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Experimental Study On Properties Of Concrete By Replacement Of Fine Aggregate With Ecosand And Coarse Aggregate With Steel Slag

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Abstract: Concrete is a very strong and versatile mouldable construction material. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. Aggregates are obtained from natural rocks and river beds. River sand poses the problem of acute shortage in many areas due to large requirements in construction industry. The need for aggregates demands for the usage of any other alternative source. Thus the concept of replacement of fine aggregate with ecosand and coarse aggregate with steel slag seems to be promising. In this study an attempt is made to use steel slag, a by-product from steel industry as replacement for coarse aggregate in concrete and ecosand which is a by-product of cement manufacturing process as fine aggregate replacement. Initial optimization of materials was done with 28 days compressive strength on concrete cubes. M_{30} grade of concrete was used. Tests on compressive strength, flexural strength, split tensile strength were conducted on specimens at 7, 14 and 28 days. It was concluded that replacing about 40 percent of steel slag aggregates for coarse aggregate and 30 percent of ecosand for fine aggregate will not have any adverse effect on the strength of the concrete.

1.Introduction:

Concrete is a mouldable construction material composed of cement (commonly Portland cement) as well as other cementitious materials such as fly ash, aggregate (generally a coarse aggregate made of crushed rocks such as limestone, or granite, plus a fine aggregate such as river sand), water and chemical admixtures. Concrete has high compressive strength and low tensile strength. India has an enormous growth in the steel Industries and steel slag a by-product of the same has to be disposed off properly; else they may cause environmental hazards to the surroundings. The use of steel slag reduces the need of natural rock as a construction material.

River sand poses the problem of acute shortage in many areas due to large requirements in construction industry. Rapid and prolonged sand mining causes scouring of river beds and also the loss of natural minerals present in the river leads to environmental effects. The unit cost of sand increases day by day and there is a need for an alternative material. Thus ecosand which is a by-product obtained from cement manufacturing process is used as an alternate material for river sand.

The compressive strength, flexural strength, splitting tensile strength, modulus of elasticity of slag concrete was slightly higher , while drying shrinkage was lower than the natural gravel concrete[1]. The usage of steel slag and crushed limestone as aggregates in concrete showed that the durability and physical properties of concrete with steel slag aggregates was better than limestone aggregates[2]. The electric arc furnace slag as both fine and coarse aggregate showed an appreciable decrease in the compressive strength but not to great levels as compared to normal moist curing and is acceptable, especially in the geographical region for which its use is proposed, where the winter temperature hardly falls below 0°C[3]. The steel slag **as** aggregates in concrete showed that 28 days strength was increased by 21% with replacement of natural aggregates, while there was no increase in the setting time of concrete mixtures[4]. The mechanical strength and durability of steel slag aggregate concrete can be improved by proper mix proportions[5]. The 50 to 75% of steel slag aggregate replacement by volume for natural aggregates will not do any harm to concrete and also it will not have any adverse effects on the strength and durability[6]. The freezing and thawing resistance of steel slag aggregate in concrete showed that its resistance was better than the recycled aggregates and almost same as crushed stone[7] .The steam curing process generally adopted for the manufacture of aerated concrete becomes even cheaper by using eco sand and fly ash. The possibility of utilizing steel slag, produced in Croatian plants as a concrete aggregate showed strength of the slag based concrete gained strength of about 86% of the reference concrete and the slag concrete is also susceptible to the similar corrosion attack as the natural dolomite aggregate[8]. Increase in replacement level of steel slag above 60% decreases the workability of concrete; however this property varies depending upon the source of steel slag and its optimum replacement was found as 60 % [9].

In this study, it is proposed to utilize steel slag as replacement for coarse aggregate and ecosand as replacement for fine aggregate respectively. Tests on compressive strength, flexural strength, split tensile strength were conducted on specimens at 7, 14 and 28 days.

Experimental

Materials used

The materials used are ordinary Portland cement of 53 grade, river sand as fine aggregate, normal coarse aggregate, steel slag, eco sand, and water.

