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Experimental Study of Fiber Reinforcement Mortar and its Application in Masonry Structure

Ishak mohammad[1], Niraj kumar[2], Mohd.jishan[3]

[1]Jagannath university, Jaipur
[2]Jagannath university, Jaipur
[3]Saraf Institute of Engg.& technology, Hanumangarh

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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. Masonry is made up of two distinct and very different components –the brick themselves, and, the mortar which have different material properties, with brick usually having a higher strength and stiffness compared to mortar. Further mortar is usually cementations material having little tensile strength and showing brittle behavior. Use of appropriate reinforcement in mortar could substantially improve the performance of brick masonry of shear, bond, compression, energy, absorption (toughness) and crack resistance and this thesis investigated the improvements in the case when short fibers are used.

An attempt was made to study the properties of fiber reinforcement mortar (FRM) and its application in masonry structures using appropriate experiments. Cement sand mortars were cast using different volumes of fibers and tested in compression and spilt tension. After narrowing down the range of suitable mix proportions, compression and shear bond tests were performed using appropriately prepared brick masonry units (BMUs) prepared with plain mortar and FRM.

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.

Test using BMUs ,showed that the compressive strength increased by about 15 to 20 % upon using the FRM also ,it Was found that these sample retained a basic level of structural integrity even beyond the ultimate loadthe failure of BMUs made with plain mortar showed more disintegration and a brittle failure. The Kcr, which is a measure of cracks propagation, was found to reach a much higher level for the unit with FRM.Since the cost of FRM is only about 10% higher than plane mortar, the overall an impact on using felt building almost negligible, it is felt that masonry structure with better seismic performance can become reality, though some more field level experiment are required.

Keywords - cement I.S 1489:(Part I fly ash based) ,RECRON 3s fiber,fine aggregate,coarse aggregate,brick-I class,water,standard sand.

I. INTRODUCTION

Cementations materials are brittle and weak in tension though they can resist large compressive stresses. Embedding materials capable of resisting tensile loads, and having them take the load after the surrounding cementations matrix has cracked, is a

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standard method of addressing this inherent weakness of cementations matrices. Such reinforcements can either be short fibers, continuous reinforcements, or even in the form of a fabric. In fact, normal reinforced concrete, fiber reinforced concrete and composite concrete sections can be considered examples of this principle.

Cement mortars are used extensively in brick and stone masonry, especially in India, and the idea of reinforcing them with appropriate fibers is relatively new. The mortar is used between successive layers of brick, and in slightly different form to plaster the brick (or stone) walls a typical example of brick masonry construction in a multi-story reinforced concrete frame construction. The mortar layers between brick layers can be clearly seen. As is clear, masonry is made up of two distinct and very different components – the bricks and the mortar, with the former usually having a higher strength compared to the latter.

This thesis focused on some issues related to brick masonry construction using fiber reinforced mortar. Now, use of reinforcement in the mortar is essential in order to improve the performance in terms of shear bond, compression and cracking characteristics. Recently, research has been carried out to examine the potential of thin sheet cement-based products reinforced with hand lay-up of fabrics, showing very promising results [Swamy, R. 1990; Peled A. in 1998, 1999, and 2000]. Also, a variety of short polymer fibers have become easily available in India, and their use could be a fairly cost effective method of enhancing the ductility and strength of the mortar, and also the brick masonry made using such fibers reinforced mortar (FRM). An attempt was made here to experimentally study the properties of FRMs, prepared with short polyester fibers and the effect of its application in the behavior of brick masonry structure in compression and shear. Cement sand mortars were cast using different volumes of fibers and tested in compression and split tension. After narrowing down the range of suitable mix proportions, compression and shear bond tests were performed using appropriately prepared brick masonry units (BMUs) with plain mortar and FRM

Scope of present work

Studies in the aftermath of recent earthquakes have shown that failure of brick masonry building caused enormous loss of life and property, with the failure of the mortar joints very prominent. Now, with brick masonry buildings being the mainstay of the Indian housing and building sector at large, it is important that we find out ways and means to improve the performance of such buildings under an earthquake load. For that we have to improve their lateral load carrying capacity and ductility. One of the options available to engineers is to improve the performance of the weakest link in brick masonry i.e., mortar which can be brought about by the introduction of fibers in the mortar matrix.

