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Experimental Investigation of Fly Ash Based Solid Block Masonry Prism by Using M-Sand as Partial Replacement of Fine Aggregate

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Abstract

This paper presents an experimental investigation on fly-ash based solid block masonry prism using m-sand as partial replacement of fine aggregate. Masonry prisms were constructed with various mortar grades 1:4, 1:5, and 1:6, and the respective compressive strength of cement mortar was tested for 7days, 28days, and 90days. River sand M-sand is one be the suitable replacement for river sand. In this experimental work, a solid block is produced by a constant replacement of cement by 10%of fly ash and fine aggregate by M-sand of proportion 0%, 20%, 40%, 60%, 80%, and 100%. Masonry prisms are tested for various mortar proportions to determine the compressive strength. The mechanical properties of solid block prism are compared with code provisions such as IS:1905-1987 and ASTM C1314. The result clearly states that the compression strength of the masonry prism is affected by the mortar grade.

Keywords -*Fly ash, Masonry prism, M-sand, Compressive strength*

I. INTRODUCTION

A solid block prism is an arrangement of a masonry unit with mortar built as a test specimen for finding its properties. According to ASTM-447 standard test methods, prisms are tested to determine the compressive strength. To ensure the flexural bond strength, prisms are also constructed. With a stepwise increase in the industrial revolution and urbanization in a state, plenty of infrastructure development is made. Due to overutilization of natural sources, either river sand or any construction material from a natural source creates shortage. To overcome these problems, new materials should be employed as a new construction material. Our attempt is taking fly ash as a partial replacement for cement and replacing fine aggregate with manufactured sand. Flue ash is another word for fly ash. It is normally created in combustion, and it gives the fine particles with flue gases.

Over 80million tons of fly ash is generated each year from thermal power plants in India. The amount we utilize is less than 10% only. It is used in concrete blocks as a partial replacement for cement to minimize the amount of cement used in concrete blocks. Using fly ash as a building material is purely depends on its mineral structure and pozzolanic property. Natural sand is generally regarded as a fine aggregate and also a stone that moves through the 600micron also called as fine aggregate. Ninety percentage of fine aggregate passes through 4.75mm IS sieve, and in rare cases, some passes through 150micron. Fine aggregate is used for constructing a thin wall and reinforced concrete elements. It is also used in the runway (airport) and highway due to its fineness. Their properties are given below. Cement is one of the most widely used building materials which act as a binding agent. Its work is to adhere to building units like bricks, stone, tiles.

The cement is a word which came from roman called caementicium it explains the masonry. Later pulverized brick and volcanic ash supplement are mixed to the burnt lime to get a hydraulic binder. Then day by day, it is often called cementum and cement. Usually cement is classified into two types, namely hydraulic and non-hydraulic cement. The addition of water hardens hydraulic one. Carbonation hardens the non-hydraulic cement. Ordinary portland cement of grade 53 is the cement that we used in this project. In our project, m-sand is used in the range of 20%, 40%, 60%, and 100%. It is an eco-friendly one, gives less damage to the environment, and has zero silt content. Moisture content is available when it is washed by water. Manufactured sand normally gives higher strength than river sand.

Kushal, Amitkumarbiswal et al.[2017] investigated the use of fly ash in concrete by replacing cement with fly ash in a range of 0%, 25%, 50%, 75%, and 100%. From the results, they stated 25% replacement of cement by fly ash achieves maximum strength.

M.S.Krishnahygrive, I.Siva Kishore et al. [2017]investigated the compressive strength of fly ash concrete by replacing cement with fly ash in the range 20%, 30%, 40%, 50%, and finally, they achieve the maximum strength in 20% replacement of cement by fly ash.

Amit Mittal, Kaisare, made an experimental study on using fly ash in concrete by replacing cement with fly ash in the range 20%, 30%, 40%, and 50%. Result clearly shows that 20% replacement gives considerable strength.

