# EXPERIMENTAL STUDY OF FIBER REINFORECMENT MORTAR AND ITS APPLICATION IN MASONRY STRUCTURE

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***ABSTRACT: Structures built with brick units bonded together by mortar in between are called brick masonry structure, and very common in India. Use of appropriate reinforcement in mortar could substantially improve the performance of brick masonry of shear, bond, compression, energy, absorption (toughness) and crack resistance .In the first part of study, the tests were carried out in accordance with ASTM C780, and other relevant Indian specification. For testing the BMUs, the compression tests were carried out according to standardized procedures, but an original procedure had to be developed for testing the BMU in shear. As far as the effect of fiber addition or mortar properties is concerned, it was found that as fiber is added to the matrix, the compressive strength increases by only 5-10% while the ultimate deformation decreases. However, the increase in the split tensile strength and the toughness was found to be 18-25% and 4-5 times, respectively. Whereas specimens without fiber content between 0.1% and 0.25%, showed capability to take load even after the ultimate load has been reached.***

## I. INTRODUCTION

FIBER REINFORCED CONCRETE

Fiber reinforced concrete is a concrete mix that contains short, discrete fibers that are uniformly distributed and randomly oriented. The fibers used are steel fibers, synthetic fibers, glass fibers and natural fibers. The fibers in members resist the opening of the cracks due to micro cracking and increase the ability of the members to withstand loads. 5 Fibers available in different sizes and shapes can be classified into two basic categories, those having a higher elastic modulus than concrete matrix and those with lower elastic modulus. Steel, glass and carbon have high elastic moduli than cement mortar matrix. Polypropylene and vegetable fibers are the low modulus fibers. High modulus fibers improve both flexural and impact resistance simultaneously whereas low modulus fibers improve the impact resistance of concrete but do not contribute much to flexural strength .Reinforcing bars in concrete are continuous and carefully placed in the structure to optimize their performance, whereas fibers are discontinuous and are randomly distributed throughout the concrete matrix. Fibers act as crack arresters restricting the development of cracks and transforming an inherently brittle matrix with its low tensile and impact resistance, into a strong composite with superior crack resistance. This results in improved ductility and distinctive post cracking behaviour prior to failure.

Materials used as short fibers

Recron 3s fibre

Recron 3S is a modified polyester fibre. It is generally used as secondary reinforcing material in concrete and soil to increase their performance. Recron 3S sample used in experiment was of 12mm length and manufactured by Reliance Industries Limited. Physical parameters of Recron 3S fibre as obtained from RIL Safety data sheet.

Use of Recron-3S as a reinforcing material is to increase the strength in various applications like cement based precast products, filtration fabrics etc. It also provides resistance to impact, abrasion and greatly improves the quality of construction during foundation, retaining wall design etc .Polypropylene fibre is the most widely used inclusion laboratory testing of soil reinforcemen. Currently Polypropylene fibre is used to enhance the soil strength properties, to reduce the shrinkage properties and to overcome chemical and biological degradation .

## II. LITRATURE REIVEW

M.H. Saghofi, H. Shariatmadar, Ali K. (2019) [1]investigate and evaluate the feasibility of using high-performance fiber-reinforced cement composites (HPFRCC) to satisfy the requirement of transverse reinforcement in beam-column joint under seismic loads. The basic mechanical properties of the HPFRCCs are determined by compression, uniaxial tension, and direct shear tests. Four half-scale exterior beam-column connections are cast and tested under cyclic loads. The crack-ing patterns, hysteresis behavior, ductility, energy dissipation with damping characteristics and joint shear capacity of the HPFRCC beam-column connections are analyzed, investigated, and compared to the cyclic responses of normal concrete connections designed with/without seismic criteria of ACI. The test results revealed that HPFRCC connec-tions considerably enhances shear and flexural capacity and also improved the deformation and damage tolerance behavior in post-cracking stage comparing to normal concrete connections in ultimate stages. Also, the failure mode of HPFRCC specimens changed from shear mode to flexural mode comparing to the connections without seismic details..

N. Zemour, A. Asadian, E.A. Ahmad, B. Benmokrane, K.H. Khayat (2019) [2]nvestigated the effect of several parameters on the bond behavior of spliced glass fiber-reinforced polymer (GFRP) reinforcing bars in self-consolidating concrete (SCC) and normal concrete (NC). A total of 21 full-scale reinforced concrete (RC) beams were tested under four-point bending up to failure. Six influential design Code parameters were investigated, specifically concrete type, casting position, casting height, splice length, beam height, and longitudinal reinforcement type. The experimental results and observations reveal that the SCC and NC beams behaved similarly in terms of failure load, crack pattern, failure mode, and load-deflection response. The bond strength of the spliced bars in the SCC beams was slightly lower than that of the NC.

