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Strengthening of Brick Masonry Using Basalt Fiber Reinforced Cement Mortar

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Abstract: Brick masonry is one of the primary structures and it plays a role in Reinforced Concrete (RC) frame structure. It is very weak in tension and has low ductility response. Normally in brick masonry, cement mortar reaches failure before brick attains the failure. For strengthening the brick masonry, it is essential to increase the strength of the cement mortar. Basalt fiber is added with cement mortar in different proportions as 0.5%, 1% and 1.5% of weight of cement. Compressive strength and Young's modulus of brick masonry were tested with and without of basalt fiber in cement mortar. Similarly, cube compressive strength of cement mortar was also tested in the same manner. The experimental results show that 1% of basalt fiber in the cement mortar gives the optimum value of properties of the brick masonry.
Keywords : Brick masonry, Cement mortar, Basalt fiber.

1. Introduction

Brick is one of significant material which is utilized as construction material in brick masonry structure. Brick masonry is the combination of brick and cement mortar with desired design mix proportions from available natural and artificial materials. Brick is oftenly used in both structural and non-structural elements because of the availability of the same from neighbour industries. When compare to steel and concrete, it is very cheap material. Also brick masonry can impart as infilled wall in the openings of RC frame structure. The significant of material such as bricks and stones can improve the thermal resistant from mass of building and can protect the building from fire. Another important parameter is cement mortar and it is utilized to bind the bricks together. The cement mortar is made up of cement, fine aggregate and water with desired water/cement ratio. In general, brick masonry is very strong in compression but weak in tension. So it is necessary to enhance the ductility of brick masonry in RC frame structures. When compare to bare frame, the infilled wall which is present in multi-storey building, gives a significant contribution in stiffness, energy dissipation capacity and reduce the collapse risk[1]. Therefore, fiber is one of the necessary materials and it mixed with the cement mortar. The main role of fiber is to improve the ductility of brick masonry and avoids cement mortar joint failure in the brick masonry structure. Fiber which is used in cement mortar or concrete of structural components is discontinuous, discrete of reinforcing material, having certain characteristics properties. Normally, steel fiber, synthetic fiber and natural fibers are used in construction industry. Mostly fibers are increasing the tensile strength, durability and toughness of the concrete, reduce the air voids and control creep of concrete. In recent years, many research efforts are there to utilize the fiber for the production of concrete in the construction Industry. The utilization of fibers in cement mortar is lesser because cement mortar employs a vital role in non-structural elements like infilled wall, pavement block and light weight structures. Besides, natural fibers are less

