous and isotropic property. Here we took murrum soil as our material, under laterite soil murrum is dirt. Iron and aluminium are abundant in laterite, both as soil and rock formation. Although murrum soil is sometimes referred to be a rock type, rocks are not what it is. The deeply worn layer from which silica has been leached distinguishes it. As a result, there is a concentration of aluminium, iron, and hydroxide oxides rather than humus. The iron compounds in these soils give them their reddish colour. The Murrum sand passing through a sieve of size 4.75 mm is taken into consideration. The Specific gravity test was conducted using pycnometer and got a value of 2.66g/cc.

**3.1.2 M-SAND:** M-sand is manufactured from crushed rock or granite. It is used as a substitute for river sand. The M-sand passing through a sieve of 4.75 mm size. In this project's work, a fine aggregate consisting of zone II of IS 383- 1970 M-sand that passes through a sieve of 4.75 mm size is used. It may be deduced from the results of the material testing this has a specific gravity of 2.60 and a water absorption rate of 1%.

**3.1.3 CEMENT:** In this project we used freshly manufactured Portland Pozzolana Cement (PPC). PPC was chosen because it has pozzolanic components, fly ash and was easily accessible. The cement qualities were confirmed to several requirements listed in IS 1489-1991 part 1 and it was tested for various preparations in accordance with IS: 4031-1988. The cement used has a specific gravity of 3.14 and a typical consistency of 32%.

**3.1.4 STEEL FIBRE:** Crimped steel fibres are being used as a fibre material in interlocking mud bricks to avoid cracks and increase the strength of blocks. The steel fibre is having good bending strength, shear strength and is designed in a way to manage temperature and shrinkage cracking. These mainly bridge between cracks, which forms a complex structure in different orientation and direction. These are rigid materials which has their tensile strength vary from 345 to 1380 MPa, modulus of elasticity is 200 Gpa and melting point is 1550 degree Celsius. (Fig 4.1)



**Fig 4.1 Steel Fibre**

**3.1.5 JUTE FIBRE**

Jute fibres are completely biodegradable and reusable, making them green resources. Jute fibres are effective insulators of both thermal and acoustic energy. Cellulose 64.4 %, hemicellulose 12%, pectin 0.2 %, lignin 11.8%, water soluble 1.1%, wax 0.5% and water make up the chemical makeup of jute fibre 10 %, this is the second important fibre cultivated after cotton (Fig 4.2).



**Fig 4.2: Jute Fibre**

**3.1.6 PVC FIBRE**

This Polyvinyl Chloride in another words PVC fibre, is a waste material generated out of extracting the copper wire separately and then cutting the electrical wires into 30 mm pieces and so after those pieces are cut longitudinally into two quarters and one half. In this way we produce the fibre from waste material. (Fig 4.3)



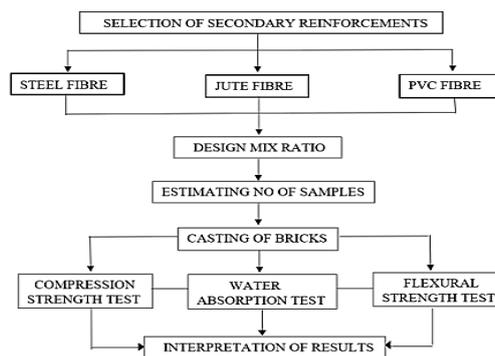
**Fig 4.3 PVC fibre**



**Fig 4.4 Interlocking Mud Brick**

**4.METHODOLOGY:**

The flow chart below shows the methodologies we adopted in this study from design of mix to the interpretation of the results.