Utkarsh R. Nishane (2017) [3] provide the concepts of using fibres in order to reinforce matrices weak in tension is more than 4500 years old.since Portland cement concrete started to be used widely as a construction material attempts were made to use fibres for arresting cracks enhance the strength etc. The development of fibre reinforcement for concrete was very slow before 1960's. Fibers are generally used as resistance of cracking and strengthening of concrete. In this project we are going to compare the compressive strength of 3, 7 and 28 days of aramid fibres to the ordinary concrete and fibre reinforced concrete i.e. glass fibres and steel fibres. The concrete is design for M20 grade of concrete. According to various research papers, it has been found that steel fibers give the maximum strength in comparison and glass fibre is used for crack resistance but aramid simultaneously gives strength and can be used for crack resistance. Now a days there exists many reinforcement techniques for improving the strength of those materials which lacks load carrying and less durable capacity.

Material and Mathodology

Characterization of materials used

Cement: IS 1489: (Part 1 Fly Ash based ): The Portland Pozzolana Cement is a kind of Blended Cement which is produced by either intergrinding of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly blending them in certain proportions. Portland Pozzolana Cement whose properties were determined and given in the Table 3.1 was used for preparing the mortar.

| Properties | Average |
|---|---|
| Standard consistency | 30.5 |
| Initial Setting time (min.) | 35 |
| Final Setting time (min.) | 290 |
| 3-days compressive Strength (MPa) | 23.3 |
| 7-days compressive Strength (MPa) | 34.5 |
| 28-days compressive Strength (MPa) | 45.1 |
| Specific Surface ($m^2$/kg) | 298.4 |

Table 1 Properties of Cement

Fibers

The RECRON 3s fiber was used in the study and the properties as given bythemanufacturer (M/s Reliance Industries Limited) are shown in Table 3.2 Recron 3S is a modified polyester fibre. Recron 3S sample used in experiment was of 12mm length and manufactured by Reliance Industries Limited. Physical parameters of Recron 3S fibre as obtained from RIL Safety data sheet. It also provides resistance to impact, abrasion and greatly improves the quality of construction during foundation, retaining wall design etc .. Currently Polypropylene fibre is used to enhance the soil strength properties, to reduce the shrinkage properties and to overcome chemical and biological degradation.

| | |
|---|---|
| Chemical Family | Modified polyester |
| Material Identification | Polymer |
| Physical State | Solid (fiber) |
| Appearance | White |
| Cross Section | Triangular |
| Melting point | >250$^0$c |
| Soluble in Water | Insoluble |
| Density | 1.4g/cc |
| Elongation(Length wise) | 45 to 65% |
| Tensile strength(Length wise) | ~600 MPa |

Table 2 Properties of RECRON 3s Fiber

Fine Aggregates – sand as a fine aggregate is used .the sand was natural river sand passing through the 4.75 mm sieve.the average fineness modulus of sand was 2.35.

Coarse Aggregate – nearby compressed stone be used as a coarse aggregate which contain the dimension of 20mm size used for project.

Brick – brick were manufactured by PBK.these brick were made from clay collected from agricultural land,handmoulded and fired after sun dried.bricks in general were well burnt and can be classified as first class brick.

Water – mixing and hydration process is used as potable water uses.

Tests on Mortar

Test Specimen– mortar cube,mortarcylinders,brickmasonary unit.

Testing Of Compressive Strength For Mortar Unit

These were carried out to clearly understand the effect of different levels of fiber addition on the compressive and split tensile strength of mortar of varying composition. Whereas cubes measuring 50cm2 (area of one face) and 50 x 100mm cylinders were used to measure the compressive strength and the split tensile strength, respectively

Split Tensile Test

A total of 3 specimens were tested for each mix at different ages according to U T M (split tensile testing under hydraulic compression machine).

Testing Of Compressive Strength For Brick Masonary Unit

Brick masonry units were tested in compression The former, brick masonry units under compression (BMUC), was made with five bricks separated by about 10mm thick mortar (plain and FRM) .

Most of the units were tested between 28 to 30 days after casting. Total 54samples (54*5=270 bricks used ) for each mix proportions for CM (1:6) ,CM (1:5),CM(1:4) with 0%, 0.1% and 0.25 % of fiber contents. The testing was done in an U T M at structures laboratory.

## III. RESULT AND DISCUSSION

Parameters to be studied from the results are:

Compressive Strength

Mortar cubes were tested for compressive strength to find the ultimate load for CM (1:3), CM (1:4), CM (1:5) and CM

  

(1:6).

