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Study on Fracture and Durability properties of concrete replaced with Eco-Sand and Silica fume

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Abstract - *The project presents the results of the experimental and theoretical investigations of the mechanical crack formations and durability in the reinforced concrete beams subjected to static bending.A series of sequential 4- point bending tests leading to the formation of cracks in the reinforced concrete beams is discussed. At each step a series of impulsive load is produced to form vibrations. An attempt of partial replacement of fine aggregate (M sand) by Eco sand and a partial replacement of silica fume at various proportions is done to increase the durability and the durability tests such as sulphate, chloride, acid attack and water absorption tests are to be conducted.*

Key Words: Scanning Electron Microscopic analysis, Youngs modulus of concrete, Eco sand, Silica fume, partial replacement

I.INTRODUCTION

This paper presents to examine the experimental and theoretical investigations of the mechanical crack formations of reinforced concrete beams. This also gives an experimental and theoretical investigations of the durability of reinforced concrete beams. This helps to learn and professionalise techniques such as Digital Image Correlation Technique, X-Ray micro computed Technique and the young's modulus of the concrete is also studied.

This emphasises on monitoring the crack formation and assessing the quality measures aimed at strengthening concrete structures. The result concentrates on obtaining a durable concrete retaining in its original form with quality and serviceability when exposed to environment.

II.Effects on addition of eco sand

Eco sand are very fine particles, a bi-product from cement manufacture which can be used to increases efficiency in concrete. Eco sand is finely powdered crystalline silica which can replace up to a varying percentage of conventional sand usage in concrete and mortars. Its micro-filling effect reduces pores in concretes and provides better moisture resistivity and thus durability. It has more consistent grading than many extracted aggregates. Effective use for waste material and thus cost effective and performs as well as naturally occurring sand. The use of eco sand rather than extracted or dredged natural sand will help designers and contractors address issues of sustainability. The present study is checking the compressive strength of concrete block using eco sand as fine aggregate.

The eco sand has various advantages such as energy efficient, fire resistant, reduction of dead load, environmentally friendly, durable, light weight, low maintenance, and low construction cost.

III. Effects on partial replacement of cement with silica fume

Silica fume is a by-product of silicon industry. It is formed by the reduction of high purity quartz in an electric arc furnace. The fumes that arises are condensed and this condensed silica fume consist of 90% of SiO2. This silica fume is purified and is used. Silica fume has got different names such as micro silica, silica dust, and condensed silica fume. Silica fume possess both pozzolanic property as well as cementitious property. It is obvious that using recycled aggregate in concrete reduces the strength of concrete. The main reason for reduced strength is due to the presence of residual mortar. Residual mortar is to be considered while designing the mix. The decrease in strength due to recycled aggregate is compensated by the addition of silica fume. So, the combination of both these materials can be done effectively without compromising the strength of concrete.

Mechanism

Strength gaining of silica incorporated concrete is mainly due to pozzolanic action of silica fume. The silica present in silica fume combines with the calcium hydroxide which is a product of hydration to from C-S-H gel which possess cementitious property. This imparts strength to the concrete. Second reason is the fineness of silica fume. Due to larger surface area silica fume will get densely packed in

the cement paste and in aggregates and reduces the wall effect in transition zone.

IV.MATERIAL PROCUREMENT AND PROPERTIES

A.General

Following are the materials used for the study, Finely graded silica (Eco sand) as fine aggregate, Cement – OPC 53 grade, Coarse aggregate, Fine Aggregate – Manufactured sand.

B.Collection and properties of eco sand

Finely graded silica is brought from ACC cements Coimbatore. It is one of the .By-product coming from cements manufacturing process. Chemical composition of the material is given in Table.1.

Table 1 Chemical properties of eco sand

CHEMICAL	PERCENTAGE
SiO2	58-60%
Al2O3	2-3%
Iron	1-3%
MgO	0.4-1%
CaO	20-25%

Table 2 Physical Properties of Eco sand

PROPERTIES	RESULT
Specific gravity	2.62
Fineness modulus	0.0259

C. Specific gravity

The particle size distribution of finely graded silica is generally similar to that of silt (less than a 0.075mm). A fineness test was conducted on the eco sand sample as per IS 2386: 1963(Part 1) standard. The values obtained in the fineness test conducted on the eco sand sample are recorded in Table 3.

