Study on Properties of Concrete using Robosand as Fine Aggregate

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Abstract

Concrete is widely used material in the world. Based on global usage it is placed at second position after water. Natural river sand which is one of the constituents used in the production of conventional concrete has become highly expensive and also scarce. Sand is basic concrete making construction material required in large quantities. Robosand is one among such materials to replace river sand, which can be used as an alternative fine aggregate in mortars and concrete. In this present research work, M20 and M30 grades of concrete are used as reference mixes. The fine aggregate (natural sand) was replaced with percentages 0% (for conventional concrete mixture), 20%, 40%, 60%, 80% and 100% of robosand by weight and tests were conducted on the properties of fresh and hardened concrete. Slump-cone test, Compaction factor test and Vee-Bee Consistometer tests were performed to evaluate the workability characteristics of fresh Concrete. Compressive strength, Flexural strength and Split tensile strength were determined at the age of 7, 28, 56 and 91 days respectively. The results indicate that workability decreases with increase in robosand percentage which is due to the high water absorption capacity of robosand. The compressive strength is observed to be increasing up to 60% replacement of robosand and then decreased. Similar correlation was observed in both split tensile strength and flexural strength.

Keywords: Robosand, Natural Sand, Concrete, Mortar, Replacement, Compressive Strength, Split Tensile Strength, Flexural Strength

I. INTRODUCTION

Concrete is the most widely used construction material in the world. In concrete aggregates are considered as one of the main constituents of concrete since they occupy 70-80 percent of the volume of concrete matrix. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provides an alternative for the construction industry. Robosand is the best alternative material for the replacement of fine aggregate in concrete mix

A. Objectives of present work

The objective of the study is to conduct feasibility study producing Concrete using robosand.

- To design and proportioning the concrete mix for M20 and M30 grades of concrete as per IS 10262:2009.
- To study the properties of concrete in fresh and hardened state.
- To evaluate the workability characteristics in terms of slump, compaction factor, and Vee-Bee time for M20 and M30 grades of concrete by replacing the fine aggregates with robosand by percentages of weight i.e., (0%, 20%, 40%, 60%, 80%, 100%).
- To evaluate percentage increase in compressive strength, flexural strength and split tensile strength, for M20 and M30 grades of concrete with robosand.

II. MATERIALS

Ordinary Portland cement of 43 grade is used confirming to IS: 8112-1989. Crushed granite metal (graded) with 20 mm to a proportion of 60% and 10 mm to a proportion of 40% is used as coarse aggregate which is tested according to IS: 2386-1963 Part 1 to VIII. River sand according to IS: 383-1970confirming to zone – II is used as fine aggregate. Robosand confirming to Zone – II as per IS: 383-1970 is used. Fosrocconplast SP 430 is used as admixture.

Table - 1
Properties of Coarse aggregate

S. No	*Property*	*Value*
1.	*Specific gravity*	*2.84*
2.	*Bulk Density:* *Loose state* *Compacted state*	 *1551.02 kg/m^3* *1692.11 kg/m^3*
3.	*Water Absorption*	*0.90%*
4.	*Flakiness Index*	*14.13%*
5.	*Elongation Index*	*21.29%*
6.	*Crushing value*	*21.33%*
7.	*Impact Value*	*15.40%*
8.	*Fineness Modulus*	*7.31*

Table - 2
Properties of Fine aggregate (River sand)

S.NO	*PROPERTY*	*VALUE*
1	*Grading of sand*	*Zone II as per IS383*
2	*Specific gravity*	*2.61*
3	*Bulk density* *i) Loose state* *ii) Compacted state*	 *1608.65 kg/m^3* *1708.06 kg/m^3*
4	*Fineness modulus*	*2.48*
5	*Silt content*	*1%*
6	*Surface moisture*	*0.7%*

Table - 3
Properties of cement

S. No	*Property*	*Value*
1.	*Specific gravity*	*3.15*
2.	*Fineness of cement*	*3.5%*
3.	*Normal consistency*	*30%*
4	*Setting Time*	*30%*
	Initial Setting time	*167 min*
	Final setting time	*295 min*
5.	*Compressive Strength 3days*	*24.7 N/mm^2*
	7days	*35.63 N-mm^2*
	28 days	*45.94 N/mm^2*

