A Study on Mechanical Properties of Concrete Using Silica Sand as Partial Replacement of Cement

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Abstract

An experimental study is conducted on "SILICA SAND", industrial waste mixed with cement concrete in partial replacement of cement as it contains high percentage of silicon. Silica sand is a by-product of glass manufacturing industries. The concrete of M25 design mix with various percentages of Silica sand such as 0%,5%,10%,15%,20%,25% & 30% replacing cement has been used in the investigation. Experimental study is carried out to investigate the compressive strength, split tensile strength and flexural strength of concrete with replacement of Silica sand. The test program consists of carrying out compressive strength test on cubes, split tensile strength test on cylinders and flexural strength test on beams.

Keywords: *Silica Sand, Compressive Strength, Flexural Strength, Split Tensile Strength*

I. INTRODUCTION

Cement is one of the most produced materials around the world. Due to the importance of cement as a construction material, and the geographic abundance of the main raw material, limestone, cement is produced in virtually all countries. The widespread production is also due to the relatively low price and high density of cement However, the production of Portland cement, an essential constituent of concrete, leads to the release of a significant amount of CO2 and other greenhouse gases (GHGs).

SILICA is the most abundant mineral found in the crust of the earth. It forms an important constituent of practically all rock-forming minerals. It is found in a variety of forms, as quartz crystals, massive forming hills, quartz sand (silica sand), sandstone, quartzite, tripoli, diatomite, flint, opal, chalcedonic forms like agate, onyx etc… Silica sand contain a high proportion of silica (up to 99% SiO2) in the form of quartz and are used for applications other than as construction aggregates. They are produced from both loosely consolidated sand deposits and by crushing weakly cemented sandstones.

SILICA SAND is a by-product of glass industries. Silica sand is available in Chinthalapalli, Pudicherla, Komarolu of Orvakal Mandal, kurnool district. Silica sand of size less than 75 microns can be used in making concrete mix as the partial replacement of cement.

II. DESCRIPTION OF MATERIALS

A. Fine aggregate:

1) Sieve Analysis of Fine Aggregate:

The sand obtained from Hundri river near Kurnool is used as fine aggregate in this project investigation. The sand is free from clayey matter, silt and organic impurities etc. The sieve analysis is conducted to determine the particle size distribution of fine aggregate. The different sieve sizs used for sieve analysis of fine aggregate are 4.75mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm. The analysis results are presented in table below and the sand confirms to zone-II and the fineness modulus is 3.00.

Table 2.1 Sieve Analysis of Fine Aggregate

S.No.	Sieve size	Wt. retained in gms	%age wt retained	Cumulative %age wt. retained(F)	%age passing (100-F)
1	4.75mm	8	0.8	0.8	99.2
2	2.36mm	6	0.6	1.4	98.6
3	1.18mm	182	18.2	19.6	80.4
4	600 µm	268	26.2	46.4	53.6
5	300 µm	391	39.1	85.5	14.5
6	150 µm	117	11.7	97.2	2.8

2. Specific gravity of Fine Aggregate:

Specific gravity of fine aggregate can be find out by Pycnometer bottle is show in the table as below.

Table 2.2 Specific Gravity of Fine Aggregate

S.no.	Description	Value
1	Weight of dry and empty pycnometer (W_1)	425g
2	Weight of pycnometer + coarse aggregate (W_2)	925g
3	Weight of pycnometer + coarse aggregate + water (W_3)	1680g
4	Weight of pycnometer + water (W_4)	1368g
5	Specific gravity $= \frac{w2-w1}{(w2-w1)-(w3-w4)}$	2.65

B. Coarse Aggregate:

1) Sieve Analysis of Coarse Aggregate:

The coarse aggregate is free from clayey matter, silt and organic impurities etc. Fineness modulus of coarse aggregate is 4.07. aggregate of normal size 20mm downgraded 60%retained on 12.5mm sieve and remaining 40% is taken from the sieve 12.5mm (passing) and 4.75mm (retained) is used in the experimental work, which is acceptable according to IS:383-1970.

