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Green Concrete using GGBS, River Pebbles and CRF as Partial Replacement to Cement and Aggregates

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Abstract: ***Concrete is the most commonly and widely used building material applied in all forms of construction, with an annual production exceeding 2 billion metric tons per year, it is the single most widely used manufactured substance on earth owing to its remarkable versatility as a building material. But the production of raw materials of concrete has certain detrimental effects on environment, mostly the production of cement and coarse aggregated obtained from crushing plants and continuous mining of river beds for getting the natural sand. Eight to 10 percent of the world's total CO2 emissions come from manufacturing cement. The global warming gas is released when limestone and clays are crushed and heated to high temperatures. Whereas production of granitic coarse aggregates on large scales and indiscriminate mining of river beds for sand, to overcome the demand of concrete raw materials has resulted in serious environmental and social problems. Therefore there is an urgent need to find alternative or green materials of concrete to preserve and protect our natural resources for future, by replacing them partially or fully to achieve sustainable development in construction industry. Green concrete is defined as a concrete which uses waste material as at least one of its components, or its production process does not lead to environmental destruction, or it has high performance and life cycle sustainability This paper mainly discusses the potential use of ground granulated blast furnace slag (GGBS), naturally available river pebbles, crushed rock fines (CRF) as partial replacements to cement, sand and coarse aggregates for making green concrete. This research evaluates the strength of hardened concrete, by partially replacing cement by various percentages of ground granulated blast furnace slag, natural sand by CRF and coarse aggregates by river pebbles for M40 grade of concrete at different ages. From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period. The optimum use of green materials as replacement to cement, sand and coarse aggregates is characterized by high compressive strength and good workability***

Keywords— **green concrete, sustainable concrete, GGBS, Crushed rock fines**

I. Introduction

Concrete is one of the major construction materials being utilized worldwide. Concrete is made usually from a properly proportioned mixture of cement, water, fine and coarse aggregates and often, chemical and mineral admixtures. Cement and fine aggregate is the main ingredient used to make concrete, which are obtained from natural resources. Cement is an artificial material manufactured with the naturally available limestone, silica and gypsum. Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete mix. Due to rapid urbanization in India and countries, construction industry is growing at an alarming rate and in order to meet the requirements of construction materials the mining and quarrying sector has grown rapidly, leading to depletion of the natural resources. Due to heavy increase in construction activities, the crushed granite stone which are the conventional coarse aggregate is under depletion thus causing shortage. In order to meet the sand requirement indiscriminate mining of rivers for sand has become quite common and inevitable. The sand activities have resulted in large number of environmental and social problems. Production of cement on large scale to meet the global demand has led to CO2 emissions thus causing negative environmental effects. To meet the global demand of concrete in the future, it is becoming a challenging task to find suitable alternative construction materials which can fully or partially replace the natural aggregate without affecting the property of concrete and make green concrete for sustainable future. The different materials that can be used as an alternative for natural fine aggregate include blast furnace slag, manufactured sand, crushed glass, copper slag, recycled aggregates, fly ash, steel slag etc. The use of such materials not only result in conservation of natural resources but also helps in maintaining good environmental conditions by effective utilization of these by-products which will otherwise remain as a waste material. Blast furnace slag is such a material which could be used as a partial replacement for fine aggregate. Blast furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. These materials are otherwise considered to be a potential waste material which is been dumped near the industrial area. Utilization of industrial byproducts and wastes as fine aggregate, coarse aggregate and as supplementary binding materials in concrete has economic, environmental and technical benefits. Research results indicated that the incorporating these materials in concrete has already been proven to improve the strength and durability performance of concrete. This paper outlines the influence of Ground Granulated Blast furnace Slag (GGBS) as partial replacement to cement, waste river pebbles obtained after sieving sand as partial replacement of coarse aggregate, crushed rock fines(CRF) as partial replacement to natural to sand ; on mechanical properties of concrete. The strength of concrete is

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determined by replacing the main concrete ingredients with alternative materials in various percentages for M40 mix

II. Green concrete and Sustainability

Production of green concrete for future will require adoption of cleaner technologies, the main points to be considered are:

a) reduction of CO2 emissions in the environment
b) reduction in energy consumption or fuel derived from fossil in the cement manufacturing process
c) reduction of substances that can endanger health or the environment such as the use of several types of chemicals in the concrete mixture,
d) savings the use of cement through substitution with fly ash waste in the higher portion or the use of other waste
e) use of new cement replacement materials, such as inorganic polymers, alkali-activated cement, magnesia cement, and sulfoaluminate cements, and
f) various possibilities of recycling cement/concrete and the use of alternative aggregates.

