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Experimental Study on Various Effects of Partial Replacement of Fine Aggregate with Silica Sand in Cement Concrete and Cement Mortar

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Abstract -- *The main objective of this paper is to study the effects of silica sand when used as a partial replacement to fine aggregate (natural sand). Natural sand in and around river bed plays an important ecological. The global consumption of natural sand has become very high due to excessive use of concrete. Hence the role, it acts as a giant aquifer and habitat for species. As a result of urbanization and increase in construction projects and activities, the available sources of natural sand is getting depleted. Demand for natural sand has become quite high and there is shortage of good quality natural sand. This research deals with the utilization of an alternative material, silica sand as partial replacement of natural sand. Silica sand is a by-product obtained as a result of cement manufactured by wet process. Silica sand acts as a filler material that is inert but enhances the process of hydration by physical activity. Due to the micro filling property of silica sand, the pores in concrete are reduced which improves moisture resistivity of concrete. Silica sand is replaced at 20%, 40%, 60%, 80% and 100% by weight of cement and the results are compared with the strength of conventional concrete. M25 grade concrete is taken for study. The optimum percentage arrived is 60% and it is to be noted that on 100% replacement the result obtained is on par with the results of conventional concrete.*

Keywords*: silica sand, conventional concrete, fillers, hydration, micro filling, resistivity*

1. INTRODUCTION

Concrete is generally considered to be the most widely used material on Earth. Concrete is a composite material which consists of cement, aggregate and water. Aggregate is a broad category of coarse particulate material used in construction, including sand, gravel, Crushed stone. Aggregate serves as reinforcement that provides strength to the composite material. Cement, when mixed with water acts as a binding material. Lower water to cement ratio will give better strength to concrete but will result in low workability whereas with higher water to cement ratio concrete with higher workability and less strength is achieved. In order to overcome this problem super plasticizers are used. Super plasticizers are high range water reducing agent which is capable of removing excess water that does not take part in hydration process without altering the strength of the concrete. In this paper, silica sand is used to replace cement in concrete. Silica sand is a by-product obtained from wet process of manufacturing cement. In this paper the silica rich waste is used as partial replacement to fine aggregate. The global consumption of natural sand has become very high due to excessive use of concrete. Increased extraction of natural sand from river bed causes many problems like lowering of underground water table, disturbs the aquatic life, disturbs the tectonic plates in the distribution of seismic effects, changes the profile of river beds etc.

Silica sand is finely powdered crystalline silica which can be used as a replacement of cement and fine aggregate. Its micro-filling effect reduces pores in concretes and provides better moisture resistivity and thus durability. The silica sand has various advantages such as energy efficiency, fire resistance, reduction of dead load, environmentally friendly, durable, light weight, low maintenance and low construction cost. Using silica sand in concrete can reduce the cost of concrete and may increase the strength to some extent. Silica sand is a preferred for construction material due to its higher surface hardness and density. Many research works are carried out to study the effects of such materials when used as a substitute to cement or sand. In this paper, an attempt has been made to explore the possibility of using silica sand as a replacement material for fine aggregate. M25 grade concrete specimens were replaced with 20%, 40%, 60%, 80% and 100% of cement with silica sand. As very fine particles are used, water demand increases, as a result of which water cement ratio tends to increase. Hence 1.5% of super plasticizer is used. The Compressive strength and Split tensile strength of the specimens was found on the 7th, 14th and 28th days. Optimal replacement percentage achieved is 60% and on replacing 100% of fine aggregate with silica sand, the result obtained is on par with conventional concrete.

2. LITERATURE REVIEW

Sudhahar A et al (2012), carried out an investigation of extracted silica sand (EDS) wastes as fine aggregate in concretes and mortars. M25 grade of concrete has been used for study and it has been concluded that 15.5% of increase in compressive strength has been achieved with 50% replacement of fine aggregate with EDS on 28^{th} day. Also the use of EDS is found to improve the packing quality inside the concrete and thus improves its permeability and durability.

Vishnumanohar A (2015), carried out an experimental investigation on use of "Finely graded silica" (Eco sand, i.e. waste material from cement manufacturing process) as partial replacement of fine aggregate in concrete. Tests were carried out to find out the physical and chemical properties of finely graded silica and this finely graded silica was replaced with fine aggregate partially (15%,30%,45% & 60%). A mix of M25 and M40 concrete was selected for the replacement. The result obtained for M40 grade of concrete was 56.1 N/mm^2 at 28^{th} day and for M25 concrete was 32.07 N/mm^2 at 28^{th} day on 15% replacement of fine aggregate by ecosand. This shows that the maximum strength was achieved by 15% of fine aggregate replacement with eco sand in concrete. While increasing the percentage of eco sand the compressive strength value was getting decreased. From the SEM analysis, it was inferred that at a 15% replacement the mix remains homogeneous as the micro pores are filled and the transition zone was densified.