In the present investigation, the objective was to study the properties of Fiber Reinforced Mortar (FRM) and its application in masonry structures using appropriate experiments. In the first part of the study, cement sand mortars generally used at sites (i.e. Correspondingly to mortars having the ratio of cement to sand between 1:3 to 1:6) were cast using different volumes of fibers and tested in compression and split tension. The tests were carried out in accordance with ASTM C 780, and other relevant Indian specification.

II. MATERIAL AND TESTING

MATERIAL

Cement - Cement: IS 1489: (Part 1 Fly Ash based):Portland Pozzolana Cement whose properties were determined and given in the - Table 1.1 was used for preparing the mortar.

Table 1 Properties of Cement

Properties	Average
Standard consistency	30.5
Initial Setting time (min.)	35
Final Setting time (min.)	600
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

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. 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.

Table 2 Properties of RECRON 3s Fiber

Chemical Family	Modified polyester
Material Identification	Polymer
Physical and Chemical Properties	
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

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,hand moulded 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.

TEST SPECIMEN – mortar cube,mortar cylinders,brick masonary unit.

CURING OF CUBE – curing was done for 7 days and 28 days.

TESTING – Following test were done duing the project

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

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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 - Compressive strength is the capacity of a material to with stand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. It is observed from the data obtained by compressive testing.

SPLIT TENSILE STRENGTH - Split tensile strength is a measure of a material's ability to resist a diametric compressive force placed on a cylindrical specimen with its axis placed horizontally between the platens of a test machine. The load application induces splitting tensile stresses on the face, and hence the name of the test.

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

Table 3 Average compressive strength at 7 days

% 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

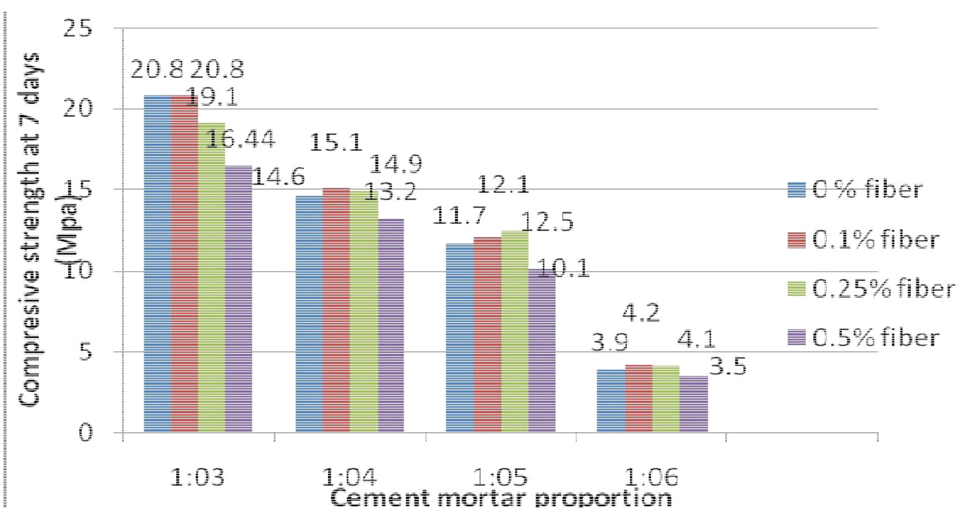

Figure1:Compressive strength variation of mortar cubes with respect % of fiber at 7 days.

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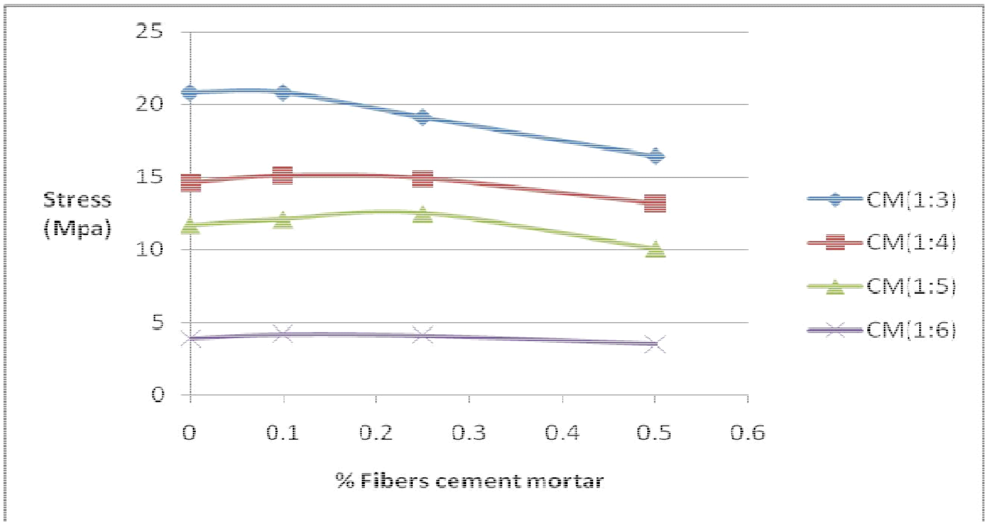

