Study on Alternative Materials for Sand in Cement Mortar for Masonry

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ABSTRACT

Sand is the most commonly preferred fine aggregate used in construction, which is becoming scares. This scarcity has made it very significant to find an alternative and also to assess its suitability in construction practices. Emphasizing the same, the present work focuses on assessing the various basic properties of alternative materials like Manufactured Sand (M- Sand) and Granulated Blast Furnace Slag (GBFS) in comparison with the conventional river sand. This work attempts to evaluate the characteristics of mortar prepared using alternatives materials to the conventional river sand. The effect of the characteristics of mortar on the masonry strength is also assessed. Two proportions of mortars viz. 1:3 and 1:6 are tried. The results make it evident that well-graded M-Sand and GBFS can be effectively adopted as an alternative to the conventional river sand in cement mortar used in masonry structures.

Keywords — Manufactured Sand; Granulated Blast Furnace Slag; Mortar; Water Cement Ratio

I. INTRODUCTION

The booming growth of the construction industry with a major thrust to the infrastructural project has increased the demand for fine aggregate material river sand. The river sand is treated as a major construction material due to its abundant quantity. The properties of river sand make it best suited for preparing mortar mix and concrete. River sand is formed due to the natural weathering of rocks over a period of millions of years. The river sand which is mined from the river beds has a disastrous environmental implication like river bed degradation, river buffer zone encroachment, deterioration in the quality of river water, and depletion of groundwater. The uncontrolled mining of river sand damages the ecology which is irreversible. Further, the restriction on the extraction of sand from the river has resulted in the rise of the price of sand which is severely affecting the subsistence of the construction industry [1]. Henceforth adopting an alternative to the conventional river sand is of prime importance and has become imminent. The alternatives to river sand will support the construction industry which is endured due to lack of river sand and also would reduce to unpleasant environmental effects due to river sand mining.

Manufactured sand is currently being used as an alternative to the river sand in the construction activities which is produced by crushing coarse stone aggregate in special rock crusher. The crushed materials are washed to remove the finer particles and dust to meet the particle size grading requirement for construction purposes. The stringent quality of M Sand has made it to evolve as a viable alternative to the conventional river sand [2].

The Granulated Blast Furnace Slag (GBFS) is also used as an alternative to fine aggregate in construction which is a byproduct of the iron industry. In the process of iron production, the fluxes like dolomite and limestone are introduced to the blast furnace as charge material along with coke as fuel. On the process of combustion, the carbon monoxide is produced which converts iron ore into molten iron products and slag. The byproduct iron slag is non-metallic and inert material containing silicates, alumina - silicates and calcium - alumina silicate as its main component. The adoption of GBFS as an alternative to river sand in the construction industry will reduce the dependency on river sand and also minimizes the disposal problem of byproduct slag from the iron industry [3] [4].

Though the adoption of alternatives for the river sand is of pivotal importance, the suitability of its usage is to be assessed based on the specific needs of the construction industry. The quality of the alternative to the river sand has a direct implication on the quality and ease of construction. Henceforth, before adopting the alternatives to the river sand, its engineering properties are to be assessed and compared with that of conventional river sand.

The experimental work presented here focuses on studying the properties of alternative materials for river sand in masonry construction.

The properties of fine aggregate such as bulk density, water absorption, moisture content, and gradation are assessed for river sand and alternatives like M sand and GBFS to make a comparative study. The mortars are produced with 1:3 and 1:6 Cement: Fine Aggregate ratio with conventional river sand and alternatives M Sand and GBFS. The properties of mortar such as flow, compressive strength, modulus of elasticity, and stress-strain characteristics are assessed.

The mortars produced with river sand and its alternative M sand and GBFS are used in brick masonry and the properties of masonry like compressive strength and shear bond strength are studied.

II. OBJECTIVE OF STUDY

The main objective of the study is to assess the suitability of using alternative fine aggregates as a replacement to the conventional river sand in cement mortars used in brick masonry. Two different cement mortars 1: 3 (Cement: Fine aggregate) and 1:6 (Cement: Fine aggregate) have been tried. Manufactured sand from four different locations and Granulated Blast Furnace Slag (GBFS) have been considered to replace the conventional river sand in cement mortars. The suitability of using alternative fine aggregates in masonry has been made by determining the compressive strength and shear bond strength of brick masonry prisms. The stack bonded masonry prisms were constructed with clay brick masonry units of compressive strength of 3.5 MPa with mortars (1C:3FA and 1C:6FA) consisting of various fine aggregate inclusive of both alternative fine aggregate and conventional river sand.

III. MATERIAL CHARACTERIZATION

1. Cement

The commercial Ordinary Portland Cement (OPC) of 53 grade conforming to IS 12269 - 1989 [5] is used in this experimental study. The various properties of cement were determined as per IS: 4031 - 1988 [6]. Table 1 shows the results obtained.

1) **Table 1: Properties of Cement**

Properties	Test Results
Normal Consistency, %	28 %
Specific Gravity	3.08
Vicat Initial Setting Time (Minutes)	35 Mins
Vicat Final Setting Time	258 Mins

(Minutes)	
Compressive Strength at 3 days	32.58 MPa
Compressive Strength at 7 days	45.27 MPa

2. Fine Aggregate

The details of the fine aggregates considered in the experimental study are given in table 2 along with their location. The different characteristics of alternative fine aggregates were assessed through the test conducted in accordance with the Bureau of Indian Standards to compare the same with the properties of river sand.

Table 2: Details of Fine Aggregate

Fine Aggregate	Source	Identification
River sand	Mysore, Karnataka, India	RS
Manufactured Sand	Bidadi, Karnataka, India	MS1
Manufactured Sand	Chinnakurali, Karnataka, India	MS2
Manufactured Sand	Hirekatti, Karnataka, India	MS3
Manufactured Sand	Ramangara, Karnataka, India	MS4
Granulated Blast Furnace Slag	Salem, Tamil Nadu, India	GBFS

Table 3, shows the different properties of fine aggregate assessed and the relevant Indian Standards adopted for the same.

B.