SiO_2	99.19%
Fe_2O_3	0.01%
CaO	0.0033%
Al_2O_3	0.013%

Table 2.3 Sieve Analysis of Coarse Aggregate

S. No	Sieve size	Weight retained in gms	% weight retained	Cumulative % weight retained	% passing (100-F)
1	20mm	0	0	0	100
2	16mm	2520	25.2	25.2	74.8
3	12.5mm	1840	18.4	43.6	56.4
4	10mm	3093	30.9	74.5	25.5
5	4.75mm	2530	25.3	99.8	0.2

S. no.	Description	Value
1	Weight of dry and empty pycnometer (W_1)	425g
2	Weight of pycnometer + coarse aggregate (W_2)	1425g
3	Weight of pycnometer + coarse aggregate + water (W_3)	2020g
4	Weight of pycnometer + water (W_4)	1375g
5	Specific gravity $= \frac{w2-w1}{(w2-w1)-(w3-w4)}$	2.82

2) Specific Gravity of Coarse Aggregate:

Specific gravity of coarse aggregate can be found out by using pycnometer bottle as shown below

Table 2.4 Specific Gravity of Coarse Aggregate

C. Silica Sand:

Silica is a very fine material composed solely of Silicon and Oxygen, the two most abundant elements in the earth's crust. Silica is hard, chemically inert and has a high melting point, attributable to the strength of the bonds between the atoms. Silica sand is not flammable, combustible or explosive. It is not known to be toxic. It is not known to be an environmental hazard. Silica sand is insoluble in water. Silica sand should be kept dry and out of the element.

1) Physical Properties:

Table 2.5 Physical properties of Silica Sand

Particle shape	Granular crushed and ground
Colour	White or colourless
Odour	None
Specific gravity	2.65

The chemical formula of silica sand is SiO_2. The chemical composition of silica sand is

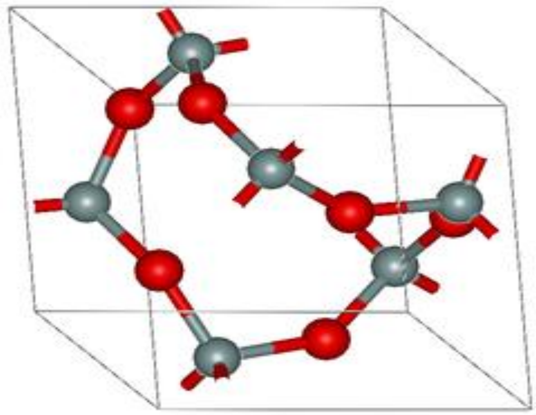


Fig.2.1 Structure of Silica Sand

2) *Chemical Properties:*

Table 2.6 Chemical Properties of Silica Sand

Boiling point	4046°F/2230°C
Melting point	3110°F/1710°C
Vapour pressure (mm Hg)	None
Vapour density (air=1)	None
Evaporation rate	None

D. Cement:

Ordinary Portland cement 53-grade of DECCAN brand confirming to B.I.S standards is used in the present work. The cement is tested for its various properties as per IS: 4031-1988 and found to be confirming to the requirements as per IS: 12269-1987.

Table 2.7 Physical Properties of Cement

Finenessof cement	5%
Specific gravity of cement	3.12
Soundness of cement	1.1mm
Standard consistency of cement	32.5%
Compressive strength of cement for 28 days	49N/mm^2

E. Water:

The locally available potable water, which is free from concentration of acid and organic substances, is used for mixing the concrete.

S.No	Parameter	Results	Permissible limit as per IS 456-2000
1	Organic	46mg/lit	200mg/lit
2	In organic	386mg/lit	3000mg/lit
3	Sulphates	40.32mg/lit	400mg/lit
4	Chloride	51.77mg/lit	2000mg/lit For R.C.C 500mg/lit
5	Suspended matter	183mg/lit	2000mg/lit
6	P^H	8.6	Not less than 6

Table 2.8 – Chemical Analysis of Water

***NOTE**: -All the above parameters are within permissible limits, as mentioned in IS456 – 2000.*

3.RESULTS AND DISCUSSION

The mix proportion for M25 mix with W/C ratio 0.45, 0% of silica sand as Reference Mix, M25 with 5%of silica sand as Mix-1, M25 with 10%of silica sand as Mix-2, M25 with 15% of silica sand as Mix-3, M25 with 20% of silica sand as Mix-4, M25 with 25% of silica sand as Mix-5. The cubes, beams and cylinders were tested for compressive strength ,split tensile strength and flexural strength. These tested were carried out at age of 7 days and 28 days.

