Performance Study On Ggbs Concrete With Robosand

Ramakrishna Samanthula, Mahendra Reddy Polimreddy

Abstract: Concrete is the most famous and extensively used building material, owes to its advantageous properties, production and maintenance over steel and timber. Concrete is a matrix consists of basic ingredients namely binding material, fine aggregate, coarse aggregates and water. Conventional binding material cement has now become expensive and its production involves undesirable environmental consequences such as heavy production of Carbon dioxide (CO_2). Conventional fine Aggregate River sand has become scarce and its excessive use causes degradation of river bed and reduction in ground water recharge. To offset with these two challenges, an attempt has been made to produce concrete with supplementary and alternative materials. Ground granulated blast furnace slag which is byproduct of steel production, has been used to partially replace the cement. Robosand is manufacturing sand produced from granite stone, has been used as an alternative fine aggregate that completely replaces the river sand which is far superior than river sand in all aspects. Various combination have been made with different proportions of Cement, Ground Granulated Blast Furnace Slag, Robosand, Coarse aggregate and Water. Properties of concrete have been studied in fresh and hardened state for all combinations made and deducted the conclusions.

Index Terms: Robosand, GGBS, Slag, Supplementary Cementitious material, Alternative fine aggregate, Crushed sand, Rock sand

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1 Introduction

Ingredients of concrete now became scarce and expensive. Production and excessive use of some conventional ingredients of concrete causes undesirable environmental consequences. Natural River sand is one of the constituents used in the production of concrete has become expensive and scarce. Hence there is a large demand for alternative building materials that replace the river sand without scarifying desired properties of concrete in fresh and hardened states. The crusher dust produced from granite crushers is one of such alternative building materials that replaces the river sand and named as ROBO SAND. It is popularly known by several names such as Crushed sand, Rock sand, Green sand, Robosand, Poabs sand, Barmac sand, and Pozzolona sand. This Robosand is far superior than conventional river and its unit price is little less or near to river sand. Conventional binding material in concrete is cement which has now become expensive and its production is not an eco-friendly activity. Hence there is great demand for alternative and supplementary cementitious materials. Ground Granulated Blast Furnace Slag (GGBS) is byproduct from iron manufacturing process.

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It is supplementary cementitious material which partially replaces the cement in concrete. GGBS unit price is almost half of the price of cement. Its replacement has considerable advantages in properties of concrete in fresh and hardened state. A study is required to assess the effects of combination of GGBS and Robosand in fresh and hardened state of concrete.

2 MATERIALS

Mix Proportions for M25 Grade Concrete

Nominal mix proportions adopted for M25 Grade concrete were Cement : Fine Aggregate : Coarse Aggregate - 1:1:2. Water to Cement Ratio was 0.36. (18 liters per 50 kg of cement)

Ingredients of Mix

Cement – OPC 53 Grade
Sand – Zone-II (IS 383)
Coarse Aggregate – Angular, 12.5-20 mm (IS 10262-2009)
Water – Potable
Robosand – Zone II (As per IS 383)

Cement Properties

Grade of Cement - OPC 53
Fineness - 2 % (Dry Sieving Method)
Specific Gravity - 3.23
Consistency - 31 %
Initial Setting Time - 110 minutes
Final Setting Time - 210 minutes
Soundness - 3 mm (Chatelier's Apparatus)

River Sand Properties

Zone – II
Fineness modulus - 3.009
Specific Gravity – 2.52

Robosand Properties

Zone – II
Fineness Modulus – 2.44
Specific Gravity – 2.68

Table1: GGBS Properties

Description	Test Results	Requirement as per BS:6699-1992
Magnesium Oxide (% bymass)	7.96	14 (max)
Sulphur Content (% by mass)	0.34	2 (max)
Sulphide Sulphur (% by mass)	0.44	2 (max)
Loss on Ignition (% by mass)	NIL	3 (max)
Insoluble Residue (% by mass)	0.32	1.5 (max)
Chloride (% by mass)	0.016	0.1 (max)
Moisture content (% by mass)	0.32	1 (max)
Manganese Conent (%by mass)	0.11	2 (max)
Glass content (% by Optical Microscopy)	94	67 (min)
Chemical Modulli a) CaO + MgO + SiO_2 b) (CaO + MgO)/SiO_2 c) CaO/ SiO_2	 80.06 1.24 1.02	 66.66% (min) >1 <1.4
Fineness (m^2/kg)	335	275 min
Setting time by Vicat method	210	>IST OF OPC
Soundness(Le-Chatlier Expansion(mm))	Nill	10 max

Coarse Aggregate Properties
Size - 12.5 – 20 mm
Flakiness Index – 13.2 %
Elongation Index – 12.5 %
Specific Gravity – 2.65
Impact Value – 21.47 %
Water Absorption - 0.43 %

For this study, five different combinations of mix were prepared in five phases. Each combination was tested and studied individually. The different combinations in five phases were shown below.