Abdulhalimkarasinand Murat Dogruyol [2014] take an experimental study on strength and durability for utilization of fly ash in the concrete mix. The result shows that a 20% replacement gives a bit different in strength properties.

S.Muralikrishnan, T.Felixkala, P.Asha, et al.[2018] studied the properties of concrete using m-sand as fine aggregate by replacing fine aggregate with m-sand. Their result shows that 50% replacement of m-sand has high flexural strength than the standard concrete mix.

Y.Boopathi, J.Doraikannan [2016] studied the m-sand as a partial replacement of fine aggregate in concrete. They use m-sand as a replacement for fine aggregate in the range 0%, 20%, 40%, 60%, and 80%. Their test result shows that 60% replacement gives maximum strength.

AMZ Zimar, GKPN Samarawickrama, WSD Karunarathna [2018] aimed to determine the effect of manufactured sand as a replacement for fine aggregate in concrete. Here they use m-sand as a fine aggregate in the range of 0%, 30%, 50%, 70%, and 100%. They stated an increase in m-sand, which decreases the strength of concrete.

Yajurvedreddy, Swetha, Dhani [2015] studied the properties of concrete with manufactured sand as a replacement to natural sand. This paper investigates the strength and durability of concrete by using m-sand to replace natural sand in the range 0%, 20%, 40%, 60%, and 100%. The result shows that 60% replacement gives considerable strength in concrete.

Sachin Kumar, Roshan s kotian [2018] investigated the m-sand as an alternative to the river sand in construction technology. Here they compare the strength of river sand and m-sand. Finally, they concluded that manufactured sand gives the same or greater value than river sand in compressive, flexural, split tensile strength tests.

In our current experimental work, the result displays more consumption of m-sand, i.e., when increasing the proportion of replacing m-sand, which gradually decreases the strength of concrete.

II. EXPERIMENTAL PROGRAM

A. Casting of a solid block

Nowadays, bricks are replaced by concrete blocks in masonry construction. Three types of blocks are generally available, namely solid, hollow, and cellular. In our project, we are using a solid concrete block of size 300mm x 150mm x 200mmcasted in a block manufacturing plant in Madurai near Azhagar temple. There are two types of manufacturing processes for concrete blocks, viz. humanmade and machine-made. Our blocks are machine-made ones. Blocks are made in the mix ratio 1:1.5:3 with 10% fly ash as a partial replacement for cement and m-sand in the range 20%, 40%, 60%, 80%, and 100% fine aggregate. After casting the block, cured it for 14days and then allowed to dry for 3-4 weeks. By placing a solid block one by one in vertical order, prisms are made with various mortar mix (1:4 1:5 1:6). Then it is subjected to continuous curing. Finally, the specimen is tested in a universal testing machine (UTM) to determine the compressive strength. Apply the load slowly and watch the testing specimen carefully. When it is starting to crack, stop applying the load, and note the reading.

Fig.1 Casting of a solid block

B. Compressive strength test for cement mortar

It is the capability of a structure or any material to carry loads on its surface without any crack or deflection. Compressive strength test for mortar is determined by using the measurement of a mortar cube to calculate the cross-sectional area. Size of cube (70.6 x 70.6 x 70.6)mm. Place the mortar cube in the center of the loading area. Make the cube's surface in contact with the compressive testing machine and then gradually apply the load. Observe the specimen; when it starts to break, stop applying the load and note the reading (Ultimate load). By using the load, divide it by the cross-sectional area, which gives the compressive strength.