Table - 4
Properties of Fine aggregate (Robosand)

S.NO	*PROPERTY*	*VALUE*
1	*Grading of robosand*	*Zone II as per IS383*
2	*Specific gravity*	*2.69*
3	*Bulk density* *i) Loose state* *ii) Compacted state*	 *1658 kg/m^3* *1796 kg/m^3*
4	*Fineness modulus*	*3.18*
5	*Silt content*	*Absent*
6	*Surface moisture*	*0.9%*
7	*Water absorption*	*2.27%*

III. MIX DESIGN

The mix design is done according to IS: 10262-2009. The mix proportions adopted for M20 grade concrete is 1:2.248: 4.124 with water/cement ratio of 0.48 and cement content of 320 kg. For M30 grade concrete the adopted mix Proportion is 1:1.673:3.127 with water/cement ratio of 0.44 and cement content of 400 kg. A total of 6 mixes for each grade is adopted i.e for M20 grade concrete, 0%, 20%, 40%, 60%, 80% and 100% replacement of robosand with river sand and for M30 grade concrete, 0%, 20%, 40%, 60%, 80% and 100% replacement of robosand with river sand was used.

IV. RESULTS AND DISCUSSIONS

A. Workability in Terms of Slump

Slump study is conducted with and without admixture. It can be observed that as the percentage of the replacement of fine aggregate with robosand increases the slump is decreasing as the water absorption capacity of robosand is more compared to river sand hence the workability also decreases.

Table - 5
Variation of slump for M20 grade concrete with different replacement percentages of Fine aggregate by robosand with and without admixture

Grade of concrete	*M20*					
% Replacement of Robosand	*RS-0%*	*RS-20%*	*RS-40%*	*RS-60%*	*RS-80%*	*RS-100%*
Slump without admixture (mm)	*27*	*25*	*21*	*17*	*14*	*10*
Slump with admixture (mm)	*54*	*49*	*44*	*36*	*31*	*28*
Admixture %	*0.2*	*0.35*	*0.5*	*0.6*	*0.65*	*0.7*

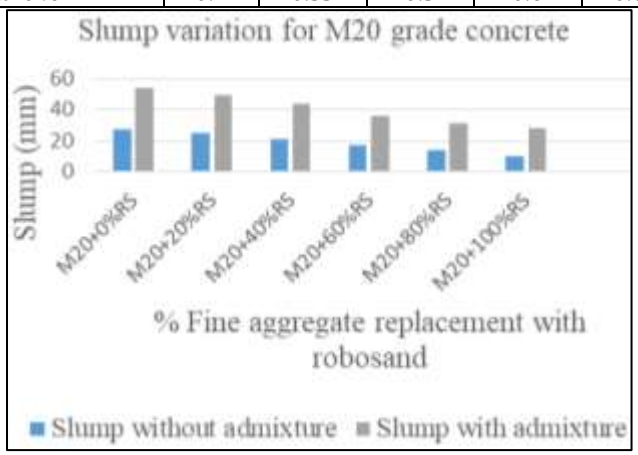

Fig. 1: Variation of slump with and without admixture for M20 grade concrete with different replacement percentages of fine aggregate by robosand

Table - 6
Variation of slump for M30 grade concrete with different replacement percentages of fine aggregate by robosand with and without admixture

Grade of concrete	*M30*					
% Replacement of Robosand	*RS-0%*	*RS-20%*	*RS-40%*	*RS-60%*	*RS-80%*	*RS-100%*
Slump without admixture (mm)	*26*	*22*	*18*	*14*	*12*	*10*
Slump with admixture (mm)	*52*	*47*	*41*	*37*	*32*	*27*
Admixture %	*0.3*	*0.4*	*0.55*	*0.6*	*0.65*	*0.75*