Table 3: Properties of Fine aggregate and relevant Indian Standards

Properties	Relevant Indian Standards
Specific gravity, Bulk density, Water Absorption, Moisture Content	IS 2386 – 1963 part 3 [7]
Percentage of fine particles less than 75 µ	IS 383 – 1970 part 2 [8]
Sieve analysis	IS 2386 – 1963 part 1 [9]

The results obtained are given in table 4 and the gradation curve for various fine aggregate are shown in figure 1

Table 4: Properties of River Sand and its alternatives

Properties	Test Results					
	RS	MS1	MS2	MS3	MS4	GBFS
Specific Gravity	2.61	2.44	2.45	2.23	2.60	2.49
Bulk Density (kN/m^3)	14.23	16.10	15.97	16.17	15.16	15.56
Water Absorption (%)	1.0	2.83	2.96	2.85	2.76	3.16
Moisture Content (%)	2.23	1.2	0.96	1.12	1.36	0.85
Fine Particles less than 75µ (%)	4.4	2.2	5	0	0	2
Sieve Analysis	Zone III	Zone IV	Zone III	Zone III	Zone III	Zone I

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

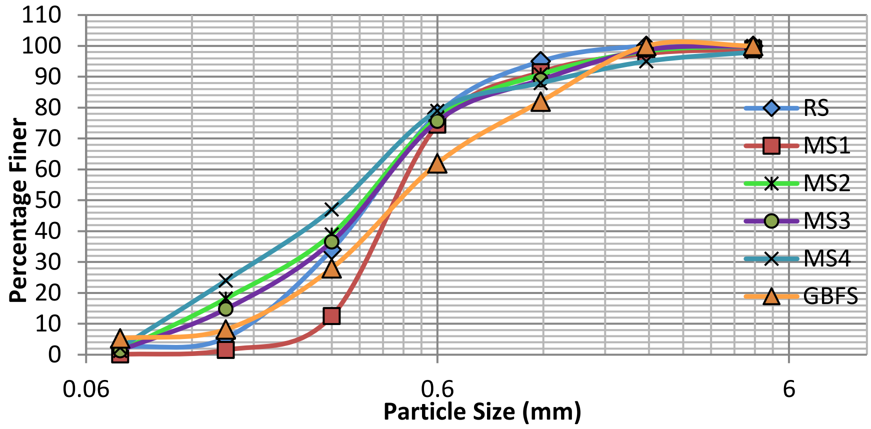

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Figure 1: Particle size distribution curve for fine aggregates

From table 4, it is seen that the Specific gravity of the fine aggregates varies from 2.23 to 2.61. The bulk density is of the range 14 to 17 kN/m^3 for different fine aggregate. The water absorption results show that the conventional river sand has the least water absorption capacity at 1.0% and GBFS has recorded the water absorption of 3.18% which is marginally more than the maximum value of 3.0 % specified by BS: 812-2 [10].

C.

3. Brick

The compressive strength and water absorption for the bricks used in the masonry were determined as per the guidelines of IS 3495-1976 [11]. Table 5, shows the results obtained.

Table 5: Properties of Brick

Dimension of Brick (mm)	Properties	Test Results
225 X 105 X 70	Compressive Strength (MPa)	3.5
	Water Absorption (by weight) (%)	18.93

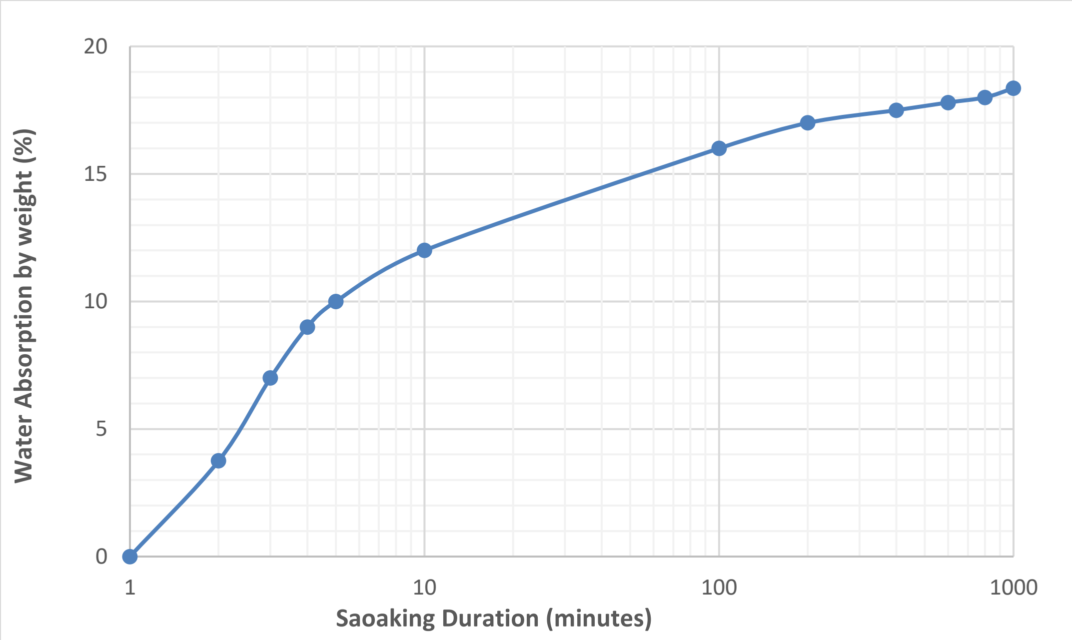

Figure 2: Water Absorption of bricks V/S duration of Soaking

4. Cement Mortars

The cement mortars of proportion 1:3 (1C:3FA) and 1:6 (1C:6FA) are adopted in this study. The cement mortars were prepared by using manufactured sand as a replacement to the conventional river sand. Also, GBFS is tried as a replacement. In both cases, the river sand is completely (100%) replaced. To compare the properties, the cement mortars were also prepared using conventional river sand in both proportions. The performance of mortar is assessed by conducting the flow and compressive strength tests

A. Mortar flow Test

The mortar should spread sufficiently on the masonry units to provide proper adhesion between the masonry units. To possess sufficient spread the mortar should be workable (flow). The composition of the mortar and water-cement ratio affects the workability or flow of mortar.

In this experimental work, the workability of mortars of 1:3 and 1:6 (Cement: Fine aggregate) proportions are assessed through the flow table test conducted as per BS: 4551-1980 [12]. Table 6 and 7 shows the variation of flow of 1: 3 cement mortar and 1:6 cement mortar for different water-cement ratios respectively. The same has been represented in Figures 3 and 4.

