Comparative Study on the Effect of Concrete using Eco Sand, Weathered Crystalline Rock Sand and GBS as fine Aggregate Replacement

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***Abstract*—Concrete plays a vital role in the design and construction of the nation's infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. These are obtained from natural rocks and river beds, thus degrading them slowly. This issue of environmental degradation, and need for aggregates demands for the usage of any other alternative source. Thus the concept of replacement of fine aggregate with ecosand , weathered crystalline rock sand and granulated blast furnace slag (GBS) seems to be promising. In this study an attempt is made to use eco sand which is a commercial by-product of cement manufacturing process introduced by ACC Cements, weathered crystalline rock which is type of rock is abundantly available at low cost in tropical areas and granulated blast furnace slag(GBS) is a byproduct obtained from the steel manufacturing industry as fine aggregate replacement. M20 grade of concrete is used. A through literature review was conducted to study and investigate the properties of these materials. The properties of materials used for replacement also were determined. Different percentage addition of replacement materials are prepared for conducting the test. The strength characteristic in concrete with replacement of eco sand and weathered crystalline rock sand was studied in detail. Since the delay in procuring GBS, casting and testing of GBS are to remains to be done.**

Keywords—Eco sand, Granulated Blast Furnace Slag(GBS), Weathered crystalline rock sand.

I. INTRODUCTION

Concrete is a major building material which is been used in construction industry throughout the world. It is an extremely versatile material and can be used for all types of structures. Concrete is a composite construction material composed mainly of cement, aggregate and water. The cement and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. The aggregates are of two kinds, coarse aggregate such as crushed limestone or granite and fine aggregate such as river sand or manufactured sand. Various chemical admixtures can also be added to achieve varied properties. Water is mixed in concrete so that the concrete gets its shape and then gets hardened through a process called hydration.

Aggregate occupy almost 70-75% of the total volume of concrete. The civil engineering construction particularly in the field of reinforced concrete has increased and as a consequence the availability of aggregate has reduced by a large amount. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Natural aggregates are obtained from natural rocks. They are inert, filler materials and depending upon their size they can be separated into coarse aggregates and fine aggregates. The hike in cost of fine aggregate is another major issue in the construction field. Hence, an alternative construction material which can fully or partially replace the fine aggregate without affecting the property of concrete would be advantageous. 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 aggregate etc. The use of such materials not only results 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.

Eco sand, weathered crystalline rock sand and GBS are such materials which could be used as a partial replacement of natural fine aggregate. Eco sand which is a commercial by-product of cement manufacturing process introduced by ACC Cements, weathered crystalline rock which is type of rock is abundantly available in tropical areas as fine aggregate replacement and GBS is the byproduct obtained from the steel manufacturing industry. Through this project, the use of eco sand, weathered crystalline rock sand and GBS as replacement for the fine aggregate in concrete is studied.

II. MATERIALS USED

A. Cement

The cement used for the work is DALMIA OPC 53 grade cement.

B. Weathered Crystalline Rock Sand

Weathered Crystalline Rocks are metamorphic rocks seen in the tropical areas like Kerala. They are formed by the weathering action on the rocks. Weathered crystalline rock is the outer layer of the underlying hard rock. Hence excessive mining is not required to obtain these types of rocks. In Kerala, weathered crystalline rock is used for the construction of small compound walls instead of random rubble and laterite bricks. Weathered crystalline rock sand is used for plastering works.

Fig 1. Weathered crystalline rock sand

C. Eco sand

Eco sand is very fine particle is a byproduct obtained from the process of manufacture of cement, through semi-wet process. It is introduced by ACC Cements, Coimbatore. The main constituent of the eco sand is crystalline silica. It is crystalline white in color.

Fig 2. Eco sand

D. Garanulated blast furnace slag (GBS)

GBS is an industrial byproduct obtained from the steel manufacturing industry. The consumption of slag in concrete not only helps in reducing green house gases but also helps in making environmentally friendly material. During the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces iron ore into molten iron product. Fluxing agents separate impurities and slag is produced during separation of molten steel. Slag is a nonmetallic inert waste byproduct primarily consists of silicates, alumino silicates, and calcium-aluminasilicates.

Fig 3. GBS

E. Coarse Aggregate

Coarse aggregate is considered to be the strongest and least porous component of concrete. It is also a chemically inert material. Locally available crushed granite aggregate of 20mm down size conforming to IS 383-1970 was used.

F. Water

Water is an important ingredient of concrete, as it actively participates in chemical reaction with cement. In the present investigation, potable water was used for mixing and curing.