M. Prabu et al (2015), reported the details on use of GGBS and eco sand as partial replacement by weight of cement and sand at 0%, 10%, 20%, 30%, and 40%. Fresh concrete tests and hardened concrete tests like compressive strength test, split tensile strength and flexural strength was carried out. Result shows that 20% replacement of eco sand and 30% replacement of GGBS gives optimum strength. The compressive strength obtained with replacement of 20% of eco sand was 31.16 N/mm^2 and that of conventional concrete was 26.78 N/mm^2 (16.35 % increase was achieved). The 28^{th} day strength obtained for conventional concrete was 26.78 N/mm^2 whereas the compressive strength obtained for specimen with 30% of GGBS and 20% of eco sand was 30.06 N/mm^2 (12.248% increase was achieved). The flexural and split tensile strength obtained for conventional concrete was 2.9 N/mm^2 and 2.210 N/mm^2 respectively where as for specimen with 30% of GGBS and 20% of eco sand was 3.868 N/mm^2 (33.38% increase) and 2.419 N/mm^2 (9.45% increase) respectively.

Eldhose M Manjummekudy et al (2014), carried out an investigation on use of eco sand and granulated blast furnace slag (GGBS) obtained as byproduct from the steel manufacturing industry as fine aggregate replacement. M20 grade of concrete was used for this study. In the case of eco sand maximum compressive strength was attained for concrete cubes made with 25% (30.88 N/mm^2) and 75% (29.11 N/mm^2) replacement of fine aggregate using eco sand (ES25 & ES75). It has been reported that, as the amount of fines increase, it minimizes the void content in the system and hence providing a denser packing of aggregates.

3. MATERIAL PROPERTIES

3.1 General

Following are the materials used for the study, finely graded silica (silica sand), Cement – OPC 53 grade conforming to IS 12269-1987, Coarse aggregate, Fine aggregate – Natural sand (IS383-1970).

3.2 Silica Sand

Silica sand is a by-product obtained from cement manufacturing process. Silica sand is fine powder which can replace up to a different percentage of conventional sand usage in concrete. Its micro-filling effect improves the particle packing of the concrete and hence improves moisture resistivity of concrete.

3.2.1 Chemical Properties

The chemical composition of silica sand was tested at Private research laboratory. The chemical composition of silica sand is shown in table 3.1.

Table 3.1 Chemical properties of Silica sand

Description	*Percentage*
LOI	29.28
SiO_2	28.93
Al_2O_3	2.00
Fe_2O_3	0.76
CaO	37.33
MgO	0.53

3.2.2Physical Properties

The physical property of silica sand was tested at Concrete laboratory and the results are shown in table 3.2.

Table 3.2 Physical properties of Silica sand

Properties	***Results***
Specific gravity	2.43
Fineness modulus	2.70

3.3 Fine Aggregate

Fine aggregate used for this study is natural river sand (IS383-1970). Fine aggregate is used to achieve uniformity in the mixture and also helps the cement paste to hold the coarse aggregate particle in suspension.

3.3.1Physical Properties

The physical property of fine aggregate was tested at Concrete laboratory and the results are shown in table 3.3.

Table 3.3 Physical properties of fine aggregate

Properties	***Results***
Specific gravity	2.63
Fineness modulus	3.72

3.4 Coarse Aggregate

Coarse aggregate of size 20mm is used for this study. Coarse aggregate controls shrinkage of Concrete and provides volume stability to the concrete.

3.4.1Physical Properties

The physical property of coarse aggregate was tested at Concrete laboratory and the results are shown in table 3.4.

Table 3.4 Physical properties of coarse aggregate

Properties	***Results***
Specific gravity	2.720
Fineness modulus	3.076

3.5 Cement

Cement is a binding material that holds together with the other ingredients of concrete. Ordinary Portland cement of grade 53 is used for this study.

3.5.1Physical Properties

The physical property of cement was tested at Concrete laboratory and the results are shown in table 3.5.

Table 3.5 Physical properties of cement

Properties	***Results***
Specific gravity	3.15
Fineness modulus	0.16

3.6 Super plasticizer

Super plasticizer confirming super flow PC711 was used to improve workability. Super plasticizers are high range water reducing agent which is capable of removing excess water that does not take part in hydration process without altering the strength of the concrete. As very fine particles are used for this study, water demand increases, as a result of which water cement ratio tends to increase. Hence 1.5% of super plasticizer is used.