Various Combinations of mixes
Phase 1: River Sand + Coarse Aggregate + Cement + Water
Phase 2: Robosand + Coarse Aggregate + Cement + Water
Phase 3: Robosand + Coarse Aggregate + 75% Cement + 25% GGBS + Water
Phase 4: Robosand + Coarse Aggregate + 50% Cement + 50% GGBS + Water
Phase 5: Robosand + Coarse Aggregate + 30% Cement + 70% GGBS +Water
Note: Water to cement ratio (0.36) was constant for all combinations.

3 EXPERIMENTS

Slump Test
Slump cone test has been adopted to measure the workability of concrete. The slump cone was placed on a horizontal and non-absorbent surface and filled in 3 equal layers of fresh concrete, each layer being tamped 25 times with standard tamping rod. The top layer was struck off level and the mould is lifted vertically without disturbing the concrete cone. The subsidence of concrete in millimeters was measured as the slump.

Compression Test
Cubes of dimensions 150 x 150 x 150 mm were casted and cured for various curing periods. Compression testing machine of capacity 2000KN has been to test the cubes and to measure the compressive strength of concrete. Rate of loading was 14MPa per minute. Peak load divided by cross sectional area of cube was estimated as compressive stress. The average compressive stress of 3 cubes was recorded as compressive strength of concrete.

Split Tensile Strength Test
Cylinders of 150 mm diameter and 300 mm length were casted and cured for various curing periods. Universal Testing Machine of capacity of 1000KN has been use for this test. Rate loading was 1.5 MPa per minute. The below formula was to calculate the split tensile strength of concrete. From theory of elasticity the following formula for the evaluation of the splitting tensile strength f_{ct} is obtained.

$$F_{ct} = \frac{2p}{\pi d L}$$

P = Peak load
D = Diameter of cylinder
L = Length of the cylinder

Average value of three test specimens was recorded as split tensile strength of concrete

Flexural Strength Test
Beams of dimensions 100 x 100 x 500 mm were casted and cured for various curing periods. Central Point Loading method has been adopted for this test. Test has been performed in the Universal Testing Machine of capacity 1000KN. Rate of loading was 180kg per minute. Peak load was determined and flexural stress of each specimen was calculated. Average of value of 3 specimens was recorded as flexural strength of concrete.

4 RESULTS

Table 2: Workability

Mix	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Slump (mm)	85	15	0	0	0

Table 3: Compressive Strength

Age	Phase 1 (MPa)	Phase 2 (MPa)	Phase 3 (MPa)	Phase 4 (MPa)	Phase 5 (MPa)
3 Days	41.75	41.73	38.55	26.10	24.59
7 Days	47.74	49.74	47.50	42.53	34.06
28 Days	48.39	59.00	56.79	59.68	46.62

Table 4: Split Tensile Strength

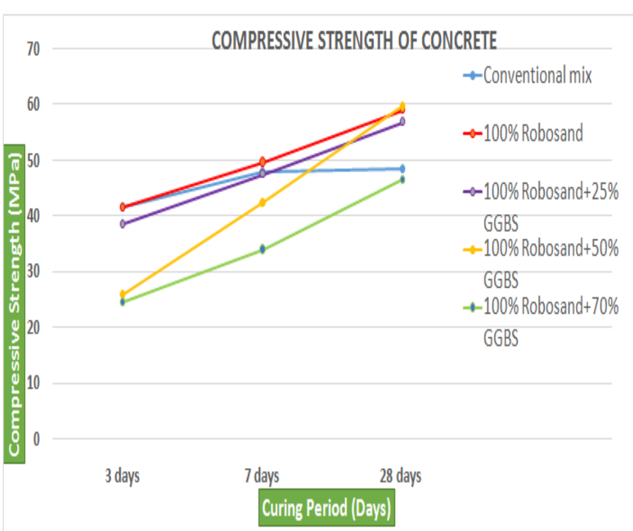
Age	Phase 1 (MPa)	Phase 2 (MPa)	Phase 3 (MPa)	Phase 4 (MPa)	Phase 5 (MPa)
7 Days	2.37	3.11	2.85	2.49	2.18
28 Days	2.80	3.96	3.56	3.48	3.02