Table 6: Details of Water Cement Ratios and flow values for 1:3 Mortar

W/C Ratio	Mortar Flow (%)					
	RS	MS1	MS2	MS3	MS4	GBFS
0.4	7.14	14.28	5.70	7.00	14.00	14.20
0.5	14.00	28.57	11.42	14.30	23.00	20.00
0.6	21.14	38.60	21.42	28.50	31.00	25.70
0.7	38.57	62.70	38.57	40.00	60.00	35.70
0.8	57.14	78.20	57.14	54.28	75.00	50.00

0.9	79.27	86.23	85.71	78.57	92.80	78.50
1.0	103.57	116.20	110.10	100.00	114.00	98.57

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Table 7: Details of Water- Cement Ratios and flow values for 1:6 Mortar

W/C Ratio	Mortar Flow (%)					
	RS	MS1	MS2	MS3	MS4	GBFS
0.6	8.50	28.75	7.14	5.70	14.20	7.14
0.7	14.50	42.85	14.20	14.28	21.40	14.20
0.8	31.42	60.00	21.40	24.28	32.00	31.40
0.9	40.00	45.62	35.71	35.71	57.10	43.00
1.0	51.42	76.44	50.00	50.00	71.40	57.14
1.1	65.71	82.71	71.42	64.28	82.85	74.00
1.2	74.28	94.84	85.71	85.71	92.85	85.70
1.3	107.00	112.20	105.57	107.14	104.00	100.00

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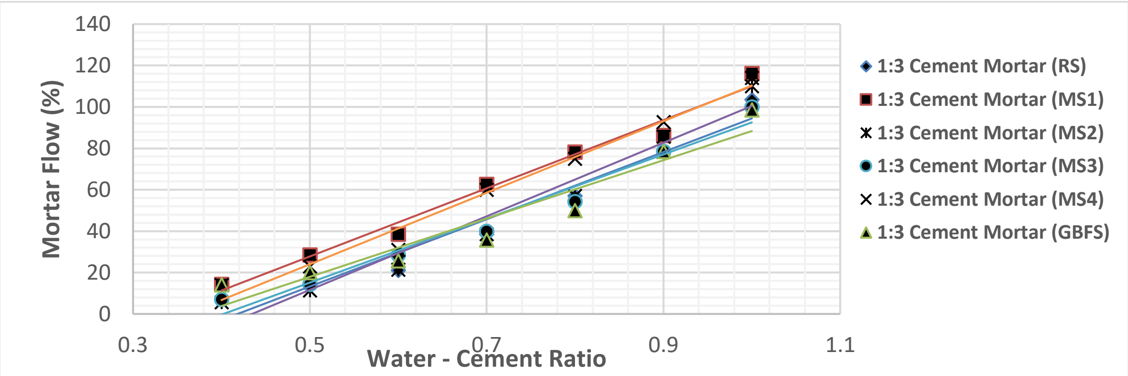

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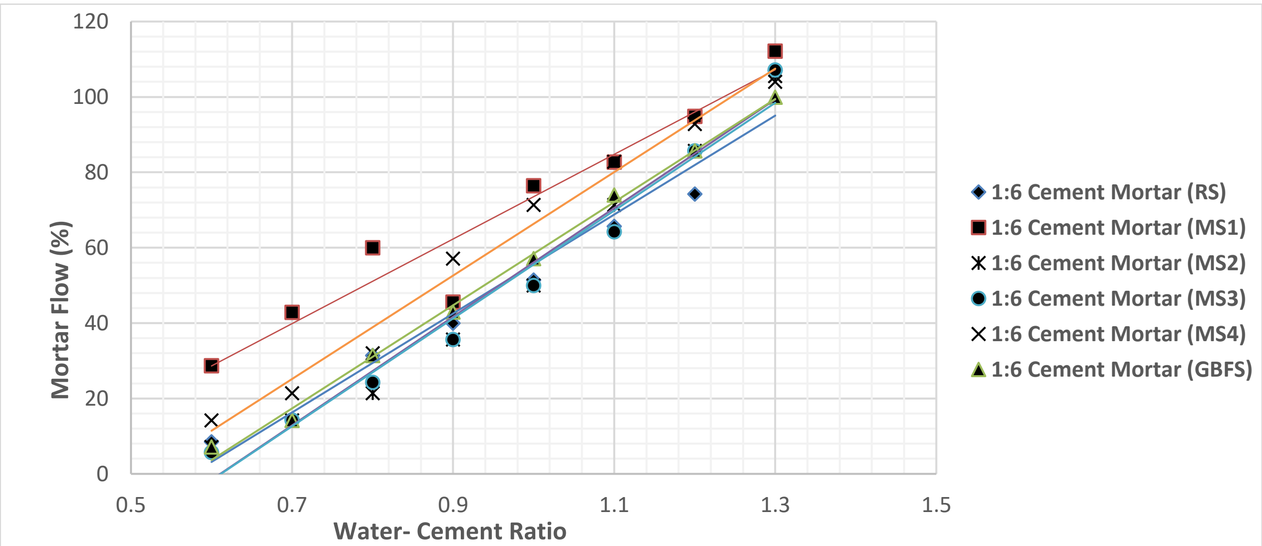
Figure 3: Variation of Mortar Flow with water to cement ratio for 1:3 Cement Mortar



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 4: Variation of Mortar Flow with water to cement ratio for 1:6 Cement Mortar

From Figures 3 and 4, it can be seen that the flow depends on the water-cement ratio. To achieve good spread or workability the flow should be in the range of 60 to 100 percent. It is evident from the results that for 1:3 and 1:6 cement mortars prepared with Manufactured Sand (MS1) have better performance than mortars prepared with conventional river sand with better spread and workability at all water-cement ratios. Further, the mortars prepared with other alternative fine aggregates have better spread and workability for all water-cement ratios as that of mortars prepared with conventional river sand

B. Compressive Strength of Cement Mortar

The compressive strength of cement mortars were determined to assess the feasibility of using sand and GBFS in cement mortars as an alternative to the river sand. The replacement has been tried in the two different proportions of mortars viz., 1:3, and 1:6. The compressive strength in each case is determined at various mortar flow corresponding to the water-cement ratio ranging from 0.6 to 1.3. The tests were conducted as per IS: 2250 – 1981 [13]. The test results are shown in tables 8 and 9 for cement mortar proportions of 1:3 and 1:6 respectively.

