EFFECT OF REPLACEMENT OF SAND BY BOTTOM ASH AND CEMENT REPLACEMENT BY SILICA FUME ON THE CHARACTERISTIC PROPERTIES OF CONCRETE

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Abstract - *This paper presents an experimental investigation on the effect of replacement of sand by bottom ash and cement replacement by silica fume on the characteristic properties of concrete. The bottom ash is added in replacement of sand by 0%, 20%, 40%, 60%, 80% and 100%. The silica fume is added in partial replacement of cement by 20% by weight of cement. The experiment was conducted on M30 grade concrete. The strength properties studied in this work are compressive strength, tensile strength, shear strength, flexural strength and impact strength. Also, the workability characteristics are studied through slump cone test, compaction factor test, Vee-Bee consistometer test. Along with these, near surface characteristics like water absorption and sorptivity are also studied.*

Key Words: **Bottom ash; silica fume; workability; sorptivity; strength.**

1. INTRODUCTION

Concrete is a composite material consisting of cement, fine aggregate, coarse aggregate and water, and is widely used in construction of normal and high rise structures. Fine aggregate plays an important role in dense packing of concrete mix and reducing the voids in the concrete and also beneficially alters the mechanical properties of concrete in fresh and hardened stage. Hence fine aggregate is an important constituent in the concrete mix. Normally natural river sand is used as fine aggregate in concrete mix. As the construction activities have increased now a days, consumption of natural sand is becoming very high. Hence demand for natural sand is increasing day by day. To meet rapid growth of infrastructure, continuous extraction of natural sand from river beds is in practice. This is causing serious damage to natural resources such as disturbing the aquatic life, loosening of impervious strata, deepening of river beds, as well as agriculture due to lowering of ground water table. And also as the availability of natural sand is scare, it is becoming a costly material. So, to avoid all these problems related to environment and to protect it, it is essential to find some other suitable material that shall be put in concrete mix as a replacement material for natural sand. Thus some of the industrial wastes are being effectively used as a replacement material for natural river sand in the production of concrete mix such as copper slag, bottom ash, glass powder, foundry sand, spent fire bricks, GGBS, quarry dust, construction and demolition wastes etc.

Cement is one of the important binding material used in concrete to bind the concrete ingredients together. The production of Ordinary Portland cement is not only costly and energy intensive but also results in emission of considerable amount of carbon content to the environment. It is approximated that one ton of CO_2 gets emitted during the production of one ton of Portland cement. This emitted CO_2 harms the atmosphere and causes serious damages. The problem of CO_2 emission can be minimized by two ways. One is using suitable alternate binding material instead of cement in concrete. This is completely not possible now a days due to unavailability of such binding material and the second way is to reduce the usage of cement in concrete to some percentages i.e. by partially replacing the cement with suitable pozollanic materials. Compared to first, the second way is easiest and can be practiced by construction industries. A supplementary cementing material (SCMs) contributes to the enhancing of mechanical properties of concrete by pozzolanic activity. Some of SCMs like fly ash, rice husk ash, limestone fine, metakaoline, silica fume etc can be used in concrete along with Portland cement. Incorporating substitute materials in concrete results in making concrete most economical, increased strength, less permeable concrete etc.

2. EXPERIMENTAL PROGRAM

2.1 Materials used

2.1.1 Cement

The type of cement used in the experimentation is OPC-43. The properties of cement are ascertained as per the IS 8112–1989 and the table 1 gives the physical property of cement.

Table 1: Physical properties of cement

Properties	Result	Permissible limits as per IS: 8112:1989
Fineness	4%	It should not be more

		than 10%
Normal consistency	32%	<34%
Specific gravity	3.15	
Setting time a) Initial b) Final	43 min 360 min	Should not be less than 30 minutes Should not exceed 600minutes

2.1.2 Fine aggregates:

Natural river sand confirming to IS: 383-1970,of zone-II is used. Fineness modulus and specific gravity of natural sand is calculated as per the procedure confirming to IS: 2386. Table 2 gives the properties of fine aggregates.

Table 2: Physical properties of fine aggregates:

Property	**Results**
Particle shape and size	Round 4.75mm down
Fineness modulus	2.80
Specific gravity	2.60
a) Bulk density in loose state b) Bulk density in hardened state	1486 kg/m³ 1692 kg/m³

2.1.3 Coarse aggregate

Locally available crushed aggregates confirming to IS: 383-1970 is used in this experimental work and have size 20mm and down. Table 3 gives the properties of coarse aggregates.

