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Experimental Study On High Performance Concrete By Partial Replacement Of Fine Aggregate By Manufactured Sand Using 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 presents the investigation of partial replacement of manufactured sand by natural sand and cement with silica fume in High Performance Concrete (HPC). Concrete mixes were evaluated for compressive strength and split tensile strength. The ordinary Portland cement was partially replaced with silica fume by 5%, 7%, 10%, 12%, 14% and 15%. Natural sand was replaced with manufactured sand by five proportions (i.e. 10%, 25%, 50%, 75% and 100%). Concrete mix has been designed for grade M40 as per IS 10262 – 2009. For this grade of concrete 6 different types of concrete mixes and controlled mix were prepared and tested for the compressive strength and split tensile strength. The results indicated that there is an increase in the compressive and tensile 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.

Key words- Manufactured Sand, Silica fume, Compressive strength, Split tensile strength, High Performance Concrete

I. INTRODUCTION

Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixture and supplementary cementations materials (SCMs). Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Metakaolin, Silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. 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.

Concrete is the most commonly used material for construction and their design consumes almost the total cement production in the world. The use of large quantities of cement produces increasing CO_2 emissions, and as a consequence the green house effect. A method to reduce the cement content in concrete mixes is the use of silica fume.

Silica fume is a byproduct in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume consists of fine particles with a surface area of 20,000 m^2/kg when, measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement. Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material particle.

Addition of silica fume to concrete has many advantages like high strength, durability and reduction in cement production. The optimum silica fume replacement percentage for obtaining maximum 28- days strength of concrete ranged from 10 to 20 %. Cement replacement up to 12% with silica fume leads to increase in compressive strength, for M40 grade of 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. In this paper suitability of silica fume has been discussed by replacing cement with silica fume and Fine Aggregate is replaced with Manufactured Sand at varying percentage and the strength parameters were compared with conventional concrete.

II. EXPERIMENTAL INVESTIGATION

A. Materials

Cement: Ordinary Portland Cement of Ultratech brand of 53 grade confirming to IS: 12269- 1987 was used in

S.No	Property	Result
1	Specific Gravity	2.2
2	bulk density	576 (Kg/m^3)
3	Size ,(Micron)	0.1
4	Surface Area , (m^2 /kg)	20,000
5	SiO_2	(90-96)%
6	Al_2O_3	(0.5-0.8)%

*As per manufacturers manual

the present study. The properties of cement are shown in Table I.

TABLE I
PROPERTIES OF CEMENT

S.No	Property	Result
1	Normal Consistency	31%
2	Initial Setting Time	40 min
3	Specific Gravity	3.15
4	Fineness of Cement	5%
5	Soundness of Cement	1mm

Fine Aggregate: Natural sand as per IS: 383-1987 was used. Locally available River sand having bulk density 1860 kg/m^3 was used. The properties of fine aggregate are shown in Table II.

TABLE II
PROPERTIES OF FINE AGGREGATE

S.No	Property	River Sand	Manufactured Sand
1	Specific Gravity	2.7	2.88
2	Fineness Modulus	2.04	2.04
3	Grading Zone	II	II
4	Water Absorption	2.55%	7.5%
5	Mortar Strength	23.74 N/mm^2	32.61 N/mm^2

Coarse Aggregate: Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20mm and 12.5 mm were used. The properties of fine aggregate are shown in Table III.

TABLE III
PROPERTIES OF COARSE AGGREGATE

S.No	Property	Result
1	Crushing Strength	27.3%
2	Specific Gravity	2.75
3	Water Absorption	0.3%
4	Fineness Modulus	7.20

Silica Fume: Silica fume (Grade 920 D) used was confirming to ASTM-C (1240-2000) and was supplied by “ELKEM INDUSTRIES” was named Elkem – micro silica 920 D. The properties of silica fume are shown in Table IV.

TABLE IV
PROPERTIES OF SILICA FUME

Super Plasticizer: In this investigation super plasticizer-CONPLAST-SP 430 in the form of Sulphonated Naphthalene polymers complies with IS: 9103-1999 and ASTM 494 type F was used to improve the workability of concrete. The properties of super plasticizer are shown in Table V.

