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COMPARATIVE EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT USING STEEL SLAG AND M - SAND AS COARSE & FINE AGGREGATE IN CONCRETE

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ABSTRACT: *Experiments were carried out on the physical properties of concrete ingredients and the properties of fresh concrete were observed. Having the mix data a concrete mix with steel slag and M sand (CSM) was designed using absolute volume method. A conventional concrete mix (CC) was designed as per Indian standards for M_{30} grade concrete. The effect of using Steel slag and M sand as aggregates by 100% replacement of conventional crushed granite coarse aggregate and Natural River sand respectively on the properties of concrete were studied. The Investigation of the effect of Partial replacement of coarse aggregate and full replacement fine aggregate by steel slag and M sand respectively on the strength properties of concrete was discussed.*

Keywords: M-sand, Steel Slag, Mix design, Natural River sand, Durability

INTRODUCTION

In India, Supreme Court banned for mining the river sand and becomes very scarce material. Due to non-availability of material, the cost is high. On the other hand, to save the environment the construction industry tries to save the natural raw material and to reduce the energy consumption. In this work an industrial waste like steel slag and processed quarry waste M sand are used in concrete. Use of such materials in concrete making not only helps to conserve natural resources, but also helps to reduce the cost of concrete.

India has an enormous growth in the steel industries and steel slag a byproduct of the same has to be disposed of properly: else they may cause environmental hazards to the surroundings. Steel slag is a byproduct from either the conversion of iron to steel in a basic oxygen furnace (BOF), or the melting of scrap to make steel in an electric arc furnace (EAF). 2-4 tons of wastes are produced during the manufacture of every single tonne of steel. Although a large amount of the wastes from the steel industry are used in other applications, there is still about 35% unused steel slag dumped as waste (Motz,andGeiseler, 2001)

M-sand is crushed aggregates produced from hard granite stone which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute of river sand. The size of manufactured sand (M-Sand) is less than 4.75mm. it has special morphology features such as rough surface, irregular particle shape, angular edges and distinguish characteristics of stone powder contained (XinXin Ding,2016).It is also called as machine made sand, artificial sand or crushed stone sand.

As there is a serious shortage of river sand M sand become the green and economical substitute for river sand in concrete making. In the manufactured sand fabrication process fine particles are inevitably generated. Usually those particles that are smaller 75 µm are called stone dust or stone powder. A certain content stone dust is allowed to exist in M sands, but the limits are different under various standards, and the maximum is 10%. However the actual content of stone dust in manufacturing process always exceeds the required value under standards. The excess dust needs to be washed out before use (J.Wang, 2008).

The study of the effects of granite dust on concrete performance focuses on two aspects. One is the cement replacement and the other is the fine aggregate replacement. Recently research works have been focused on

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usage of M sand for replacing natural sand in concrete. This work aims mainly to study the mechanical characteristics of the concrete with steel slag as coarse aggregate replacement and M sand as fine aggregate replacement. Designing the conventional concrete for M_{30} grade and Steel slag concrete the properties of both concretes is observed by conducting compressive strength test; Flexural strength, modulus elasticity for concrete and the results are compared.

MATERIALS AND METHODS

This aims mainly to study the mechanical characteristics of the concrete with Steel slag as coarse aggregate replacement and M sand as fine aggregate replacement. Designing the conventional concrete for M_{30} grade and Steel slag concrete the properties of both concretes is observed by conducting compressive strength test, Flexural strength, modulus elasticity for concrete.

FLOW CHART

The methodology adopted for carrying the work is done in two phases. The list of works in each phase are given in the flow chart as below

