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OPTIMIZATION OF PARTIAL REPLACEMENT OF M-SAND BY NATURAL SAND IN HIGH PERFORMANCE CONCRETE WITH SILICA FUME

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ABSTRACT

The huge quantity of concrete is consumed by construction industry all over the world. In India, the conventional concrete is produced using natural sand from river beds as fine aggregate. Decreasing natural resources poses the environmental problem and hence government restriction on sand quarrying resulted in scarcity and significant increase in its cost. This paper present the optimization of partial replacement of manufactured sand by natural sand with silica fume in High Performance Concrete (HPC). Concrete mixes were evaluated for compressive strength and flexural strength. The ordinary portland cement was partially replaced with silica fume by 1.5%, 2.5 %, and 5% and natural sand was replaced with manufactured sand by four proportions (ie 10%, 30%, 50%, 70%). The results indicated that there is an increase in the compressive and flexural strength of HPC nearly 20% and 15% respectively with the increase of manufactured sand percentage. Addition of up to 50% of manufactured sand as sand replacement yielded comparable strength with that of the control mix. However, further additions of manufactured sand caused reduction in the strength. The optimum percentage of replacement of natural sand by M-sand is 50%. The results also revealed that increase in percentage of partial replacement of silica fume, increased the compressive and flexure strength of High Performance Concrete.

KEYWORDS: *High Performance Concrete, Silica fume, M-sand, compressive strength, flexure strength, Optimum Percentage.*

I. INTRODUCTION

Sand is the one of main constituents of concrete making which is about 35% of volume of concrete used in construction industry. Natural sand is mainly excavated from river beds and always contain high percentage of in organic materials, chlorides, sulphates, silt and clay that adversely affect the strength, durability of concrete & reinforcing steel there by reducing the life of structure, when concrete is used for buildings in aggressive environments, marine structures, nuclear structures, tunnels, precast units, etc. Fine particles below 600 microns must be at least 30 % to 50% for making concrete will give good results [1]. Normally particles are not present in river sand up to required quantity. Digging sand, from river bed in excess quantity is hazardous to environment. The deep pits dug in the river bed, affects the ground water level. Erosion of nearby land is also due to excessive sand lifting. In order to fulfill the requirement of fine aggregate, some alternative material must be found. The cheapest and the easiest way of getting substitute for natural sand is by crushing natural stone to get artificial sand of desired size and grade which would be free from all impurities is known as Manufactured sand. Concrete made with crushed stone dust as replacement of natural sand in concrete can attain the same compressive strength, comparable tensile strength, modulus of rupture and lower degree of shrinkage as the control concrete[2]. From Literature Review it is observed that compressive and split tensile strength of M30 grade concrete increased by replacing 30% of natural sand with M-Sand[3].

High Performance Concrete (HPC) is defined as a concrete that meets special performance and uniformity requirements that cannot always be achieved routinely by using conventional materials and normal mixing, placing and curing practices. For producing HPC, Industrial wastes, such as silica fume, blast furnance slag, fly ash are being used as supplementary cement replacement materials and are also being used as pozzolanic materials in concrete. When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete[4].

Silica fume is a by product of the smelting process in the silicon and Ferro silicon industry and it will enhances both the mechanical characteristics and durability of concrete.