Ecosand

Ecosand is a by-product obtained from cement manufacturing process *via* semi-wet process, a product by ACC cements. It is finely powdered crystalline silica which can be replaced up to 50% of conventional sand usage in concrete and mortars. Its micro-filling effect reduces pores in concretes and provides better moisture resistivity, durability and has more consistent grading than many extracted aggregates. The use of ecosand rather than extracted or dredged natural sand will help designers and contractors to address the issues related to sustainability. The ecosand has various advantages such as energy efficient, fire resistant, reduction of dead load, environmentally friendly, durable, light weight, low maintenance and low construction cost. The non-absorbent nature and smooth surface texture benefits workability and reduces water requirement. The cost of ecosand is less than river sand, yet its behaviour and characteristics has to be studied. Its specific gravity is 2.63 and the particle size is less than 15 μm sieve. Fig 1.1 shows the ecosand sample used in the present investigation.

Fig.1.1 Ecosand sample

Steel slag

Steel slag is an industrial by product obtained from the steel manufacturing industry. The blast furnace steel slag is brought from SDV Steels, Kondapalli, Vijayawada, Andhra Pradesh. It is produced in large quantities during the steel-making operations. Steel slag can be used in the construction industry as aggregates in concrete by replacing natural aggregates. Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Most of the volume of concrete is aggregates, and replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. Its specific gravity is 2.6 and Fig 1.2 shows the steel slag sample and table 1.1 shows the chemical composition of steel slag.

Fig.1.2 Steel slag sample

Table 1.1 Chemical composition of steel slag

Constituents	Percentage
Iron	97 % - 99 %
Carbon	0.3
Manganese	0.7
Phosphorous	0.02
Silicon	0.2

Optimisation of Ecosand:

Optimum replacement of ecosand has been found by considering 28 days strength of concrete cubes of size 150x150x150mm. Concrete cubes were cast for M_{30} grade by varying fine aggregate with eco sand by 0%, 10%, 20%, 30%, 40% and 50. Three cubes for each replacement ratio were cast. It was found that the optimum level of replacement of ecosand was 30%. Table 1.2 shows the 28 days strength of concrete cubes tested.

Table 1.2 Optimization of ecosand

S.No	% Replacement of ecosand	28 days Compressive strength (MPa)
1	0	32.86
2	10	34.31
3	20	37.87
4	**30**	**40.02**
5	40	38.23
6	50	37.79

2. Casting and Testing of Specimens

Mix Design

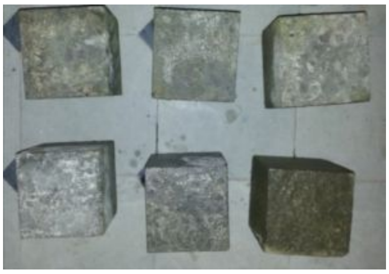
Based on the mix design, the mix proportions for M_{30} grade concrete using steel slag as coarse aggregate replacement are presented in Table 2.1.

Table 2.1 Mix proportions for Slag replacement

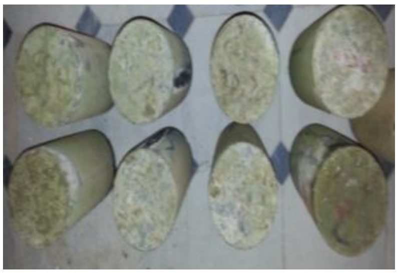
S.No	Replacement of steel slag in %	Water cement ratio	Mix Proportion
1	0	0.45	1:1.22:2.4
2	20	0.45	1:1.22:2.39
3	40	0.45	1:1.22:2.37
4	60	0.45	1:1.22:2.35

Compressive and Split tensile strength

For compressive strength , cubes of size 150mm x 150mm x 150mm and for split tensile strength cylinders of size 150mm x 300mm were casted. Cast iron moulds were used for casting of these cubes. 30% replacement of ecosand for fine aggregate and 0%, 20%, 40% and 60% replacement of steel slag for coarse aggregate mix was used to cast the specimen. Cubes for compressive strength are tested at 7 days, 14 days and 28 days using compression testing machine of 2000kN capacity. Split tensile strength test was carried out at 7, 14 and 28 days for the cylinder specimens of size 150mm diameter and 300mm length, using compression testing machine of 2000kN capacity as per IS 516 - 1959. Fig 2.1 shows the cube and cylinder specimens casted. The compression testing setup is shown in Fig 2.2.



