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Performance of Normal Concrete with Eco Sand (Finely Graded Silica) As Fine Aggregate

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ABSTRACT : *Concrete is the most undisputable and indispensable material being used in infrastructure development throughout the world. Umpteen varieties of concretes (FAC, HVFAC, FRC, HPC, HSC, and others) were researched in several laboratories and brought to the field to suit the specific needs. Although natural fine aggregates (i.e., river sand) are so far and/or will be superior to any other material in making concrete, their availability is continuously being depleted due to the intentional overexploitation throughout the Globe. Hence, partial or full replacement of fine aggregates by the other compatible materials like sintered fly ash, crushed rock dust, quarry dust, glass powder, recycled concrete dust, and others are being researched from past two decades, in view of conserving the ecological balance. In this direction, an experimental investigation of strength and durability was undertaken to use "Finely graded silica" (Eco sand) (i.e. waste material from cement manufacturing process) for partial replacement of fine aggregate in concrete. This research includes tests to find out the physical and chemical properties of finely graded silica and also replacing this finely graded silica with fine aggregate partially (15%,30%,45% & 60%) . A mix of M_{25} and M_{40} concrete is selected for the replacement. For the compression testing cubes of size 150x150x150mm prepared and they were tested at 3,7,28 and 90 days.*

KEYWORDs: *compressivestrength,ecosand,super plasticizers,normal concrete,Partial replacement*

I. INTRODUCTION

1.1 General

Concrete is a well known composite construction material composed primarily of aggregate, cement and water. There are many formulations which provide varied properties. The aggregate is generally coarse gravel or crushed rocks such as limestone or granite, along with a fine aggregate such as sand. The cement commonly Portland cement and other cementitious materials such as fly ash and slag cement serve as a binder for the aggregate. Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process called hydration. The water reacts with the cement which bonds the other components together eventually creating a robust stone-like material. Concrete has relatively high compressive strength, but much lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel). Concrete can be damaged by many processes such as the freezing of trapped water.

1.2 Main reasons to incorporate eco sand in concrete

Now-days, all over the world, construction activities are taking place on huge scale. Due to this there is great increase in cost of construction. Natural river sand is one of the key ingredients of concrete, is becoming expensive due to excessive cost of transportation from sources. Also large scale depletion of sources creates environmental problems. Unfortunately, production of cement also involves large amount of carbon dioxide gas into the atmosphere, a major contributor for green house effect and the global warming. To overcome these problems there is a need of cost effective, alternative and innovative materials.Industrial by products are those which is coming from different industries other than the main proposed product. It can also call as a sub product of different processes coming in manufacturing. In recent days these products are recycled and reused for other purposes to reduce cost and problems coming from disposal. These are 50% more cheaply than the original raw materials. In cement manufacturing process, a cement plant consumes 3 to 6 GJ of fuel per ton of clinker produced, depending on the raw materials and the process used. Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications.

Selected waste and by-products containing useful minerals such as calcium, silica, alumina, and iron can be used as raw materials in the kiln, replacing raw materials such as clay, shale, and limestone. Because some materials have both useful mineral content and recoverable calorific value, the distinction between alternative fuels and raw materials is not always clear. For example, sewage sludge has a low but significant calorific value, and burns to give ash containing minerals. Eco sand (finely graded silica) is a by-product coming from cement manufacturing process, mainly cement industries those use silica as a raw material is mainly producing eco sand as by-product.

1.3 What are called eco sand?

Eco sand are very fine particles, a bi-product from cement manufacture which can be used to increases efficiency in concrete.. 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 cube using eco sand, cement and supo flow. The eco sand has various advantages such as energy efficient, fire resistant, reduction of dead load, environmentally friendly, durable, light weight, low maintenance low construction cost.

1.4 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. Ecosand 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 ecosand 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 ecosand as fine aggergate. The ecosand has various advantages such as energy efficient, fire resistant, reduction of dead load, environmentally friendly, durable, light weight, low maintenance, and low construction cost.

II. MATERIAL PROCUREMENT AND PROPERTIES

2.1 General

Following are the materials used for the study, Finely graded silica(Eco sand) ,fine aggregate, Cement – OPC 53 grade, chettinad cement conforming to IS 12269 – 1987,Coarse aggregate, Fine Aggregate – Natural sand (IS383 – 1970),Super plasticiser(supo flow)

2.2 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
SiO_2	58-60%
Al_2O_3	2-3%
Iron	1-3%
MgO	0.4-1%
CaO	20-25%

Table 2 Physical Properties of Eco sand

PROPERTIES	RESULT
Specific gravity	2.42
Fineness modulus	0.028

3.2.1 Sieve Analysis

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

Sieve Designation (micron)	Mass retained	%Retained	%passing	Cumulative %retained
4.75	0.00	0.00	100	0
2.36	0.01	0.005	99.95	0.005
1.18	0.02	0.01	99	0.015
600	0.05	0.025	97.5	0.04
300	1.68	0.84	16	0.88
150	0.14	0.07	93	0.95
Pan	0.10	0.05	95	1.00