Figure 2:Compressive strength variation of mortar cubes with respect % of fiber at 7 days.

Table 4 Average compressive strength at 28 days

Percentage 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

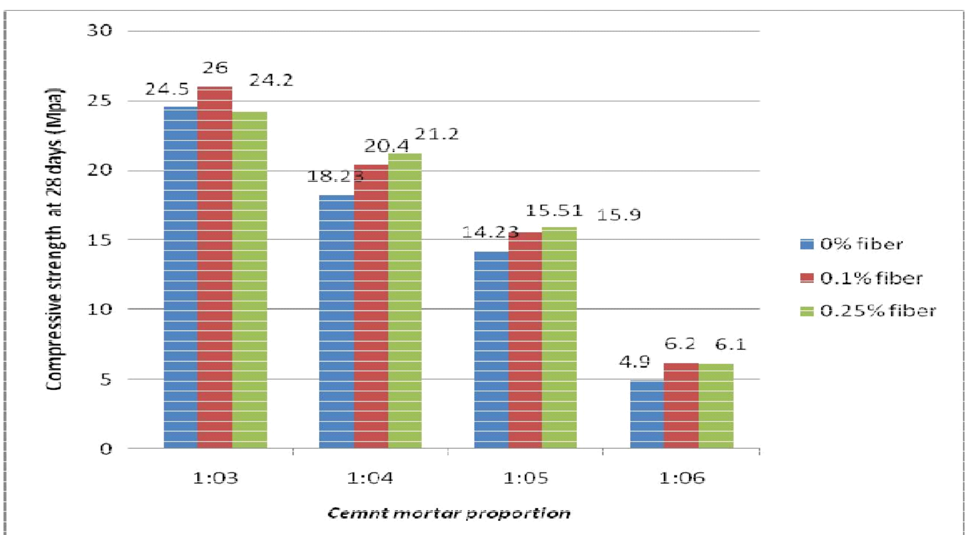

Figure 3:Compressive strength variation of mortar cubes with respect % of fiber at 28 days.

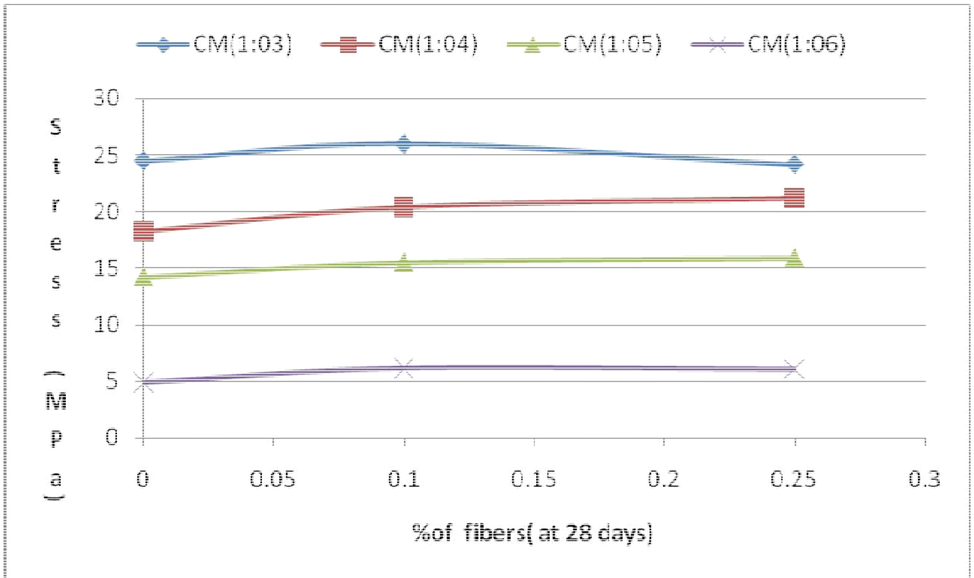

Figure 4:Compressive strength variation of mortar cubes with respect % of fiber at 28 days.

