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Properties of Concrete with GBS and RCA

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ABSTRACT

The present experimental study considers, to partially/fully replace all three components namely, 30% replacement of ordinary portland cement (OPC) by ground granulated blast furnace slag (GGBS), 100% replacement of natural fine aggregate (NFA) by granulated blast furnace slag (GBS) and 0-20-40-60-80-100% replacement of natural coarse aggregate (NCA) by recycled concrete aggregates (RCA). Here, the influences of GGBS, GBS and RCA on the compressive strength of M30 grade of concrete with the constant water cement ratio of 0.50 at 7, 14 and 28 days along with Split Tensile Strengths at 28 day are presented. The observed results show higher strengths in the replacement of 100% NFA, 30% OPC and 0% RCA as compared to the conventional concrete. On further study observes in reducing the concrete strengths owing to the replacement of NCA by RCA. The optimum replacement of RCA at 28 day, was obtained as 80%.

Keywords: *Natural coarse aggregate, Natural fine aggregate, Granulated blast furnace slag, Ground granulated blast furnace slag, Recycled concrete aggregates, Strength*

INTRODUCTION

Concrete is widely used as construction material in buildings and civil infrastructures. It is not considered as environmental friendly as it consumes around 70% of natural aggregates in its production. Aggregates supplies has also emerged as a problem with the present days. This issue directs the use of alternative materials as the aggregate for the production of concrete such as steel slag, C & D waste, e-waste etc. Recycled concrete aggregate (RCA) and steel slag requires high investment and large land for the disposal of these wastes that affects the human health. Steel slag, the waste by-product of the iron and steel industry produces Ground granulated blast furnace slag (GGBS) and Granulated blast furnace slag (GBS) is used as the alternative to cement and natural fine aggregate (NFA) respectively. RCA, the demolition concrete waste is used as the alternative to natural coarse aggregate (NCA).

GGBS is used as supplementary cementing material to replace a percentage of Ordinary Portland cement. It is used as cement as it contains cementations properties and it has a low absorption capacity. GBS is used as replacement of NFA as it satisfies all the code requirement of fine aggregates to be used in concrete. RCA is used as replacement of natural coarse aggregate (NCA) for the sustainability and economical reasons.

The replacement of materials is carried out based on the studies from last decades. The studies in the last decades were focused on the use of alternative materials to prevent the environmental degradation. Various studies were carried out on the use of replacement of materials used in concrete. The study carried out with the alternative materials with RCA, GGBS and GBS is focused in this paper. Various previous studies applied for the use of RCA, GBS and GGBS in the manufacturing of concrete. Ganesh Babu and Rama Kumar [1] concluded that it is required to have an additional 8.5% and 19.5% increase in the total cementitious materials at 50% and 65% cement replacement levels of GGBS. Oner and Akyuz [2] observed the optimum level of GGBS as 55%, with the further addition of GGBS in the concrete reduces the strength as GGBS acts as the filler material rather than the binding material. S R Yadav [3] concluded that with 25-30% of RCA might not affect the concrete properties. However, if the recycled aggregate used in concrete contains more than 65% of adhered mortar, the impact on concrete property has not evaluated. Wagih et al [4] had carried out on comparative studies of 100% replacement of Natural coarse aggregate (NCA) by Recycled concrete aggregates (RCA), and 75% NCA and 25% RCA. The results showed no significant change in concrete properties. Subathra Devi and Gnanavel [5] had studied on properties of concrete manufactured using steel slag. The results indicated that the compressive, tensile and flexural strengths increase with steel slag as fine aggregate and coarse aggregate as compared to the conventional concrete. The deflection of RCC beams increases as the load on the beam increases, for the both replacements. Jonathan Andal et al, [7] they observed that concrete with RCA of preserved quality performed significantly better in compressive strength, drying shrinkage, and salt scaling resistance. Furthermore, the use of 30% RCA with preserved quality produced concrete of comparable quality of that of concrete with natural aggregate. Joseph et al [8] had carried out an experimental study on evaluation of recycled concrete aggregates for their suitability in construction activities. They found that compressive strength had no significant change in strength as compared to the concrete prepared with the use of natural aggregates. For the split tensile strength control mix was achieved at the replacement of 25% of natural aggregates by RCA. For the others mixes, the fall in strength was also observed.

Based on the above studies, we have carried out an experimental study on the use of GGBS, GBS and RCA for the replacement of cement, NFA and NCA respectively. Aspects related to their effect on fresh and hardened concrete properties are also studied.

MATERIALS

Cement. Ordinary Portland cement (OPC) is of 53 grade. The supplementary material GGBS (Fig-1) is used as 30% replacement of OPC. OPC is tested as per the Indian standard specification (IS 4031- 1996). Various properties of cement and GGBS are as shown in Table 1.