Other significant contribution are policies or regulations of various countries/institutions/industries and willingness of the community to use green concrete. The key factors that are used to identify whether the concrete is green are: amount of Portland cement replacement materials, manufacturing process and methods, performance and life cycle sustainability impacts. Green concrete should follow reduce, reuse and recycle technique or any two process in the concrete technology. The three major objective behind green concept in concrete is to reduce green house gas emission (carbon dioxide emission from cement industry); to reduce the use of natural resources such as limestone, shale, clay, natural river sand, natural rocks that are being consume for the development of human mankind that are not given back to the earth; and the use of waste materials in concrete that results in the air, land and water pollution. This objective behind green concrete will result in the sustainable development without destruction natural resources (Suhendro B., 2014)

III. Review of Literature

Chandrashekhar.A,Maneeth P.D (2014) obtained the result of experimental investigation envisages the potential utilization of river stones as a coarse aggregate in the replacement of crushed stone aggregate in concrete. The main aim of their study was to determine fresh and hardened properties of concrete made with river stone and to compare with those using crushed stone aggregate and to ascertain whether river stone can be good aggregate for concrete. They have found through their investigations that river stones can be effectively used as partial replacement to coarse aggregates in concrete.Nimitha Vijayaraghavan and A. S. Waya (2013) obtained the results of experimental investigations of partial and full replacement of natural sand. The main aim of their study was to compare the compressive strength and workability of concrete with Crushed Rock Fine (CRF) and natural sand in varying proportions. The results showed that concrete with Crushed Rock Fine (CRF) possessed higher compressive strength whereas workability decreased with increasing proportion of Crushed Rock Fine (CRF). Swaroop A.H.L et.al (2013), studied the durability of concrete with fly ash and GGBS, they studied the effect of hydrogen sulphate and sea water on concrete made with above waste materials. They concluded that concrete made by fly ash and GGBS had good strength and durable properties compared to conventional concrete.Shanmugaoriya et al. (2012) concluded from experimental researchers that compressive and flexural strength of concrete can be improved by partial replacement of cement by silica fumes and manufacture sand for natural fine aggregates. They suggested that optimum replacement of natural sand by Crushed Rock Fine (CRF) is 50%.Elsayed (2011) investigated experimentally in his study the effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF) and fly ash (FA). The results were compared to the control concrete, ordinary Portland cement concrete without admixtures. The optimum cement replacement by FA and SF in this experiment was 10%. The strength and permeability of concrete containing silica fume, fly ash and high slag cement could be beneficial in the utilization of these waste materials in concrete work, especially in terms of durability. Mahendra R. Chitlange et al. (2010) experimentally proved that due to addition of steel fiber to natural sand concrete and Crushed Rock Fine (CRF) concrete there is a consistent increase in flexural and split tensile strength whereas there is only a marginal rise in compressive strength.Saeed Ahmad et al.(2008) have found that compressive strength of various mix ratios increased from 7% to 33% whereas workability decreased from11% to 67% with increasing proportion of Crushed Rock Fine (CRF). Shyam Prakash et al. (2007) say that Crushed Rock Fine (CRF) satisfies the requirements fine aggregates such as strength, gradation, and shape angularity. It is also possible to produce Crushed Rock Fine (CRF) falling into the desired grade. They say that the mechanical properties of Crushed Rock Fine (CRF) depend upon the resource of its raw material, i.e., parent rock. Hence the selection of quarry is very important to quality fine aggregate

From the critical review of literature it is observed that above researchers and many others have worked on finding suitable alternatives for cement, sand and coarse aggregates so as to reduce the consumption of these natural resources. At the same time many other waste products/by-products from industry have been tried as replacement for the above natural resources and they have found satisfactory results. These waste materials are thus used as green materials for achieving sustainable concrete. Among many waste products GGBS and fly ash are most widely used as partial replacement to ordinary Portland cement. Present work envisages the use of GGBS, CRF and river pebbles in development of concrete and makes an attempt for contribution to sustainable and greener concrete for future development.