Table 8: Compressive strength of 1:3 Cement mortar for varying water-cement ratio

Fine Aggregate Type	W/C Ratio	Mortar Flow (%)	Compressive strength in MPa
RS	0.6	21.14	6.726
	0.7	38.57	7.023
	0.8	57.14	7.615
	0.9	**79.27**	**9.363**
	1.0	103.57	5.570
MS1	0.6	38.60	6.815
	0.7	62.70	7.170
	0.8	78.20	7.830
	0.9	**86.23**	**9.570**
	1.0	116.20	5.215
MS2	0.6	21.42	6.370
	0.7	38.57	6.920
	0.8	57.14	7.556
	0.9	**85.71**	**9.215**
	1.0	110.10	4.770
MS3	0.6	28.50	6.193
	0.7	40.00	7.019
	0.8	**54.28**	**7.674**
	0.9	78.57	9.748
	1.0	100.00	5.037
MS4	0.6	31.00	6.218
	0.7	60.00	7.793
	0.8	**75.00**	**9.481**
	0.9	92.80	6.015
	1.0	114.00	3.970
GBFS	0.6	25.70	5.274
	0.7	35.70	6.480
	0.8	50.00	7.585

	0.9	**78.50**	**9.037**
	1.0	98.57	5.304

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Table 9: Compressive strength of 1:6 Cement mortar for varying water-cement ratio

Fine Aggregate Type	W/C Ratio	Mortar Flow (%)	Compressive strength in MPa
RS	0.9	40.00	2.993
	1.0	51.42	3.644
	1.1	65.71	4.580
	1.2	**74.28**	**6.311**
	1.3	107.00	1.926
MS1	0.9	45.62	2.756
	1.0	76.44	3.615
	1.1	82.71	4.870
	1.2	**94.84**	**6.128**
	1.3	112.20	2.314
MS2	0.9	35.71	2.637
	1.0	50.00	3.674
	1.1	71.42	4.750
	1.2	**85.71**	**6.015**
	1.3	105.57	2.163
MS3	0.9	35.71	2.578
	1.0	50.00	3.822
	1.1	64.28	4.300
	1.2	**85.71**	**5.867**
	1.3	107.14	2.011
MS4	0.9	57.10	2.607
	1.0	71.40	3.822
	1.1	**82.85**	**6.044**
	1.2	92.85	4.320
	1.3	104.00	2.281
GBFS	0.9	43.00	2.044
	1.0	57.14	2.756
	1.1	**76.12**	**5.511**
	1.2	85.70	3.890
	1.3	100.00	2.015

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

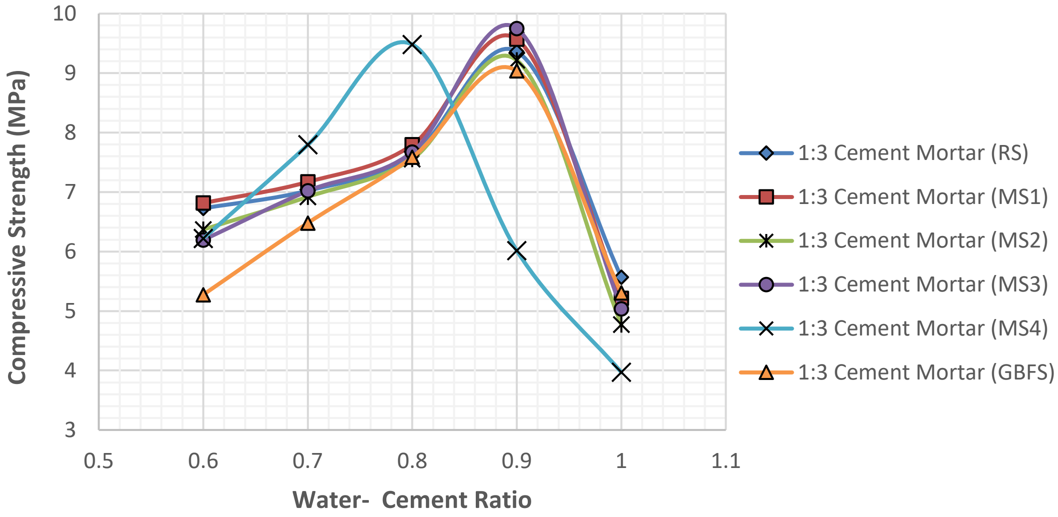


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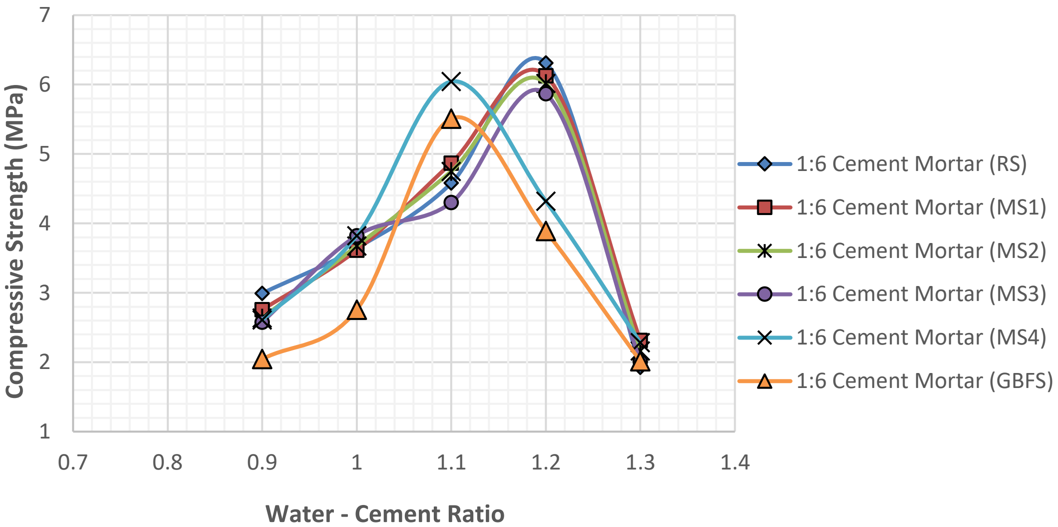
Figure 5: Variation of compressive strength with water-cement ratio of 1:3 cement mortar



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 6: Variation of compressive strength with water-cement ratio of 1:6 cement mortar

From the results, it can be seen that the 1:3 cement mortar prepared using river sand has achieved a compressive strength of 9.363 MPa at a water-cement ratio of 0.9 and mortar flow of 79.27%. The cement mortar prepared using alternative fine aggregate have compressive strength almost the same as that of cement mortar prepared using river sand. The value of compressive strength varies from 9.037 MPa to 9.748 MPa for water-cement ratio varying from 0.8 to 0.9 with a mortar flow of 75% to 86%. Compressive strength of 1:3 cement mortar prepared with GBFS has a minimum compressive strength of 9.037 MPa whereas the 1:3 cement mortar prepared with manufactured sand of type MS3 has a maximum compressive strength of 9.748 MPa.

From the results, it can be seen that the 1:6 cement mortar prepared using river sand has achieved compressive strength of 6.311 MPa at a water-cement ratio of 1.2 and mortar flow of 74.28%. The cement mortar prepared using alternative fine aggregate have compressive strength almost the same as that of cement mortar prepared using river sand. The value of compressive strength varies from 5.511 MPa to 6.311 MPa for water-cement ratio ranging from 1.1 to 1.2 with mortar flow of 74% to 95%. Compressive strength of 1:6 cement mortar prepared with GBFS has a minimum compressive strength of 5.511 MPa whereas the 1:6 cement mortar prepared with river sand has a maximum compressive strength of 6.311 MPa.