Table 1 Mix Proportion for 1:4 mix ratio

Mix	Cement(Kg)	Fine aggregate (Kg)
CM	450	2000

Table 2 Mix Proportion for 1:5 mix ratio

Mix	Cement(Kg)	Fine aggregate(Kg)
CM	370	2050

Table 3 Mix Proportion for 1:6 mix ratio

Mix	Cement(Kg)	Fine aggregate(Kg)
CM	320	2200

Table 4 Water-Cement Ratio for mortar

Mix Ratio	Water-cement ratio(w/c)
1:4	0.6
1:5	0.6
1:6	0.7

Table 5 Mix Proportion of solid concrete blocks

Mix designation	Cement (kg/m^3)	Fly ash (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	M-sand (kg/m^3)	Water (kg/m^3)
CM	410	-	1140	860	-	246
SF10	369	41	1140	860	-	246
SF10M20	369	41	1140	688	172	246
SF10M40	369	41	1140	516	344	246
SF10M60	369	41	1140	344	516	246
SF10M80	369	41	1140	172	688	246
SF10M100	369	41	1140	-	860	246

C. Compressive strength test for masonry prism

Compressive strength test for prism is done by using the measurement of a solid block prism to calculate the cross-sectional area. Place the prism in the center of the loading area. Fit the piston and make contact with the surface of the specimen. Apply the load slowly and observe the specimen. After seeing the crack stop applying the load and note the reading (ultimate load). By using the load, divide it by the cross-sectional area, which gives the compressive strength.

The mix proportion of the solid block is tabulated in Table 5.

III. RESULTS AND CONCLUSION

The test results for mortar cube and masonry prism are arranged in tabular form with a chart. Table 5 indicates the compressive strength of the mortar cube, and table 6, 7, and 8 indicates the compressive strength of masonry prism.

Table 6 Compression Strength of mortar Cube

Mix ID	Mix ratio	7days(N/mm^2)	28days(N/mm^2)
SCM	1:4	9.62	12.14
SCM	1:5	8.43	11.35
SCM	1:6	6.17	9.25

Mortar cube of Mix Ratio 1:4 has high compressive strength. Table 6, Table 7, and Table 8 give us the compressive strength and actual compressive strength of prism with a mortar mix ratio of 1:4, 1:5, and 1:6, respectively.

Table 6 Actual Compressive Strength of prism with mortar mix ratio - 1:4

Mix	Mortar thickness (mm)	h/t	Compressive strength of prisms (Mpa)				Maximum Compressive strength of prisms (f_p)(Mpa) as per Code provision			
			Initial crack	Final crack	Initial crack	Final crack	IS:1905-1987		ASTM C1314	
			7days		28days		CF	f_p	CF	f_p
SCM	10	4.1	6.23	7.32	8.33	10.55	1.15	12.13	1.56	16.45
SF10	10	4.1	6.31	7.38	8.41	10.61	1.15	12.21	1.56	16.55
SF10M20	10	4.1	6.41	7.47	8.52	10.71	1.15	12.31	1.56	16.71
SF10M40	10	4.1	6.52	7.63	8.62	10.89	1.15	12.52	1.56	16.98
SF10M60	10	4.1	6.89	7.82	8.85	11.23	1.15	12.91	1.56	17.51
SF10M80	10	4.1	6.48	7.58	8.57	10.98	1.15	12.62	1.56	17.12
SF10M100	10	4.1	6.37	7.43	8.48	10.84	1.15	12.46	1.56	16.91

Table 7 Actual Compressive Strength of prism with mortar mix ratio - 1:5

Mix	Mortar thickness (mm)	h/t	Compressive strength of prisms (Mpa)				Maximum Compressive strength of prisms (f_p)(Mpa) as per Code provision			
			Initial crack	Final crack	Initial crack	Final crack	IS:1905-1987		ASTM C1314	
			7days		28days		CF	f_p	CF	f_p
SCM	10	4.1	6.22	7.29	8.31	10.52	1.15	12.09	1.56	16.41
SF10	10	4.1	6.27	7.32	8.38	10.64	1.15	12.23	1.56	16.59
SF10M20	10	4.1	6.38	7.45	8.49	10.79	1.15	12.41	1.56	16.83
SF10M40	10	4.1	6.49	7.59	8.58	10.91	1.15	12.54	1.56	17.01
SF10M60	10	4.1	6.82	7.78	8.81	11.38	1.15	13.08	1.56	17.75
SF10M80	10	4.1	6.64	7.61	8.64	10.97	1.15	12.61	1.56	17.12
SF10M100	10	4.1	6.52	7.53	8.51	10.81	1.15	12.43	1.56	16.86