The partial replacement of cement with silica fume reduces the content of cement used in the construction industry, which protects the ecosystem with a small percentage in the reduction of green house gases. The optimum silica fume replacement percentage for obtaining maximum 28- days strength of concrete ranged from 10 to 20 % [5]. Silica fume in High Performance concrete will develop strength sufficient for construction purposes. Its use will lead to a reduction in cement quantity required for construction purposes and hence sustainability in the construction industry as well as aid economic construction. Cement replacement up to 10% with silica fume leads to increase in compressive strength, for M30 grade of concrete [6]. Silica fume is known to improve both the mechanical characteristics and durability of concrete. The principle physical effect of silica fume is fineness can fill the space between particles of coarse aggregates and cement grains and improves strength. Utilization of Silica fume with fly ash was found to increase the compressive strength of concrete at early ages with the highest strength obtained when silica fume was used at 10% of weight of cement [7].The super plasticizer Conplast SP430 was used as chemical admixture. Conplast SP430 is based on Sulphonated Napthalene Polymers and it is a brown liquid instantly dispersible in water. It has been specially formulated to give high water reductions upto 25% without loss of workability and produce high quality concrete to enhance strength and durability with low binder ratio 0.26 to 0.4. Increasing dosage of super plasticizer by weight of binder(Cement and Silica fume) improved the performance of concrete and contribute more to improvement of its workability properties as well as mechanical properties with reduced W/B ratio [8].

The present investigation was carried out to study the optimization of partial replacement of manufactured sand by natural sand with silica fume in High Performance Concrete (HPC). Further, the study helps to identify a suitable material for natural sand and to minimize the usage of cement content in the concrete by alternate material to some proportion.

The research significance, experimental investigation, results & discussion and conclusion are dealt in elaborate manner in this paper.

II. RESEARCH SIGNIFICANCE

Normal concrete lacks required strength and durability which are more often required for large concrete structures such as high rise buildings, bridges and structures under severe exposure condition. Due to booming construction activities natural sand is becoming scarce due to excessive non scientific methods of mining from the river beds. For these reasons it is necessary to produce a concrete with improved strength and performance, with suitable materials. This research shows the effective utilization of by product silica fume and M-sand in High Performance Concrete.

III. EXPERIMENTAL INVESTIGATION

3.1 Materials:

3.1.1 Cement: Ordinary Portland cement of 53 Grade conforming to IS 8112 -1989 [9], and the specific gravity of cement was found to be 3.15. The physical properties of cement given in Table 1

Table 1. Physical Properties of cement

Component	Results (%)	Requirements of IS : 8112
Fineness, m^2/kg	320	Minimum 225
Initial setting Time , minutes	135	Minimum 30
Final setting Time, Minutes	190	Maximum 600

Standard consistency	26.4	-
Soundness, Le chatelier, mm	1.0	Maximum 10

3.1.2 Fine Aggregate:

Natural Sand: Locally available River sand having bulk density 1860 kg/m^3 was used and the specific gravity is 2.56. The Fineness modulus of river sand is 2.64.
Manufactured sand: M- Sand was used as partial replacement of fine aggregate. It was collected from TECHNOMAX Building Solutions India Pvt. Ltd. Coimbatore, India. The bulk density of manufactured sand was 1860 kg/m^3, specific gravity and fineness modulus was found to be 2.56 and 3.10 respectively.
The percentage of particles passing through various sieve were compared with natural sand and it was found to be similar. The results are presented in Table.2.

Table 2 Sieve analysis of River sand &M-Sand

Sieve Size	River sand % Passing	M-Sand % Passing
4.75mm	98	99.78
2.36mm	96	87.14
1.18mm	78	63.12
600µm	51	45.75
300 µm	26	25.50
150 µm	7	7.98

3.1.3 Coarse Aggregate: Crushed angular aggregate with maximum grain size of 12.5mm and down graded was used and having bulk density 1691kg/m^3. The specific gravity and fineness modulus was found to be 2.89 and 2.75 respectively.

3.1.4 Silica Fume (Grade 920 D): The silica fume was partially replaced for cement. Silica fume was collected from ELKEM South Asia Pvt. Ltd. Mumbai, was named Elkem – micro silica 920 D conforming to ASTM C1240. It is available in dry densified form. The density and specific gravity was found to be 640 kg/m^3 &2.2 respectively.