C. Elastic properties of mortar

The stress and strain relationship for the mortars with maximum compressive strength of 1:3 and 1:6 proportions and different fine aggregate were obtained in accordance with IS: 516- 1959 [14]. To assess the elastic property, the mortars with maximum compressive strength are considered for both 1:3 and 1:6 proportion of the cement mortars with various fine aggregates.

Stress-Strain measurements were carried by applying compressive load on saturated cylindrical specimens of 150 mm height and 300 mm diameter. The specimens were saturated by soaking the 28 days cured specimen in water for 48 hours. The saturated cylindrical specimens were tested at a constant strain rate of 1.25 mm per minute with a compression testing machine. The change in length of the specimen was calculated using a longitudinal compress meter. Modulus of elasticity of all the mortars was calculated by drawing initial tangent modules at the stress of 25% of ultimate stress on the stress-strain curve.

The calculated Modulus of Elasticity for 1:3 and 1:6 Cement Mortar is shown in Table 10 and Table 11 respectively. The same has been represented in Figures 7 and 8.

Table 10: Elastic Modulus for 1:3 Cement Mortar in Compression

Fine Aggregate	Water cement Ratio	Mortar flow (%)	Compressive strength in MPa	Modulus of Elasticity (MPa)
RS	0.9	79.27	9.363	3393
MS1	0.9	86.23	9.570	4072
MS2	0.9	85.71	9.215	3360
MS3	0.9	78.57	9.748	3550
MS4	0.8	75.00	9.481	3400
GBFS	0.9	78.70	9.037	3054

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Table 11: Elastic Modulus for 1:6 Cement Mortar in Compression

Fine Aggregate	Water cement Ratio	Mortar flow (%)	Compressive strength in MPa	Modulus of Elasticity (MPa)
RS	1.2	74.28	6.311	3299
MS1	1.2	117.0	6.128	2828

MS2	1.2	85.71	6.015	2639
MS3	1.2	83.60	5.867	2545
MS4	1.1	82.85	6.044	2980
GBFS	1.1	76.17	5.511	2648

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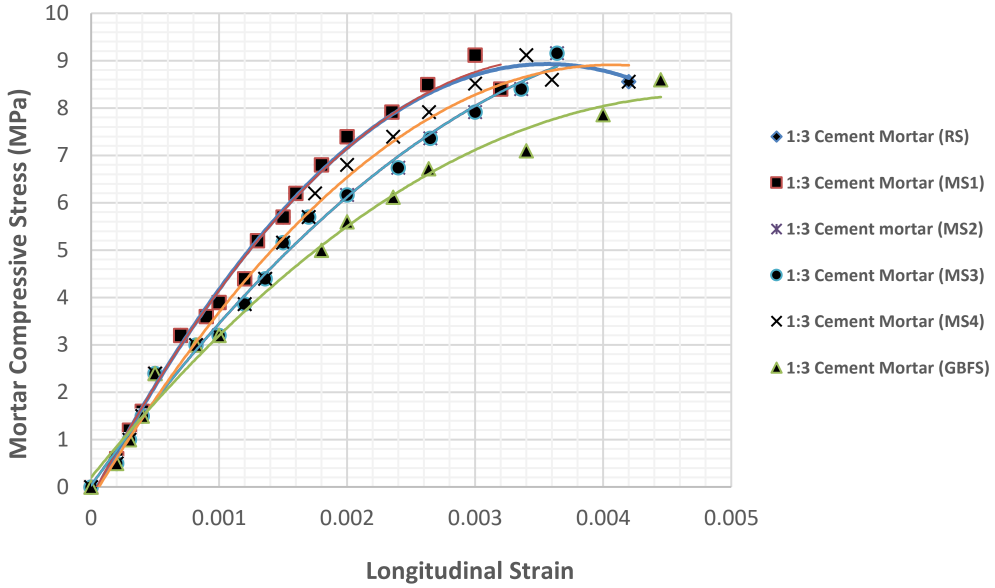

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Figure 7: Compressive Stress v/s Strain variation curve for of 1:3 mortar in Compression

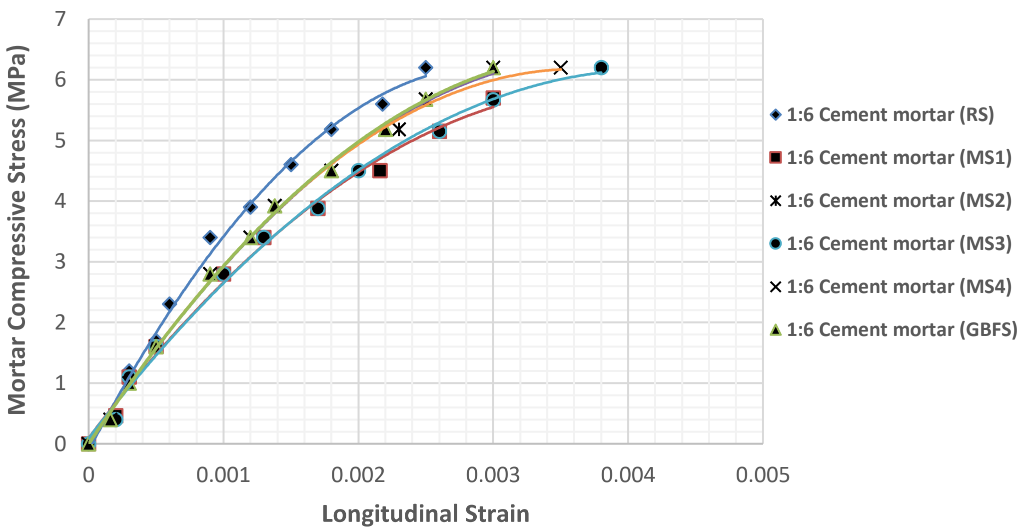

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Figure 8: Compressive Stress v/s Strain variation curve for of 1:6 mortar in Compression

From figure 7 and 8, it can be observed that the stress-strain curve is initially linear and as the stress increases further, the curve becomes nonlinear showing softening behavior. The curve shows a drooping portion in few mortars, in the rest of the mortars, the curve becomes horizontal indicating ductile behavior. The modulus of elasticity is sensitive to the compressive strength which depends on the mix proportion. It is also observed that the modulus of elasticity of 1:3 cement mortar is higher than that of 1:6 cement mortar. Amongst the 1:3 cement mortars, the mortar prepared with M Sand (MS1) recorded the highest modulus of elasticity of about 4072 MPa for a water-cement ratio of 0.9. Whereas amongst the 1:6 cement mortar, the mortar prepared with river sand recorded maximum modulus of elasticity 3299 MPa for water to cement ratio of 1.2.