Total weight of fine aggregate = 2kg **Fineness modulus = 0.0289**

Table 4 IS classification

IS classification	Value range
Gravel	4.75 – 80
Sand	0.075-4.75
Silt	0.002-0.075

2.3 Other materials

2.3.1 Fine Aggregate

Fine aggregate used for this study are natural river sand (IS383 – 1970)

Table 5 Physical properties of fine aggregate

PROPERTIES	RESULTS
Specific Gravity	2.30
Water absorption (%	0.5%

2.2.2 Coarse Aggregate

Coarse aggregate confirming a size of 20mm were used for this study

Table 6 Physical properties of coarse aggregate

PROPERTIES	RESULTS
Specific Gravity	2.32
Water absorption	0.5%

2.2.3 Cement

53 grade ordinary Portland cement is used for the 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.

2.3 Super plasticiser

Super plasticizer confirming (Supo-flow) BS 5075 part3 and ASTM C-494 type G & IS 9103-1999 was used to improve workability and to reduce water consumption by 30%.Superplasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspension are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (theology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases. However, their working mechanisms lack of a full understanding, revealing in certain cases cement-super plasticizer incompatibilities Super plasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspension are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (theology) of suspensions such as in concrete applications.Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases. However, their working mechanisms lack of a full understanding, revealing in certain cases cement-super plasticizer incompatibilities

III. RESULT AND DISCUSSION

3.1 Chemical composition of finely graded silica

Table no 5.1 explains about the chemical composition of material. Eco sand is containing 50-60% of SiO_2 which will not be harmful for the concrete.

3.2 Sieve analysis

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 Table11

Table 11 Sieve analysis result

Sieve Designation (micron)	Mass retained	%Retained	%passing	Cumulative %retained
4.75	0.00	0.00	100	0
2.36	0.01	0.005	99.95	0.005
1.18	0.02	0.01	99	0.015
600	0.05	0.025	97.5	0.04
300	1.68	0.84	16	0.88
150	0.14	0.07	93	0.95
Pan	0.10	0.05	95	1.00

Total weight of fine aggregate = 2kg **Fineness modulus = 0.0289**

Table 11 shows the sieve analysis result on finely graded silica (eco sand). Classification can be done as per Table 12.

Table 12 IS classification

IS classification	Value range
Gravel	4.75 – 80
Sand	0.075-4.75
Silt	0.002-0.075

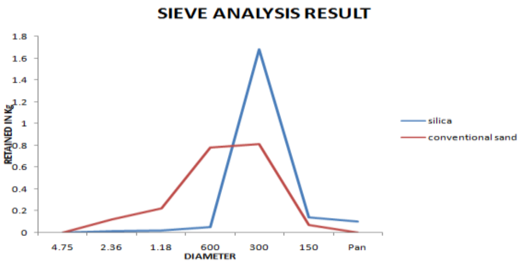

Fig.1 sieve analysis

3.3 Compressive strength of m_{25} mix

Table 14 Compressive strength of m_{25} mix

REPLCEMENT OF SILICA	3-days (N/mm^2)	7-days (N/mm^2)	28-days (N/mm^2)	90-days (N/mm^2)
15%	10.09	28.73	32.07	48.22
30%	7.64	24.93	28.50	43.21
45%	7.63	22.80	25.80	37.85
60%	6.74	21.54	24.78	32.65

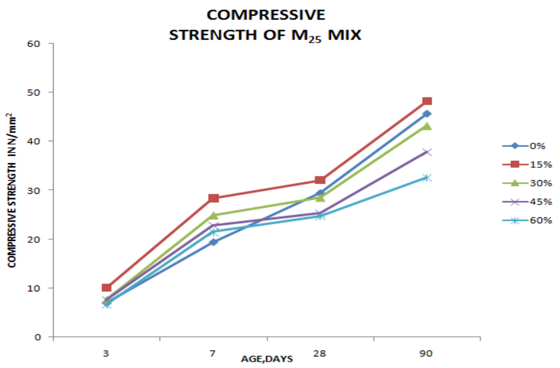

Fig.2 Compressive strength of M_{25} mix

From the comparative analysis of compressive strength of M25 mix cubes, it is shown that at a replacement of 15% the cubes are getting a higher strength than the conventional mix. All other replacements are achieved a low strength compared to the conventional mix.