**Fig 4.5 Methodology flow charts**

The fibre which we are using is from three different origins, artificial, natural and waste materials. As Steel fibre was obtained directly from the manufacturer, it comes in precise size, and shape. Jute fibre is also being procured from manufacturer but not in precise form, rather it is available in long straight form, which we manual cutting into 30 mm strips by marking, the last one PVC fibre was manually procured from a houses electrical waste, where we separated the copper wire from PVC material, then we cut that hollow cylindrical structure into 30 mm sizes again by marking, now if the fibre is left in its original hollow cylindrical form, then there won't be good friction between soil particles and fibre pieces, this creates voids in bricks, which the brick leads to lose its integrity, so to avoid this, the hollow cylindrical PVC fibre piece is again cut in longitudinal direction into three pieces, such that the cross sectional view will be two quare circles and one half circle, this forms a good bonding capacity between soil particles and fibre materials, we ensured the bonding capacity to be high between fibres and particles, steel fibre has good bonding fibre due to its crimped shape, jutes bonding is also good due to its porous nature, now these fibres are well mixed into soil mix manually, these ,mix are carefully poured into moulds and the after hydraulic press , these comes out as an strong well bonded fibre reinforced interlocking mud brick, this is initially left for 24 hrs in shade, after this time period the brick in water cured for about 7 days, it is left free in a pit containing water when this 7 days are over it is sun dried for about 1 day, now in this stage it is ready to dispatch and attains its required strength, now, this is been brought to testing laboratory, firstly water absorption and efflorescence test taken, another side we prepared the mud interlocking brick by applying mortar on depressed and projected parts to make the surface

levelled for obtaining exact results of compressive strength test and flexural strength test, after applying mortar it is left for 3 days curing, then the strength test are performed in respective testing machines.

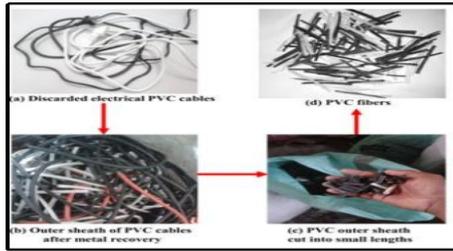


Fig 4.6 Process of PVC fibre



Fig 4.7 Half-cut PVC fibre

#### 4.1 BLENDING OF FIBRES INTO SOIL MIX

We have blended the fibres into the mixture as per mix proportions and have been noted separately for each fibre.



Fig 4.8 Blending of Fibres into Soil

#### 4.2 CASTING OF BRICKS IN HYDRAULIC COMPRESSOR

We have casted the bricks under hydraulic compressor of 1.2 tonne pressure and the brick comes out as two upper half portions which is projected outward and the mid bottom is projected inward.



Fig 4.9 Casting of Bricks in Compressor

#### 4.3 CURING PIT

After 24 hours of casting the bricks have been cured in water for 7 days at less than 12 degrees Celsius. Due to the presence of cement and as per IS 1077(1992) the brick is cured for 7 days. After curing, the bricks are allowed to dry under the hot sun for a period of 24 hours.



Fig 4.10 Curing Of Bricks

#### 4.4 APPLYING MORTAR ON BRICKS

After curing mortar is applied on the top projection of bricks and also applied on the bottom inward portion such that both surfaces have an equal level. Which is generally applied for one inch on both sides. The mortar is applied in a ratio of 1:3.



Fig 4.12 Applying of mortar



Fig 4.13 Mortar applied bricks

#### Average Dry Weight of Fibre infused Interlocking Mud Bricks:

We have taken these values into account for the testing of bricks (i.e., Water absorption)

#### 4.5 MIX PROPORTIONS:

Dimensions: The standard size of Interlocking brick shall be as follows

**Table 4.1: Dimensions of brick**

Length (mm)	Width (mm)	Height (mm)
300	200	125

The mix proportion is one important factor for any project to be successful and to produce good results, in this we have taken the mix proportion based on standard journals and mainly by considering its volume and density of that fibre which is to be blended into the soil mix. Now volume is standard for all interlocking bricks, if the density is low, we have added high percentage of fibre, and if the density of fibre is high, we have added less amount of fibre. And by this way, we worked certain mix ratios and finally fixed them into the following percentages.