Some properties of GGBS don’t satisfy the Indian code standards. But still the GGBS can be used as the replacement of OPC as it contains cemtentitious properties such as Tricalcium Silicate, Dicalcium Silicate, Tetracalcium- Alumino Ferrate and Di-Calcium Ferrate which positively affects the strength characteristics. But it does not contain much of Tri-Calcium Aluminate, therefore the setting time of GGBS is much more than that of OPC.

Table 1 Properties of cement

Properties	OPC	GGBS Cement	Standard Values (IS 12269)
Specific Gravity	3.05	2.88	3 – 3.15
Fineness (m^2/Kg)	383	406	Min 225

AGGREGATES

Four types of aggregates are used in this study including the naturally available river sand and GBS (Fig-2) as fine aggregate, Dolomite stone and RCA (Fig-3) as coarse aggregates. The tests are carried out with reference to the Indian standard specification IS 2386. Some of the properties of fine and coarse aggregates are shown in Table 2 and Table 3.

The GBS satisfy all required standards hence the replacement of NFA is considered as 100%. The RCA used as coarse aggregate does not satisfy all standards such as water absorption. Therefore, proper precautionary measures are to be taken care on the use of RCA in concrete during the process of mixing.



Fig 1. GGBS **Fig 2 GBS** **Fig 3 RCA**

GGBS : Ground granulated blast slag

GBS : Granulated blast slag

RCA : Recycled concrete aggregates

Table 2 Properties of fine aggregates

Properties	River Sand (NFA)	GBS	Standard Values (IS 2386)
Specific Gravity	2.68	2.87	2.5 – 3.0
Water absorption (%)	0.68	0.82	< 1%
Fineness Modulus (%)	3.62	4.23	2 – 4.5
Bulk Density (Kg/m^3)	1590.21	1611.18	1520 – 1680

Table 3 Properties of Coarse aggregate

Properties	NCA	RCA	Standard Values (IS 2386)
Specific Gravity	2.804	2.422	2.4 – 3.0
Water absorption (%)	0.68	4.33	0.1 – 2
Fineness Modulus (%)	2.14	1.48	2 - 2.4
Bulk Density (Kg/m^3)	1616.76	1409.12	1520 – 1680
Crushing Value (%)	38.4	55.73	< 45
Impact Value (%)	14.63	22.07	< 20
Abrasion Value (%)	35.68	34.56	< 40

EXPERIMENTAL DETAILS

Seven mixtures (M0, M1, M2, M3, M4, M5, M6) are prepared. The conventional concrete is with the mix design of cement content 395 Kg/m^3. Other 6 mixtures are prepared with the replacement of all 3 primary materials by weights i.e, cement, NFA, NCA by GGBS, GBS and RCA as shown in Table-5. All concrete mixtures are mixed in laboratory. From each concrete mixture, three specimens of 150mm cubic are casted to determine the compressive strength. Similarly, three specimens of 150mm diameter and 300 mm depth cylinder were cast for the determination of split tensile strength for each concrete mixture.

Casting of cubes is conducted in 3 layers being compacted internally by using tamping rod and the top surface levelled using trowel. After casting, all moulds are covered above to prevent the water evaporation from the concrete and left for curing for 24hrs at the room temperature. After 24hrs, concrete specimens are demoulded and cured under water for 7, 14 and 28 days strength determination.

As per the recommendation procedure of Bureau of Indian Standards IS 10262-1982, mix ratio is designed with the test results of workability, specific gravity, water absorption and free surface moisture for the materials. Design is stipulated for good degree of quality control and mild exposure.

Table 4 Mix proportion for M30 grade concrete

Sl no	Particulars	
1	Cement	395Kg/m^3
2	Water content	197Litres
3	Fine aggregates	810Kg/^{3}
4	Coarse aggregates	1057Kg/m^3

The mix proportion by weight is obtained as 1:2.06:2.68 (cement fine aggregate: coarse aggregate) with the water cement ratio of 0.5.

The slump test is carried out to determine the workability of green concrete, as soon as the concrete is in the mixing process, as per IS 1199- 1959. The mould for slump cone test measures base diameter of 200 mm, while the top diameter of 100 mm and 300 mm height. 3 layers of concrete is filled in slump cone, each layer is tamp 25 times with the tamping rod of diameter 16mm to remove the voids and the top most surface is levelled off. The height of the slump is measured with the cone removed vertical using scale or graduated tamping rod.

The main objective of the study, is to determine the optimum replacement of RCA with 30% GGBS and 100% GBS, which is determined by testing the concrete for compression as the concrete is primarily used to withstand compressive stresses. The indirect test is conducted to determine the tensile strength known as split tensile strength.