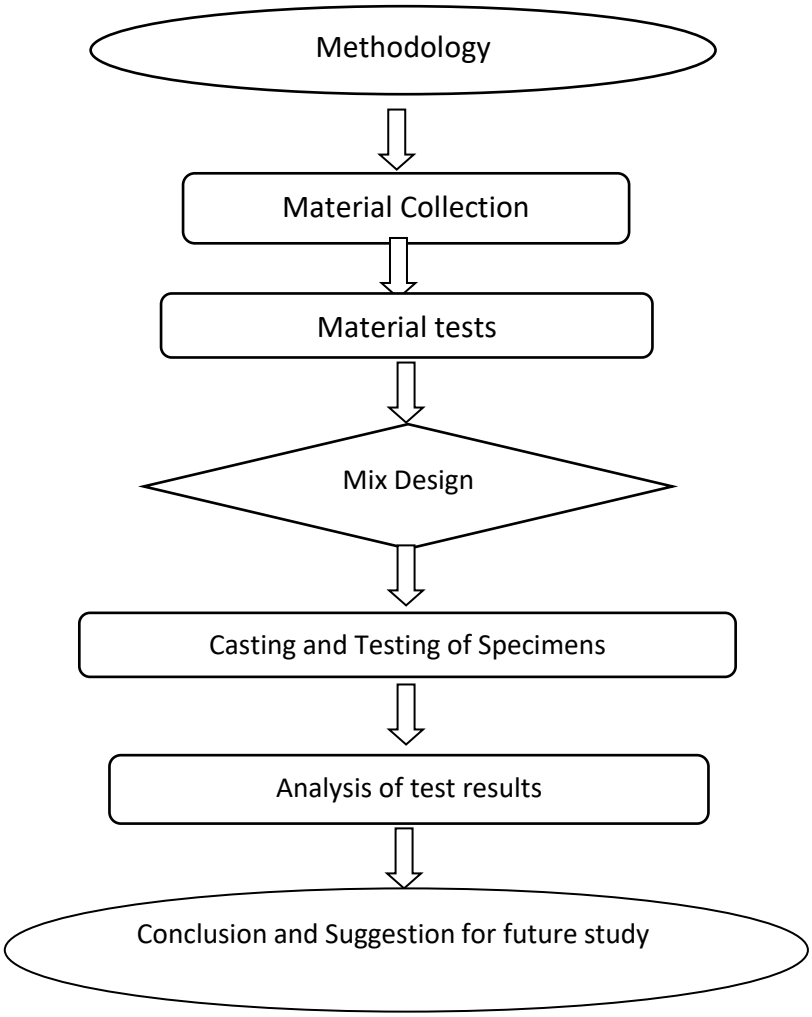

Fig. 1 Flow chart for methodology

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EXPERIMENTAL PROGRAMME

MATERIAL PROPERTIES

Cement

The cement used in this experiment is OPC-43 grade. The specific gravity of cement is 3.13.

River Sand

The sand used in this study was locally available river sand and passing through 4.75mm IS sieve. The specific gravity of fine aggregate was 2.62.

M sand

M sand obtained from Private mineral quarry, Tindivanam, Tamilnadu was used in this study. The specific gravity and fineness modulus of M Sand were 2.66 and 2.76 confirming Zone II.

Crushed Granite Aggregate

Crushed blue granite stone conforming to IS: 383-1970. Coarse aggregates of size 20mm and below having specific gravity and finess modulus 2.70 and 7.30 was used.

Steel Slag Aggregate

Fig. 2 Steel slag Aggregate

Steel slag used in this study was obtained from KISCON Steel industries, Karaikal. The specific gravity and fineness modulus of the steel slag is 2.15 and 7.22. (Fig. 2). The chemical composition of steel slag supplied by the company is tabulated below. In this experiment light weight steel slag was used.

TESTING OF MATERIALS

Specific Gravity

The specific gravity of cement, fine aggregate, coarse aggregate and fly ash are determined as per IS: 2386 (part 3) 1963 and the test results are shown in below.

Table.1 Specific Gravity Test Results

Sl. No.	Material Used	Specific Gravity	Fineness Modulus
1	Cement	3.13	-
2	River Sand	2.62	3.13
3	M sand	2.66	2.76
4	Coarse Aggregate	2.70	7.30
5	Steel slag	2.15	7.22

Fineness Modulus

Fineness modulus of fine and coarse aggregate was determined as per IS: 383-1970 and given the Table 1. Sieve analysis results for fine aggregate confirmed that the zone III.