**Table 4.2: Mix proportion of brick**

STEEL FIBRE (Density - 7850 kg/m <sup>3</sup> )	JUTE FIBRE (Density - 1500 kg/m <sup>3</sup> )	PVC FIBRE (Density - 1290 kg/m <sup>3</sup> )
S 1 : 0.1% 68 g/ brick	J 1 : 0.4% 51.89 g/ brick	P 1 : 0.6% 67.28 g/ brick
S 2 : 0.2% 136.4 g /brick	J 2 : 0.6% 70.79 g /brick	P 2 : 0.8% 81.12 g /brick
S 3 : 0.3% 202.6 g/ brick	J 3 : 0.8% 94.36 g/ brick	P 3 : 1 % 101.40 g /brick

**4.6 COMPRESSIVE STRENGTH TEST:**



Fig 4.14: Compressive Testing Machine



Fig 4.15: Brick While Applying Load

The main indicator of brick's strength is its compressive strength. It is significant since it provides information on all of its attributes. The ability of a material to withstand loads before failing is known as its compressive strength. It refers to brick's capacity to withstand loads applied to it without cracking or deflection. The compression causes a material's size to decrease. To evaluate the compressive strength of the mix, interlocking mud bricks with different mix ratios varying in the percentage of fibres were casted. According to the IS 516-1959 standard test technique, a Compression Testing Machine (CTM) was used to test each specimen that had been cast for compression. The Interlocking mud brick is placed with its largest surface area being in horizontal position on testing machine, the load is being applied on the interlocking mud brick axially at a constant rate of 14 N/mm<sup>2</sup>/ minute (as per IS standards), the maximum load is being noted at the bricks failure and only this maximum load has to be taken into account.

**Table 4.3: Compressive Strength Data**

MIX ID	COMPRESSIVE STRENGTH (MPa)			AVERAGE (MPa)
	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3	
Standard brick	5.25	5.22	5.05	5.17
S1 (0.1%)	4.36	4.04	3.98	4.13
S2 (0.2%)	3.72	3.92	3.65	3.77
S3 (0.3%)	3.62	3.83	3.56	3.67
J1 (0.4%)	5.72	5.78	6.04	5.85
J2 (0.6%)	5.9	6.1	5.76	5.92
J3 (0.8%)	5.4	5.1	5.25	5.25
P1 (0.6%)	6.22	5.98	5.74	5.98
P2 (0.8%)	7.13	7.25	7.22	7.20
P3 (1%)	6.04	6.22	6.28	6.18

**4.7 WATER ABSORPTION TEST**

To assess a brick's durability, including its quality, and weathering behavior, a water absorption test is performed on the brick. Brick is more resistant to harm from freezing if its water absorption is less than 7%. A water absorption test may be used to determine how compact bricks are because brick pores absorb water. Bricks absorb more water as the number of pores increases. Therefore, bricks that absorb less than 3% of water can be described as vitrified. This test measures how much water the bricks can absorb, and the test's methodology is described below. The Interlocking brick is cooled down to room temperature, and its weight is noted as w<sub>1</sub>. Later on the dried brick is immersed into clean water at room temperature of 27 degrees for about 24 hours, after 24 hours the brick is taken out of water and any traces water to be removed with a damp cloth and now the brick is weighed again and noted as (w<sub>2</sub>), now the duration of these activities should be within 3 minutes after the specimen has been removed from water.

$$\text{Water Absorption} = ((\text{Saturated weight} - \text{Dry weight}) / \text{Dry weight}) \times 100$$

**Table 4.4: Water absorption of brick**

MIX ID	DRY WEIGHT (kg)	SATURATED WEIGHT (kg)	ABSORPTION (%)
Standard Brick	15.68	15.00	4.5
S1 (0.1%)	14.65	15.57	6.5
S2 (0.2%)	14.10	15.14	7.4
S3 (0.3%)	13.18	13.62	3.3
J1 (0.4%)	13.34	13.88	4.1
J2 (0.6%)	12.96	13.06	3.9
J3 (0.8%)	12.78	13.20	3.3
P1 (0.6%)	13.50	14.00	3.7
P2 (0.8%)	13.32	13.62	2.2
P3 (1%)	12.98	13.28	2.3

#### 4.8 FLEXURAL STRENGTH TEST

As interlocking bricks have distinct shapes on the top and bottom sides, flexural strength tests were conducted on both sides of the bricks. By applying mortar in a width and length that are equivalent to the width of the specimen, the load will be positioned in the middle of the brick. During the test, the specimen was held at both ends, allowing it to freely spin in both the longitudinal and transverse directions. Prior to the test, all samples were oven dried for 24 hours to maintain a consistent mass. To determine the flexural strength of the Brick, the distance between the plane of failure and the specimen's midspan toward the span was measured.