Table 3 Sieve analysis result

S.NO	SIEVE SIZE	WEIGHT RETAINED	% OF WEIGHT RETAINED	CUMULATIVE %	% OF PASSING
1	4.75mm	12 g	2.4	2.4	97.6
2	2.36mm	39 g	7.8	10.2	89.8
3	1.18mm	154 g	30.8	41	59
4	300 microns	250 g	50	91	9
5	150 microns	25 g	5	96	4
6	Pa	2 g	0.4	-	-

Total weight of fine aggregate = 200 g

Fineness modulus = 0.0259

C.Silica fume

Silica Fume: Silica fume required for the study was purchased from Civil Doctor, Coimbatore. The specific gravity of silica fume was found to be 2.56

D.Fine aggregate

Fine aggregate used for this study are Manufactured sand (M sand)

Table 4 Physical properties of fine aggregate

PROPERTIES	RESULT
Specific gravity	2.68
Fineness modulus	0.028

E. Coarse aggregate

Coarse aggregate used for this study are in size of 20mm.

Table 5 Physical properties of coarse aggregate

PROPERTIES	RESULT
Specific gravity	2.56
Water absorption	0.24%

G. Cement

Ordinary Portland cement 53 grade is used for this study. Since the 53 Grade Cement is finely grinded as compared to 43 Grade Cement hence the Surface parameter is higher for 53 Grade Cement. Strength Parameter,53 Grade Cement signifies 53 MPa (Mega Pascal) compressive strength after 28 days of curing, as compared to 43 MPa for 43 Grade Cement. Hence the compressive strength development in 53 Grade Cement is higher for same curing times. Hydraulic Reactions, the formation of Cao-SiO2 gels proceed faster as compared to 43 Grade Cement and hence higher heat of hydration for the same concrete area. Hence 53 Grade Cement may require more curing as compared to 43 Grade cement.

Table 6 Properties of cement

Description	Value
Grade	53
Fineness	2.5%
Specific gravity	3.15
Consistency	30%
Initial setting time	35 min
Final setting time	650 mins

V.MIX SPECIFICATIONS FOR DIFFERENT MIXES

Table 7 Mix proportions

MIX	CEMENT %	SILICA FUME %	M SAND %	ECO SAND %
M1(M25)	100	0	100	0
M2	100	0	90	10
M3	100	0	80	20
M4	95	5	100	0
M5	90	10	100	0
M6	95	5	90	10
M7	90	10	90	10
M8	95	5	80	20
M9	90	10	80	20

VI.TEST ON SPECIMENS

Testing of specimens plays an important role in controlling the quality and quantity of concrete. All the specimens cast were subjected to testing to study the effect of partial replacement of silica fume with respect to cement and eco sand with respect to fine aggregate on strength and fracture mechanism. Thus, the experiential investigations carried out was divided into the following categories. They are

Test1: Study on strength properties

a. Compressive Strength
b. Flexure Strength

Test2: Study on fracture properties

c. Young's modulus
d. SEM analysis

Test3: Durability properties

e. Acid attack test
f. Alkaline attack test

A.STUDY ON STRENGTH PROPERTIES
COMPRESSIVE STRENGTH

The test was carried out on 150mm×150mm×150mm cubes as specified by IS 516-1959 (1989). This concrete is properly poured and tampered in the mould so as not to have any voids. After 24hours these concrete specimens are removed from the mould and put inside the water for curing. The top surface of these concrete specimen should be made even, flat and smooth. After 7 and 28 days of curing these specimens are taken from the water and tested by compression testing machine. Load should be applied gradually at the rate of 140 kg/cm^2/min till the specimen fails. Load at the failure should be noted. Three specimens where tested at each stage and average of the three specimens gives the crushing strength of concrete.

FLEXURE STRENGTH

Concrete is weak in tension and strong in compression. Directly measuring the tensile strength of concrete is very difficult. Concrete beams of size 700×150×150 mm are found to be dependable to measure flexural strength property of concrete. The systems of loading used in finding out flexural strength are central and third point loading. Flexural strength is expressed as modulus of rupture and it is given by (M/Z).

B.STUDY ON FRACTURE PROPERTIES
YOUNG'S MODULUS

Modulus of Elasticity of Concrete can be defined as the slope of the line drawn from stress of zero to a compressive stress of $\mathbf{0.45}f'_c$. As concrete is a heterogeneous material. The strength of concrete is dependent on the relative proportion and modulus of elasticity of the aggregate.