expensive than manmade fibers. This fiber gives higher in toughness, tensile strength and deformation capacities to mortar products. Basalt fiber is a natural dense, volcanic igneous rock originating at a depth of hundreds of kilometer beneath the earth and resulting the surface as molten magma. This fiber makes into a long filament which does not undergo any toxic reaction with water and do not pollute air also. The basalt fiber is a inorganic fiber material with good corrosion resistance, high tensile strength and low cost. It is a new reinforcing material used in cement mortar and it has uniform distribution, proportions and percentage of fibers with different volume fractions in cement mortar. Krishna Naraine et.al.,[5] conducted the experimental program, to study the behaviour of brick masonry under uniaxial, cyclic and compressive loading. A total of 18 specimens were conducted the test for two cases of loading were perpendicular and parallel to the bed joint. The envelope of stress-strain curve, the common point curve, and the stability point curve were established for brick masonry under loaded in both perpendicular and parallel to the bed joint. Jingyao et.al.,[4] focused on the use of an acrylic dispersion as an admixture in carbon fiber-reinforced cement. The improvement of the tensile properties was higher than those attained by using methylcellulose, styrene acrylic or latex as admixtures. Acrylic was effective though silica fume was present or not. However, for lowering the electrical resistivity, methylcellulose in combination with silica fume was most effective. Youjiang et.al.,[9] studied an experimental investigation of the tensile behaviour of synthetic fiber reinforced mortar. The test results indicated that the envelope load versus crack separation for cyclic loading tests were essentially the same as those for monotonic loading tests of corresponding specimens. Also the test result indicates that there is some reduction in macro cracks due to fiber reinforcement. Rathish Kumar et.al.,[8] evaluated the effect of fiber, mesh reinforcement and aggregate composition in the mechanical characteristics of self compacting mortar. The compressive strength, split tensile test and flexural strength of natural aggregate of self compacting mortar is greater than recycled-natural aggregate of self compacting mortar irrespective of fiber addition/mesh reinforcement. Freeda Christy et.al.,[1] examined elastic modulus and compressive strength of brick masonry. In this experiment, two type of brick masonry were tested by using of clay brick and flyash brick. In addition to brick masonry was reinforced with woven wire mesh at the alternate layer of bed joint. The reinforced brick masonry enhancing the bond strength of the structure and increases the interaction between brick and cement mortar. Ikumapayi C. Mayowa et.al.,[2] studied the compressive strength of cement mortar cube reinforced with Oil Palm Fiber (OPF). The oil palm fiber was used in different percentage from 0.2 % to 1 % by the weight of cement. The partial replacement of cement by OPF strengthened the compressive strength of mortar. Priyanka A.Jadhav et.al.,[6] investigated the effect of partial replacement of natural sand by manufactured sand on the compressive strength of cement mortar with different proportion of water-cement ratio. Manufactured sand helps to maintain the environment with economical balance and has a potential to be as an alternative to natural sand. The compressive strength of cement mortar, in which 50 % of natural sand is replaced by manufactured sand, produced higher strength than reference mix. Sumathi et.al.,[8] studied the structural behaviour of brick masonry bonded with mild steel fiber mixed into cement mortar and compared with ordinary brick masonry. The main objective of this study is to determine the required optimum mix percentage of fiber to obtain maximum compressive strength and to find the characteristic of brick masonry using mild steel fiber reinforced cement mortar. It referred that mild steel fiber in cement mortar arrested the cracks in the brick masonry structure. From this literature review, the strengthening of cement mortar is essential to enhance the performance of brick masonry structure. Addition to this, fiber in cement mortar plays crucial role in brick masonry. Most of the research is carried out through artificial fiber and it performed very difficult in casting and handling process. Inspite of artificial fiber, natural fiber impart high strength and easy handling. Therefore, the main objective of this research work is to improve the performance of brick masonry structure.

2. Research Significance

The aim of research programme is to enhance the behaviour of brick masonry because it is brittle nature, very low in tension and ductility. In this work, various tests were conducted such as compressive strength of cement mortar and Young's modulus, compressive strength of brick masonry with and without of basalt fiber in different proportions.

3. Specification of materials

3.1 Cement:

53 grade ordinary Portland cement was used as per confirming to IS: 12269 (1987). The standard consistency, initial setting time and specific gravity were determined and tabulated in table 1.

Table 1 Properties of materials

Sl.No.	Description of material	Properties of material	Value
1	Cement	Standard consistency	33 %
		Initial setting time	32 min
		Specific gravity	3.15
2	Fine aggregate	Fineness modulus	3.36
		Specific gravity	2.6
		Water absorption	2 %

3.2 Fine aggregate:

The natural sand from river was used as fine aggregate in cement mortar. The fineness modulus, specific gravity and water absorption were found and tabulated in table 1.

3.3 Compressive strength of brick

The compressive strength is necessary to find the property of brick for different grade of works. The brick with the size 225 mm x 100 mm x 75 mm, was tested as per IS: 3495-1976 using Universal Testing Machine. The test results were tabulated in table 2.

Table 2 Compressive strength of brick

Specimen No.	Compressive Strength in N/mm^2	Average value in N/mm^2
1	7.216	7.176
2	7.040	
3	7.274	

3.4 Basalt fiber

Basalt fiber is made up of crushed basalt rock. This basalt fiber requires the melting of the quarried basalt rock at 1400^0c. Then it is extruded through small nozzles to produce continuous filaments of basalt fiber. The properties of basalt fiber are retrieved from the manufacturer and it is tabulated in table 3. Figure 1 shows the photoview of basalt fiber.