Table 5: Flexural Strength

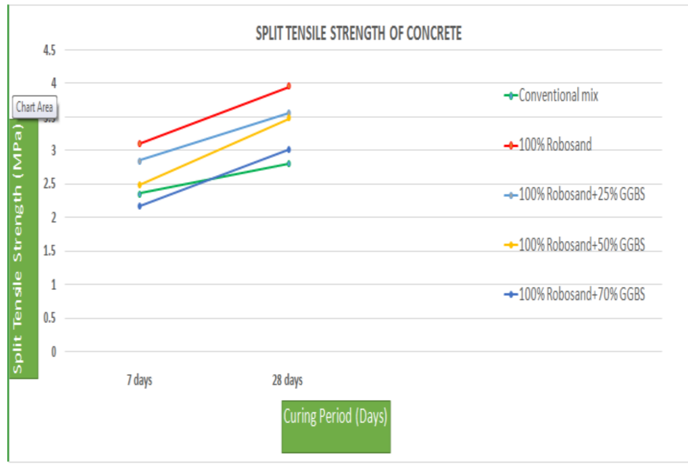
Age	Phase 1 (MPa)	Phase 2 (MPa)	Phase 3 (MPa)	Phase 4 (MPa)	Phase 5 (MPa)
7 Days	12.00	13.21	13.80	14.00	14.65
28 Days	14.43	17.49	17.31	15.95	18.08

Graphical Representation of the Results Obtained

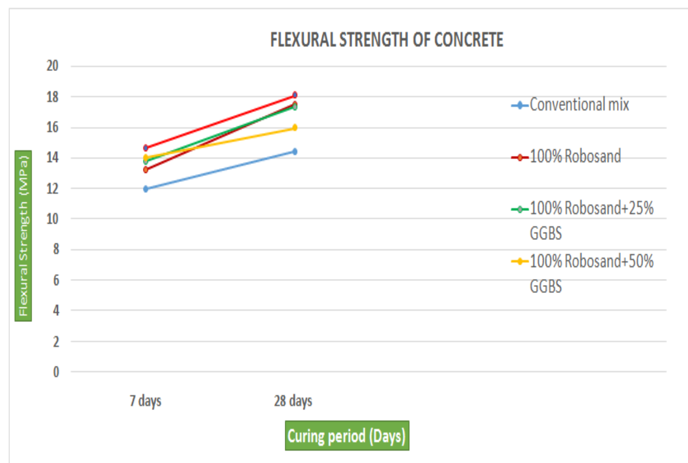
Graph 1: Compressive Strength



Graph 2: Split Tensile Strength



Graph 3: Flexural Strength



5 DISCUSSIONS

Workability

Slump of conventional mix in phase 1 in was found to be 85 mm. Slump was drastically decreased from 85 mm to 15 mm for mix of phase 2 in which Robosand completely replaced the Riversand.

Analyzed reasons for decrease in slump

- Robosand was completely dry that is there was no initial moisture content.
- Fineness modulus of Robosand was 2.445 and River sand was 3.009. It indirectly means that Robosand is comparatively finer than River sand. As fineness increases, the specific surface area increases. As specific surface area increases, water demand required to lubricate the particles at low water to cement ratio.
- Robosand is more angular and has rougher surface texture than naturally weathered sand particles. Aggregate that is more angular will have more water demands compared to river sand.
- Slump of mixes in phase 3, 4 and 5 in which 25%, 50% and 70% of GGBS was used with combination of Robosand was found to be zero. It is generally known

that GGBS particles are less water absorptive than Portland cement particles and thus GGBS concrete is more workable than Portland cement concrete. But in the presence of Robosand and GGBS, the mixes consumed more water, to lubricate the ingredients in the mixture during mixing process. It is only because of low water to cement ratio and more water demand of Robosand at low water to cement ratio. It is not to be worried because it occurs only at low water cement ratio such as 0.36. It was referred from the literature review that workability of concrete is much higher when Robosand is used in place of River sand.

Compressive Strength

Compressive strength values of mix with 100% Robosand were comparatively higher than conventional mix with River sand. It was analyzed that compressive strength of concrete mix with 100% Robosand at 28 days was 17.98% more that of 100% River sand.