To know the accurate value of elastic modulus of a concrete batch, laboratory test can be done. Also, there are some empirical formulas provided by different code to obtain the elastic modulus of Concrete. These formulas are based on the relationship between modulus of elasticity and concrete compressive strength. One can easily obtain an approximate value of modulus of elasticity of concrete using 28days concrete strength (f'_c) with these formulas.

$$E_c = 5000\sqrt{f'_c} \quad MPa$$

SCANNING ELECTRON MICROSCOPIC ANALYSIS

In this current study, the hydrated cement paste obtained from the seven powder samples are subjected to SEM analysis. The range of scale used in SEM analysis was 5 µm with the resolution of x5000. The detailed process of sample preparations for SEM analysis is described below. After Compressive testing was finished, the cube samples are crushed and the hydrated cement was collected from the innermost core of the concrete cube sample. The collected samples are sieved through 300µ sieve. The sample preparation was done by cone and quartering method for reducing the sample size. The sample was dispensed on flat surface so that it takes on a conical shape. The top of the conical shape was flattened. The cone is divided into quarters. Two opposite quarters was discarded; the other two are combined. The process was repeated until the suitable sample size was reached

C.DURABILITY PROPERTIES
ACID ATTACK TEST

For acid attack test concrete cube of size 150 ´ 150 ´ 150 mm is prepared for various percentages of silica fume addition. The specimen is cast and cured in mould for 24 hours, after 24 hours, all the specimen is demoulded and kept in curing tank for 7-days. After 7-days all specimens are kept in atmosphere for 2-days for constant weight, subsequently, the specimens are weighed and immersed in 5% sulphuric acid (H_2SO_4) solution for 60-days. The pH value of the acidic media was at 0.3. The pH value was periodically checked and maintained at 0.3. After 60-days of immersing in acid solution, the specimens are taken out and were washed in running water and kept in atmosphere for 2-day for constant weight. Subsequently the specimens are weighed and loss in weight and hence the percentage loss of weight was calculated.

ALKALINE ATTACK TEST

For alkaline attack test concrete cube of size 150 ´ 150 ´ 150 mm is prepared for various percentages of silica fume addition. The specimen is cast and cured in mould for 24 hours, after 24 hours, all the specimens are demoulded and

kept in curing tank for 7-days. After 7-days all specimens are kept in atmosphere for 2-days for constant weight, subsequently, the specimens are weighed and immersed in 5% sodium sulphate (Na_2SO_4) solution for 60-days. The pH value of the alkaline media was at 12.0. The pH value was periodically checked and maintained at 12.0. After 60- days

of immersing in alkaline solution, the specimens are taken out and are washed in running water and kept in atmosphere for 2-day for constant weight. Subsequently, the specimens are weighed and loss in weight and hence the percentage loss of weight was calculated.

VII. RESULTS AND DISCUSSION

The results obtained from the experimental system were represented both in tabular form and graphical means.

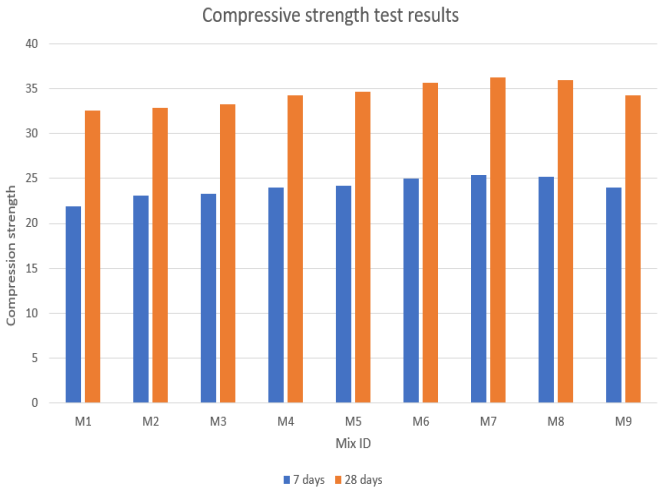
COMPRESSIVE STRENGTH TEST

It is one of the important characteristics. The concrete specimen of size 150 x 150 x 150 mm is casted and demoulded after 24 hours and cured and the tests are taken in the days of 7 and 28 days.

The test results are taken in values and mentioned in graphical form. The values are tabulated as follows.

Table 8 Compressive strength at 7 and 28 days

Mix	Mix proportions	Load (KN)		Compressive strength(N/mm²)	
		7days	28days	7days	28 days
M1	Conventional	512.34	731.92	21.92	32.53
M2	Eco sand 10%	517.6	739.5	23.09	32.87
M3	Eco sand 20%	523.68	748.12	23.27	33.25
M4	Silicafume 5%	538.8	769.72	23.94	34.21
M5	Silicafume10 %	545.6	778.95	24.23	34.62
M6	Silica fume 5% eco sand 10%	561.96	802.8	24.97	35.68
M7	Silicafume10 % eco sand 10%	571.09	815.85	25.38	36.26
M8	Silicafume 5% eco sand 20%	566.68	809.55	25.18	35.98
M9	Silicafume 10% Eco sand 20%	540.06	771.52	24.03	34.29

