Experimental study on mechanical properties of concrete using silica fume and eco sand

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Abstract
Concrete, the most often used material in civil engineering field. Hence sustainability is considered as one of the main aspects while using the natural resources as construction material. Since, the usage of natural resources like river sand is high enough to make them get depleted. To reduce these depletion sustainable materials or materials which can be obtained from waste material which has the same properties as that of the river sand can be used. Nowadays M-sand is used as an alternate material for river sand in building construction. In this experimental study, Cement is partially replaced with silica fume and fine aggregate (M-sand) is partially replaced with eco-sand.

Material testing has been done to find out the physical properties of eco sand and silica fume. Together with these two combinations a series of varying percentage has been obtained. Casting of concrete has been done in the form of cube, prism and cylinder to obtain the compression strength, flexural strength and split strength respectively for 7 days and 28 days curing for the estimated varying percentages. With the obtained results from the tests the optimum percentage for the partially replacement of eco sand and silica fume has been determined.

Keywords: Silica fume, Eco sand, M-sand, compressive strength, optimum percentage.

Introduction

Silica fume is a by-product of silicon metal and ferrosilicon alloy. It gives high strength and durability due to its reactive pazzolanic nature. It has very fine particles size less than 1 micron which is 100 times smaller than average cement particles. It is used to minimize the segregation and bleeding and also to reduce the concrete's permeability. Eco sand is a by-product obtained from the cement manufacturing process and available in large scale. It is a very fine particle which minimizes the pores in concrete. It provides better moisture resistivity and durability.

Review of Literature

Ram Kumar and Jitender Dhaka[1] did a research on the performance of silica fume as admixture in concrete for various proportions. He determined the compressive strength and split tensile strength of concrete and found 12% silica fume in concrete as the optimum content[1]. M. Indira and B. Udaykiran Reddy[2] focused their experimental investigation on partial replacement of fine aggregate with Eco sand and found 15% as optimum for using in concrete. This study also focuses on the property of the Ecosand when using in concrete[2].

Vishnumanohar A.[3] did a research on re-using different waste materials in concrete and focused on Eco-sand usage in concrete as fine aggregate. He concluded through his experimental study that 15% of Eco sand when used as partial replacement was found to be effective in concrete production[3].

Methodology

From the literatures collected it is found that Eco sand can be effective at 15% replacement for fine aggregate and silica fume 12% partial replacement for cement[1-3]. This paper aims at increasing the usage of ecosand and silica fume in concrete without compromising the strength parameters. Hence both Silica fume and Ecosand were considered as partial replacement for cement and fine aggregate in concrete.

Material Used

Cement: In 2019 (till date), its consumption is about 328 million metric tons. Ordinary Portland cement 53 grade having a specific gravity of 3.15 was used and has been tested for various proportion as per IS 403-1988.

Fine aggregate: M-sand conforming to zone II of table 4 BIS 383-1970 with specific Gravity: 2.65, fineness Modulus 3.2 and bulking of Sand 9.2%.

Coarse aggregate: Locally available quarried and crushed stones conforming to a graded aggregate of nominal size between 20 mm and 4.75 as per table of BIS:383-1970 (specific gravity - 2.69, fineness modulus – 4.55, water absorption- 0.5%).

Silica fume: The specific gravity of silica fume is generally in the range of 2.2 to 2.3. It gives high early strength to fast-track construction projects and precast applications and for high rise structures.

Ecosand: Eco-sand are very fine particles, which can be used to increases efficiency in concrete. Its micro-filling effect reduces pores in concretes (specific gravity- 2.35, fineness modulus-4.23 and bulking of sand - 18.14%).

Experimental Study

Laboratory tests (slump cone, Vee-bee test) were conducted on trial mix to determine the workability of concrete. The mix proportions were determined as per the guidelines given in IS method of concrete mix design (IS 10262:2009). The various types of mixes (M to M8) refer the different combinations of silica fume, Eco sand as partial replacement for fine and coarse aggregate in concrete.

Table 1
Mix Proportions

Mix Ratio	Cement	Silica fume	M-sand	Eco-sand
M	100%	-	100%	-
M1	100%	-	85%	15%
M2	100%	-	80%	20%
M3	100%	-	75%	25%
M4	100%	-	70%	30%
M5	90%	10%	85%	15%
M6	88%	12%	80%	20%
M7	86%	14%	75%	25%
M8	84%	16%	70%	30%

Mixing, casting and curing of specimen:

Mixing: A designed mix ratio of 1:1.7:3 was used for the concrete. Batching was done by weight and a water-cement ratio of 0.5 was used. Mixing was done manually.

Casting: For casting the cubes, cylinders and prisms standard cast-iron metal moulds were used. Cube moulds of size 100x100x100 mm and Cylinder moulds of size 150x300 mm and Prism mould of size 150x300 mm were used for concrete casting.