Water Absorption Test

The Water absorption of coarse aggregates are determined as per IS: 2386 (part 3) 1963 and the test results are shown in Table

Table .2 Water absorption Test Results

Sl. No.	Material Used	Water Absorption	Impact	Density
1	Coarse Aggregate	1.03 %	20.54	1520
2	Steel slag	1.31 %	17.20	1480

Impact Value

The Impact value of coarse aggregates are determined as per IS: 2386 (part IV) 1963 and the test results are shown in Table

Table .3 Chemical composition of Steel slag (supplied by the Steel manufacturer)

S.No.	Constituent		Percentage
1	Aluminum Oxide	Al_2O_3	1-3
2	Calcium Oxide	CaO	40-52
3	Iron oxide	FeO	10-14
4	Magnesium oxide	MgO	5-10
5	Magnesium oxide	MnO	5-8
6	Phosphorus oxide	P_2O_3	0.5-1
7	Silica	SiO_2	30-35

SLUMP TEST

The slump test is a means of assessing the workability of fresh concrete. It is used indirectly as a means of checking that the correct amount of water has been added to the mix. From several trials the slump value was 12mm for Slag concrete with water/cement ratio of 0.56. The slump for conventional concrete was 25mm with water/cement ratio of 0.50.

Mix Proportion of concrete

Table.4 Mix Proportions for Conventional Concrete M30- per m^3 of Concrete

Material	By Weight (kg/m^3)	By volume
Cement	427	0.136
Fine aggregate	634	0.242
Coarse aggregate	1161	0.430
Water	192	0.192

Mix Ratio = 1:1.485:2.719:0.45

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Casting of Specimen

Table.5 Specimens Cast

Name of Test	7 days Curing		28 days Curing		Total no. of Specimen
	CC	Slag Concrete	CC	Slag Concrete	
Compression Strength Test (100mm cube)	3	15	3	15	36
Modulus of Elasticity (150mm × 300mm Cylinder)	-	-	3	15	18
Flexural Test (100×100×500mm Prism)	-	-	3	15	18

TESTING OF SPECIMEN

Compression Test

Specimens were prepared and cured as per IS 516 (1959). They were cast in steel moulds and underwent double compaction on vibrating table. After 24 hours the specimens were demoulded and water-cured in the laboratory till the age of 28 days. The compressive strength tests were conducted on 150mm x 150 mm x 150mm size cube specimens after 7 and 28 days of hardening.

Fig. 3 Compression test

Fig. 4 E for concrete

Table .6 Compression Test on 7 days

S.No.	Concrete mix	Compression strength (N/mm^2)
1	Steel slag 0%	19.18
2	Steel slag 20 %	20.35
3	**Steel slag 40 %**	**23.23**
4	Steel slag 60 %	20.81
5	Steel slag 80 %	19.12
6	Steel slag 100 %	18.91

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In 7 days compression test on concrete cube made with Conventional and Varies combination of steel slag aggregate 0% to 100% the optimum value of compression strength obtains from slag aggregate 40% and Metal 60%

Table.7 Compression Test on 28 days

S.No.	Concrete mix	Compression strength (N/mm^2)
1	Steel slag 0%	32.16
2	Steel slag 20%	34.14
3	**Steel slag 40%**	**38.79**
4	Steel slag 60%	34.11
5	Steel slag 80%	31.82
6	Steel slag 100%	29.81

MODULUS OF ELASTICITY

The strains at the various loads in the last two cycles shall be calculated separately for each extensometer and the results shall be plotted graphically against the stress. Straight lines shall be drawn through the points for each extensometer; the slopes of these two lines shall be determined and from them the average value shall be found. If the difference between the individual values is less than 15 percent of the average value, this average value, expressed in kg/sq.cm to the nearest 1000 kg/sq cm shall be recorded as the modulus of elasticity of the concrete. If the difference is greater than 15 per cent, the specimen shall be re-centered in the testing machine and the test repeated. If the difference after re-centering and testing is still greater than 15 percent of the average value, the results of the test shall be discarded.

Table.8 E for Concrete on 28 days

S.No.	Concrete mix	Modulus of Elasticity ($10^4 N/mm^2$)
1	Steel slag 0%	2.73
2	Steel slag 20%	2.92
3	**Steel slag 40%**	**3.11**
4	Steel slag 60%	2.91
5	Steel slag 80%	2.82
6	Steel slag 100%	2.72

FLEXURAL STRENGTH TEST

Flexural strength test is done as per IS: 516 – 1959. Prisms are tested for flexure in universal testing machine. The bearing surfaces of the supporting and loading rollers are wiped clean before loading. The prism is placed in the machine in such a manner that the load is applied to uppermost surface along the two lines spaced 13.3 cm apart**.** The axis of the specimen is aligned with the axis of the loading device. The specimen is loaded till it fails and the maximum load (p) applied to the specimen during test is noted after fraction the distance (a) between the crack and nearest support is measured. The flexural strength of the specimen is expressed as the modulus of rupture.