3.4 Compressive strength of m_{40} mix

Table 15 Compressive strength of m_{40} mix

REPLCEMENT OF SILICA	3-days (N/mm^2)	7-days (N/mm^2)	28-days (N/mm^2)	90-days (N/mm^2)
15%	13.93	33.76	56.11	73.43
30%	13.63	34.67	51.22	59.22
45%	8.95	31.00	43.29	57.34
60%	7.19	28.78	41.04	56.10

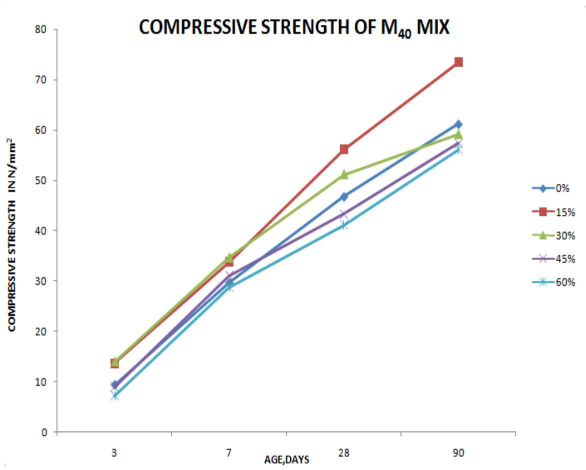

Fig.3 Compressive strength of M_{40} mix

From the comparative analysis of compressive strength of M40 mix cubes, it is shown that at a replacement of 15% the cubes are getting a higher strength than the conventional mix. All other replacements are achieved a low strength compared to the conventional mix

3.5 Characterization study

Characterization study is done on both eco sand and the crushed cube of 15% replaced fine aggregate with eco sand using SEM analysis. Here the eco sand is magnified to different ranges to study their structure and size with the help of images. The SEM images of eco sand are shown in the Fig.8 and Fig.8 respectively. In a typical SEM, an electron beam is thermionically emitted from an electron gun fitted with a tungsten filament cathode. Tungsten is normally used in thermionic electron guns because it has the highest melting point and lowest vapour pressure of all metals, thereby allowing it to be heated for electron emission, and because of its low cost. Other types of electron emitters include lanthanum hexaboride (LaB_6) cathodes, which can be used in a standard tungsten filament SEM if the vacuum system is upgraded and FEG, which may be of the cold-cathode type using tungsten single crystal emitters or the thermally assisted Schottky type, using emitters of zirconium oxide.