Table 3: Physical properties of coarse aggregate

Property	**Result**
Particle shape and size	Angular 20mm and down
Fineness modulus	6.80
Specific gravity	2.70

2.1.4 Bottom ash

Bottom ash is obtained from NTPC Limited, Kudgi, Vijayapur, Karnataka, India and the same is used in this experimental study. Table 4 gives the properties of Bottom ash.

Table 4: Physical properties of bottom ash

Colour	Grey to black
Specific gravity	2.35
Fineness modulus	2.40

2.1.5 Silica fume

Silica fume is obtained from Shri Sai Durga Enterprises, Bangalore, Karnataka, India and the same is used in this investigation. Table 5 gives the properties of Silica fume.

Table 5: Physical properties of silica fume

Specific gravity	2.30
Mean grain size	0.15 micron
Specific surface	15000 to 30000 m^2/kg
Colour	Light to dark gray

2.2 Mix proportion

The experimental investigation is based on a reference concrete mix of grade M30 using bottom ash and silica fume. The mix proportion of reference mix is 1:1.33:2.26 with a w/c ratio of 0.45.

2.3 Preparation of specimens

Following procedure is adopted for casting the specimens.

- Compute the quantity of each material required for the concrete mix.
- Weigh the quantity of cement, sand, aggregate, water by replacing sand and cement by bottom ash and silica fume.
- Dry mix all the materials thoroughly for a uniform mixture.
- An estimated quantity of water is added and mix carefully to produce an uniform concrete mix.
- Moulds are greased for easy demoulding.
- Concrete mix is filled in moulds in three layers and well compacted and surface leveled.
- Compaction is achieved by hand compaction as well as by machine compaction.
- Excess vibration should be avoided for segregation.

- After completing 24 hrs of casting specimens are demoulded and kept to a curing for a period of 28 days.
- Finally, strength tests are conducted on specimens after drying in sunlight for 24 hrs.

2.4 Testing of concrete

Concrete cubes of size 150x150x150 mm were tested for compressive strength as per IS 516:1959. To get the tensile strength, cylindrical specimens of size 150mm diameter and 300mm length were tested as per IS 5816:1999. For flexural strength, beam specimens of size 100x100x500mm were tested. Two-point loading was adopted on an effective span of 400mm to get pure bending, as per IS 516:1959. Shear strength specimens were of L shape with 150x90x60mm. Impact strength specimens were of 150mm diameter and 60mm height. Water absorption and sorptivity test were performed on cube specimens.

2.5 Results and discussions

2.5.1 Workability results

Table 6 gives the workability test results as measured from slump test, compaction factor test and Vee-Bee test carried out on concrete mix.

The observation made from the experimentation clearly indicates that, the workability as measured from slump, compaction factor and Vee-Bee is higher for concrete mix at 0% replacement of natural sand with bottom ash and the least value of is observed at 100% replacement level.

Table 6: Workability test results

% replacement of natural sand by bottom ash	Workability test results		
	Slump values (mm)	Compaction factor	Vee-bee degree (seconds)
0%	5	0.9	25
20%	4	0.88	28
40%.	3	0.86	35
60%	2	0.85	45
80%	2	0.85	48
100%	1	0.82	52

2.5.2 Near surface characteristics test results

Table 7 gives the near surface characteristics test results as measured from water absorption and sorptivity tests. Figure 1 and 2 gives the variation of water absorption and soroptivity of concrete respectively.

The observation made from the experimentation clearly indicates that the water absorption and soroptivity of concrete is maximum at 0% replacement level of natural sand with bottom ash. Increase in bottom ash content results in decrease of water absorption and soroptivity values.

Table 7 Near surface characteristics test results.

% replacement of natural sand by bottom ash	Percentage water absorption	Soroptivity (mm/min$^{0.5}$)
0	0.8	4.1
20	0.75	3.9
40	0.7	3.5
60	0.6	3
80	0.45	2.8
100	0.4	2.7