Curing: After casting, the specimens were stored in laboratory free from vibration. After 24 hours the specimens are removed from the mould and immediately submerged in the clean fresh water of curing tank.

Results and Discussion

At the age of 7 & 28 days curing the specimens were dried and tested for strength. The compressive strength, split tensile and flexural strength of specimen were determined as follows:

Table 2
Compressive strength of silica fume and Eco sand

Mixes	Average values	
	7 days (MPa)	28 days (MPa)
M	20.7	30.3
M 1	20.6	30.65
M 2	21.7	31
M 3	23.1	33.2
M 4	21.4	31.2
M 5	21.8	31.2
M 6	22.7	33.7
M 7	24.2	35.2
M 8	22.6	34.6

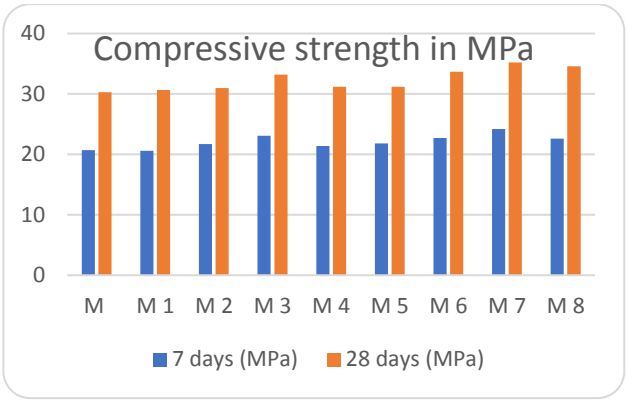

Fig. 1: Comparison of conventional concrete with silica fume and Eco sand as partial substitution

Table 3
Split tensile strength

Mixes	Average Split tensile strength at	
	7 days	28 days
M	2.53	3.33
M 5	2.89	3.58
M 6	3.12	3.74
M 7	3.49	3.89
M 8	3.31	3.43

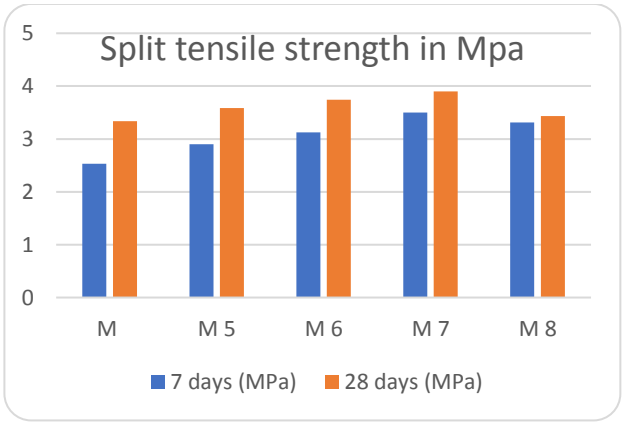

Fig. 2: Comparison of conventional concrete with silica fume and Eco sand

Table 4
Flexural Strength

Mixes	Average Flexural strength at	
	7 days (MPa)	28 days (MPa)
M	2.08	2.41
M 6	2.28	2.62
M 7	2.38	2.48
M 8	2.40	2.52
M 9	1.48	1.89

From the above results, all the mixes (M to M8) satisfies the minimum strength requirement and also shows a gradual strength increase when compared to that of conventional concrete (without Eco sand and Silica fume).

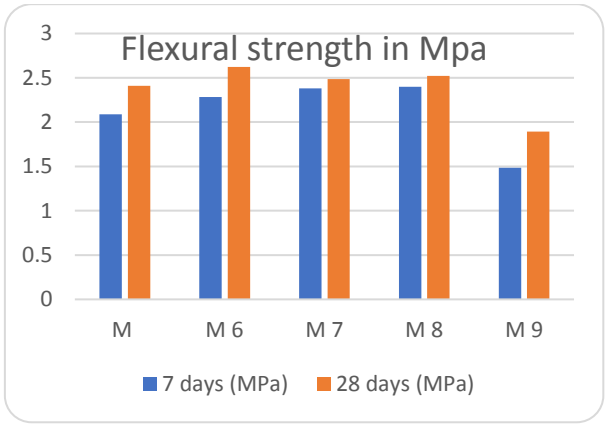

Fig. 3: Comparison of conventional concrete with silica fume and Eco sand

Conclusion

From the experimental results, it is observed that when the percentage of silica fume is increased more than 14% the strength gets decreased when compared to M7 mix but it shows a 12% increase in strength to that of conventional concrete (M mix). It is also observed that when silica fume content is increased the workability gets decreased during the casting of specimen. Hence this indicates that proper compaction is needed to maintain the homogeneity of concrete during mixing of concrete. In the other hand, the ecosand shows increase in strength even after 25% with a combination of silica fume. Considering all the observations, it is concluded from the experimental results, that the optimum content of silica fume is 14% and Eco sand is 25% for partial replacement in concrete.

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