$f_b = \frac{PxL}{bxd^2}$ when a is greater than 13.3 cm or

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$f_b = \frac{3Pxa}{bxd^2}$ when a is in between 11.0 cm and 13.3 cm

Where,

a = the distance between the line of fracture and the nearest support

b = measured breath in cm of the specimen

d = measured depth in cm of the specimen was supported, and

P = maximum load in kg applied on the specimen

L = support to support length

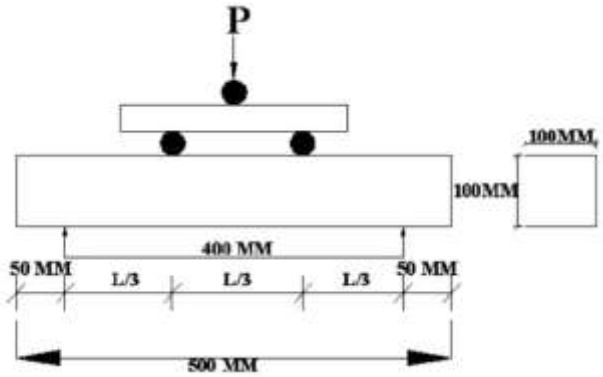

Fig. 4 Flexural Strength Test load setup

Table .9 Flexural Strength Test result on concrete Prism on 28 days

S.No.	Concrete mix	Flexural Strength (N/mm^2)
1	Steel slag 0%	3.81
2	Steel slag 20%	4.09
3	Steel slag 40%	4.32
4	Steel slag 60%	4.08
5	Steel slag 80%	3.91
6	Steel slag 100%	3.79

Fig. 6 Flexural strength test

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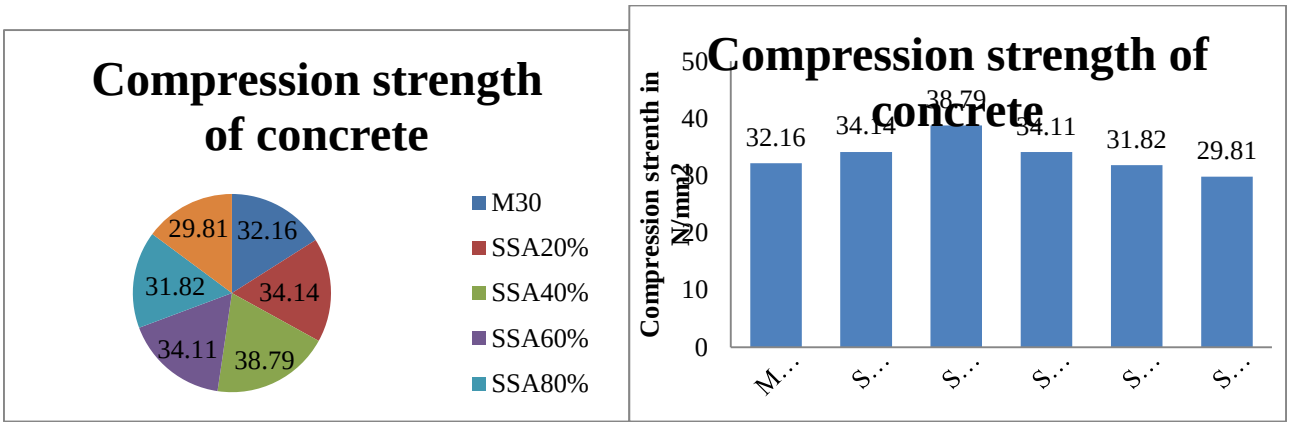

Fig .7 Pie &bar chart of compression test

RESULTS AND DISCUSSIONS

In this test results the following scientific analyse are arrived

- The comparison with conventional M30 Grade concrete with the mix of 20% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the compression strength was increased upto 9%
- The comparison with conventional M30 Grade concrete with the mix of 40% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the compression strength was increased upto 21%
- The comparison with conventional M30 Grade concrete with the mix of 60% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the compression strength was increased upto 6%
- The comparison with conventional M30 Grade concrete with the mix of 80% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the compression strength was slightly decrease to 1%.
- The comparison with conventional M30 Grade concrete with the mix of 100% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the compression strength was decrease to 7%
- Over all the compression test on 150mm cube result shown in pie chart (Fig 8.1) and Bar chart(Fig 8.2) the steel slag 40% replacement of coarse aggregate and M sand 100% replacement the Compression strength was increase upto 21% compare with Conventional M 30 grade concrete.