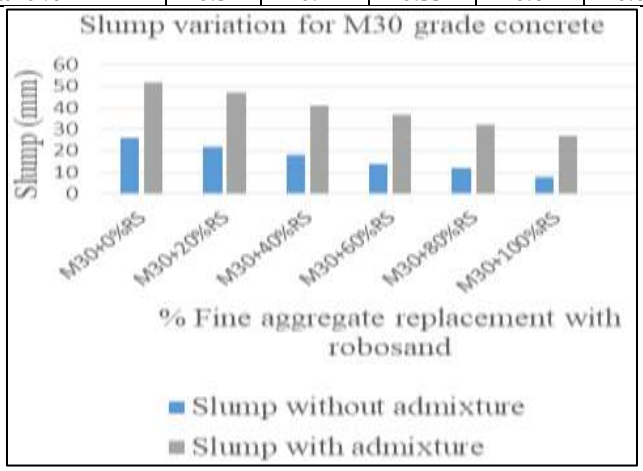

Fig. 2: Variation of slump with and without admixture for M30 grade concrete with different replacement percentages of fine aggregates by robosand

B. Workability in terms of Compaction Factor

It can be observed that as the percentage of the replacement of fine aggregate with robosand increases the compaction factor decreases. Hence it can be concluded that as % of robosand increases the workability decreases this is due to the fact that robosand has more water absorption capacity compared to natural sand.

Table - 7
Variation of Compaction factor for M20 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

Grade of Concrete	*M20*					
% Replacement of Robosand	*RS-0%*	*RS-20%*	*RS-40%*	*RS-60%*	*RS-80%*	*RS-100%*
Compaction Factor	*0.8 4*	*0.83*	*0.82*	*0.81*	*0.8*	*0.79*

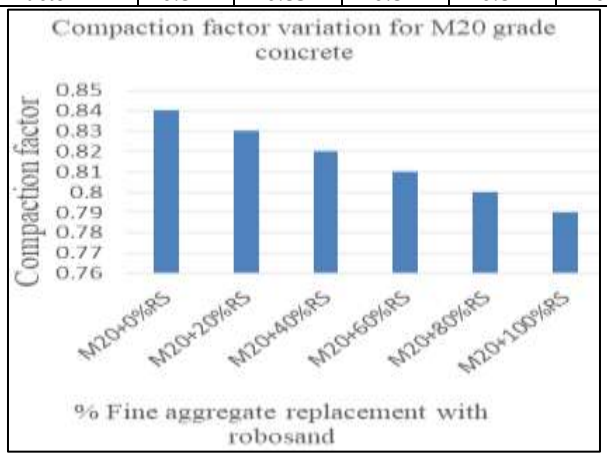

Fig. 3: Variation of compaction factor for M20 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

Table - 8
Variation of Compaction factor for M30 grade concrete with different replacement Percentages of fine aggregate by robosand with admixture

Grade of Concrete	*M30*					
% Replacement of Robosand	*RS-0%*	*RS-20%*	*RS-40%*	*RS-60%*	*RS-80%*	*RS-100%*
Compaction Factor	*0.84*	*0.83*	*0.82*	*0.81*	*0.8*	*0.79*

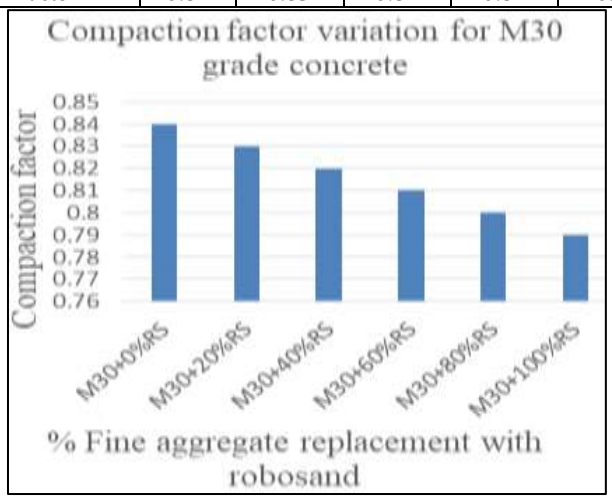

Fig. 4: Variation of compaction factor for M30 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

C. *Workability in terms of Vee-Bee time*

It can be observed that as the percentage of the replacement of fine aggregate with robosand increases the vee-bee time increases. Hence it can be concluded that as % of robosand increases the workability decreases this is due to the fact that robosand has more water absorption capacity compared to natural sand.