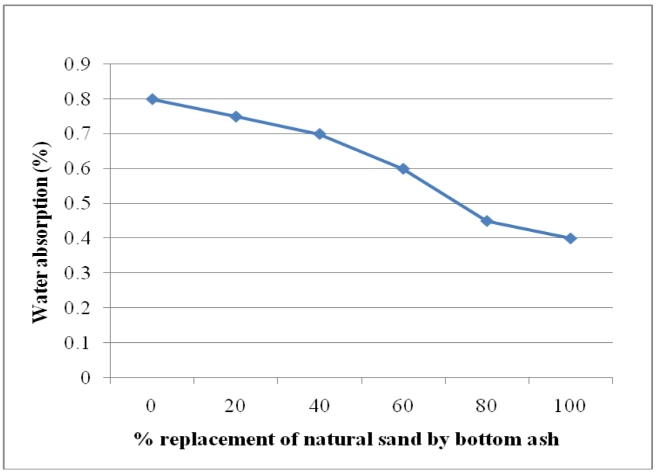

Fig 1 : Variation of water absorption

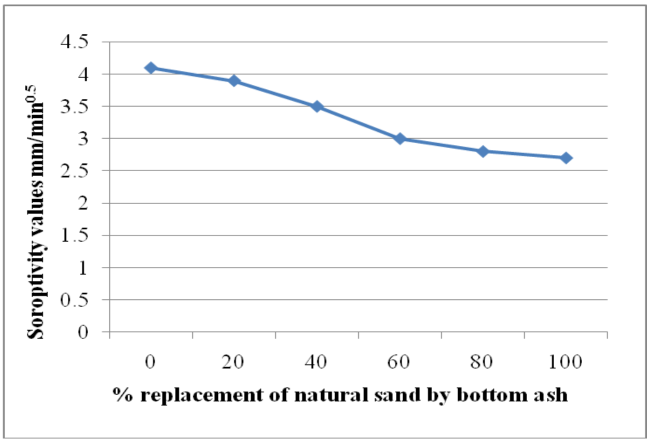

Fig 2 : Variation of soroptivity test

2.5.3 Strength test results

2.5.3.1 Compressive strength test results

Table 8 gives the compressive strength test results for concrete produced from natural sand replaced by bottom ash and partial cement replaced by silica fume. Table also gives the percentage increase or decrease of compressive strength w.r.t. reference mix. Figure 3 gives the variation of compressive strength of concrete.

From the experimental results it has been noticed that the compressive strength of concrete is higher when 40% of natural sand is replaced by bottom ash. Beyond 40% replacement, the compressive strength starts decreasing. Compressive strength of 36.30MPa is found for 40% replacement of natural sand by bottom ash. The percentage increase in compressive strength at 40% replacement level is found to be 20.72%.

This may be due to the fact that at 40% replacement level of natural sand by bottom ash, most of the pores of concrete may be filled thereby resulting in denser concrete.

Table 8: Results of compressive strength

% replacement of natural sand by bottom ash	Compressive strength of concrete (MPa)	Percentage increase or decrease of compressive strength w.r.t. reference mix.
0 (Reference mix)	30.07	0
20	33.03	+9.84
40	36.30	+20.72
60	34.67	+15.30
80	31.56	+4.96
100	30.37	+1

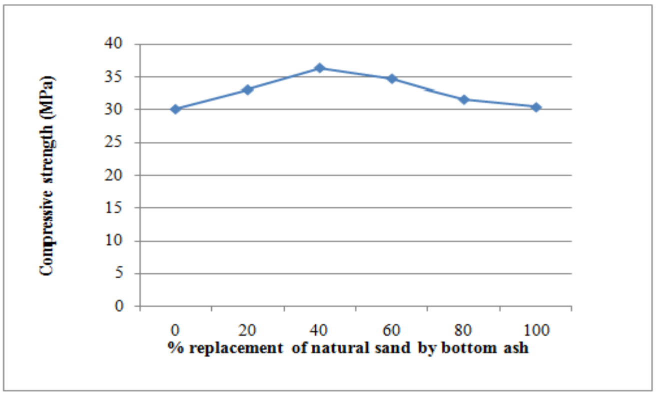

Fig 3: Variation of compressive strength

2.5.3.2 Tensile strength results

Table 9 gives the split tensile strength test results for concrete produced from natural sand replaced by bottom ash and partial cement replaced by silica fume. Table also gives the percentage increase or decrease of tensile strength w.r.t. reference mix. Figure 4 gives the variation of compressive strength of concrete.

From the experimental results it has been noticed that the split tensile strength of concrete is higher when 40% of natural sand is replaced by bottom ash. Beyond 40% replacement the tensile strength starts decreasing. Split tensile strength of 2.45MPa is found for 40% replacement of natural sand by bottom ash. The percentage increase in the split tensile strength at 40% replacement level is found to be 10.86%.

This may be due to the fact that at 40% replacement level of natural sand by bottom ash, most of the pores of concrete may be filled thereby resulting in denser concrete.