Fig 4.16: Universal Testing Machine (UTM)



Fig 4.17: Flexural behavior of brick

Table 4.5: Flexural strength of bricks

MIX ID	FLEXURAL STRENGTH		AVERAGE (Pa)
	SPECIMEN 1	SPECIMEN 2	
Standard Brick	0.672	0.7	0.686
S1 (0.1%)	0.682	0.68	0.693
S2 (0.2%)	0.172	0.183	0.177
S3 (0.3%)	0.324	0.348	0.336
J1 (0.4%)	0.344	0.321	0.333
J2 (0.6%)	0.58	0.634	0.607
J3 (0.8%)	0.25	0.237	0.243
P1 (0.6%)	0.817	0.867	0.842
P2 (0.8%)	0.652	0.664	0.658
P3 (1%)	0.664	0.688	0.676

The Modulus of rupture of each specimen is calculated in the following ways:  $S = 3W (L/2 - x) / bd^2$

S = modulus of rupture of the specimen at the plane of failure (Pa); W = maximum load indicated by the testing machine (N); L = distance between the supports (mm), b = net width (mm); d = depth, (bed surface to bed surface), of the specimen at the plane of failure (mm) and x = average distance from the midspan of the specimen (mm).

Graphical Representation of Displacement Vs Load Curve for Various Types of Fibres during the Application of Flexural Load:

#### STEEL FIBRE:

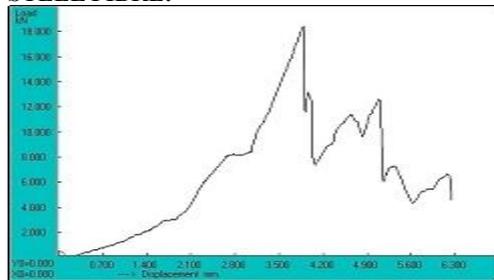


Fig 4.18: 0.1 % of Steel Fibre

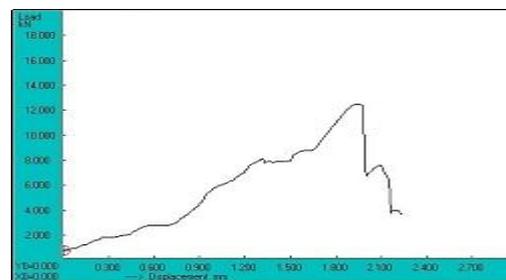


Fig 4.19: 0.2 % of Steel Fibre

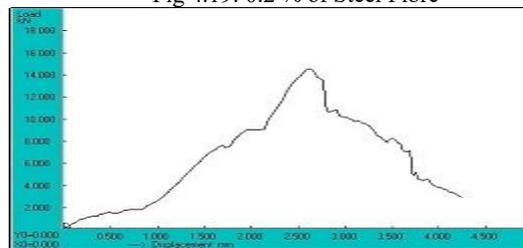


Fig 4.20: 0.3 % of Steel Fibre

#### JUTE FIBRE

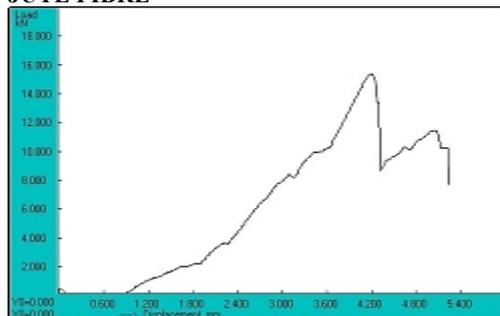


Fig 4.21: 0.4 % of Jute Fibre

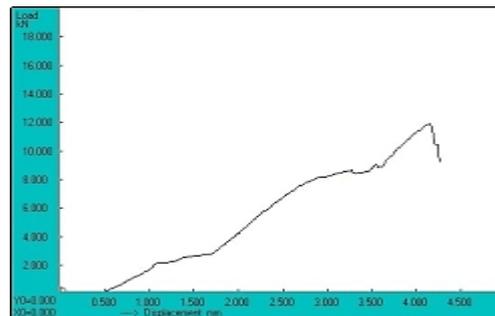


Fig 4.22: 0.6 % of Jute Fibre

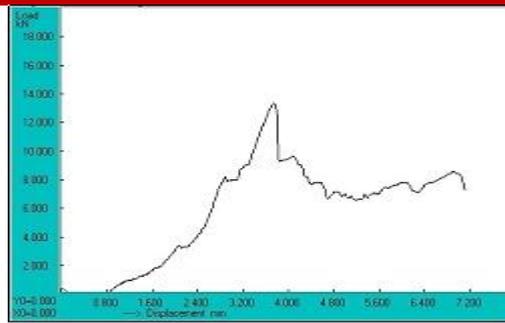


Fig 4.23: 0.8% of Jute Fibre

**PVC FIBRE**

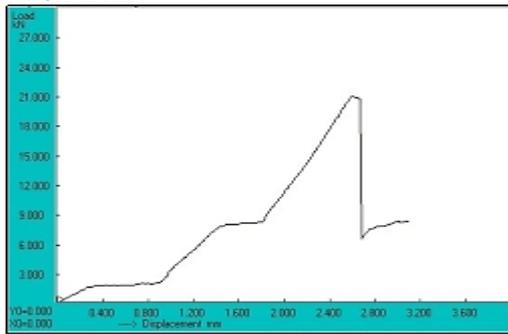


Fig 4.24: 0.6% of PVC Fibre

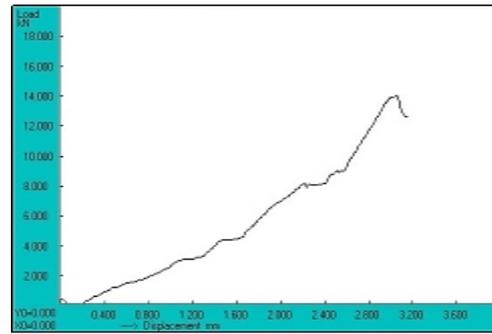


Fig 4.25: 0.8% of PVC Fibre

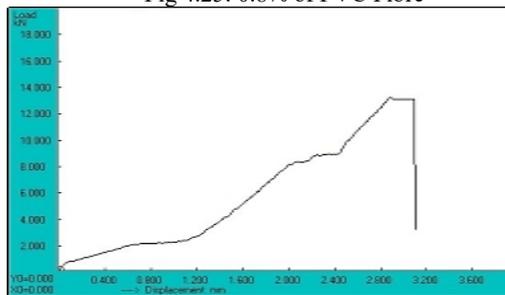


Fig 4.26: 1% of PVC Fibre

Fig 4.18, 4.19, 4.20 graphically represents the variation of displacement (in mm) due to varying loads (KN) in the Steel fibre infused interlocking mud bricks. From these figures, we found that 0.1 % of Steel fibre infused interlocking mud bricks can able to withstand high load of 18.40 KN when comparing with other mix ratios.

Fig 4.21, 4.22, 4.23 graphically represents the variation of displacement (in mm) due to varying loads (KN) in the Jute fibre infused interlocking mud bricks. From these figures, while comparing we found that 0.4 % of Jute fibre infused interlocking mud bricks can able to withstand high load of 15.35 KN

Fig 4.24, 4.25, 4.26 graphically represents the variation of displacement (in mm) due to varying loads (KN) in the PVC fibre infused interlocking mud bricks. From these figures, while comparing we found that 0.6 % of PVC fibre infused interlocking mud bricks can able to withstand high load of 21.05 KN.