Table 3.1 Weights of Materials for All Mixes

Mix design	Reference mix	Mix -1	Mix -2	Mix -3	Mix - 4	Mix -5
% addition & replacement of silica sand	0	5	10	15	20	25
Weight of silica sand (kg)	0	0.56	1.12	1.68	2.24	2.80
W/C ratio	0.45	0.45	0.45	0.45	0.45	0.45
Cement content (kg)	11.2	10.64	10.08	9.52	8.96	8.4
Fine aggregate (kg)	13.3	13.3	13.3	13.3	13.3	13.3
Coarse aggregate (kg)	23.5	23.5	23.5	23.5	23.5	23.5
Water (lit)	5.2	5.2	5.2	5.2	5.2	5.2
Compressive strength 28 days (N\mm2)	33	33.7	36	41.3	37	34.6

A. *Compressive Strength Test:*

Cubes of size 150 X 150 X 150 mm are used in the present work. The cubes are cured for 28 days. After 28 days of curing, the cubes are tested in a Compression Testing Machine (CTM).

Fig.3.1 Cube Under Loading Under CTM

Fig.3.2 Cube After Crushing

Table 3.2 Percentage Increase in Compressive Strength

S.NO	Percentage replacement	Compressive strength (28 days	% Increase
1	0%	33	-
2	5%	33.7	2
3	10%	36	8.3
4	15%	41.3	25
5	20%	37	12
6	25%	34.6	4.8

Figure 3.1 Graph Showing the Compressive Strength in N/mm^2

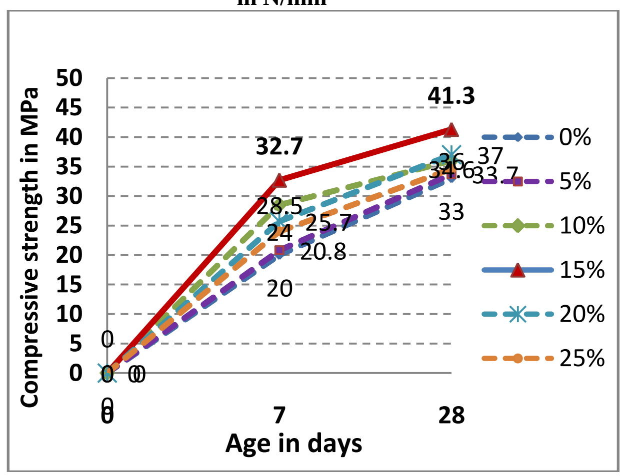
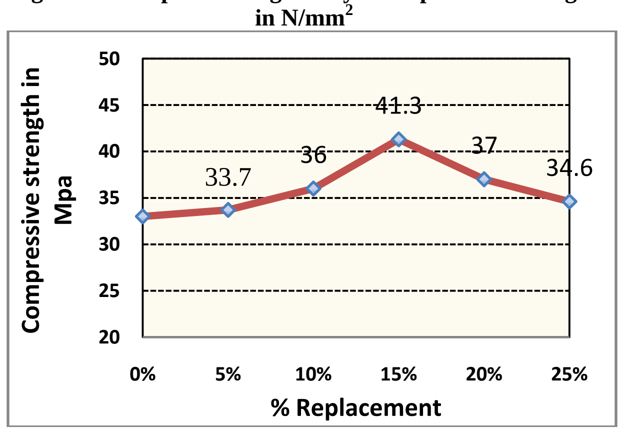