COMPRESSIVE STRENGTH OF BRICK

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

Table 5 Compressive strength for masonry units

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

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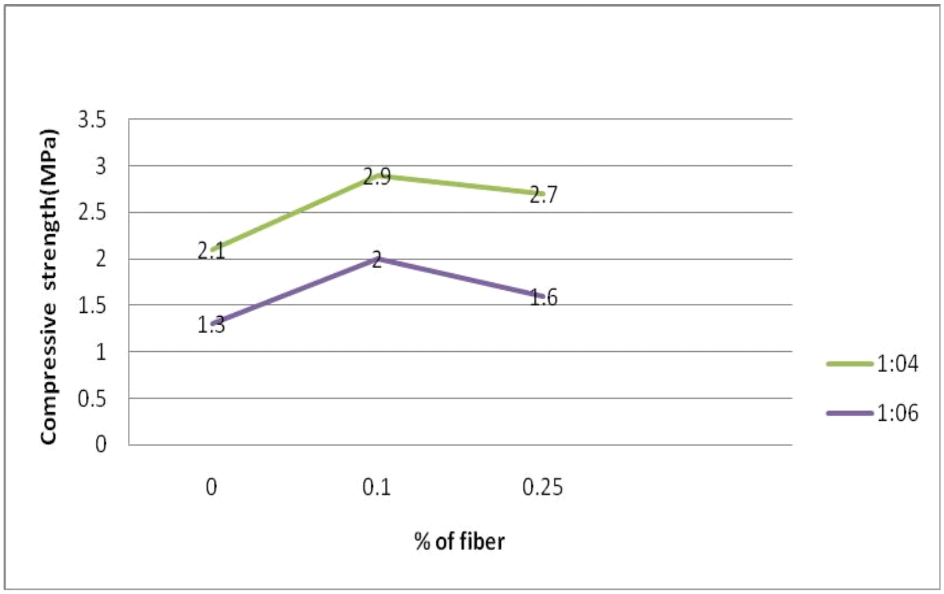

Figure 5:Compressive strength variations with respect volume of fibers

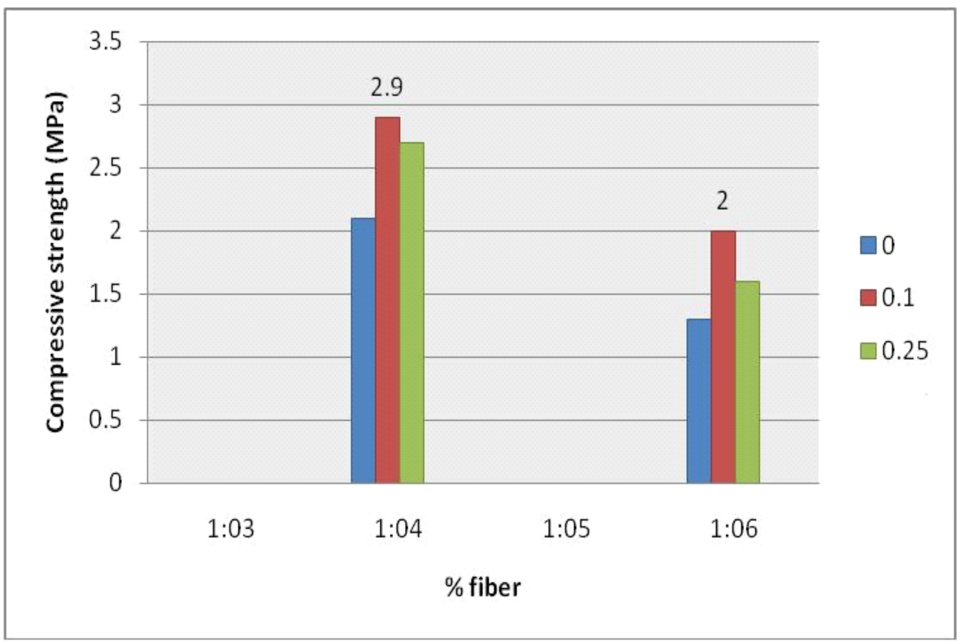

Figure 6:Histogram showing Compressive strength variation with respect volume of fibers

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 6 Figure7: and Figure8: show the relative increase in split tensile strength due to fiber addition.

