Experimental Investigation on High volume Flyash Concrete By Incorporating Foundary Sand As Fine Aggregate

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Abstract*- Sand is a current problem faced by the construction industry in the present day. Hence there is a need to identify suitable alternatives to natural river sand as fine aggregate in concrete to cater the future demand of fine aggregate. Foundry sand, a waste product obtained from metal foundry, may be identified as a potential replacement to river sand. The present study is focussed on the evaluation of foundry sand as fine aggregate in high volume fly ash concrete (HVFAC). Preliminary studies on HVFAC were carried out to find out the optimal content of fly ash by replacing cement at different percentages (i.e 0, 25, 50, 75,100). From the present investigation, it was found out the optimal content (the mix for which highest compressive strength is obtained) of fly ash was found to be 55% FAC mixes by replacing river sand. The mechanical properties of HVFAC such as Compressive Strength, Split Tensile Strength,Flexural Strength,Shear Strength were studied in detail. From the results it was found that the replacement of river sand with foundry sand resulted in the decreasing in the mechanical properties. With the highest content of foundry sand , high was the strength loss in HVFAC mixes. Although, the performance of foundry sand in HVFAC mixes was lower. The HVFAC contains foundry sand achieved sufficient strength for structural applications. From the present study, it may be concluded that foundry sand can be seen as alternative for river sand.*

Keywords- HCVFAC (High volume fly ash concrete), Foundary sand .

I. INTRODUCTION

In the current years, the global warming and ecological issues have become major issues.

The augmented emissions of CO2 and other gases from industrial establishments and infrastructure development projects have caused several changes in the climatic conditions. Concrete being the most widely and extensively used building materials forall the construction activities. The current infrastructure growth in India has increased the demand for concrete and other building materials. The higher demand for concrete has resulted in higher emissions of greenhouse gases into the atmosphere occurring from the production of OPC. The production of OPC is a very energy exhaustive method includes heating the raw materials to 1500°C (Dungan RS,2009) . The overall production of Portland cement is associated with large consumption of natural raw materials, energy along with emissions of greenhouse gases. Due to such constraints, the researchers and engineers across the globe are focussing their attention on the development and identification of alternative materials to concrete and concrete making materials. The use of industrial waste materials for concrete production has become the latest trend in the research and construction industry. Over the years, researchers have identified several industrial wastes such as Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash (FA),silica fume etc, which have been seen to provide satisfactory performance in concrete. The inclusion of such wastes may be done by replacing the cement binder or may be by replacing the naturalaggregates.

The utilisation of FA has displayed several advantages in the conventional concrete. Attempts by researchers have reported that the substitution of OPC with FA up to 30%-40% has shown several advantageous properties in the concrete. However, the use of FA higher than 50% as replacement to cement binder have also been attempted and found to have satisfactory performance. Generally the concrete containing more than 50% FA as binder may termed as High Volume Fly Ash Concrete (HVFAC). Several studies conducted on HVFAC have reported better mechanical and durability properties as compared to conventional OPC concrete (Malhotra). The HVFAC is also associated with low heat of hydration, better workability, lower shrinkage etc. However, the HVFAC has several disadvantages such as low early strength, longer curing periods etc. The use of HVFAC may prove beneficial in countries like India, China where the production of FAis very high. The utilisation of HVFAC in the major construction projects will reduce the demand for OPC concrete which in turn may reduce the production of OPC, thus reducing the CO2 emissions along with reduction in the exploitation of natural raw materials.

The increased demand of concrete has resulted in the increased demand for aggregates since aggregates form major portion in the concrete. Over the years, river sand has been used as fine aggregates in the manufacture of concrete. River sand is extracted from river beds. The increased demand has resulted in the over exploitation of the river sand causing several environmental problems. However, the mining of sand from the river beds has been restricted by several environmental and government agencies due to the negative ecological effects. The sand mining is associated with various problems, which damage the environmental balance. Due to such constraints, the availability of river sand for construction activities has become a major issue. This has resulted in immediate need to discover substitute materials to cater the requirement of river sand for construction. Materials such as copper slag, foundry sand, manufactured sand etc has been tested successfully as replacement to Natural River sand in conventional concrete. Foundry sand is one eye-catching alternative to river sand. Foundry sand is a waste product from the foundry and moulding industry. These waste by-product is easy available and lesser cost compared to naturally available river sand. The obtained waste by-product can be recycle and reuse many times till it is no longer reused and it is termed as waste foundry sand (WFS). The WFS is usually disposed off into pits or open areas. WFS can be effectively used for partial replacement of fine aggregate in concrete. WFS gives better strength and durability properties compared to naturally available sand. The use of WFS as fine aggregates in concrete will provide partial solution to the increased demand of aggregates and also will reduce the cost of disposal of WFS.
Although WFS has showed satisfactory performance in conventional concrete, there are no research carried on the use of FS in HVFAC mixes. The present study focuses to evaluate the performance of HVFAC with WFS as fine aggregates. The mechanical and durability properties of HVFAC with WFS are evaluated. Such a type of concrete comes with several advantages especially in India which has huge amount of FA production and having crisis of non-availability of river sand forconstructions.