3.1.5 Super plasticizer: In order to improve the workability of high-performance concrete, superplasticizer in the form of Sulphonated Napthalene Polymers complies with IS 9103:1999 and ASTM C 494 type F as a high range water reducing admixture (CONPLAST SP 430) was used. This had 40% active solids in solution. The specific gravity is 1.22.It is a brown liquid instantly dispensable in water.

3.1.6 Water: Fresh portable water, which is free from acid and organic substance, was used for mixing the concrete.

3.2 Mix proportions and Mix details:

Concrete mix design in this investigation was designed as per the guidelines specified in ACI 211.4R-08 - "Guide for selecting Proportions for high strength concrete with Portland cement and other cementations materials" [10]. The Table 3 shows the mix proportions of High Performance Concrete (kg/m^3). Four concrete mixtures with different proportions of silica fume ranging from 0% (for the control mix) ,1.5%, 2.5% and 5%, for each silica fume replacement natural sand was replaced with manufactured sand by four proportions (ie 10%, 30%, 50%, and 70%) casted.

Table 3 Mix proportions for HPC

MIX	SF (%)	CEMENT (KG)	SF (KG)	MS (%)	NS (KG)	MS (KG)	C.A (KG)	W/B RATIO	PLASTICIZER (Litre)	WATER (Litre)
CC	0	551.87	0	0	806.4	0	1149.8	0.32	0	177

Modified Mix with SF & MS	1.5	543.600	8.28	10	757.62	54.78	1149.8	0.32	6.52	170.48
	2.5	538.075	13.80	30	642.3	164.1	1149.8	0.32	6.457	170.55
	5	524.285	27.59	50	403.2	403.2	1149.8	0.32	6.29	170.71
				70	164.1	642.3	1149.8	0.32		

3.3 Experimental Procedure:

The specimen of standard cube of (150mm x 150mm x 150mm) and standard prisms (100mm x 100mm x 500mm) were used to determine the compressive strength and flexural strength of concrete. Three specimens were tested for 7 & 28 days with each proportion of silica fume and M-sand replacement. Totally 78 cubes and 78 prisms were cast. The constituents were weighed and the materials were mixed by hand mixing. The mixes were compacted using vibrating needle. The water binder ratio (W/B) adopted was 0.32 and weight of super plasticizer was estimated as 1.2 % of weight of binder .The specimens were demoulded after 24 h, cured in water for 7 & 28 days, and then tested for its compressive and flexural strength as per Indian Standards.

IV. RESULTS AND DISCUSSIONS

The Compressive and Flexure strength of the conventional concrete are presented in Table 4

Table 4 Compressive and Flexure strength of conventional concrete

S. No	Compressive Strength in N/mm^2		Flexure Strength in N/mm^2	
	7 Days	28 Days	7 Days	28 Days
1	36.4	61.48	6.75	10.5

4.1 Compressive strength of concrete:

The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000KN. The results are presented in Figure 1 & 2.

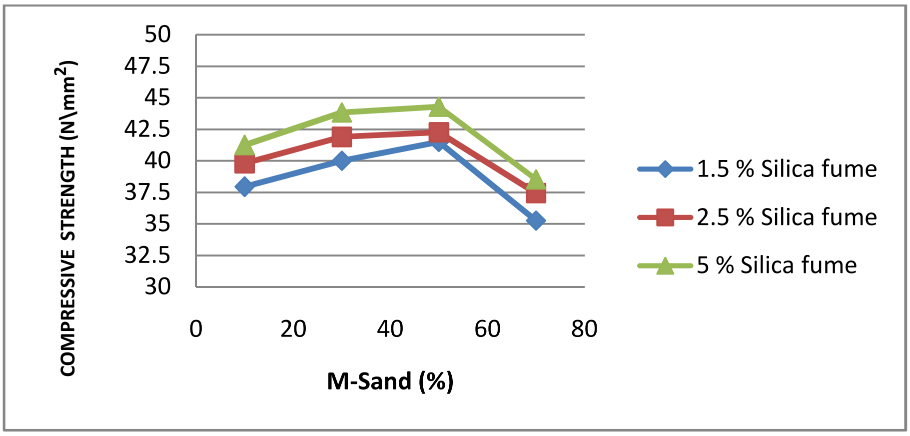

Figure 1-Compressive Strength of High Performance Concrete at the age of 7 days with various proportions of M-Sand