III. METHEDOLOGY

The methodology adopted for the present experimental investigation is as follows:

- Preliminary material study
- Mix design
- Study on fresh concrete
- Strength study on hardened concrete
- Results and discussion

The first phase of work, preliminary material study includes tests on fine aggregate, coarse aggregate, weathered crystalline rock sand, eco sand, GBS and cement used for the project work. The mix proportioning is to be done as per IS 10262: 2009 and based on the material test results. Study on fresh concrete includes slump test which is to be conducted to study the workability parameter of fine aggregate replaced concrete. The compressive strength, split tensile strength, flexural strength and Durability test of hardened concrete are to be observed in order to study the strength parameters of concrete.

IV. MATERIAL CHARACTERISATION

Specific gravity of fine aggregate was found out using pycnometer method, as per IS:2386 (PartIII)-1963 .

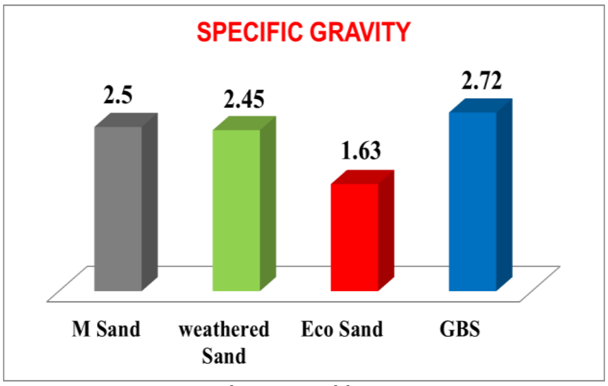

Fig 4. Specific gravity of fine aggregates

The specific gravity of fine aggregate is required to calculate the total weight of fine aggregate in concrete mix design and for calculation of volume yield of concrete. The values of specific gravity and water absorption are shown in figure 4 and 5 respectively.

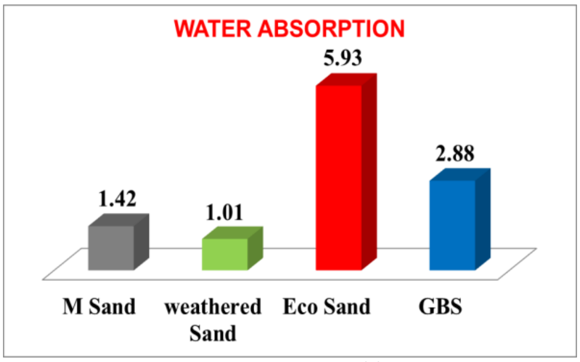

Fig 5. Water absorption of fine aggregates

Sieve analysis test was conducted on the fine aggregate as per IS : 2386 (Part I) – 1963. The particle size distribution curve was plotted based on the results are presented in Figure 6, 7,8 and 9.