Table8 Actual Compressive Strength of the prism with mortar mix ratio - 1:6

Mix	Mortar thickness (mm)	h/t	Compressive strength of prisms (Mpa)				Maximum Compressive strength of prisms (f_p)(Mpa) as per Code provision			
			Initial crack	Final crack	Initial crack	Final crack	IS:1905-1987		ASTM C1314	
			7days		28days		CF	f_p	CF	f_p
SCM	10	4.1	6.18	7.28	8.28	10.48	1.15	12.05	1.56	16.34
SF10	10	4.1	6.21	7.35	8.34	10.56	1.15	12.14	1.56	16.47
SF10M20	10	4.1	6.34	7.41	8.45	10.75	1.15	12.36	1.56	16.77
SF10M40	10	4.1	6.44	7.54	8.56	10.92	1.15	12.55	1.56	17.03
SF10M60	10	4.1	6.78	7.73	8.78	11.34	1.15	13.04	1.56	17.69
SF10M80	10	4.1	6.61	7.64	8.62	10.92	1.15	12.55	1.56	17.04
SF10M100	10	4.1	6.54	7.52	8.51	10.79	1.15	12.41	1.56	16.83

Fig. 2 shows a graph of the compressive strength of masonry prism for 7 and 28days using 1:4 cement. From table 6 and fig. 2, the compressive strength of masonry prism by 1:4 cement mortar with 10% replacement of cement by fly ash and 60% replacement by m-sand gets increased by 6.8% and 6.4% in 7 days and 28 days strength when compared to control mix. SF10MS60 gives maximum strength.

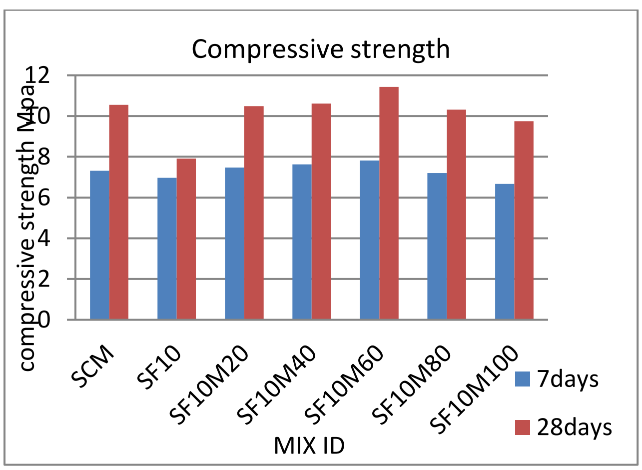

Fig. 2 Graph shows the compressive strength of masonry prism for 7 and 28days of mix ratio 1:4

Fig. 3 shows a graph of the compressive strength of masonry prism for 7 and 28days using 1:5 cement.

From table 7 and fig. 3, the compressive strength of masonry prism by 1:5 cement mortar with 10% replacement of cement by fly ash and 60% replacement by m-sand gets increased by 6.7% and 8.17% in 7 days and 28 days strength when compared to control mix. SF10MS60 gives maximum strength.