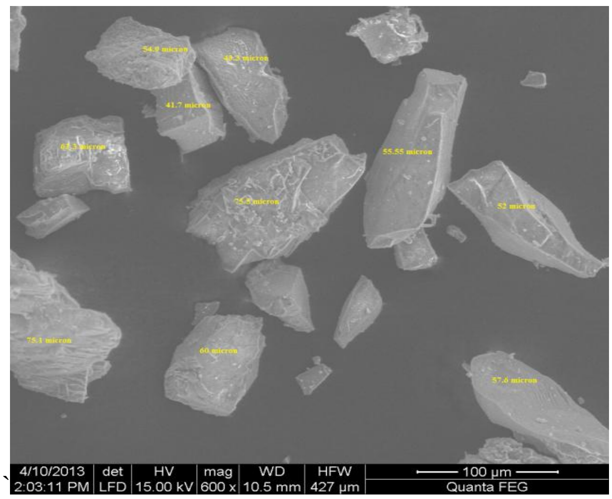

Fig .4 Eco sand at 100 µm

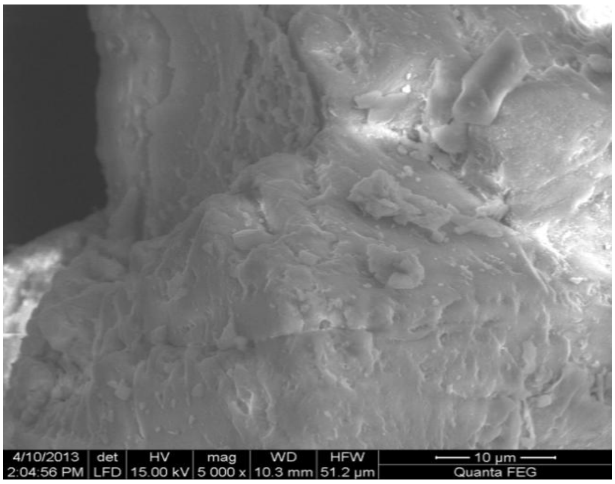

Fig .5 Eco sand at 10 µm

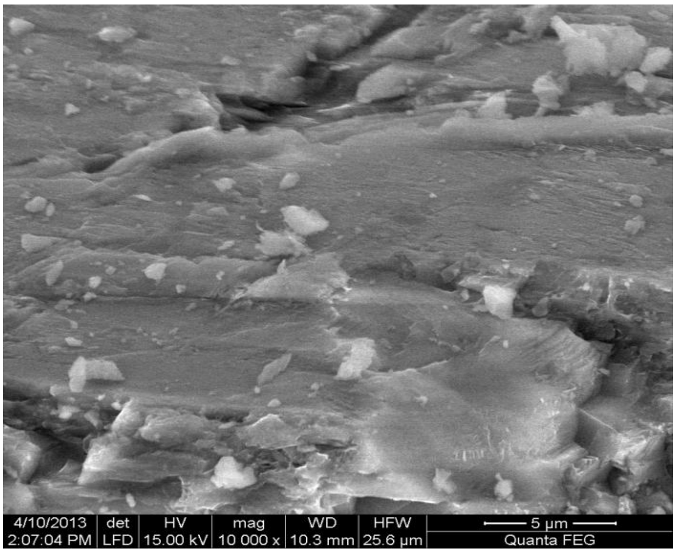

Fig no 6 Eco sand at 5 µ

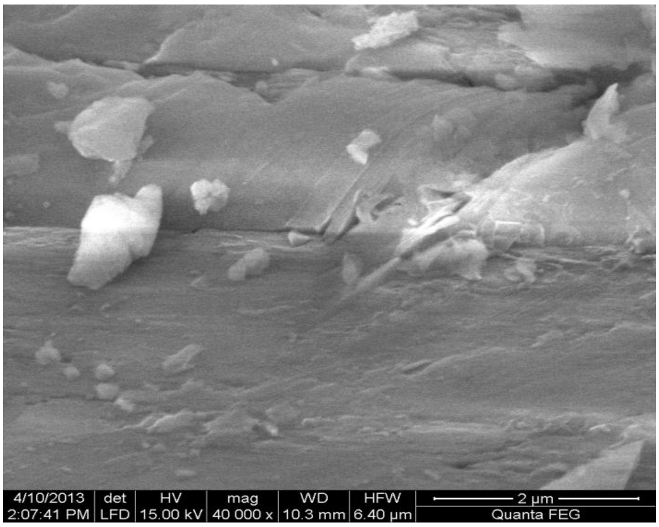

Fig no 7 Eco sand at 2 µm

From the SEM analysis conducted on the eco sand it is observed that particle sizes are between the ranges of 41 to 76 micron, the result is shown in the fig 10. In a typical SEM, an electron beam is thermionically emitted from an electron gun fitted with a tungsten filament cathode. Tungsten is normally used in thermionic electron guns because it has the highest melting point and lowest vapour pressure of all metals, thereby allowing it to be heated for electron emission, and because of its low cost. Other types of electron emitters include lanthanum hexaboride (LaB_6) cathodes, which can be used in a standard tungsten filament SEM if the vacuum system is upgraded and FEG, which may be of the cold-cathode type using tungsten single crystal emitters or the thermally assisted Schottky type, using emitters of zirconium oxide. The electron beam, which typically has an energy ranging from 0.2 keV to 40 keV, is focused by one or two condenser lenses to a spot about 0.4 nm to 5 nm in diameter. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron column, typically in the final lens, which deflect the beam in the *x* and *y* axes so that it scans in a raster fashion over a rectangular area of the sample surface. When the primary electron beam interacts with the sample, the electrons lose energy by repeated random scattering and absorption within a teardrop-shaped volume of the specimen known as the interaction volume, which extends from less than 100 nm to around 5 µm into the surface.

3.5.1 SEM result of crushed concrete cube at 15% replaced eco sand with F.A.

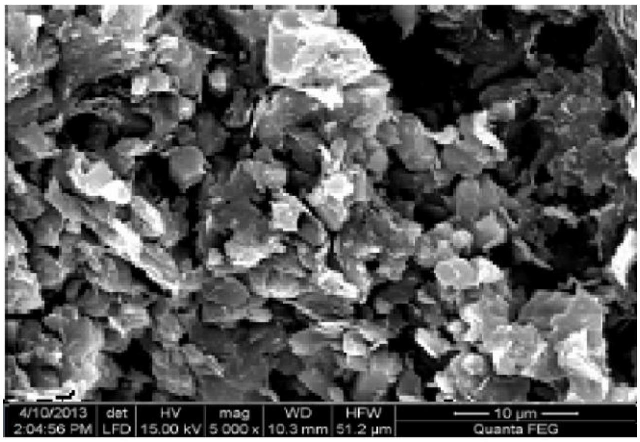

Fig no 8 SEM result at 10 µm (concrete)

IV. 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 III gradation for not only to partially replace the sand, but for making good concrete.

[3] From the obtained results we observed that the maximum strength is achieved by 15% of fine aggregate replacement with eco sand in concrete. While increasing the percentage of eco sand the compressive strength value is getting decreased.

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

[5] Higher the percentage of fine aggregate replacement higher was the strength activity index. The strength activity index nearly varies linearly with percentage replacement of fine aggregate with eco sand. The maximum strength activity index was 1.49 at 15% replacement level.

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

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