II. OBJECTIVES OF THIS STUDY

The following are the major objectives of the study

- To optimise the mix design for HVFAC containing foundry sand as fine aggregate.
- To evaluate the mechanical or strength properties such as compressive strength, split tensile strength, flexural strength, shearstrength.

III. OBSERVATIONS ANDDISCUSSION

Based on the experimental results, the following observations and conclusions are made:

CompressiveStrength

In this study, obtained results of compressive strength test for HVFAC by incorporating different percentages of foundry sand as fine aggregate are discussed here,

- It is evident from Table. 4.2, 4.3, &4.4 Compressive strength ofHVFAC with different percentages of foundry sand increases with the age.
- Compressive strength of HVFAC at different percentages of foundry sand (i.e 25, 50, 75, 100) obtained is lesser than HVFAC at 0% foundrysand.
- HVFAC with 100% foundry sand i.e F-4 developed little strength, only about 53% of its 28 days. Therefore, the early strength development isslower.
- Compressive strength of HVFAC with 100% foundry sand are less than other respective mix designations at allages.
- The target strength was 48.25 N/mm^{2}for M40 concrete for which optimum content of fly ash is obtained by trial and error method (i.e. 55% of fly ash as cementitious material) for HVFAC. For all series of HVFAC, the strength achieved is more than target strength at 90days.
- Since, HVFAC with 25% of foundry sand develop near-by compressive strength compared to HVFAC with 0% foundry sand compressive strength. It is economical to use because the disposal problem is reduced by such utilization of fly ash and foundrysand.

Table 3.1: Overall results of Compressive strength of HVFAC with different percentages of foundry sand

Designation	High volume fly ash (%)	Foundry sand (%)	Compressive strength(Mpa)			Percentage decrease in compressive strength w.r.t reference mix for 7 days	Percentage decrease in compressive strength w.r.t reference mix for 28 days	Percentage decrease in compressive strength w.r.t reference mix for 90 Days
			07 days	28 days	90 days			
F-0	55	0	27.25	47.25	62.66			
F-1	55	25	26.51	45.29	59.10	-0.027	-0.208	-0.056
F-2	55	50	24.15	38.81	52.15	-0.114	-0.178	-0.167
F 3	55	75	21.62	36.59	48.15	0.206	0.225	0.231
F-4	55	100	19.11	35.92	45.48	-0.298	-0.239	-0.274

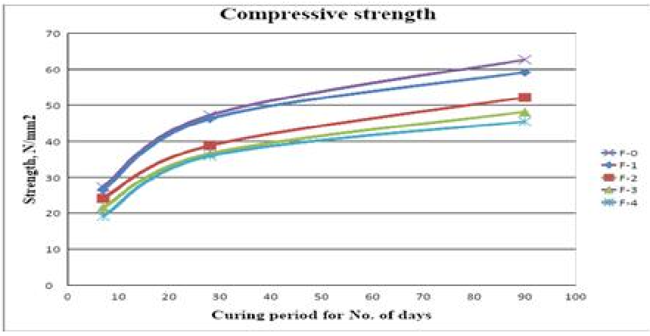

Fig 3.1: Variation of compressive strength of HVFAC

Split TensileStrength

In this study, obtained results of split tensile strength test for HVFAC by incorporating different percentages of foundry sand as fine aggregate are discussed here,

- It is evident from Table. 4.6, 4.7, & 4.8 the tensile strength of HVFAC with different percentages of foundry sand is much similar to compressive strength development.
- Split tensile strength of HVFAC increases with ages. For control mix at 90 days , the decreases of tensile strength of HVFAC with percentages of foundry sand is 5.6%, 9.6%, 13.9%, 19.6%respectively.
- Split tensile strength of HVFAC at different percentages of foundry sand (i.e 25, 50, 75, 100) obtained is lesser than HVFAC at 0% foundrysand.
- The28dayssplittensilestrengthofHVFACforalldifferentmixesoffoundry sand are in the range of 7 to 7.6% of their respective compressive strength.

Table 3.2: Over results of Split Tensile strength of HVFAC with different percentages of foundry sand.