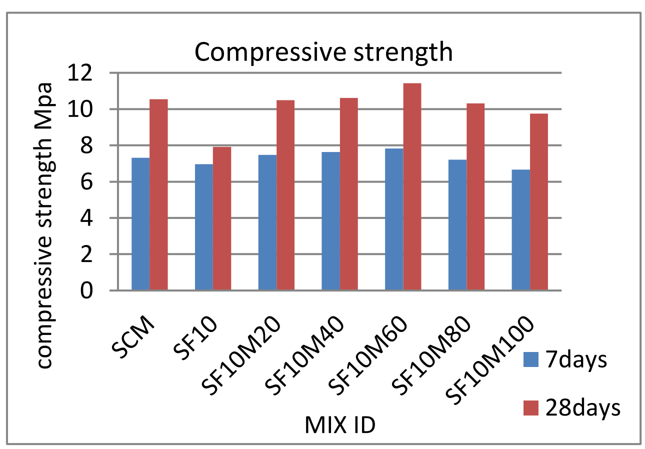

Fig. 4 Graph shows the compressive strength of masonry prism for 7 and 28days of mix ratio 1:6

Fig. 4 shows a graph of the compressive strength of masonry prism for 7 and 28days using mix ratio1:6.

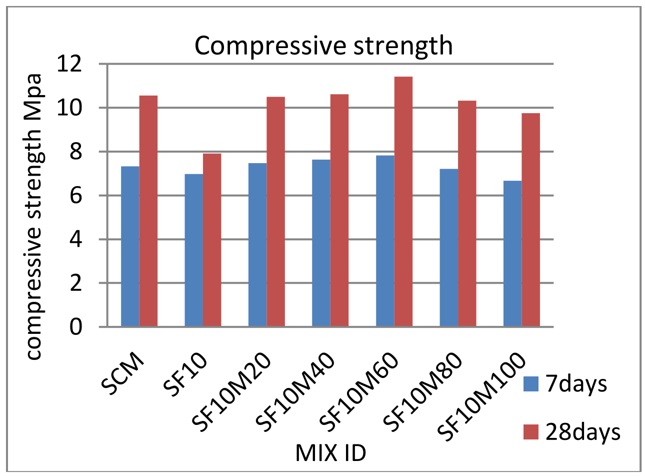

Fig. 3 Graph shows the compressive strength of masonry prism for 7 and 28days of Mix Ratio 1:5

From table 8 and fig. 4, the compressive strength of masonry prism by 1:6 cement mortar with 10% replacement of cement by fly ash and 60% replacement by m-sand gets increased by 6.18% and 8.2% in 7 days and 28 days strength when compared to control mix. SF10MS60 gives maximum strength.

VI. CONCLUSION

From the experimental study of using m-sand as a fine aggregate and cement partially replaced by fly ash, the following results are obtained.

- For the compression test on the solid block using a prism, we used three types of mortar mix viz. 1:4, 1:5, and 1:6. The compressive strength of masonry prism gets increased with the compressive strength of blocks and mortar.
- The strength of prism is increasing by changing the proportion, 10%fly ash, 10%fly ash & 20% m-sand, 10%fly ash & 40% m-sand, 10%fly ash & 60% m-sand, 10%fly ash & 80% m-sand, and 10%fly ash & 100% m-sand.
- Among these, 60% replacement of fine aggregate by m-sand with 10% fly ash in cement gives higher strength.
- Furthermore, the cement mortar mix 1:4 gives better performance, and this is due to its high ultimate load-carrying capacity.
- Cement mortar ratio also depends on the environment, type of wall, internal or external wall plastering. If the wall does not carry much load, a 1:6 mortar mix is more than enough because the wall is not carrying any structural load, and it is constructed as a partition wall.
- The compressive strength of the masonry prism is compared with the code provision IS 1905-1987 and ASTM C1314 to get the actual compressive strength by using correction factor (CF). The correction factor can be determined by using the height to thickness ratio of the prism.
- As perIS 1905-1987 and ASTM C1314, the compressive strength of the prism gets increased by 14.92% and 55.96% after applying the respective correction factor.
- In our experimental work, replacing10%fly ash in cement and 60% m-sand in fine aggregate gives better results, and it is considered a more suitable one.

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