Table 5 Composition of concrete Mix

Sample	Cement (Kg/m^3)		Fine Aggregate (Kg/m^3)		Coarse Aggregate (Kg/m^3)		Water Content (litres)
	OPC	GGBS	NFA	GBS	NCA	RCA	
M0	395	0	810	0	1057	0	197
M1	277	119	0	810	1057	0	197
M2	277	119	0	810	846	211	197
M3	277	119	0	810	634	443	197
M4	277	119	0	810	443	634	197
M5	277	119	0	810	211	846	197
M6	277	119	0	810	0	1057	197

RESULTS AND DISCUSSION

Workability of concrete. The results of slump test of the conventional concrete mix gave the true slump of 63 mm. On further experimental studies with replacement of cement, fine aggregate and coarse aggregates the slump value reduced. At 0% replacement level the slump value was observed as 62 mm. the slump value decreases, as the percentage replacement level increases, from 0% to 100% at 20 intervals for the replacement of coarse aggregate and 100% replacement of fine aggregate. Water absorbing property of RCA is higher than that of natural coarse aggregates. Hence, with the constant water cement ratio of 0.5, more water is absorbed by RCA leaving behind fewer amounts to mortar, for hydration. However, since the RCA is used in the surface dry condition the variation in slump values is slightly less at 0 % replacement level. As the replacement of NCA by RCA is more the workability of concrete is reduced, as the water absorption property of RCA is high. The workability of concrete can be improved using super plasticizers. It is observed there is no drop in workability due to the presences of GGBS.

Compressive strength of concrete. Compressive strength of concrete is commonly considered as the most important mechanical property as it usually effectively determines the quality of concrete and it is directly related with other properties. The compressive strength of each mix is determined at 7, 14 and 28 days.

7 days Strength: The 7days strength of M1 mix is greater than the strength of M0 mix due to the 100% replacement of NFA by GBS as, the bulk density of GBS is slightly higher than that of NFA. Further, on gradual replacement of NCA by RCA the strength is reduced as the properties of RCA is not efficient i.e., the bulk density is lesser and the water absorption is higher for the RCA compared to NCA. With reference to the compressive strength characterisation for 7days, strength to be attained is 65%. Therefore, the optimum results are found up to M5 mix.

14 Days Strength: As the curing period, increases or the age of concrete increases the strength characteristics increases due to the hydration of cement particles. Owing to the replacement of GBS the strength of M1 increases as compared to M0 mix. On further, owing to the replacement of NCA by RCA the strength reduces due to same reason as mentioned in the 7 days strength.

With reference to the strength characterisation for 14 days, strength to be obtained is 90%. Therefore, the optimum results are found up to M4 mix

28 Days strength: On further increase in age of concrete, the strength comparably increases as compared to 7 and 14 days strengths. The strength obtained for each mix is similarly characterized as that of 7 and 14 days i.e. the strength of M1 is more as compared to M0 due to the 100% replacement of NFA by GBS. Further, the strength reduces with the replacement of NCA by RCA.

With reference to the strength characterization, the strength to be attained for 28 days is 99%. Therefore, the optimum result is found up to M5 mix. As the heat of hydration at 28 days is more with age of concrete, the strength attained at 28 days is higher than that of 7 and 14days.