Figure 1 Photoview of Basalt fiber

Table 3 Properties of Basalt fiber

S.No.	Property	Values
1	Diameter (mm)	0.016
2	Cut length (mm)	12.7
3	Aspect ratio	794
4	Tensile strength (Mpa)	4150

4 Experimental Investigations

4.1 Cement mortar

Cement mortar plays major role in binding of bricks in the brick masonry structure. Cement mortar consists cement and sand in 1:6 ratio with required quantity of water. The cement mortar cubes with the size of 70.7 mm x 70.7 mm x 70.7 mm, were prepared and cured for 28 days. After curing the cement mortar cubes, they were tested using compression testing machine. The test set-up of cement mortar cube is shown in figure 2. Basalt fiber is added with cement mortar to improve the compressive and tensile strength of cement mortar. This fiber was mixed with cement mortar in 0.5 %, 1.0 % and 1.5 % of weight of cement. Table 4 shows the compressive strength of cement mortar with different proportions of basalt fiber.

Figure 2 Test set-up of cement mortar cube

Table 4 Compressive strength of cement mortar

Sl. No.	Size of cement mortar cube (mm)	Compressive strength of cement mortar (N/mm^2)			
		0 % of fiber	0.5 % of fiber	1 % of fiber	1.5 % of fiber
1	70.7 x 70.7 x 70.7	2.142	3.28	5.04	4.73
2	70.7 x 70.7 x 70.7	2.122	3.21	5.28	4.79
3	70.7 x 70.7 x 70.7	2.142	3.31	5.16	4.71
Average		2.135	3.27	5.16	4.74

4.2 Young's modulus of brick masonry prism

The brick masonry prism was constructed as size of 225 mm x 225 mm and 450 mm high with brick size of 225 mm x 100 mm x 75 mm using 1:6 cement mortar ratio. This study is to evaluate the stress-strain relationship of brick masonry prism with and without of basalt fiber in the cement mortar. Using a new type of fabricated compressometer, Young's modulus of brick masonry prism was found by universal testing machine and the loading setup of brick masonry prism is shown in figure 3. For brick masonry prism, the value of stress-strain is tabulated in table 5 under different percentage of basalt fiber. Finally, the optimum 1 % of basalt fiber produced high strength and it was found as 9305.94 MPa. The stress-strain curve of brick masonry is shown in figure 4.

Figure 3 Test set-up of brick masonry prism

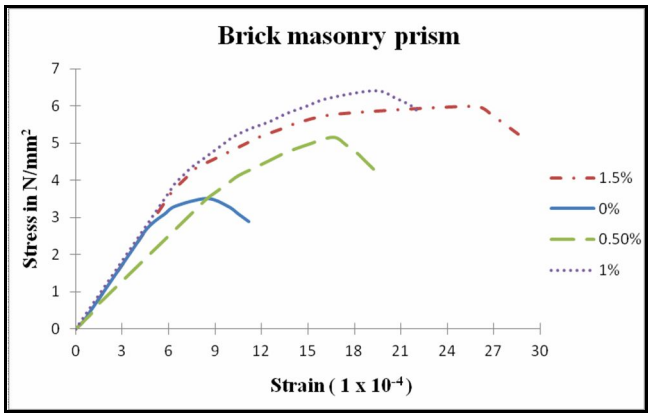

Figure 4 Stress-strain curve of brick masonry prism with different percentage of basalt fiber

4.3 Compressive strength of brick masonry prism

The characteristic strength of brick masonry depends upon the brick and cement mortar. This Prism test method evaluates the compressive strength of brick masonry. The compressive strength is the maximum load divided by cross sectional area of prism. The specimens were constructed in proper alignment and required curing was provided. Proper proportion and 1:6 cement mortar ratio was used in workable consistency for construction. After 28 days curing, the specimen was provided in smooth surface for application of compressive load. 100-tonne universal testing machine was utilized to determine the compressive strength of brick masonry prism. The steel plate was placed in between the specimen and loading frame was used to distribute the load gradually in the specimen. Table 5 shows compressive strength of brick masonry prism under different proportion of basalt fiber in the cement mortar. The ultimate compressive strength of brick masonry with different proportions of basalt fiber was found and it identified that 1 % of basalt fiber in cement mortar produces the optimum value. Figure 5 shows compressive strength of brick masonry with different proportions of basalt fiber.