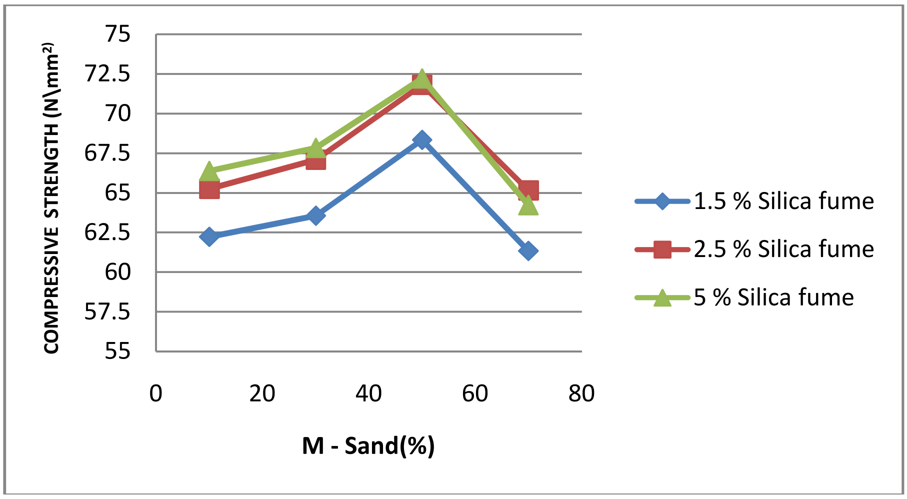

Figure 2-Compressive Strength of High Performance Concrete at the age of 28 days with various proportions of M-Sand

There is a significant improvement in the strength of concrete because of the high pozzolanic nature of the silica fume and its void filling ability. The concrete with partial replacement of 5% cement with silica fume shows 18.8% greater compressive strength than conventional concrete when compared to 2.5 % and 1.5% of the silica fume. Average increase in compressive strength of concrete was found to be 11%, 12%, 18.8% and 5% for partial replacement of natural sand by M-Sand with 10 %, 30 %, 50% and 70%.

Therefore partial replacement of sand by M-Sand increases the compressive strength upto 50%.Further increase in percentage of replacement, decreases the compressive strength. It is observed that there is consistent increase in the strength of concrete when partial replacement of natural sand by M-Sand. The sharp edges of the particles in M-Sand provide better bond with cement and Silica fume than rounded particles of natural sand resulting in higher strength up to optimum replacement. The optimum replacement of sand by M- Sand is 50%.This is conformed for all percentage replacement of cement by silica fume. The average increase in the compressive strength of High Performance Concrete due to addition of silica fume (5%) at the age of 7& 28 days with partial replacement of 50% natural sand by M-Sand showed 11.5% & 18.8% greater than conventional concrete respectively.

Scanning electron micrographs show that utilization of silica fume with fly ash resulted in a much denser microstructure thereby leading to an increase in compressive strength and the influence of silica fume in concrete improved the compressive strength along with metakaolin and optimum dosage found to be 6 % [11&12].