IV Experimental Programme

Materials

The cement used was Ordinary Portland cement (OPC) Grade 53, specific gravity was 2.84 and fineness was 4%. GGBS was

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used as partial replacement to cement up to 30%.GGBS was obtained from steel plant of Sesa at Amona-Goa. Tests conducted on cement were in accordance with IS: 4031-199. Locally available river sand as fine aggregate (4.75mm to 75 micron [0.2 to 0.003 in]) was used. The sand was free from clayey matter, salt and organic impurities. Crushed rock fine (4.75mm to 75 micron [0.2 to 0.003 in]) was used for partial replacement to natural sand. Both fine aggregate, natural and manufactured sand were from zone II. Machine crushed angular granite of 20mm and 10mm nominal size from the local source was used as coarse aggregate. It was free from impurities such as dust, clay particles and organic matter etc. River pebbles of sizes varying from 10mm to 30mm were used. These pebbles were found in large quantity at local construction site, which were found in natural sand after sieving. The physical properties of coarse aggregate were investigated in accordance with IS: 2386-1963, and are given in Table 1

Table 1 Physical Properties of aggregates

Description of material.	Specific gravity	Water absorption	Impact value	Bulk density(gm/cc)
CA,10mm	3.12	0.34	10.02	1.8
CA,20mm	3.06	0.19	10.5	1.8
River pebble	2.63	1.33	27.72	1.73
Coarse sand	2.74	1.67	-	2.02
CRF	2.79	1.9	-	2.33

Concrete Mix

M40 grade of concrete was considered for the study, Mix design was carried out according to IS: 10262:2009 and IS: 456:2000.the details of the mix are given in Table 2.various trial mixes considered for the study for the above grade are given in Table 3.TR1 is a control mix, Concrete for each mix was prepared separately and standard test for workability on fresh concrete was carried out in Laboratory using slump cone. Type of admixture used in the present study is Superplastisizer having Brand name *Chocksey*. Superplastisizer constitute a relatively new category and improved version of plasticizer, they are chemically different from normal plasticizers. Use of superplasticizers permits the reduction of water up to 30 per cent without reducing workability in contrast to the possible reduction up to 15 per cent in case of plasticizers. Results of the slump test are illustrated in Fig.1. The concrete was then placed in standard cube moulds of size (150x150x150) mm and thoroughly compacted using table vibrator. The cubes were then kept for curing under water. The cubes of each trial were tested for compression test using compression testing machine after 7 days, 14 days and 28 days of curing. The results of the tests are given in Table 4.All the results obtained were then compared with the control mix.

Table 2 Mix details

Mix	Cement (Kg)	Coarse Aggregate (Kg)	Sand (Kg)	W/C	Admixture (kg/m^3)
M40	440	1268	741	0.42	7

Table 3 Mix details

Trial	Description
1	Cement+Sand+CA+water
2	70%Cement+30%GGBS+100%CRF+50%sand+70% CA+30%Pebbles +Water
3	70%Cement+30%GGBS+100%CRF+50%sand+50% CA+50%Pebbles +Water
4	70%Cement+30%GGBS+100%CRF+100%Pebbles +Water

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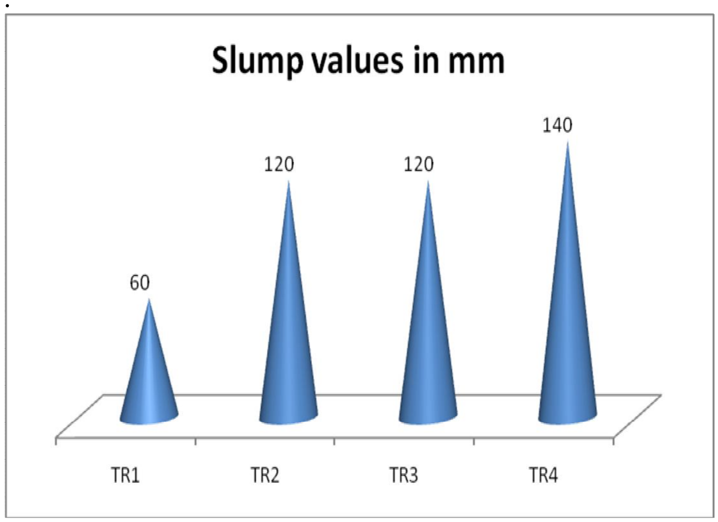

Figure 1Slump values

Tests on fresh and hardened concrete

Test on fresh concrete: slump test

Concrete mixes prepared were tested for its fresh properties like workability such as slump test. Slump test is a most commonly used method of measuring the consistency of the concrete which can be employed either in laboratory or at site of work. It is used to conveniently as a control test and given as indication of the uniformity of concrete from batch to batch. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps. The deformation shows the characteristics of concrete with respect to tendency for segregation. The results of the slump test are illustrated in Fig. 1.