Reasons for increase in compressive strength of mix with 100% Robosand

- Cubical shape of Robosand particle ensured high compressive strength. As the voids are filled properly, desired strength of concrete is achieved accurately.
- Robosand has proper gradation of coarse and fine aggregates so, voids are filled completely.
- Robosand doesn't contain impurities like silt, clay, marine products and etc. This sand doesn't contain any organic matter. Hence no scope for reduction in strength.
- Robosand is made from only one type of stone, so the binding strength properties are good and uniform.
- Initial compressive strength of concrete mix with combination of Robosand and GGBS was found to be relatively compared to mixes without GGBS. It is due to low rate of hydration in presence of GGBS, hence, slow rate of gaining strength.

At 28 days of curing, compressive strength of concrete mix with combination of Robosand and GGBS (25% & 50%) was found to relatively higher than that of conventional mix. But combination of Robosand and 70% GGBS resulted in little lower compressive strength than that of conventional mix.

Split Tensile Strength

Split tensile strength of cylinder at 7 days for mix with 100% Robosand was 23.79% higher than that in conventional mix. Decreased percentage of split tensile strength of 25% GGBS mix, 50% GGBS mix and 70 % mix were 9.12%, 24.89%, and 42.66% respectively, when compared with 100% Robosand mix. But compared to conventional mix, split tensile strength in presence of GGBS was increased 16.84% for 25% GGBS, 4.82% for 50% GGBS and decreased 8.72% for 70% GGBS. Split tensile strength of cylinder at 28 days for mix with 100% Robosand was 29.29% higher than that in conventional mix. Decreased percentage of split tensile strength of 25% GGBS mix, 50% GGBS mix and 70 % mix were 11.24%, 13.79%, and 31.12% respectively, when compared with 100% Robosand mix. But compared to conventional mix, split tensile strength in presence of GGBS was increased 21.35% for 25% GGBS, 19.54% for 50% GGBS and 7.28% for 70% GGBS.

Reasons for Increase in Split Tensile Strength

- Superior physical properties of Robosand
- Coarser surface structure of Robosand allowed cement to adhere more and increased tensile strength of concrete.

Flexural Strength

Flexural strength of beam at 7 days for mix with 100% Robosand was 9.15% higher than that in conventional mix. Increased percentage of flexural strength of 25% GGBS mix, 50% GGBS mix and 70 % mix were 4.27%, 5.64%, and 8.82% respectively, when compared with 100% Robosand mix. But compared to conventional mix, flexural strength in presence of GGBS was increased 13.04% for 25% GGBS, 14.28% for 50% GGBS and 18.08% for 70% GGBS. It was clearly noted that, at 7 days, there was gradual increment in flexural strength as slag content increased. Flexural strength of beam at 28 days for conventional mix 100% Robosand was 18.07% higher than that in conventional mix. Increased percentage of flexural strength of 25% GGBS mix, 50% GGBS mix and 70 % mix were 1.03%, 9.65%, and decreased by 3.26% respectively, when compared with 100% Robosand mix. But compared to conventional mix, flexural strength in presence of GGBS was increased 17.21% for 25% GGBS, 10.15% for 50% GGBS and 20.74% for 70% GGBS. It was clearly noted that, at 28 days, there was gradual increment in flexural strength as slag content increased.

6 CONCLUSIONS

In this paper, an attempt has been made to study the effects of Robosand as an alternative fine aggregate, on concrete properties. Combinations of Robosand and GGBS were prepared and effects of these combinations on concrete properties have been studied.

- Robosand was found to be best alternative fine aggregate to River sand which satisfied all technical specification specified in the Indian Standard Codes and it contained no impurities.
- 100% replacement of River sand with Robosand has proved superior properties of concrete in fresh and hardened state. Slump was found to be low at low water cement ratios (0.36) when 100% Riversand was replaced by Robosand. With 100% Robosand good slump can be obtained at medium water to cement ratios (0.45-0.55) and high slump can be obtained at high water to cement ratios (0.55-0.65).
- Presence of 100% Robosand improved the compressive strength, split tensile strength and flexural strength of concrete.
- It was noted that when 25%, 50% and 70% slag used in concrete with 100% Robosand, zero slump has been obtained due to low water to cement ratio and high initial water absorption of Robosand. It was studied that, it is not to be worried because at medium and high water cement ratio, slump of concrete increases to a good degree compared to conventional concrete.
- When 25% slag was used in concrete mix with 100% Robosand, initial (at 3, and 7 days) strength of concrete in compression, tension and flexural strength of was to found to low and high at 28 days compared to conventional concrete.

- Strength properties were increased when slag content was increased to 50% but decreased when it was increased to 70%. Hence 50% slag replacement was found to be optimum to use in concrete.

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