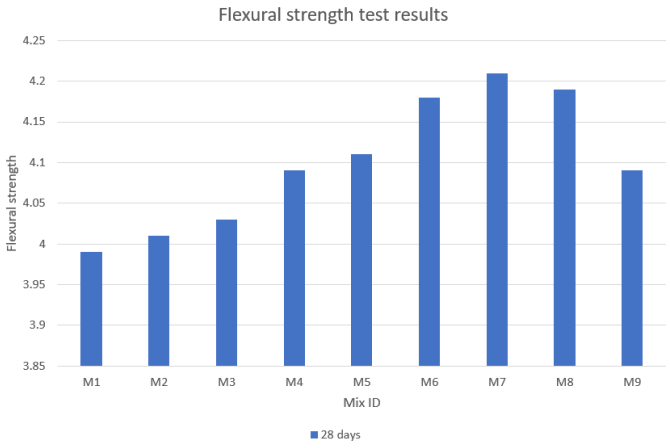


FLEXRAL STRENGTH TEST

The flexural strength test was carried out on prism of cross-section 150 mm × 150 mm × 700 mm. The flexural strength of concrete, strength increased from the replacement of silica fume 10% with cement and eco sand 20% with M sand at 7 days and 28 days. The results of flexural strength for M25 grade concrete are tabulated.

Table 9 Flexure strength at 7 and 28 days

Mix	Mix proportions	Load (KN)	Flexural strength(N/mm²)
		28days	28 days
M1	conventional	19.24	3.99
M2	Eco sand 10%	19.33	4.01
M3	Eco sand 20%	19.43	4.03
M4	Silicafume 5%	19.72	4.09
M5	Silicafume 10%	19.82	4.11
M6	Silica fume 5% eco sand 10%	20.15	4.18
M7	Silicafume10% eco sand 10%	20.30	4.21
M8	Silicafume 5% eco sand 20%	20.20	4.19
M9	Silicafume 10% Eco sand 20%	19.72	4.09



ACID ATTACK TEST

The loss of the percentage of weight was calculated for the specimens at the end of 60 days after immersing in the acid solution maintaining at 0.3pH

Table 10 Weight of specimen subjected to acid attack

S.No	Mix ID	Weight		Percentage of weight loss
		0 days	60 days	
1	M1	8.86	6.32	28.67
2	M2	8.81	6.51	26.12
3	M3	8.85	6.65	24.85
4	M4	8.9	6.86	24.9
5	M5	8.82	6.88	21.98
6	M6	8.87	7.14	19.50
7	M7	8.85	7.24	18.19
8	M8	8.89	6.96	21.70
9	M9	8.87	6.82	23.11

ALKALINE ATTACK TEST

The loss of the percentage of weight was calculated for the specimens at the end of 60 days after immersing in the alkaline solution maintaining at 12pH.

Table 11 Weight of specimen subjected to alkaline attack

S.No	Mix ID	Weight		Percentage of weight loss
		0 days	60 days	
1	M1	8.86	6.91	22.09
2	M2	8.81	7.03	20.20
3	M3	8.85	7.11	19.32
4	M4	8.9	7.14	19.77
5	M5	8.82	7.35	16.66
6	M6	8.87	7.65	13.75
7	M7	8.85	7.82	11.63
8	M8	8.89	7.76	12.71
9	M9	8.87	7.52	15.21

VIII. CONCLUSION

Based on limited experimental investigation concerning the compressive strength of concrete, the following observations are made while replacing fine aggregate with different proportions of finely graded silica.

[1] The Eco sand (finely graded silica) is a locally available, low cost, and inert industrial solid waste whose disposal is a matter of concern likes construction waste. On an overall, the Eco sand can be comparable to the natural river sand.

[2] The Eco sand satisfies the zone IV gradation for not only to partially replace the sand, but for making good concrete.

[3] From the SEM analysis, at a 15% replacement the mix remains homogeneous as the micro pores are filled and the transition zone is densified.

[4] From the experimental investigation it was found that 15% replacement level is the optimum level.

[5] The compressive strength of silica fume concrete is found to be more than normal concrete.

[6] Compressive strength increase in 7 day is due to the void filling ability of silica fume and compressive strength increase in 28 day is due to the pozzolanic activity of silica fume.

[7] 10 % replacement of silica fume shows higher strength. 20 % replacement of silica fume is found to give higher flexural strength. This is due to the fact that increased percentage of silica fume increases the bonding. 20% of silica fume is found to give higher flexural strength in both 7 and 28-day tensile strength

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