FLEXUERAL STRENGTH TEST

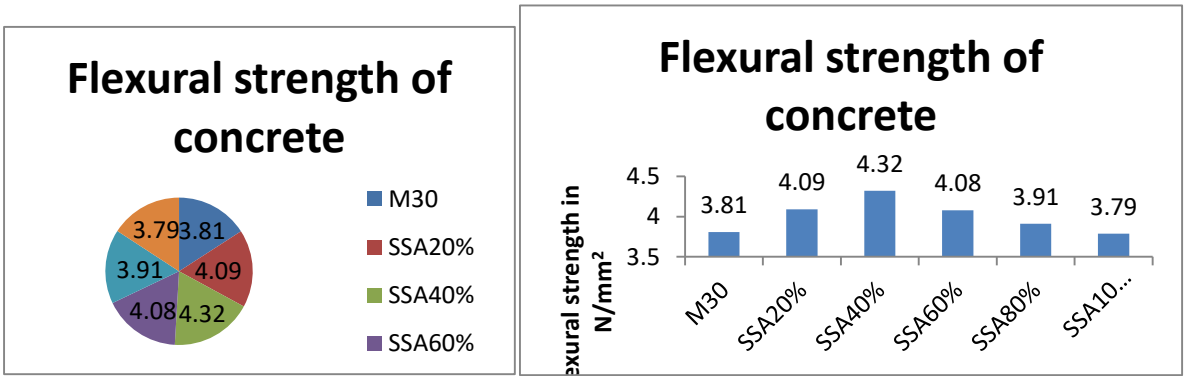

Fig .8 Pie &bar chart of flexural strength test

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In flexural strength test the following analyze has been arrived

- The comparison with conventional M30 Grade concrete with the mix of 20% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the flexural strength was increased upto 7%
- The comparison with conventional M30 Grade concrete with the mix of 40% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the flexural strength was increased upto 13%
- The comparison with conventional M30 Grade concrete with the mix of 60% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the flexural strength was increased upto 7%
- The comparison with conventional M30 Grade concrete with the mix of 20% Partial Replacement of coarse aggregate with steel slag aggregate and 80% replacement fine aggregate with M sand the result shows in Pie chart the flexural strength was slightly increased to 2%
- The comparison with conventional M30 Grade concrete with the mix of 100% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the flexural strength was equal to M30 concrete.

MODULUS OF ELASTICITY (E)