Figure 3.2 Graph Showing 28 days Compressive Strength in N/mm^2



B. *Flexural Strength Test:*

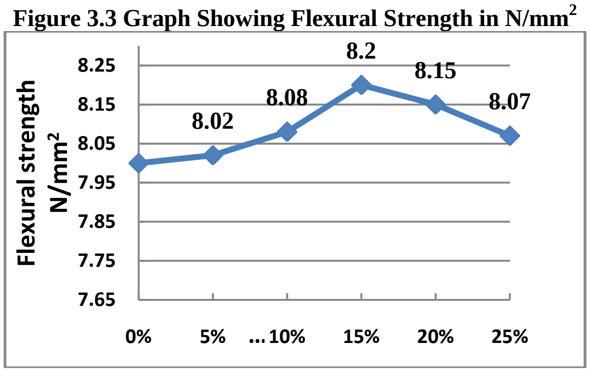
Beams are the bending test specimens used to determine the flexural strength. Beams of size 500 X

100 X 100 mm are used in the present work. After 28 days of curing, the beams are tested in a Universal Testing Machine (UTM).

Table 3.3 Percentage Increase in Flexural Strength

S.NO	Percentage Replacement	Flexural strength (28 days) in N/mm^2
1	0%	8.04
2	5%	8.02
3	10%	8.08
4	15%	8.2
5	20%	8.15
6	25%	8.07

Figure 3.3 Graph Showing Flexural Strength in N/mm^2



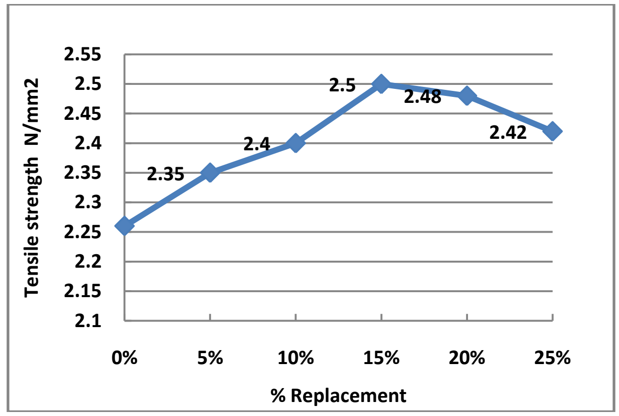
C. Split Tensile Strength:

Cylinders are the test specimens used to determine the tensile strength. Cylinders of size 150 mm diameter and length 300 mm are used in the present work. After 28 days of curing, the cylinders are tested in a Compression Testing Machine (CTM).

Table 3.4 Percentage Increase in Tensile Strength

S.NO	Percentage Replacement	Tensile strength (28 days) in N/mm^2
1	0%	2.26
2	5%	2.35
3	10%	2.4
4	15%	2.5
5	20%	2.48
6	25%	2.42

Figure 3.4 Graph showing the Split Tensile strength in N/mm^2



This increase in strength is attributed due to the formation of Tricalciumsilicahydrate(C_3SH) due to reaction between the silica in silica sand and calcium hydroxide $Ca(OH)_2$ present in the cement. This is a double reaction as C-S-H is already formed in hydration of cement which is a characteristic of pozzalonic materials. This the main cause for the increase in compressive strength. The flexural and tensile strength is not affected even at reduced cement content in the mix at different percentages of replacement indicating the significant strength characteristic of silica sand.

CONCLUSION

Based on the limited experimental investigations conducted following are the conclusions derived.

- The compressive strength of 0% replacement compared with 5%,10%, 15%, 20% and 25% replacement the strength increases up to 15% replacement corresponding to a peak value of 41.3N/mm^2 and decreases with further percent increase in replacement.
- The flexural strength increases up to 15% to a value of 8.2N/mm^2 and decreases to 8.15N/mm^2 at 20% , 8.07N/mm^2 at 25% replacements.
- The tensile strength though insignificant increases up to 15% replacement with corresponding value of 2.5N/mm^2 and decreases to 2.48N/mm^2 , 2.42N/mm^2 at 20% and 25% replacement.
- Silica sand passing through 150µm sieve acts as a filler material between cement and fine aggregate there by making concrete more dense.
- The 15% replacement of cement with silica sand is considered as optimum for durable concrete.
- The concept of green concrete by using supplementary cementitious materials like

silica sand minimizes the environmental impact of concrete.

- ❖ The utilization of these waste by-products as partial replacement of cement , it would be more beneficial to the environment by reducing the environmental pollution.

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