(a) Cube Specimen



(b) Cylinder Specimen

Fig 2.1 Concrete specimens casted

Table 2.2 Number of specimens casted

Mix Proportions	Designation	7 days		14 days		28 days	
		Cubes	Cylinders	Cubes	Cylinders	Cubes	Cylinders
M30	M1	3	3	3	3	3	3
E30 S0%	M2	3	3	3	3	3	3
E30 S20%	M3	3	3	3	3	3	3
E30 S40%	M4	3	3	3	3	3	3
E30 S60%	M5	3	3	3	3	3	3

E = ecosand S = steel slag

Fig.2.2 Testing of Cubes and cylinder

Flexural strength

The beam specimens were casted and tested for normal conditions. The size of prism beam specimens is 750 x150 x150mm. These flexural strength specimens were tested under two point loading as per I.S. 516-1959.The flexural strength of beam specimen is checked after 28days by using universal testing machine of the capacity of 2000KN. Fig 2.3 and 2.4 shows the experimental setup and failure pattern of beam specimen. Flexural strength of concrete was calculated by using the following formula given below.

$$f_{cr} = \frac{PL}{BD^2}$$

Fig 2.3 Experimental setup for flexural strength on concrete beam

Fig 2.4 Failure Pattern Of flexural strength of beam Specimen

3. Results and Discussion:

3.1. Compressive Strength Test

The casted cubes have been tested at 7, 14, 28 days and its average compressive strength test results are listed in the Table 3.1. Fig 3.1 shows the comparison of average compressive strength test results for various percentages of steel slag.

It was observed that there was a increase in average compressive strength in specimens with 30% ecosand as fine aggregate replacement material and 40% steel slag as coarse aggregate replacement material when compared with normal concrete specimens of M_{30} grade concrete. There is decrease in the compressive strength at 30% ecosand and 60% steel slag as coarse aggregate.

Table 3.1 Determination of compressive strength

Mix Combination	Designation	7 Days compressive strength (N/mm^2)	14 Days compressive strength (N/mm^2)	28 Days compressive strength (N/mm^2)
Control Mix	M1	23.36	27.75	30.06
Ecosand 30% and Steel slag 0%	M2	30.885	37.55	40.02
Ecosand 30% and Steel slag 20%	M3	33.00	39.00	43.35
Ecosand 30% and Steel slag 40%	M4	35.66	41.00	44.72
Ecosand 30% and Steel slag 60%	M5	33.89	39.88	43.97

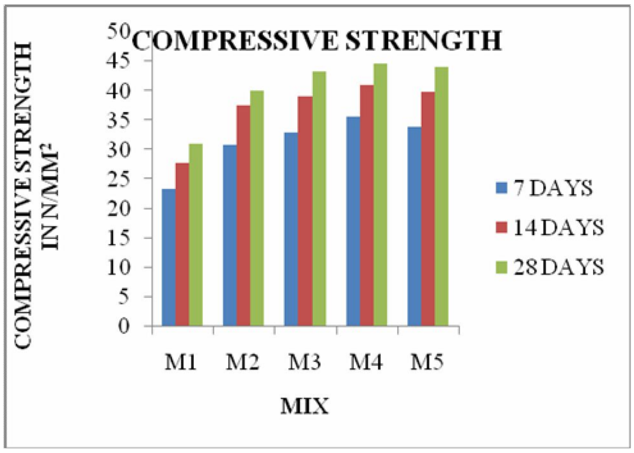


Fig 3.1 Compressive strength at various curing periods

3.2 Split tensile strength test

The spilt tensile test has been carried out for cylinders and the results are tabulated in the Table 3.2 and fig 3.2.