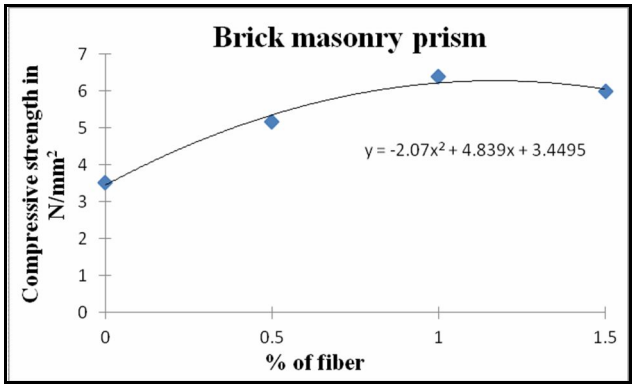

Figure 5 Compressive strength of brick masonry prism with different proportions of basalt fiber

Table 5 Properties of brick masonry with different percentage of basalt fiber

Sl. No.	Size of brick masonry in mm	Percentage of fiber	Compressive strength of brick masonry prism in N/mm^2	Young's modulus of brick masonry prism in N/mm^2
1	225 x 225 x 450	0	3.51	5767.67
2	225 x 225 x 450	0.5	5.17	7142.8
3	225 x 225 x 450	1	6.4	9305.94
4	225 x 225 x 450	1.5	5.99	6671.76

5 Results and Discussion

In brick masonry prism, cracks mainly originating in cement mortar and it causes the concentration of tensile stress on brick which leads disintegrate between brick and cement mortar. The addition of basalt fiber improves the compressive strength of brick masonry prism. When adding 1 % of basalt fiber with cement mortar, the compressive strength of brick prism improves 1.82 times higher than ordinary brick masonry.

The compressive strength of cement mortar with 1 % of basalt fiber is increased to 2.41 times than ordinary cement mortar. Table 5 shows 1 % of basalt fiber in cement mortar produces the high compressive strength and Young's modulus of brick masonry. Also it gives the optimum value of fiber in cement mortar. Figure 6 proves that relation between cement mortar and brick masonry prism in compressive strength. This basalt fibers arrest the cracks in brick masonry prism and adding of these fibers in cement mortar makes transformation of a brittle failure into a ductile failure mode. Through this experimental investigation, it is observed that adding 1 % of basalt fiber with cement mortar gives high compressive strength and control the cracks in brick masonry structure.

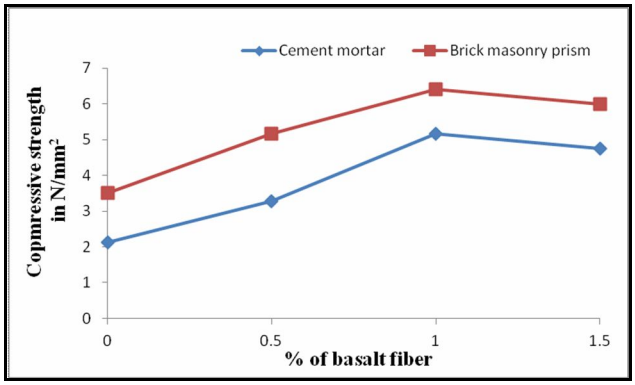

Figure 6 Compartive behaviour of cement mortar and brick masonry prism

6 Conclusions

The experimental programme evaluated that basalt fiber plays a vital role in cement mortar and improves the performance of brick masonry structure. The following points are concluded as strengthening of brick masonry structure

1. The compressive strength of cement mortar with 1 % of basalt fiber is increased to 2.41 times than the ordinary cement mortar.
2. The Young's modulus of brick masonry prism with 1 % of basalt fiber is increased to 1.61 times than the ordinary brick masonry prism.
3. The compressive strength of brick masonry prism with 1 % of basalt fiber is increased to 1.82 times than the ordinary brick masonry prism.
4. Through this experimental study, it is proved that the adding of 1 % of basalt fiber with cement mortar produces the optimum result in the performance of brick masonry.
5. At casting stage, when compare to steel fiber, basalt fiber prevents balling effect in cement mortar.

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