TABLE V
PROPERTIES OF SUPER PLASTICIZER

S.No	Property	Result
1	Specific Gravity	1.220 – 1.225
2	Chloride content	Nil
3	Air entrainment	approximately 1% additional air is entrained

*As per manufacturers manual

B. Mix Proportioning

Concrete mix design in this experiment was designed as per the guidelines M40 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-2009. The Table VI shows mix proportion of concrete (Kg/m^3).

TABLE VI
MIX PROPORTIONS

S.No	Property	Result (Kg/m^3)
1	Cement	350
2	Fine Aggregate	896
3	Coarse Aggregate	1140
4	Water	140

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 VI shows the mix proportions of High Performance Concrete (kg/m^3).Concrete mixtures with different proportions of silica fume ranging from 5%, 7%, 10%, 12%, 14% and 15% for each silica fume replacement natural sand was replaced with manufactured sand by four proportions (i.e. 0%, 25%, 50%, 75%, and 100%) casted.

C. *Experimental Procedure*

The specimen of standard cubes of (150mm x 150mm x 150mm) and standard cylinders of 150mm diameter and 300mm height were used to determine the compressive strength and split tensile strength of concrete. Three specimens were tested for 3, 7 & 28 days with each proportion of silica fume replacement for compressive strength test. Three specimens were tested for 7 & 28 days with five proportion of silica fume replacement for tensile strength test. Totally 315 cubes and 90 cylinders were cast for the compressive and tensile strength parameters. The constituents were weighed and the materials were mixed by hand mixing. The water binder ratio (W/B) (Binder = Cement + Partial replacement of silica fume) adopted was 0.36 and weight of super plasticizer was estimated as 0.65% of weight of binder. The concrete was filled in different layers and each layer was compacted. The specimens were demoulded after 24 hrs, cured in water for 3, 7 & 28 days, and then tested for its compressive and split tensile as per Indian Standards

III. TEST RESULTS AND DISCUSSIONS

A. *Compressive Strength*

The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 3, 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000kN. The results are presented in table VII.

Mix	% of M-sand	% of Silica Fume	Compressive Strength in N/mm^2		
			3 Days	7 Days	28 Days
1	0	0%	11	32	43
	25%		12	32	46
	50%		14	38	51
	75%		13	33	45
	100%		12	31	42
2	0	5%	14	36	48
	25%		16	38	50
	50%		24	43	57
	75%		21	40	50
	100%		21	39	52
3	0	7%	16	35	46
	25%		16	38	48
	50%		26	45	59
	75%		22	39	48
	100%		21	37	49
4	0	10%	18	37	50
	25%		20	39	49
	50%		26	50	63
	75%		22	42	52
	100%		20	40	53
5	0	12%	17	36	49
	25%		20	38	53
	50%		25	49	62
	75%		18	41	52
	100%		19	39	54
6	0	14%	11	32	47
	25%		12	31	45
	50%		16	40	53
	75%		13	33	47
	100%		11	31	46
7	0	15%	11	32	47
	25%		12	31	45
	50%		15	38	55
	75%		13	32	45
	100%		11	31	46

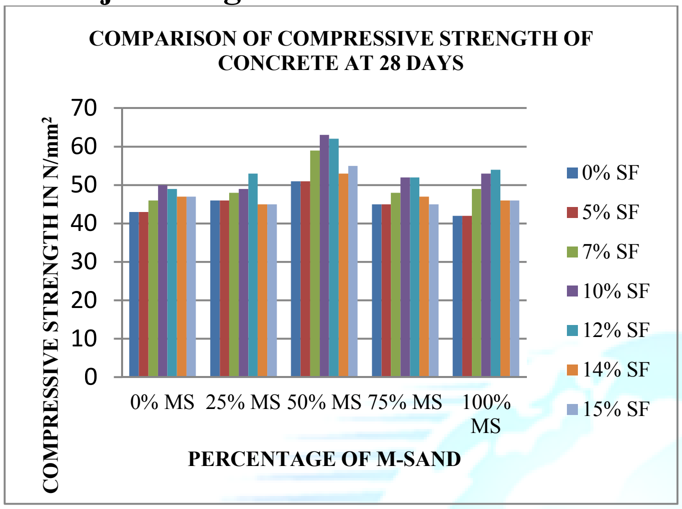

Fig 1. Comparison Results of compressive strength of concrete at 28 days.