Table 9: Results of split tensile strength

% replacement of natural sand by bottom ash	Split tensile strength of concrete (MPa)	Percentage increase or decrease of tensile strength w.r.t. reference mix.
0	2.21	0
20	2.26	+2.26
40	2.45	+10.86
60	2.31	+4.52
80	2.03	-8.14
100	1.61	-27.15

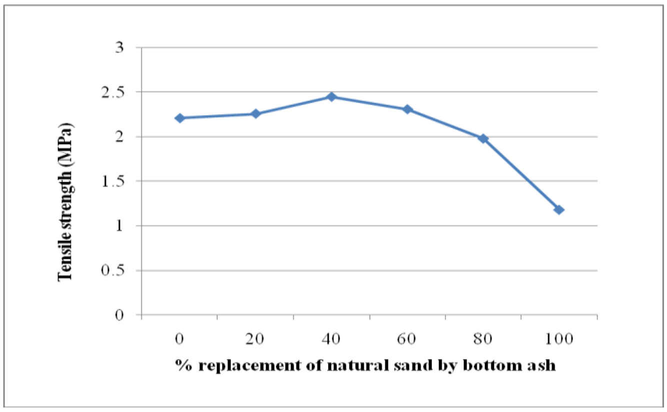

Fig 4: Variation of split tensile strength test

2.5.3.3 Flexural strength results

Table 10 gives the flexural strength test results for concrete produced from natural sand replaced by bottom ash and partial cement replaced by silica fume. Table also gives the percentage increase or decrease of tensile strength w.r.t. reference mix. Figure 5 gives the variation of compressive strength of concrete.

From the experimental results it has been noticed that the flexural strength of concrete is higher when 40% of natural sand is replaced by bottom ash. Beyond 40% replacement, the flexural strength starts decreasing. Flexural strength of 4.87MPa is found for 40% replacement of natural sand by bottom ash. The percentage increase in the flexural strength at 40% replacement level is found to be 25.84%.

This may be due to the fact that at 40% replacement level of natural sand by bottom ash, most of the pores of concrete may be filled thereby resulting in denser concrete.

Table 10: Results of flexural strength

% replacement of natural sand by bottom ash	Flexural strength of concrete (MPa)	Percentage increase or decrease of flexural strength w.r.t. reference mix.
0 (Reference mix)	3.87	0
20	4.07	+5.17
40	4.87	+25.84
60	4.13	+6.72
80	3.93	+1.55
100	3.80	-1.81

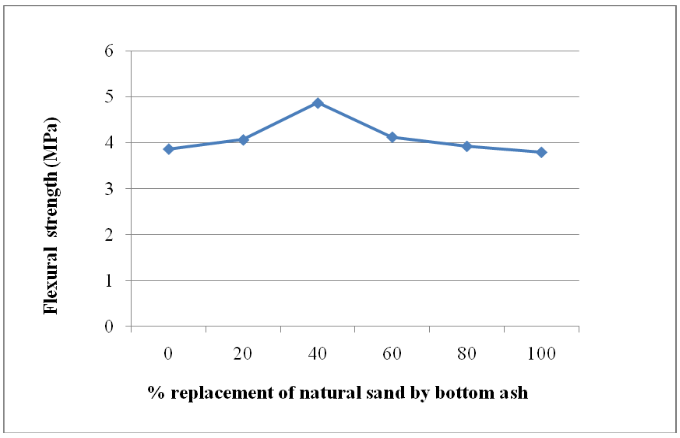

Fig 5: Variation of flexural strength

2.5.3.4 Shear strength results

Table 11 gives the shear strength test results for concrete produced from natural sand replaced by bottom ash and partial cement replaced by silica fume. Table also gives the percentage increase or decrease of tensile strength w.r.t. reference mix. Figure 6 gives the variation of compressive strength of concrete.

From the experimental results it has been noticed that the shear strength of concrete is higher when 40% of natural sand is replaced by bottom ash. Beyond 40% replacement, the shear strength starts decreasing. Shear strength of 5.56MPa is found for 40% replacement of natural sand by bottom ash. The percentage increase in shear strength at 40% replacement level is found to be 20.09%.

This may be due to the fact that at 40% replacement level of natural sand by bottom ash, most of the pores of concrete may be filled thereby resulting in denser concrete.