Designation	High volume fly ash (%)	Foundry sand (%)	Split Tensile strength(Mpa)			Percentage decrease in Split Tensile strength w.r.t reference mix for 7 days	Percentage decrease in Split Tensile strength w.r.t reference mix for 28 days	Percentage decrease in Split Tensile strength w.r.t reference mix for 90 Days
			07 days	28 days	90 days			
F-0	55	0	2.38	3.37	4.23	....	....	....
F 1	55	25	2.33	3.32	3.99	0.021	0.015	0.056
F-2	55	50	2.17	2.83	3.82	-0.088	-0.160	-0.095
F-3	55	75	2.02	2.80	3.64	-0.151	-0.169	-0.139
F-4	55	100	1.82	2.60	3.40	-0.235	-0.228	-0.195

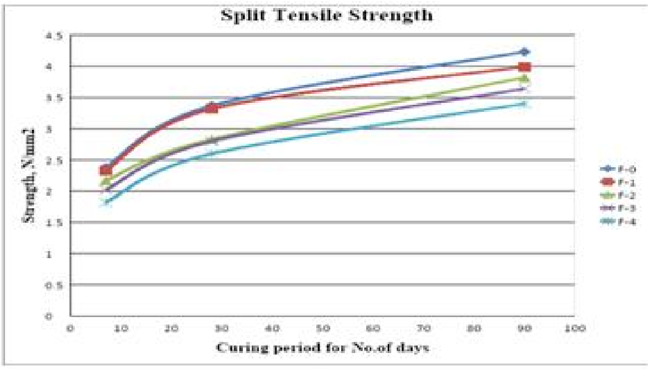

Fig 3.2: Variation of Split tensile strength of HVFAC

FlexuralStrength

In this study, obtained results of Flexural strength test for HVFAC by incorporating different percentages of foundry sand as fine aggregate are discussed here,

- Ingeneral,forallmixesofHVFACflexuralstrengthincreaseswithage, though the increase in strength for 28 days to 90 days is marginal.
- It is observed that, the flexural strength of HVFAC decreases with increase in different percentages of foundry sand for respective mixes. Flexural strength of HVFAC increases withages.
- For control mix at 90 days , the decreases of Flexural strength of HVFAC with percentages of foundry sand is 5.6%, 8.4%, 15.8%, 20%respectively.
- HVFAC with 100% foundry sand exhibits max flexural strength of 5.2 N/mm^{2}at the age of 90 days which is lesser than HVFAC with 0% foundry sand of flexural strength 6.5N/mm^2

Table 3.3: Over results of Flexural strength of HVFAC with different percentages of foundry sand.

Designation	High volume fly ash (%)	Foundry sand (%)	Flexural strength(Mpa)			Percentage decrease in Flexural strength w.r.t reference mix for 7 days	Percentage decrease in Flexural strength w.r.t reference mix for 28 days	Percentage decrease in Flexural strength w.r.t reference mix for 90 Days
			07 days	28 days	90 days			
F-0	55	0	3.27	5.20	6.50	....	....	....
F-1	55	25	3.20	5.08	6.13	-0.021	-0.023	-0.056
F-2	55	50	2.94	4.40	5.95	-0.100	-0.153	-0.084
F-3	55	75	2.72	4.25	5.60	-0.168	-0.182	-0.158
F-4	55	100	2.40	3.97	5.20	-0.266	-0.236	-0.200

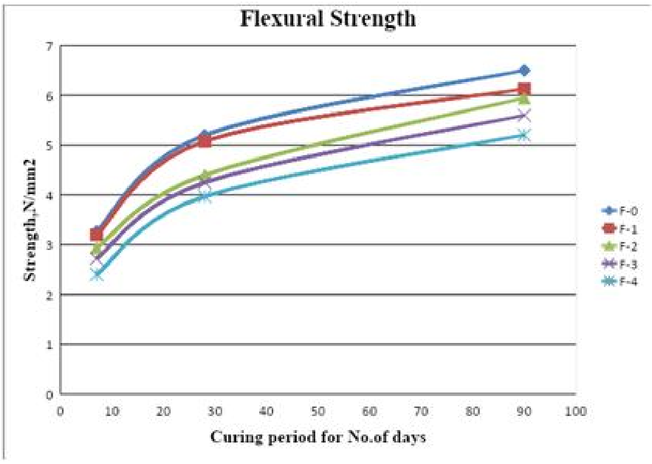

Fig 3.3: Variation of Flexural strength of HVFAC

ShearStrength

In this study, obtained results of Shear strength test for HVFAC by incorporating different percentages of foundry sand as fine aggregate are discussed here,

- It is observed that the shear strength of HVFAC decreases with increases in foundry sand content at any particularage.
- The shear strength of HVFAC at 0% foundry sand are more than shear strengthat respective percentage of foundry sand (i.e 25%, 5.%, 75%,100%).
- For all mixes of HVFAC flexural strength increases with age, though the increase in strength for 56 days to 90 days ismarginal.
- However, for all HVFAC mixes , the 28 days shear strengths are more than the max design shear strength of concrete as per IS:456-2000.
- Because of better results of shearstrength for M40 concrete. Thus, HVFAC are suitable for resisting shear.