IV. PERFORMANCE OF MASONRY

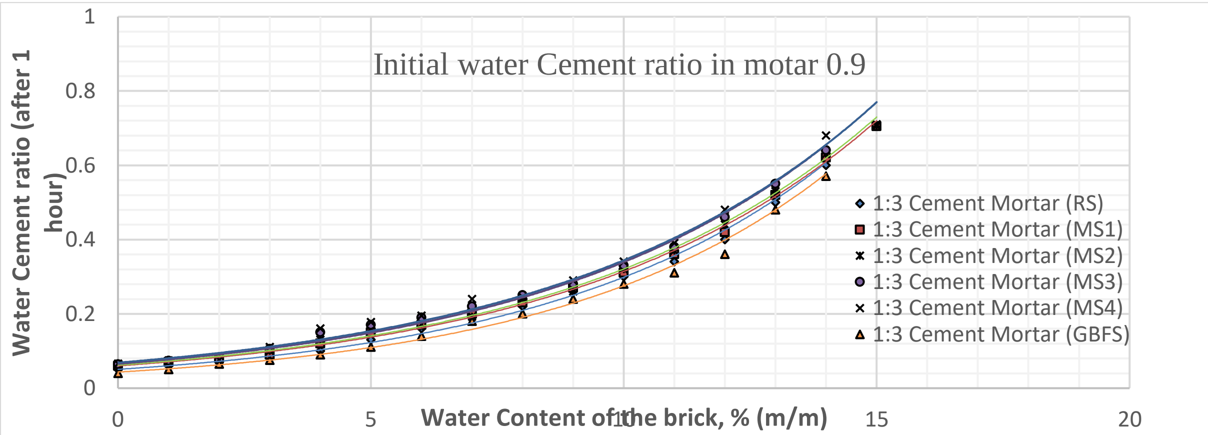
In order to assess the suitability of using the alternative fine aggregates as a replacement to the conventional river sand in the mortars to be used in masonry the compressive and shear bond strength of masonry is been determined for all cases.

A. Transport of moisture from mortar to brick in masonry

Brick is a porous material that tends to absorb water due to capillary suction. The rate of water absorption is high in dry bricks at initial stages and it generally slows down after a certain period upon reaching saturation. The study of moisture transport from mortar to brick in masonry is of vital importance as the loss of moisture from the mortar. This property of bricks affects the behavior of masonry as it is likely to absorb moisture from the mortar making it deficient of water. The deficiency of water in mortar may lead to improper hydration and reduction in the bond between brick and mortar. Hence, the brick needs to be soaked in water to prevent the absorption of moisture from the mortar.

The moisture transport from mortar to brick in masonry is assessed by the method suggested by Groot (1993) [15]. Initially, the oven-dried bricks are soaked in water for varying durations. This partially saturated brick is covered with a 10mm thick fresh mortar of known water-cement ratio and another similarly saturated brick is kept on the top. The top brick is removed after one hour and the mortar is scooped out to measure the changes in water-cement ratio.

The same method is adopted in this study for both 1:3 and 1:6 Cement mortar with various fine aggregates. Figure 9 shows the variation of water-cement ratio for 1:3 cement mortar prepared with various fine aggregates for the varying water content of the brick.



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 9: Variation of the water-cement ratio of 1:3 cement mortar water content of the brick

It can be observed from figure 9 that although the 1:3 (cement: M Sand) mortars have a water-cement ratio of 0.9, the water-cement ratios are reduced to about 0.2 in a duration of one hour. Hence to maintain a water-cement ratio of 0.5 or more the bricks should be partially saturated for about 13 to 14%. It is therefore clear that the brick should have a moisture content of about 75% of saturation value for which the brick should be soaked for about a minimum of 20 minutes.

Figure 10, shows the variation of water-cement ratio for 1:6 cement mortar prepared with various fine aggregates for the varying water content of the brick.

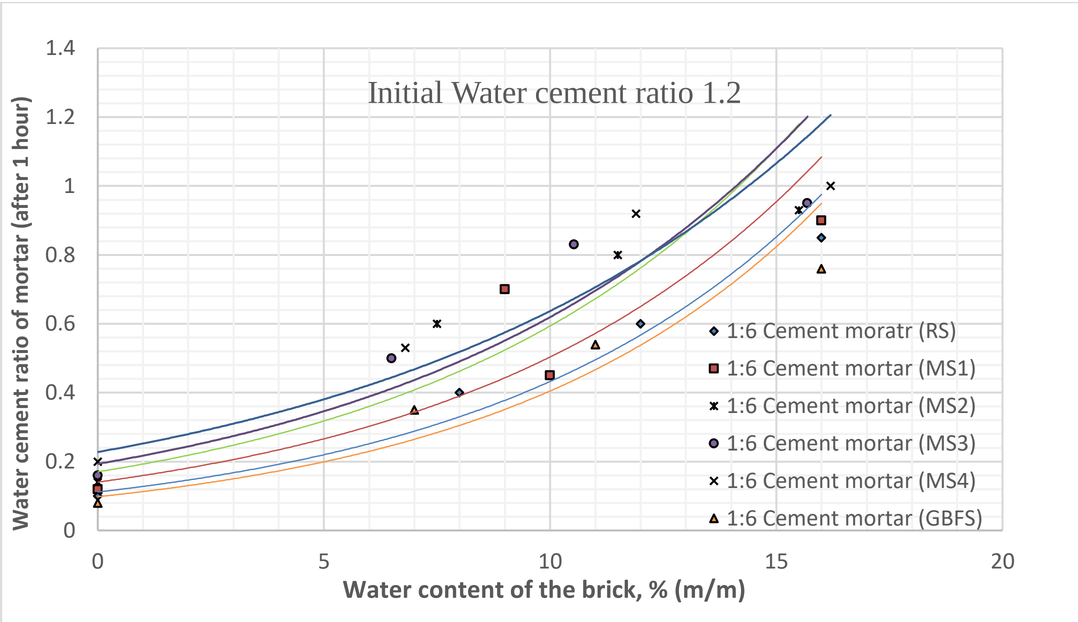


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Figure 10: Variation of the water-cement ratio of 1:6 cement mortar water content of the brick

It can be observed from figure 10 that although the 1:6 (cement: M Sand) mortars have a water-cement ratio of 1.2, the water-cement ratios are reduced to about 0.2 to 0.25 in a duration of one hour. Hence to maintain a water-cement ratio of 0.5 or more the bricks should be partially saturated for about 8 to 10%. It is therefore clear that the brick should have a moisture content of about 50 % of saturation value for which the brick should be soaked for about minimum 10 minutes