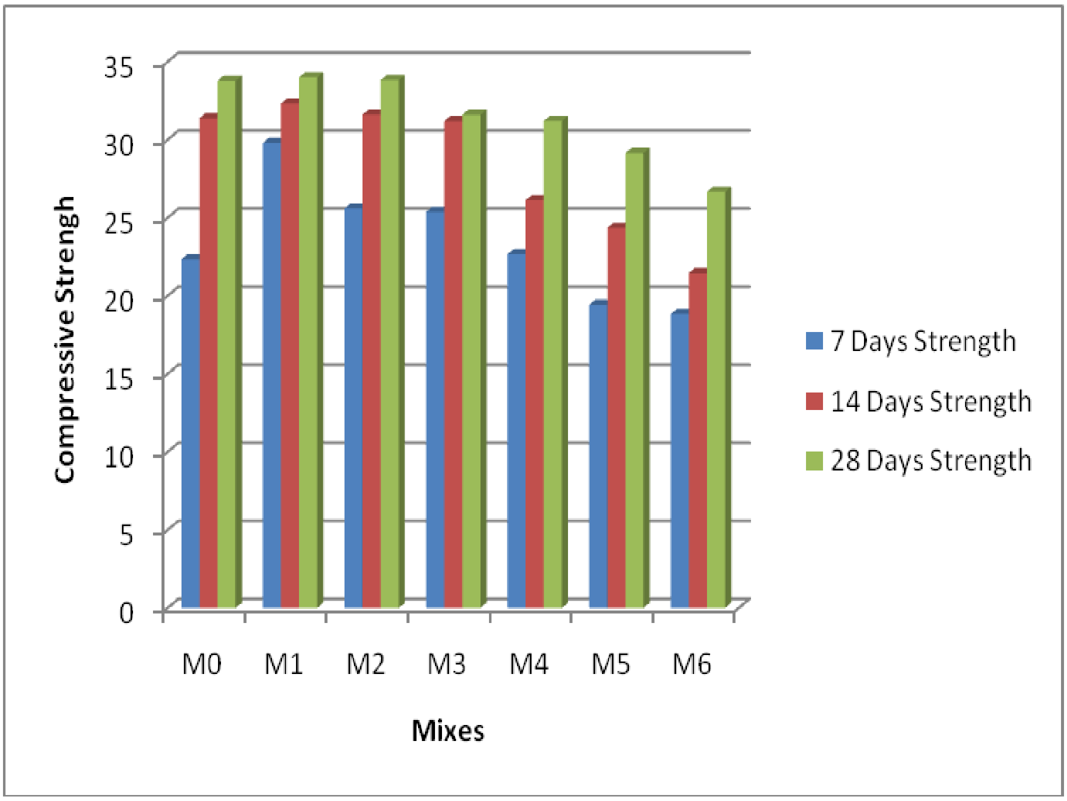

Fig 4. Compressive strength results for 7, 14 and 28 days for different mix proportions

Split tensile strength. The split tensile strength behaves similar to the concrete cubes

- The strength is increased on the replacement of NFA by GBS
- Further, the strength is reduced by the partial replacement of NCA by RCA at the replacement interval of 20% up to 100%.
- The optimum results are obtained up to M5 mix.

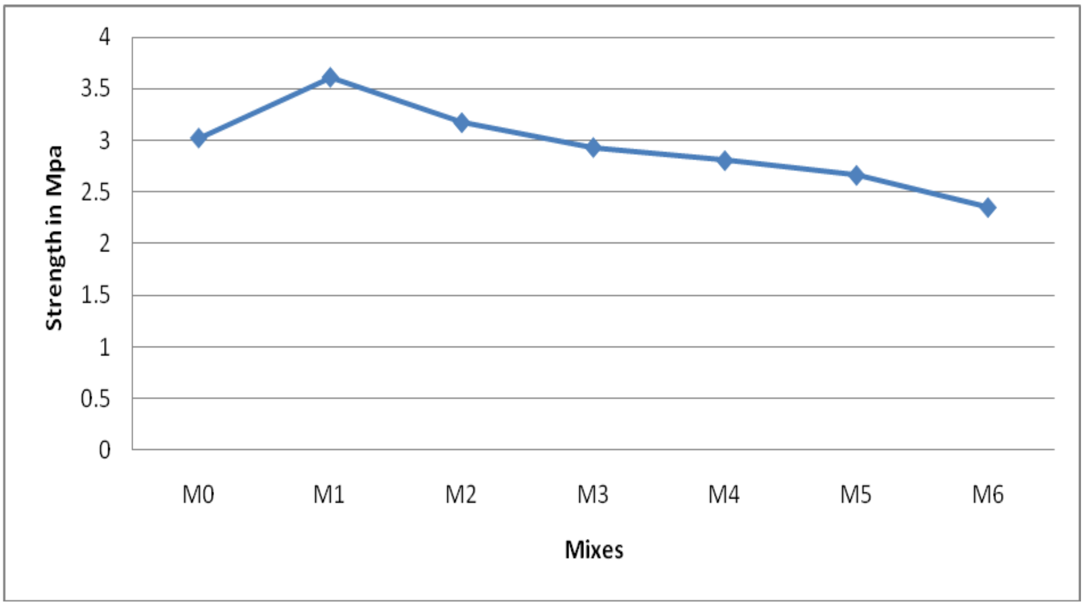

Fig 5. Split tensile strength attained at 28 days

CONCLUSION

The following conclusions were drawn from the experimental investigation:

- The use of 30% GGBS as the replacement of OPC has no significant effect on the strength characteristics of the concrete on each mixes.
- Compressive strength and split tensile strength test on each mix indicate that the use of GBS as NFA increases the strength properties.
- On gradual introduction of RCA from 0% to 100% with the interval of 20% reduces the strength due to various RCA properties, which can be avoided by undertaking various alternative measures.
- The workability of the concrete reduces as compared to M0 mix concrete due to the replacement of aggregates by RCA and GBS and the workability can be improved by the use of various plasticizers which not only increases the workability but also have a significant effect on the strength properties.
- The optimum replacement of NCA by RCA is obtained at 80% for both compressive and split tensile strength, which can be further increases to 100% replacement with the use of plasticizers.
- The replacement of aggregates by RCA and GBS make the production of concrete cost effective as RCA is produced from demolition od building and GBS is the industrial by-product from steel industry.

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