**RESULTS AND DISCUSSION**

**5.1 COMPRESSIVE STRENGTH TEST**

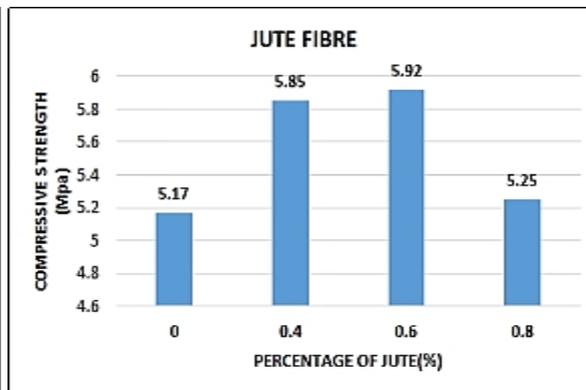
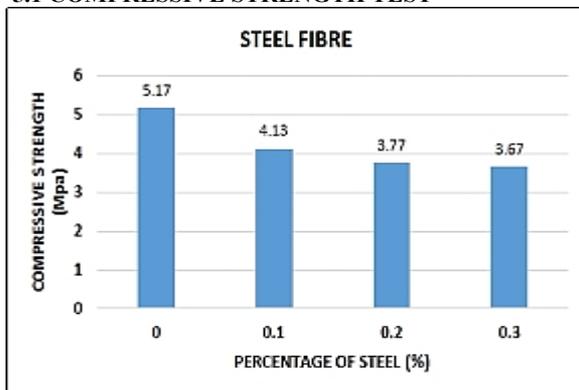


Fig 5.1: Compressive Strength of Steel Fibre Fig 5.2: Compressive Strength of Jute Fibre

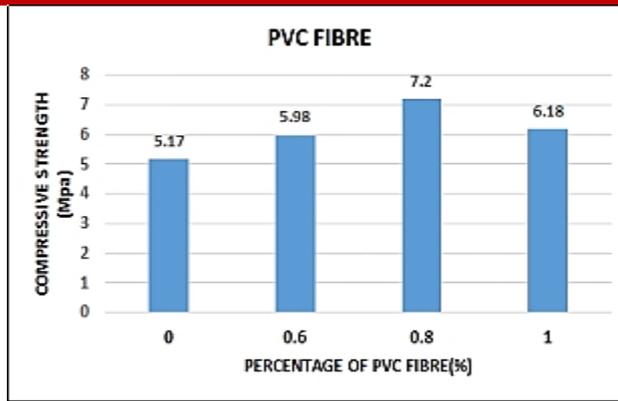


Fig 5.3: Compressive Strength of PVC Fibre

The best-performing Steel fibre (0.1%) mix produces 20.2% lesser compressive strength on comparing with interlocking mud brick. Similarly, the best performing Jute fibre (0.6%) produces 14.5% higher compressive strength when compared to interlocking mud bricks. The best performing PVC fibre (0.8%) produces 39.2% higher compressive strength when compared to interlocking mud bricks. Hence, from this analysis we could say that the PVC fibre produces more compressive strength when compared to ordinary interlocking mud bricks and all other fibres. So, PVC fibre stands out in first place, in terms of compressive strength analysis.

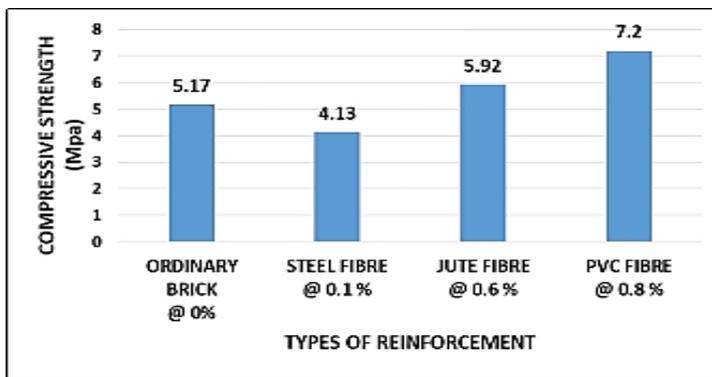


Fig 5.4: Comparison of Compressive Strength of all Fibre Reinforced Mud Interlocking Brick with Ordinary Interlocking Mud Brick.