By the above observations the following discussions were made

- Increase of foundry sand content lead to decrease of Strength properties because high surface area of fine particles in foundry sand reduces the water cement gel in concrete due to improper bonding between cement paste and aggregate takes place. Thus, mechanical properties of HVFAC decrease by the addition of foundrysand.
- As the percentage of foundry sand increased, the strength or mechanical properties of the concrete isdecrea

Table3.4: Over results of Shear strength of HVFAC with different percentages of foundrysand.

Designa tion	High volume fly ash (%)	Foun dry sand (%)	Shear strength(Mpa)			Percentage decrease in Shear strength w.r.t reference mix for 7 days	Percentage decrease in Shear strength w.r.t reference mix for 28 days	Percentage decrease in Shear strength w.r.t reference mix for 90 Days
			07 days	28 days	90 days			
F-0	55	0	3.25	4.92	5.60	....	....	....
F-1	55	25	2.99	4.69	5.30	-0.080	-0.046	-0.045
F 2	55	50	2.74	4.22	5.55	0.157	0.142	0.159
F-3	55	75	2.56	3.92	5.18	-0.212	-0.203	-0.215
F 4	55	100	2.37	3.51	4.77	0.270	0.286	0.277

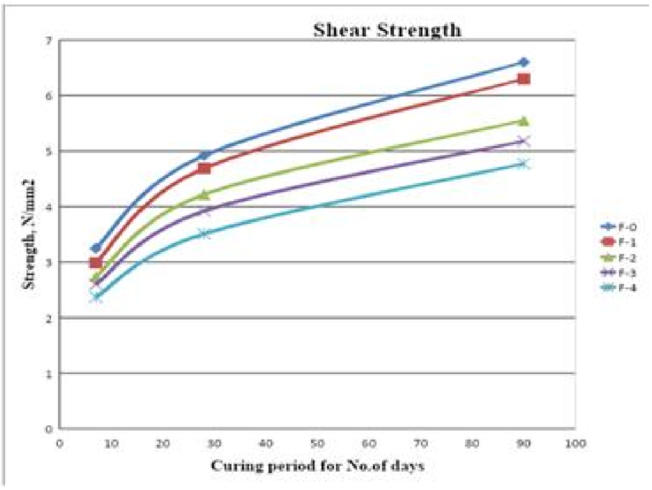

Fig 3.4: Variation of Shear strength of HVFAC

IV. CONCLUSIONS

1. The Compressive strength of HVFAC for different percentage of foundry sand (i.e,F-1, F-2, F-3, F-4) is decreased by 5.6%, 16.7%, 23.1%, 27.4 % respectively when compared with HVFAC with foundry sand of F-0 replacement at 90days.
2. The Split tensile strength of HVFAC for different percentage of foundry sand (i.e, F-1, F-2, F-3, F-4) is decreased by 5.6%, 9.6%, 13.9%, 19.6% respectively when compared with HVFAC with foundry sand of F-0 replacement at 90days.
3. The Flexural strength of HVFAC for different percentage of foundry sand (i.e,F-1, F-2, F-3, F-4) is decreased by 5.6%, 8.4%, 15.8%, 20% respectively when compared with HVFAC with foundry sand of F-0 replacement at 90days.
4. The Shear strength of HVFAC for different percentage of foundry sand (i.e, F-1, F-2, F-3, and F-4) is decreased by

4.5%, 15.9%, 21.5%, and 27.7% respectively when compared with HVFAC with foundry sand of F-0 replacement at 90days.

5. Compressive strength,Split tensile strength,Flexural strength,Shear strength of the HVFAC decreased with increase in percentage of foundrysand.
6. For each percentage of foundry sand,decrease of mechanical properties observedwith the increase in age..
7. Addition of foundry sand in HVFAC affects the slump ofconcrete.
8. The Mechanical properties of HVFAC at 55% of FA, 75% of River sand and 25% of FS (i.e,F-1) develops near-by strength compared to HVFAC at reference mix (i.e,F-0). Hence, it is recommended to replace55% of FA, 75% of River sand and 25% of FS to attain target meanstrength.

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