Fig 2. Testing of compressive strength of concrete.

TABLE VII
RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE

B. Split Tensile Strength

The results of Split Tensile strength were presented in Table VIII. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000kN.From Fig 3 the increase in strength is 4.16 N/mm^2 and 4.17 N/mm^2 at 7 and 28 days. The maximum increase in split tensile strength is observed at 12% replacement of silica fume. The optimum silica fume replacement percentages for tensile strengths have been found to be a function of w/cm ratio of the mix. The optimum 28-day split tensile strength has been obtained in the range of 5–10% silica fume replacement level.

TABLE VIII
RESULTS OF SPLIT TENSILE STRENGTH OF CONCRETE

Mix	% of M-sand	% of Silica Fume	Split tensile strength in N/mm^2	
			7 Days	28 Days
1	0%	5%	3.64	3.74
		7%	3.88	3.95
		10%	4.06	4.12
		12%	4.11	4.15
		14%	3.64	3.82
2	50%	5%	3.85	3.86
		7%	3.92	3.98
		10%	4.15	4.15
		12%	4.16	4.17
		14%	3.72	3.82
3	100%	5%	3.58	3.6
		7%	3.76	3.79
		10%	4.02	4.05
		12%	4.09	4.12
		14%	3.59	3.82

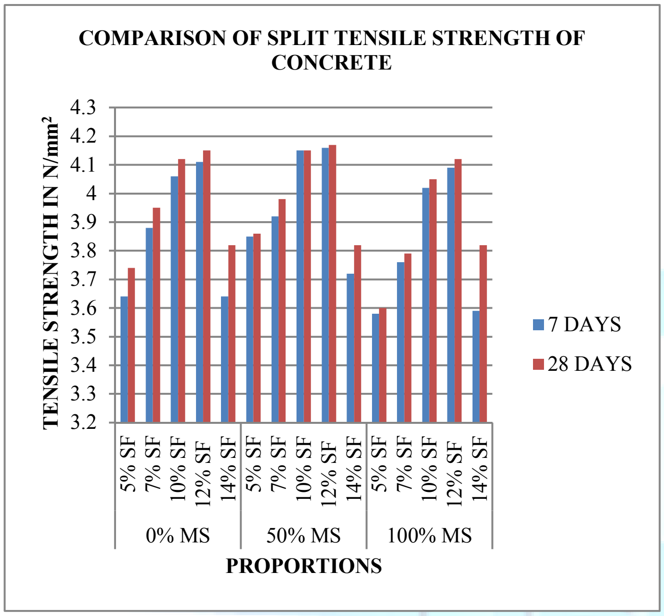

Fig 3. Comparison Results of split tensile strength of concrete.

IV.CONCLUSION

The experimental investigation where carried out to study the mechanical properties of concrete using M-sand as Fine aggregate and Silica Fume as Cement. Natural sand was replaced by M-sand by 0%, 25%, 50%, 75%, 100% and Silica Fume was replaced at 5%, 7%, 10%, 12%, 14%, 15%.From the observation of mix proportion, it has been concluded that the partial replacement i.e. 50% M-sand and 50% River sand achieved the higher strength. It is observed that the compressive strength and tensile strength of concrete can be improved by partial replacement of Silica fume for cement and M-sand for fine aggregate. M-Sand can be used as partial replacement for the natural sand, and the compressive and tensile 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 46.51% at 28 days by replacing 50% of natural sand with M-sand and 10% of cement by silica fume. The percentage of increase in the tensile strength is 11.5% at 28 days by replacing 50% of natural sand with M-sand and 5% of cement by silica fume. Water requirement or normal consistency of a mix increases with increment in percentage of Silica Fume and M-sand replacement. With the use of super-plasticizer, it is possible to get a mix with desired slump at a low water to cement ratio. The maximum increase in characteristic strength is observed for 10 to 12% replacement of silica fume. For this dose, the relative increase in compressive strength is found to be up to 14%.It is observed that up to 12% replacement of cement with silica fume the compressive strength increases with increasing dose of silica Fume and then reduces slightly. It is observed that the split tensile strength of concrete increases with increase in silica content up to 12% replacement of cement. 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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