**5.2 WATER ABSORPTION**

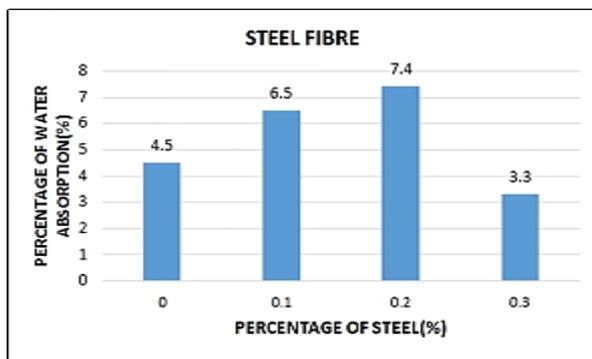


Fig 5.5: Water Absorption of Steel Fibre

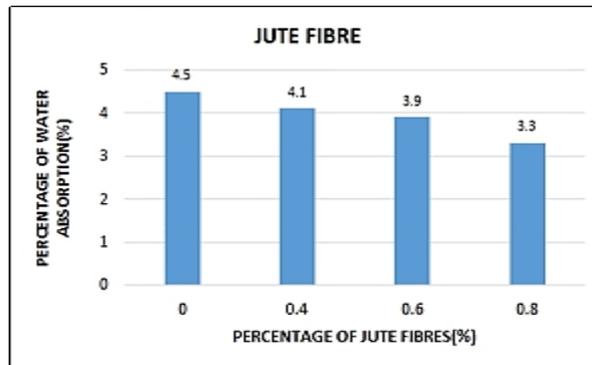


Fig 5.6: Water Absorption of Jute Fibre

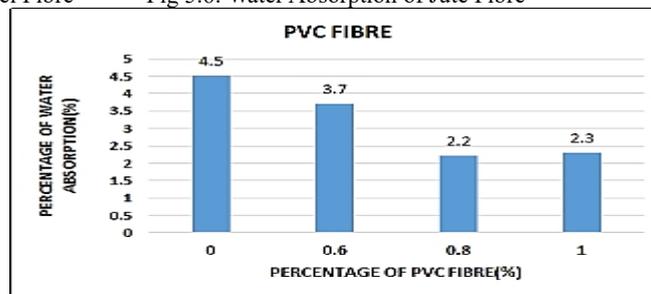


Fig 5.7: Water Absorption of PVC Fibre

Here out of all 9 mix designs from three different fibres, 0.8% mix of PVC fibre absorbs the least water, as we said earlier cracks do occur due to changes in weather conditions, that is it has less adaptability to water, which tells that ordinary interlocking mud brick is having high water absorption capacity, but PVC mix of (0.8%) has 51% lesser water absorption capacity, which has drastically increased its adaptability towards water.

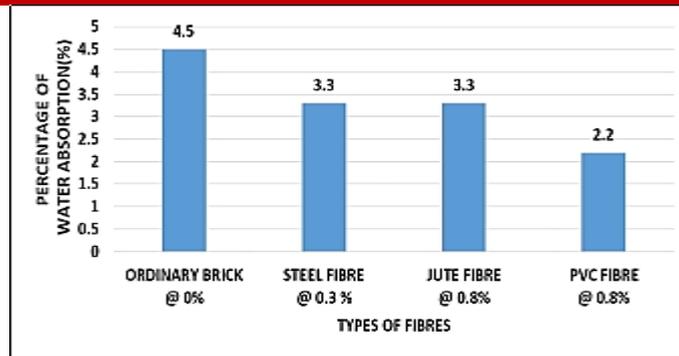


Fig 5.8: Comparison of Water Absorption of Ordinary Fibre Reinforced Mud Interlocking Brick with Fibre Reinforced Mud Interlocking Mud Brick