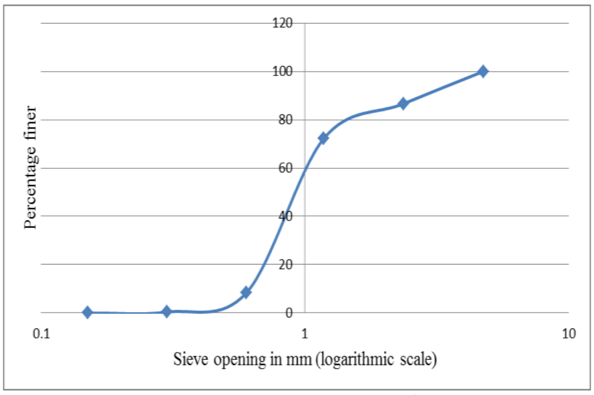

Fig.6 Particle size distribution curve for M-sand

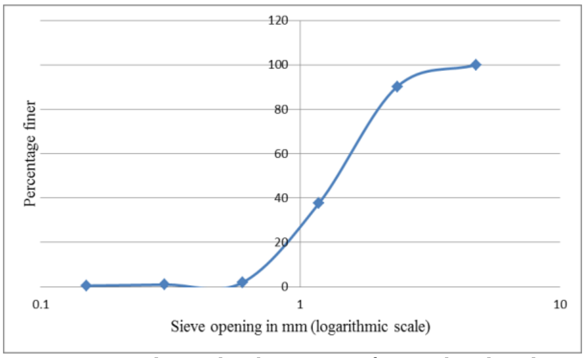

Fig 7. Particle size distribution curve for Weathered sand

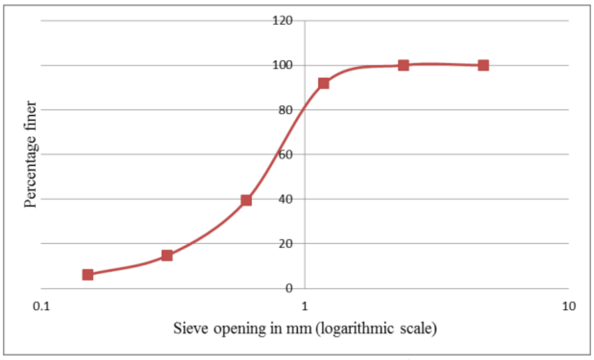

Fig.8. Particle size distribution curve for Eco sand

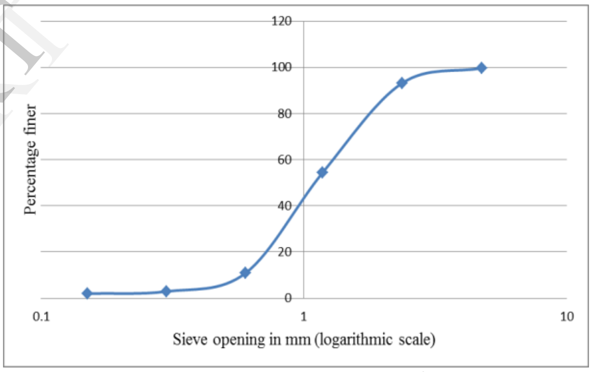

Fig.9 Particle size distribution curve for GBS

As per IS specification, value of fineness modulus of fine aggregates lies between 2 and 3.5

V. MIX PROPRTIONING

The mix design is carried out as per IS 10262:2009. The grade of concrete adopted for this study is M20. Maximum size of aggregate taken is 20mm and grading of sand is zone II. The mix designation and the quantities of materials required for each are given in Table 1.

- Mix Proportion : 1 : 1.90 : 3.69 : 0.4

Table 1. Mix designation and material quantity control mix

Material	*Calculated Quantity*
w/c	0.4
Cement (kg/m3)	335
Fine aggregate (kg/m3)	638
Coarse aggregate (kg/m3)	1239
Water (lit/m3)	134

VI. TESTS AND RESULTS

A. On Fresh Concrete

The workability of fresh concrete is measured using slump test. Test result is shown in table 2 as below.

Table 2. Results of slump test

Mix designation	*Mix ID*	*Slump value (mm)*
Normal mix	NM	90
Weathered crystalline sand concrete	WC25	80
	WC50	90
	WC75	110
	WC100	120
Eco sand concrete	ES25	80
	ES50	60
	ES75	50
	ES100	40
GBS	GB25	80
	GB50	70
	GB75	60
	GB100	60

The value of slump increases with the incremental percentage of weathered sand replacement. The increment in workability of concrete with the increase in percentage of weathered crystalline sand is attributed to the low water absorption characteristics of weathered crystalline sand. In case of Eco sand concrete, slump value was seen to be decreasing with increased percentage of Eco sand. This may be because of the reason that, as the amount of fines in concrete increases, water requirement to meet the specified slump also increases. For fixed water cement ratio (0.4), this may lead to a reduction in slump value. In case of GBS, the slump value was seen to be decreasing with increased percentage of GBS.

B. On Hardened Concrete

The 7days and 28 days strength were found for compressive strength test and 28 days strength for other tests. The results are given in the following Table 3, 4 and 5. The maximum compressive strength was obtained for concrete cubes made with 100% replacement of fine aggregate using weathered crystalline sand.

Table 3. Results of 7 and 28 day compressive strength

% Replacement	*Average compressive strength (N/mm^2)*					
	Weathered Sand		EcoSand		GBS	
	7 Day	28 Day	7 Day	28 Day	7 Day	28 Day
0	18.20	27.83	18.20	27.83	18.20	27.83
25	18.31	30.96	21.67	30.88	17.64	26.22
50	24.44	35.25	19.55	28.75	22.42	33.56
75	26.54	37.40	19.85	29.11	22.02	32.56
100	28.24	41.18	20.44	30.88	21.24	31.20

The maximum split tensile strength was obtained for concrete cubes made with 100% replacement of fine aggregate using GBS.

Table 4. Results of 28 day split tensile strength

% Replacement	*Average split tensile strength (N/mm^2)*		
	Weathered Sand	EcoSand	GBS
	28 Day	28 Day	28 Day
0	2.25	2.25	2.25
25	2.67	2.6	2.26
50	2.63	2.4	3.11
75	3.32	2.4	3.54
100	3.46	2.35	3.76

The maximum flexural strength was obtained for concrete cubes made with 100% replacement of fine aggregate using Weathered crystalline sand.