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Table 6 Split tensile strength values

S.		Split tensile strength in MPa			
No.	% of fiber	0	0.1	0.25	0.5
1.	CM(1:03)	0.15	0.19	0.14	0.14
2.	CM(1:04)	0.12	0.16	0.1	0.08
3.	CM(1:05)	0.08	0.1	0.09	0.08
4.	CM(1:06)	0.06	0.08	0.08	0.07

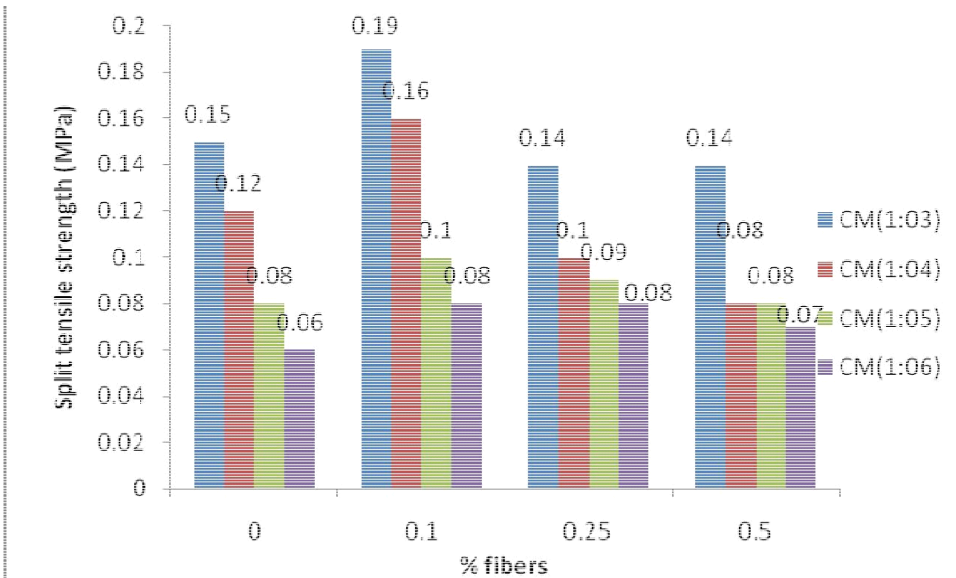

Figure 7:Histrogram showing Variation of split tensile strength variation with fiber volume (28 days)

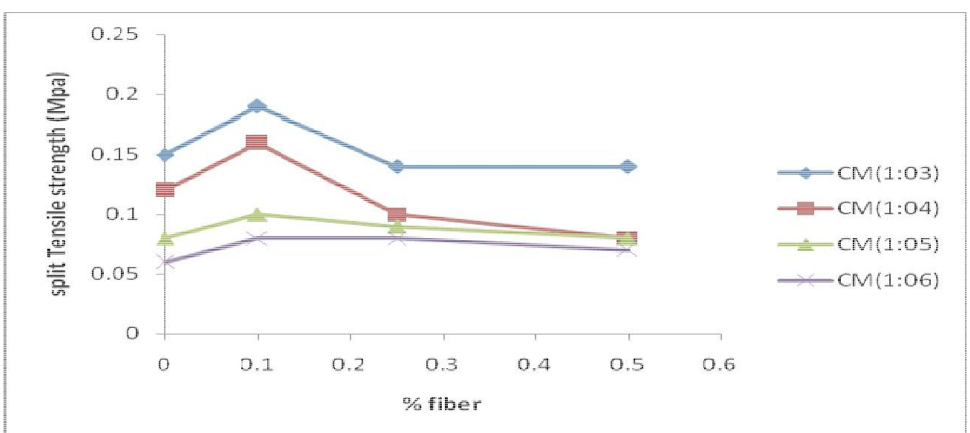

Figure 8:Variation of split tensile strength variation with fiber volume

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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 to 4). 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 Figure1: 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 7: and Figure 8: show 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 FIBRE 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.

APPLICATION OF PRESENT WORK

The test results show that the plain masonry brick units failed due to brittle failure on loading beyond the ultimate load while the FRM units where ductile in failure and deformed far more than the plain masonry units. One of the main criteria in the design of earthquake resistant structures is the ductile behavior of the structure and in this aspect a FRM structure will show better performance than plain masonry structure.

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