3.7 Details of Concrete Mix

In the present investigation, M25 mix is designed based on IS 10262:2009. The water cement ratio adopted is 0.4 and the mix ratio adopted is 1 : 2.2 : 3.6.

3.8 Test Results

3.8.1 *Compressive Strength*

The cube compressive strength of concrete was determined by conducting test on 150 mm x150 mm x150 mm cube specimens at 7, 14 and 28 days of curing. After curing the cube specimens were tested on compression testing machine and the values obtained are given in table 3.7.

Table 3.6 Compressive strength

Replacement percentage	7th Day (N/mm^2)	14th Day (N/mm^2)	28th Day (N/mm^2)
0%	18.22	22.05	29.73
20%	19.73	25.79	34.03
40%	21.69	29.05	37.00
60%	23.57	31.38	39.30
80%	20.22	27.45	35.20
100%	18.87	23.36	30.01

The variations in compressive strength of M25 concrete with respect to replacement percentage and age are shown in fig 3.1

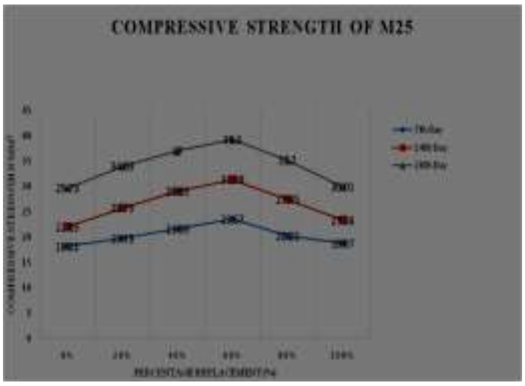

Fig 3.1 Compressive strength

3.8.2 Split Tensile Strength

The tensile strength of concrete was determined by conducting test on cylinder of diameter 150 mm and height of 300 mm. After curing the specimens were tested on compression testing machine and the values are given in table 3.8.

Table 3.8 Tensile strength

Replacement percentage	7th Day (N/mm^2)	14th Day (N/mm^2)	28th Day (N/mm^2)
0%	2.27	3.15	3.92
20%	2.49	3.35	4.30
40%	3.54	3.49	4.43
60%	2.43	3.27	4.20
80%	2.36	3.10	4.00
100%	2.21	2.87	3.82

The variations in split tensile strength of M25 concrete with respect to replacement percentage and age are shown in the fig 3.2

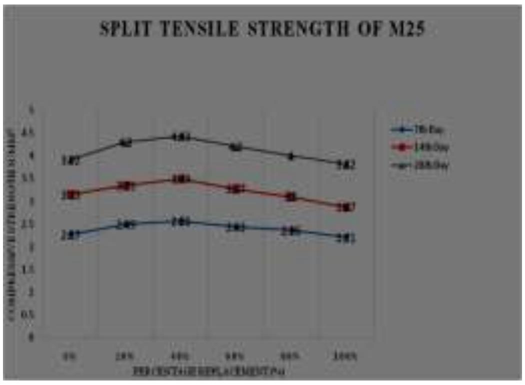

Fig 3.2 Tensile Strength

3.9 Sem Analysis

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. Silica sand is magnified to different ranges to study its structure and size. The SEM image of silica sand at 10µm is shown in the Fig.3.3.

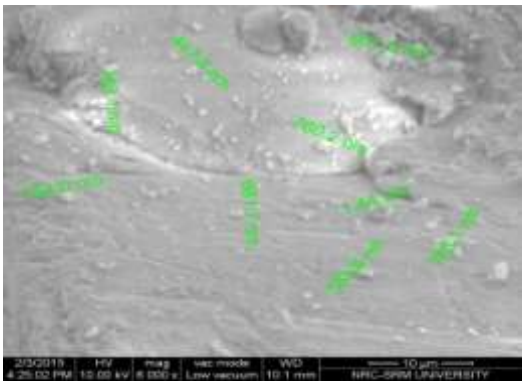

Fig 3.3 Silica sand at 10µm

4. CONCLUSION

a) The nearer to optimum replacement percentage arrived in case of compressive strength was 60% and in case of split tensile strength it was 40% at 28 days.
b) It was found that the compressive strength increases by 32% on 60% replacement and tensile strength increases by 13% on 40% replacement at 28 days.
c) SEM analysis was also carried out to study the particle size of silica sand by magnifying it to different ranges. As it is found to be crystalline in nature it can be used as a filler material.

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