### 5.3 FLEXURAL STRENGTH TEST

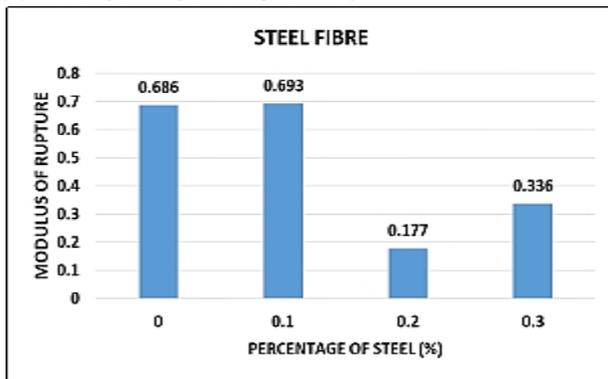


Fig 5.9: Flexural Strength of Steel Fibre

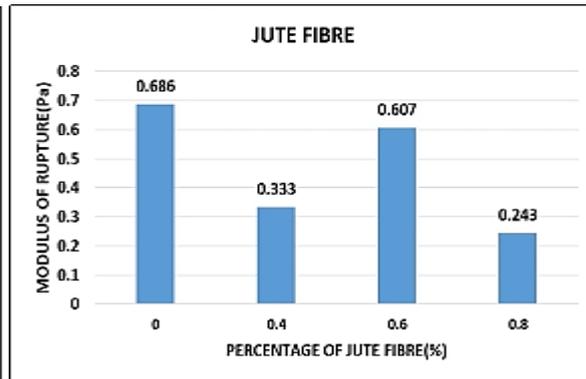


Fig 5.10: Flexural Strength of Jute Fibre

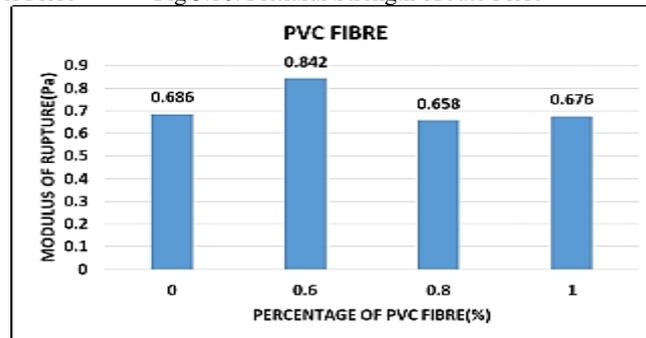


Fig 5.11: Flexural Strength of PVC Fibre

The results in flexural strength were good enough and the best-performing Steel fibre (0.1%) mix produces 1.1% higher compressive strength on comparing with interlocking mud brick. Similarly, the best performing Jute fibre (0.6%) produces 12.3% lesser compressive strength when compared to interlocking mud bricks. The best performing PVC fibre (0.6%) produces 22.74% higher compressive strength when compared to interlocking mud bricks.

Here, when compared to ordinary interlocking mud bricks, not all the design mix performed well, only two mixes out of nine mixes have greater flexural strength values than ordinary bricks.

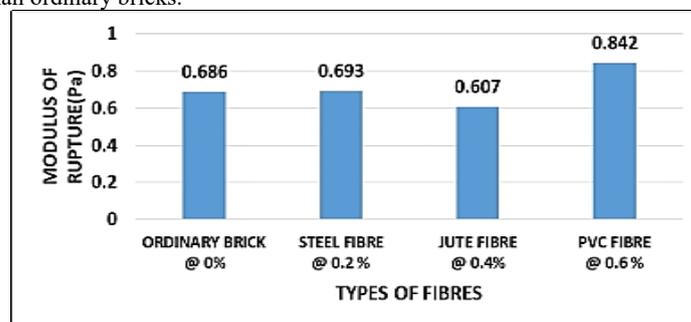


Fig 5.12: Comparison of Flexural Strength of Ordinary Fibre Reinforced Mud Interlocking Brick with Fibre Reinforced Mud Interlocking Mud Brick

### 6. CONCLUSIONS:

Based on the results of experiments in this study, the following conclusions were made,

- This project's results were so satisfying and it came up with very good results, PVC fibre exceptionally performed well in almost all the test, starting from cost point of view, the PVC is cheapest among all fibres, it is 30 times lesser than steel fibre and 70 times lesser than jute fibre, above all this material which we took is a waste product obtained from house and commercial electrical projects, these are available in the

markets in tons.

- Also PVC has shown good resistance towards water absorption, it is mainly due to PVC's flexibility and the shape which we have cut the PVC fibres, the soil particles have perfectly settled in between the half cut PVC fibres, coming to the next test ie flexural strength test results its again PVC has topped, but other fibres have not excelled as anticipated.
- Only one design mix in steel and another design mix in PVC has crossed the value of ordinary mud interlocking brick, we could say that fiber reinforcing isn't suitable for interlocking mud brick to obtain greater flexural strength.
- Jute fibre on an average performed well in compressive strength test, also cost wise the jute fibre is very high in price, which makes it un-economical to blend with soil mix, it has shown good results towards water absorption, as we soaked fibres into water before casting and finally it has not produced good results in flexural strength test.

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