The specimens were tested under load control, and only the ultimate load was noted.Three specimens were tested under each condition and Table 3 shows the average compressive strength and variation for the different cases for 7 days and 28 days respectively

| % of fibers | Average compressive strength at 7 days | | | |
|---|---|---|---|---|
| | 1:03 | 1:04 | 1:05 | 1:06 |
| 0 | 20.8 | 14.6 | 11.7 | 3.9 |
| 0.1 | 20.8 | 15.1 | 12.1 | 4.2 |
| 0.25 | 19.1 | 14.9 | 12.5 | 4.1 |
| 0.5 | 16.44 | 13.2 | 10.1 | 3.5 |

Table 3 Average compressive strength at 7 days

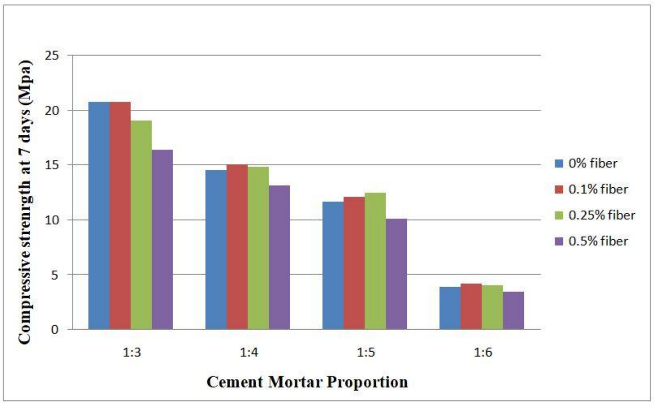


Figure-1Compressive strength variation of mortar cubes with respect % of fiber at 7 days.

| % of fibers | Cube compressive strength in Mpa | | | |
|---|---|---|---|---|
| | 1:03 | 1:04 | 1:05 | 1:06 |
| 0 | 24.5 | 18.23 | 14.23 | 4.9 |
| 0.1 | 26 | 20.4 | 15.51 | 6.2 |
| 0.25 | 24.2 | 21.2 | 15.9 | 6.1 |

Table 4 Average compressive strength at 28 days

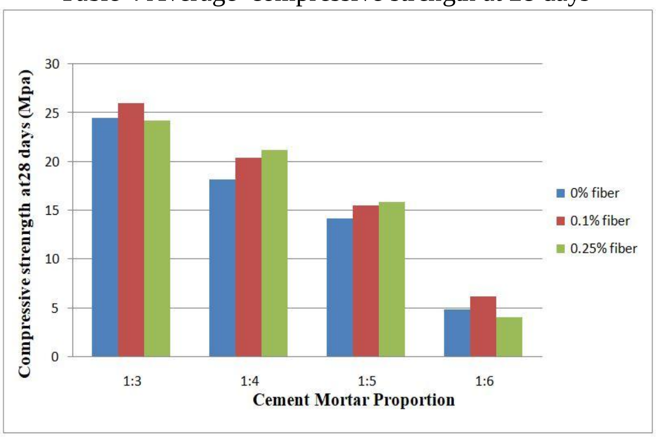


Figure-2 Compressive strength variation of mortar cubes with respect % of fiber at 28 days.

Split Tensile Strength

Mortar cylinders were tested for split tensile strength to find the ultimate load and behavior of specimens after ultimate load, toughness and crack resistance due to the presence of the presence of fibers in the matrix.

The average value obtained from the result of split tensile test specimens is summarized in Table 5 Figure 3 show the relative increase in split tensile strength due to fiber addition.

| Split tensile strength in MPa | | | | |
|---|---|---|---|---|
| % of fiber | 0 | 0.1 | 0.25 | 0.5 |
| CM(1:3) | 0.15 | 0.19 | 0.14 | 0.14 |
| CM(1:4) | 0.12 | 0.16 | 0.1 | 0.08 |
| CM(1:5) | 0.08 | 0.1 | 0.09 | 0.08 |
| CM(1:6) | 0.06 | 0.08 | 0.08 | 0.07 |

Table 5 Split tensile strength values

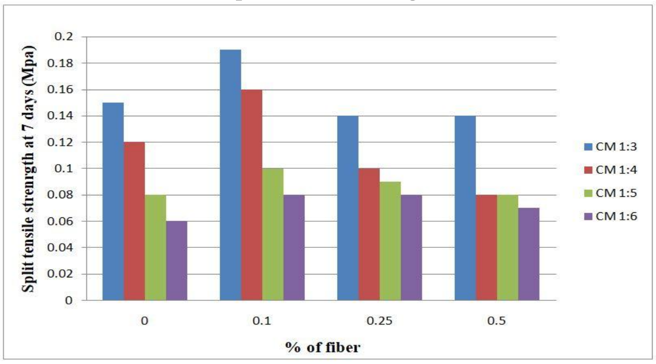


Figure 3Histrogram showing Variation of split tensile strength variation with fiber volume (28 days)

Compressive Strength Of Brick

BMUs with five bricks and four intervening layers of mortar were tested in compression and the following properties noted.