Hence to maintain the water-cement ratio of about 0.5 in both 1:3 and 1:6 mortar in masonry prisms, the bricks were prewetted for about 20 minutes before preparation of masonry

B. Compressive strength of clay brick masonry

The Compressive strength of brick masonry was determined by conducting compressive strength on the stack bonded masonry prisms of clay bricks of compressive strength 3.5 MPa. The bricks were pre-wetted for about 20 minutes before laying. The mortar thickness between the bricks was maintained at 10 mm. The adopted height to thickness (h/t) ratio of the masonry prism is 3.72. The masonry prisms were cured for a period of 28 days and were pre-wetted for 48 hours before testing. The masonry prisms were tested for compressive strength of masonry as per the IS: 1905- 1981 [15]. Figure 11, shows the masonry prism setup used in the compression test. The compressive strength was determined for all cases of 1:3 cement mortar and 1:6 cement mortar with alternative fine aggregates and conventional river sand.

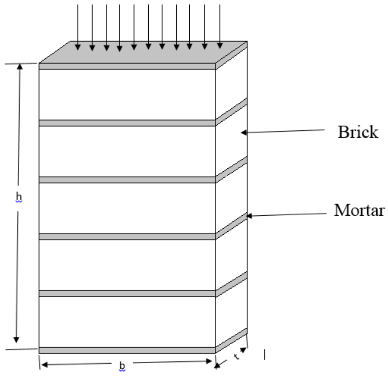


Figure 11: Masonry prism set up for Compression Test

A. C. Shear bond strength of clay bricks triplets in different mortars

The bond between the masonry unit and mortar greatly influences the masonry strength. Bond strength is very important especially when the masonry is subjected to in-plane and out of plane bending. As the bond strength increases, the masonry compressive strength also increases. Henceforth the Shear bond strength of clay brick masonry has been examined through masonry triplets. Clay bricks assembly as shown in figure 12 is used to assess the shear bond strength of clay brick mortar joints. The arrangements are made in the triplet in such a way that the shear load can be applied at the middle block. The middle block is free to move in the vertical direction, whereas the end blocks are restrained. In this experimental study, the shear bond strength of clay brick masonry triplets with cement mortar with various fine aggregate has been determined. The compressive strength of Clay bricks used was 3.5 MPa. The mortar joint thickness of 10 mm was maintained throughout. All the triplets were cured for 28 days by keeping in moist condition before testing.

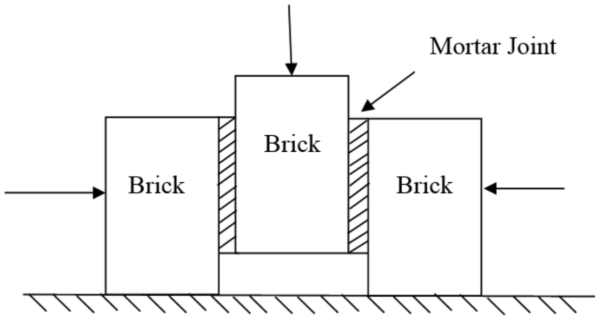


Figure 12: Shear Bond Strength Specimen Set Up

V. RESULTS AND DISCUSSIONS

A. Compressive strength of brick masonry

The results of prism compressive strength of brick masonry prepared with Cement Mortars of proportions 1:3 and 1:6 Mortar are given in table 12 and table 13 respectively and the same has been represented figures 13 and 14.

Table 12: Compressive Strength of masonry with 1:3 mortar

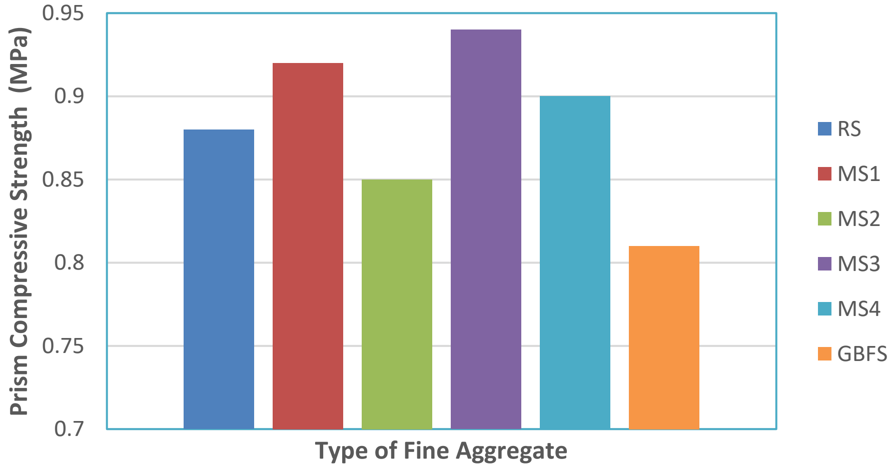
Fine Aggregate	Water cement Ratio	Mortar cube compressive strength (MPa)	Prism Compressive Strength (MPa)	Masonry Efficiency (η) (%)
RS	0.9	9.363	0.88	25.14
MS1	0.9	9.570	0.92	26.28
MS2	0.9	9.215	0.85	24.28
MS3	0.9	9.748	0.94	26.85
MS4	0.8	9.481	0.90	25.71
GBFS	0.9	9.037	0.81	23.71

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Table 13: Compressive Strength of masonry with 1:6 mortar

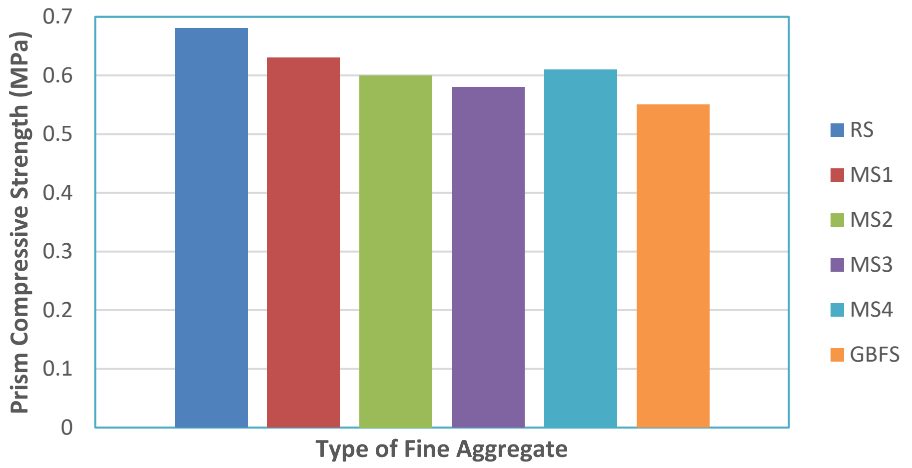
Fine Aggregate	Water cement Ratio	Mortar cube compressive strength (MPa)	Prism Compressive Strength (MPa)	Masonry Efficiency (η) (%)
RS	1.2	6.311	0.68	19.42
MS1	1.0	6.128	0.63	18.00
MS2	1.2	6.015	0.60	17.14
MS3	1.2	5.867	0.58	16.57
MS4	1.1	6.044	0.61	17.14
GBFS	1.1	5.511	0.55	15.71