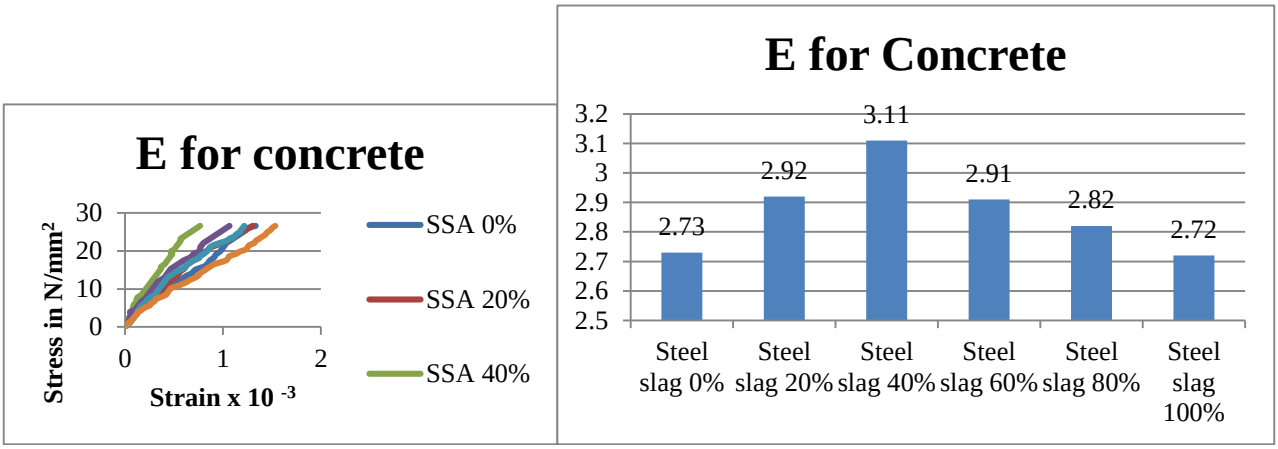

Fig.9 Pie& bar chart E f value

- The comparison with conventional M30 Grade concrete with the mix of 20% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the E value was increased upto 7%
- The comparison with conventional M30 Grade concrete with the mix of 40% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the E value was increased upto 14%
- The comparison with conventional M30 Grade concrete with the mix of 60% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the E value was increased upto 6.5%
- The comparison with conventional M30 Grade concrete with the mix of 80% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the E value was slightly increased upto 3%
- The comparison with conventional M30 Grade concrete with the mix of 100% Partial Replacement of coarse aggregate with steel slag aggregate and 100% replacement fine aggregate with M sand the result shows in Pie chart the E value equal to conventional M30 concrete

Discussions

- For M30 Grade conventional mix concrete Compression strength is 32.16 N/mm^2 , Flexural strength is 3.81 N/mm^2, E for concrete value is 2.73x10^5 N/mm^2 and Durability properties Water absorption percentage 1.60%, Acid attack test compression strength is 29.75 N/mm^2, RCPT test chloride penetration is 819 coulombs are obtained
- For Steel slag 20% replacement and M Sand 100% mix concrete Compression strength is 34.14 N/mm^2 , Flexural strength is 4.09 N/mm^2, E for concrete value is 2.92x10^5 N/mm^2 and Durability properties Water absorption percentage 1.75%, Acid attack test compression strength is 31.58 N/mm^2, RCPT test chloride penetration is 984 coulombs are obtained
- For Steel slag 40% replacement and M Sand 100% mix concrete Compression strength is 38.79 N/mm^2 , Flexural strength is 4.32 N/mm^2, E for concrete value is 3.11x10^5 N/mm^2 and Durability properties Water absorption percentage 1.86%, Acid attack test compression strength is 35.88 N/mm^2, RCPT test chloride penetration is 1247 coulombs are obtained
- For Steel slag 60% replacement and M Sand 100% mix concrete Compression strength is 34.11 N/mm^2 , Flexural strength is 4.08 N/mm^2, E for concrete value is 2.91 x10^5 N/mm^2 and Durability properties Water absorption percentage 1.96%, Acid attack test compression strength is 31.55 N/mm^2, RCPT test chloride penetration is 1150 coulombs are obtained
- For Steel slag 80% replacement and M Sand 100% mix concrete Compression strength is 31.82 N/mm^2 , Flexural strength is 3.91 N/mm^2, E for concrete value is 2.82 x10^5 N/mm^2 and Durability properties Water absorption percentage 2.06%, Acid attack test compression strength is 29.44 N/mm^2, RCPT test chloride penetration is 1317 coulombs are obtained
- For Steel slag 100% replacement and M Sand 100% mix concrete Compression strength is 29.81 N/mm^2 , Flexural strength is 3.79 N/mm^2, E for concrete value is 2.72 x10^5 N/mm^2 and Durability properties Water absorption percentage 2.19 %, Acid attack test compression strength is 27.58 N/mm^2, RCPT test chloride penetration is 1419 coulombs are obtained

CONCLUSION

With reference to the experimental program carried out the following conclusions are arrived.

- The properties of concrete using steel aggregate in various combination the best result obtain from slag aggregate 40% and blue metal 60% for 28 days compression test the strength increased by 21% extra compared with conventional concrete.
- The flexural strength of steel slag concrete at slag aggregate 40% and blue metal 60%. increased by 13% extra compared with conventional concrete.
- E value for steel slag concrete with the Steel slag 40% and Blue metal 60% got 14% more value than the conventional concrete.
- The durability characteristic properties of slag aggregate concrete is lower compare with conventional concrete but by results, the Slag aggregate concrete may be used in construction.

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