| S. No. | Types Of Unit | First Cracking Strength (fcr) | Ultimate Compressive Strength (fbwp) Mpa | Mortar Compressive Strength (fmk) | Brick Crushing Strength(fbp) MPa | Kbwp |
|---|---|---|---|---|---|---|
| 1 | BMUC60 | 0.6 | 1.3 | 4.9 | 15.6 | 0.14 |
| 2 | BMUC61 | 1.1 | 2 | 6.2 | 15.6 | 0.2 |
| 3 | BMUC62 | 0.9 | 1.6 | 6.1 | 15.6 | 0.16 |
| 4 | BMUC40 | 0.8 | 2.1 | 18.23 | 15.6 | 0.12 |
| 5 | BMUC41 | 1.5 | 2.9 | 20.4 | 15.6 | 0.16 |
| 6 | BMUC42 | 1.3 | 2.7 | 21.2 | 15.6 | 0.14 |

Table 6 Values for different masonry units

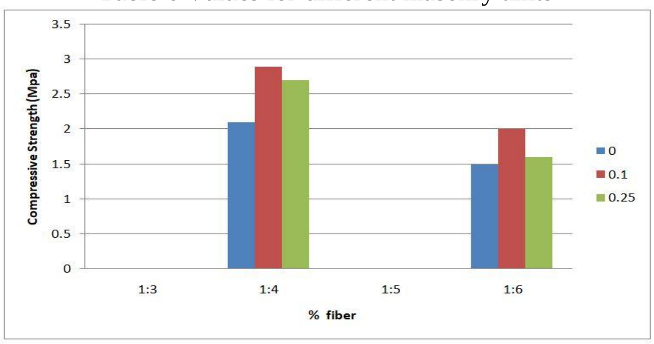


Figure 4 Histogram showing Compressive strength variation with respect volume of fibers

  

On The Basis Of Result Following Observation Are Made

- As volume content of fiber increases up to 0.1% of total volume the ultimate strength increases (As shown in Figure 1.a to 1.d). An increase in strength of 5-10% was seen up to a volume of 0.1% fiber content. The likely cause for initial increase in strength is that the presences of fibers have delayed the proportion of micro cracks thus enabling the mortar to withstand larger stresses. However a further increase in the fiber content up to 0.25% has led to a corresponding drop in the strength. This is due to the fact that above the 0.1% volume the presence of fibers tends to reduce the bonding between cement and aggregate 1eading to a consequent decrease in strength.
- Photographs after failure shown in Figure 1 show that plain mortar specimens showed very little load carrying capacity after maximum load and almost disintegrated soon after ultimate load. However specimens with fibers showed considerable load carrying capacity beyond the maximum load. This is because cement mortar fails due the propagation of micro cracks which develop on loading. However in the case of fiber reinforced mortar the progress of micro cracks are temporarily arrested by the presence of fibers.
- At the fiber volume of 0.1% the maximum split tensile strength increases by 15 to 20% compared to the plain mortar. The fiber carries increasing load after first cracking of the matrix when the pullout resistance of the fiber is greater than the load at first cracking thus the matrices doesn't resist any tension and the fibers carry the entire load. As the tensile stresses increase the additional stress is transferred to the matrix through bond stresses. Thus the increase in strengths leads to formation of additional cracks till either the fibers fail(in tension) or the accumulated local debonding leads to the fiber pull out.
- However in Figure 1show that at the fiber content of 0.5 % the strength is lower than that at 0.1%. This can be attributed to two reasons one as the fiber content is increased it displaces the materials, thus consequently decreasing the volume of cement. The other cause is as the % of fibers dispersed parallel to weak directions is more when the volume of fiber content is increased thus leading to slippage at lower stresses.

## IV. CONCLUSION

1. Properties Of Fiber Reinforced Mortar

- Compressive strength more or less similar, even though as volume content of fiber increases up to 0.1% of total volume the ultimate strength increases by 5-10% of plain mortar specimens. However further increase in the fiber content has led to a same strength as plain reinforced specimens. But the split tensile strength increases by 18 to 25% for 0.1 % fiber content samples. However a further increase in the fiber content up to 0.25% has led to a corresponding drop in the strength.
- The plain mortar fails suddenly when ultimate split tensile strength is exceeded while FRM continues to sustain considerable loads even at deflections in excess of fractured deflection of plain mortar. However it is seen that when fiber content. is 0.5 % the strength is decreasing. This pattern is observed in compression also.

2 Behaviour Of BMUs Made With FRM

- The compressive strength of masonry units with FRM is 15 to 20 % more than that of plain mortar specimens.
- The specimens without fiber failed soon after the development of crack and indicate a brittle failure. Just after the peak load, the load carrying capacity i.vas lost completely. The crack traverses completely through the bricks and the mortar. But the specimens with different fiber contents resist load even after the development of cracks, due to the transfer of load from matrix to the fibers bridging across the cracks.

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