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 13: Variation of Masonry prism Compressive strength with 1:3 mortar



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 14: Variation of Masonry prism Compressive strength with 1:6 mortar

From the results of compressive strength of masonry with 1:3 Cement mortars, it is evident that the masonry prism compressive strength with M Sand (MS3) cement mortar is recorded higher compressive strength of 0.94 MPa this may be because the mortar prepared with M Sand (MS3) possessed marginally higher compressive strength of 9.57 MPa.

Whereas, amongst the masonry with 1:6 cement mortar, the prism compressive strength of Masonry with river Sand cement mortar also recorded higher strength of 0.68 MPa this may be due to the reason that mortar prepared with river sand possessed marginally higher compressive strength of 6.311 MPa.

It is well evident that the compressive strength and efficiency of the masonry is influenced by the compressive strength of the mortar used. As the compressive strength 1:3 cement mortar is more, the masonry prism compressive strength and efficiency is also more when compared to that of masonry prism with 1:6 cement mortar.

B. Shear bond strength of clay bricks triplets

The results of shear bond strength of clay brick triplets prepared with Cement Mortars of proportions 1:3 and 1:6 mortar are given in table 14 and table 15 respectively and the same has been represented figures 15 and 16.

Table 14: Shear Bond Strength of masonry with 1:3 mortar

Fine Aggregate	Water cement Ratio	Mortar cube compressive strength (MPa)	Shear Bond Strength (MPa)
RS	0.9	9.363	0.35
MS1	0.7	9.570	0.32
MS2	0.9	9.215	0.30
MS3	0.9	9.748	0.26
MS4	0.8	9.481	0.29
GBFS	0.9	9.037	0.25

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Table 15: Shear Bond Strength of masonry with 1:6 mortar

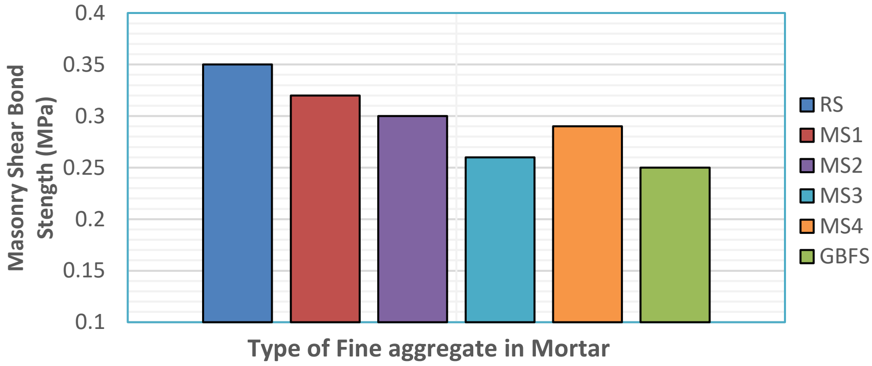
Fine Aggregate	Water cement Ratio	Mortar cube compressive strength (MPa)	Shear Bond Strength (MPa)
RS	1.2	6.311	0.29
MS1	1.0	6.128	0.26
MS2	1.2	6.015	0.23
MS3	1.2	5.867	0.24
MS4	1.1	6.044	0.23
GBFS	1.1	5.511	0.19

**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

The results of shear bond strength of masonry with 1:3 cement mortar show that the cement mortar prepared with river sand has a higher shear bond strength of 0.35 MPa and the masonry with cement mortar of GBFS as fine aggregate has recorded the least shear bond strength value of 0.25 MPa.

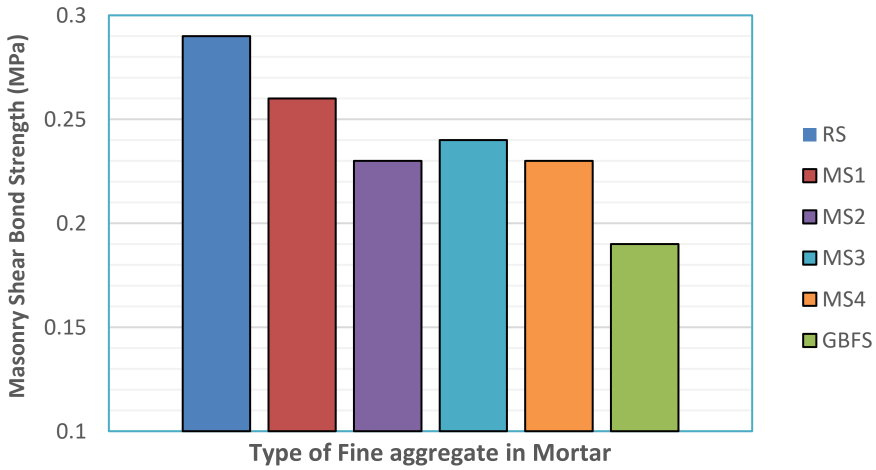
Similarly, among1:6 cement mortar the cement mortar prepared with river sand has a higher shear bond strength of 0.29 MPa and the masonry with cement mortar prepared with GBFS as fine aggregate has the least shear bond strength value of 0.19 MPa.

It also can be observed that the compressive strength of mortar has no prominent influence on the shear bond strength of masonry but the gradation and the texture of fine aggregate used influences the shear bond strength.



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 15: Variation of Masonry Shear Bond strength with of 1:3 mortar



**RS- River Sand; MS- Manufactured Sand; GBFS- Granulated Blast Furnace Slag*

Figure 16: Variation of Masonry Shear Bond strength with of 1:6 mortar

VI. CONCLUSION

Based on the experimental results it can be concluded that the Manufactured sand can be effectively used as an alternative to the conventional river sand in the masonry as there is only slight variation in the test results of masonry produced using conventional river sand and M Sand. Further, the gradation of the fine aggregate used in the masonry mortars influences the shear bond strength of masonry.

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