Table 5. Results of 28 day flexural strength

% Replacement	*Average flexural strength (N/mm^2)*		
	Weathered Sand	EcoSand	GBS
	28 Day	28 Day	28 Day
0	5.60	5.60	5.60
25	6.40	6.32	5.2
50	6.00	4.58	6.4
75	6.10	4.64	6.4
100	6.80	5.20	6.45

VII. COST ANALYSIS

The cost analysis plays an important role in deciding the economic design. Aggregates are the main ingredient of concrete which is costlier and also rarely available. Hence the costlier materials can be replaced, so it is necessary to make cost analysis. Quantity of fine aggregate required and their cost per m^3 of concrete for M20 grade is shown in Table 6 and Figure 10.

Table 6. Cost of materials per m^3

Material	Cement (kg/m^3)	M sand (kg/m^3)	Weathered sand (kg/m^3)	Eco sand (kg/m^3)	GBS (kg/m^3)	C A (kg/m^3)
Total Quantity	335	638	638	638	638	1239
Total Cost (Rs)	2613	2683.56	2012.67	2515.84	3190	2866.50

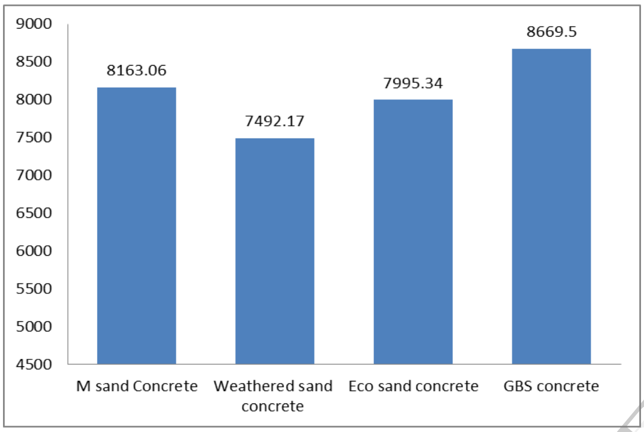

Fig.10. Total cost for 1 m^3 of concrete

This shows that fine aggregate replacement by weathered sand and eco sand increases cost saving in the production of concrete.

VIII. CONCLUSIONS

Based on the present study the following conclusions were derived:

1. From the workability study it was seen that the concrete prepared with the replacement of fine aggregate with weathered crystalline rock sand resulted in a better workability when compared to the control mix and Eco sand replaced concrete. Comparing the workability parameter of weathered crystalline sand concrete, eco sand concrete and GBS concrete, the weathered crystalline sand concrete was found to be more workable because of the low water absorption characteristics of weathered crystalline sand based on the slump test conducted.

2. It can be seen that the 7 day and 28 day compressive strength of normal mix is lesser when compared to the concrete mixes prepared with different percentage of Weathered crystalline sand. The maximum compressive strength for 7 and 28 day was found to be in the mix with 100% replacement of fine aggregate (WC100).

3. In the case of eco sand maximum compressive strength was attained for concrete cubes made with 25% and 75% replacement of fine aggregate using eco sand (ES25 & ES100). As the amount of fines increase, it minimizes the void content in the system and hence providing a denser packing of aggregates.

4. For GBS, the maximum compressive strength was obtained for concrete cubes made with 50% replacement of fine aggregate using GBS. When the percentage of GBS increases, the free water available in the mix also increases. This may lead to the formation of pores in the concrete structure. The increased porosity of concrete weakens the bond between the concrete components causing a reduction in the concrete compressive strength.

5. The maximum split tensile strength is attained for concrete cylinders made with 100% replacement of fine aggregate using weathered crystalline rock sand. For eco sand replaced concrete, the split tensile strength of concrete cylinders was seen to increase initially and beyond 25% replacement of fine aggregate it tends to decrease. But in general the split tensile strength of concrete cylinders with different percentage replacement was found to be comparable. The variation in strength can be attributed due to the difference in packing density.When the percentage of GBS is increased, the split tensile strength of concrete also increased. This may be due to the minimum voids in concrete and cause increase in strength.

6. The flexural strength of weathered crystalline sand concrete was found to be greater than the flexural strength of control mix concrete. Maximum flexural strength was observed for fine aggregate replacement of 100% using weathered sand. Overall, the flexural strength of different percentage replacement was found to be comparable.

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