Test on hardened concrete: compression test

The compression test was conducted using UTM on cubes at the age of 7 days, 14days and 28days of curing respectively and confirming to IS 516-1959. Cubes stored in water were not tested immediately on removal from water in damp condition. The actual dimension and weight of the specimen was noted. The specimen was placed on the testing platform of the compression testing machine in such a way that the load was applied to the top and bottom surface. The load was applied without shock and increase until the resistance of the specimen to the increasing load broke down and no greater load was sustained. The total load applied at failure was recorded. The maximum load applied divided by its cross sectional area given the compressive strength. Averages of two specimens were taken; provided the individual variation was not more than ± 15% of average. Cubes after curing were tested for compression for each trial after 7 days, 14 days and 28 days. The results are presented in Table 4 and graphical representation is illustrated in Figure 2. It was observed that Compressive strength for all the trials is more than the minimum required strength of 26 Mpa, 36 Mpa and 40 Mpa respectively at 7 days, 14 days and 28 days.

Table 4 Compressive strength results

Trial	Compressive strength		
	7 days	14 days	28 days
TR1	43.92	52.5	52.2
TR2	43.75	44.25	49.59
TR3	41.92	53.7	58.03
TR4	34.86	46.45	53.82

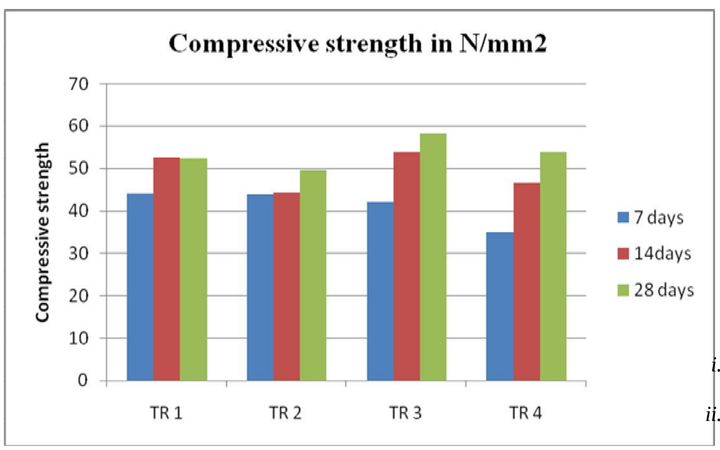

Figure 2 Compressive strength comparison for trial mixes

It is **o**bserved from the results of slump test that values of slump have increased tremendously in all the trials compared to standard Trial 1. Slump of TR2 and TR3 is increased by 2 times, TR4 by 2.33 times TR1.

It is **o**bserved from the results of 7 days compression test that the values have decreased in Trial 2,Trial 3 and Trial 4 as compared to Trial 1.Compressive strength of TR2 is decreased by 0.99 times,TR3 by 0.95 times and TR4 by 0.79 times compared to TR1. In case of 14 days test the Compressive strength of TR2 is decreased by 0.84times, TR4 by 0.88 times whereas strength of TR3 showed an increase by 1.02 times as compared to TR1.In case of 28 days Compressive strength of TR3 is increased by 1.11 times and TR4 by 1.03 times as compared to TR1, whereas Compressive strength of TR2 is decreased by 0.94 times

V Conclusions

Workability of concrete mixes increases with the increase in percentage of river pebbles this is mainly because of smooth surface and round shape of river pebbles. If the workability had kept constant, the water content for some of the concrete mixes could have been reduced thus benefiting the mechanical properties of concrete

From the observations it is seen that the trial mix using alternative materials does not show early strength development. Among all the trials considered in the study TR3 mix containing 70%Cement+30%GGBS+100%CRF++50%CA+50%Pebbles +Water, showed higher compressive strength at 14 days and 28 days compared to control mix results. Therefore it can be seen that natural sand can be fully replaced by CRF and CA can be replaced by 50% with river pebbles to achieve economy and sustainability. Also cement can be efficiently replaced by GGBS for efficient waste utilization and economy without compromising on strength. Increase in percentage of GGBS by more than 30% can also be tried for further economy. However tests on durability and flexure of concrete should be carried out for using the above concrete for application to major works but can be efficiently used for minor concreting works for economy, sustainability and environment friendly as green concrete.

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