Table 3.2 Determination of Split Tensile Strength

Mix combination	Designation	7 days split tensile strength (N/mm^2)	14 days split tensile strength (N/mm^2)	28 days split tensile strength (N/mm^2)
Control Mix	M1	2.23	2.57	2.82
Ecosand 30% and steel slag 0%	M2	3.075	3.13	3.46
Ecosand 30% and Steel slag 20%	M3	3.21	3.16	3.53
Ecosand 30% and Steel slag 40%	M4	3.26	3.20	3.69
Ecosand 30% and Steel slag 60%	M5	3.41	3.53	3.63

It was observed that there was a increase in average split tensile strength in specimens with 30% ecosand as fine aggregate replacement material and 40% steel slag as coarse aggregate replacement material when compared with normal concrete specimens of M_{30} grade concrete.

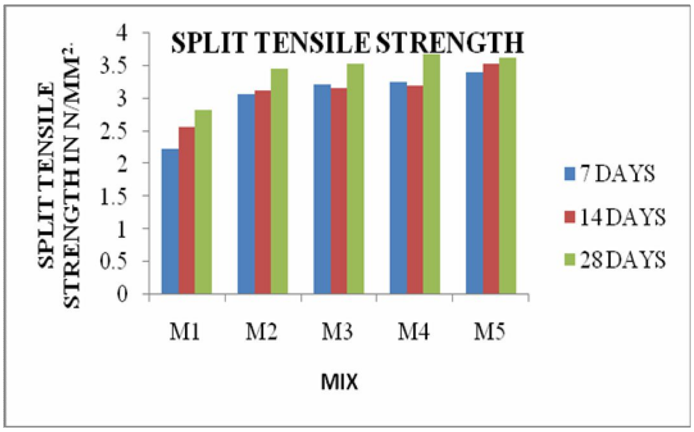


Fig 3.2 Split tensile strength at various curing periods

3.4. Flexural strength test

The flexural strength test for beam with 30% of ecosand and 60% of steel slag has been carried out has been carried out and the results have been tabulated in the Table 3.3. Fig 3.3 shows the load vs deflection behaviour.

Table 3.3 Determination of flexural strength

Mix combination	Designation	Flexural strength at 28 days N/mm^2
Control Mix	M1	5.23
Ecosand 30% and steel slag 0%	M2	4.92
Ecosand 30% and Steel slag 20%	M3	4.98
Ecosand 30% and Steel slag 40%	M4	5.12
Ecosand 30% and Steel slag 60%	M5	4.81

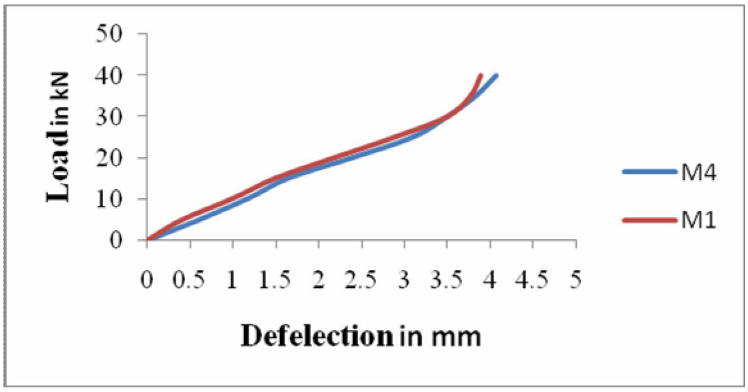


Fig 3.3 Load vs Deflection behaviour

It was observed that there was a increase in flexural strength in specimens with 30% ecosand as fine aggregate replacement material and 40% steel slag as coarse aggregate replacement material when compared with normal concrete specimens of M30 grade concrete.

Conclusions

In this investigation a novel approach of replacement of coarse aggregate with steel slag and fine aggregate with ecosand is promising. This experimental investigation has provided better method for strong and durable concrete. It also gives solution to disposal problem of steel slag and ecosand.

1. The optimum level of replacement of ecosand in fine aggregate is 30%. The increase in strength lesser than 30% is due to of smaller size of ecosand, good compaction and decrease in strength beyond 30% is attributed to water absorption capacity of ecosand.
2. Optimum level of replacement for steel slag is found to be 40 %. The increase in strength initially is attributed to shape effect and decrease in strength beyond 40% is attributed to porosity of steel slag.
3. When these two optimized values were used together it was found that it gave concrete with good strength compared to conventional concrete.

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