4.2 Flexural strength of concrete:

The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 7 and 28 days. The beams were tested using Flexure Testing Machine (FTM) of capacity 100KN. The results are presented in Figure 3&4

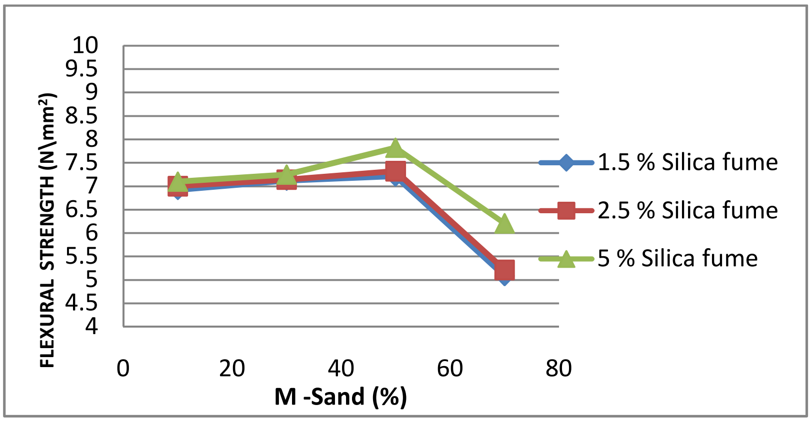

Figure 3-Flexural strength of High Performance Concrete at the age of 7 days with various proportions of M-Sand

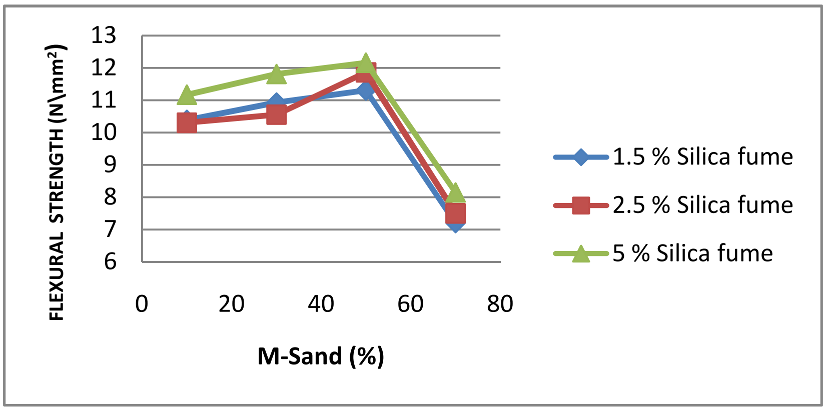

Figure 4-Flexural strength of High Performance Concrete at the age of 28 days with various proportions of M-Sand

The Flexural strength of the High Performance Concrete increases with the increase in percentage of Silica Fume along with M-sand. The maximum flexural strength obtained with 5% silica fume was 12% & 15% which is greater than conventional concrete at the age of 7 and 28 days. For the same silica fume percentage, the increase in strength was found to be 6%, 12%, 15% and 2% for partial replacement of natural sand by M-Sand with 10 %, 30 %, 50% and 70%. The flexure strength of HPC also shows that the partial replacement of 50% natural sand with M-sand is optimum. It is observed that the ultra fine silica fume particles, which consist mainly of amorphous silica, enhance the concrete flexure strength by pozzolanic and physical actions.

The flexure strength at the age of 28 days of silica fume concrete continuously increased with respect to controlled concrete and reached a maximum value of 12% replacement level for M40 and M50 grades of concrete [13].

V. CONCLUSIONS

The following conclusions are drawn from this investigation:

- It is observed that the compressive strength and flexure strength of concrete can be improved by partial replacement of Silica fume for cement and M-sand for fine aggregate.
- From the above experimental results it is proved that, M-Sand can be used as partial replacement for the natural sand, and the compressive and flexure strengths are increased as the percentage of M-Sand is increased up to optimum level. The optimum percentage of replacement of natural sand by M-sand is 50%

- The percentage of increase in the compressive strength is 18.88% and the flexure strength is 13.2% at the age of 28 days by replacing 50% of natural sand with M-Sand and 5% of cement by silica fume.
- High Performance Concrete with silica fume can be effectively used in high rise buildings since high early strength is required, and the construction period can be reduced.
- The dwindling sources of natural sand and its high cost could encourage the adoption of M-sand by 50% replacement of natural sand.

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