Table 11: Results of shear strength

% replacement of Natural sand by bottom ash	Shear strength of concrete (MPa)	Percentage increase or decrease of shear strength w.r.t. reference mix.
0 (Reference mix)	4.63	0.00
20	4.81	+3.89
40	5.56	+20.09
60	5.00	+7.99
80	4.81	+3.89
100	4.44	-4.10

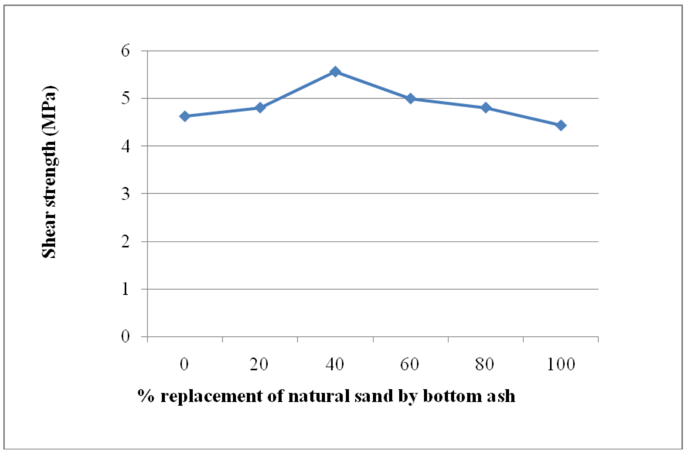

Fig 6: Variation of shear strength

2.5.3.5 Impact strength results

Table 12 gives the impact strength test results for concrete produced from natural sand replaced by bottom ash and partial cement replaced by silica fume. Table also gives the percentage increase or decrease of tensile strength w.r.t. reference mix. Figure 7 gives the variation of compressive strength of concrete.

From the experimental results it has been noticed that the impact strength of concrete is higher when 40% of natural sand is replaced by bottom ash. Beyond 40% replacement, the impact strength starts decreasing. Impact strength of 5249.20N-m is found for 40% replacement of natural sand by bottom ash. The percentage increase in shear strength at 40% replacement level is found to be 78.59%.

This may be due to the fact that at 40% replacement level of natural sand by bottom ash, most of the pores of concrete may be filled thereby resulting in denser concrete.

Table 12: Results of impact strength

% replacement of natural sand by bottom ash	Impact strength of concrete (N-m)	Percentage increase or decrease of impact strength w.r.t. reference mix.
0 (Reference mix)	2939.27	0
20	3596.29	+22.35
40	5249.20	+78.59
60	4225.64	+43.76
80	3610.12	+22.82
100	2558.90	-12.94

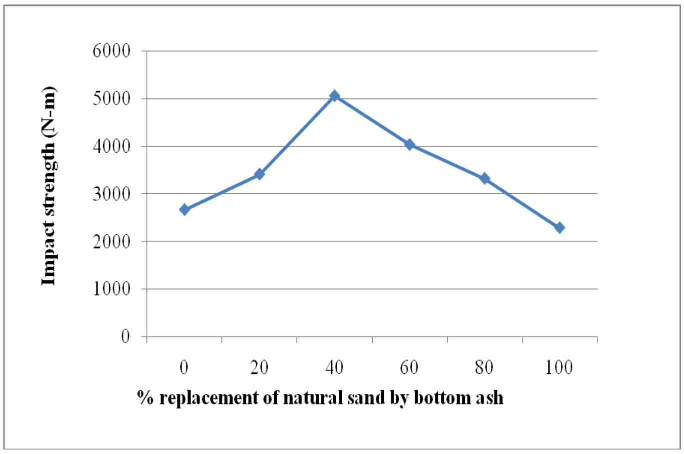

Fig 7: Variation of impact strength

3. CONCLUSIONS

Following conclusions are obtained based on the observation made.

- The workability of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is higher when 0% natural sand is replaced by bottom ash.
- The water absorption and soroptivity values of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is minimum when 100% natural sand is replaced by bottom ash.
- The compressive strength of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is higher when 40% natural sand is replaced by bottom ash and its value is 36.30MPa.
- The split tensile strength of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is higher when 40% natural sand is replaced by bottom ash and its value is 2.45MPa.
- The flexural strength of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is higher when 40% natural sand is replaced by bottom ash and its value is 4.87MPa.
- The shear strength of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is higher when 40% natural sand is replaced by bottom ash and its value is 5.56MPa.
- The impact strength of concrete produced with replacement of natural sand by bottom ash and partial cement replaced by silica fume is higher when 40% natural sand replaced by bottom ash and its value is 5249.20N-m.

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