Table - 9
Variation of Vee-Bee time for M20 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

Grade of Concrete	*M20*					
% Replacement of Robosand	*RS-0%*	*RS-20%*	*RS-40%*	*RS-60%*	*RS-80%*	*RS-100 %*
Vee-Bee time (sec)	*10*	*12.6*	*13.4*	*14.7*	*15.4*	*17.3*

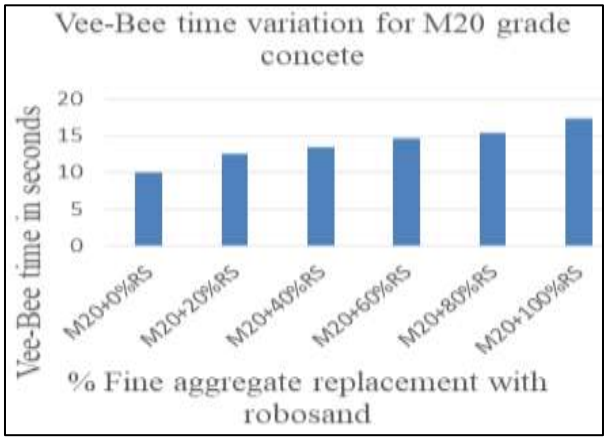

Fig. 5: Variation of Vee-Bee time for M20 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

Table - 10

Variation of Vee-Bee time for M30 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

Grade of Concrete	*M30*					
% Replacement of Robosand	*RS-0%*	*RS-20%*	*RS-40%*	*RS-60%*	*RS-80%*	*RS 100%*
Vee-Bee time (sec)	*10.2*	*13.6*	*15.7*	*16.4*	*17.2*	*18*

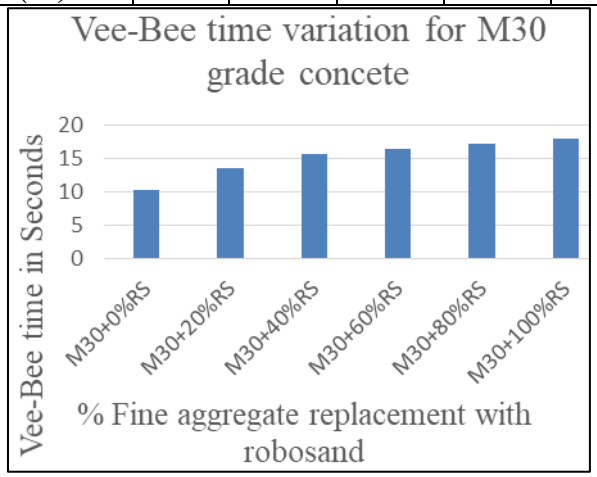

Fig. 6: Variation of Vee-Bee time for M30 grade concrete with different replacement percentages of fine aggregate by robosand with admixture

D. Effect of addition of robosand for M20 Mix

The compressive strength, split tensile strength and flexural strength of M20 grade concrete is determined by conducting the tests on cubes of size 150X150X150 mm, cylinders of 100mm diameter and 300mm length, prisms of 100X100X500 mm. The tests were conducted according to IS: 516- 1959 for compressive strength test and flexural strength test and flexural strength test was conducted according to IS: 5816-1999. The compressive strength, split tensile strength and flexural strength are increasing from 0%,20%,40%,60% replacement of fine aggregate with robosand and then they are decreasing from 80% and 100% replacement of fine aggregate with robosand For M20 grade concrete the compressive strength at 28 days is of order 0%, 5.74%, 12.52%, 20%, 16.21%, 11.69%, the split tensile strength at 28 days is of order 0%, 7.44%, 16.66%, 19.85%, 13.47%, 11.34% and the flexural strength at 28 days is of order 0%, 6.48%, 9.16%, 13.93%, 10.87%, 8.25% for 0%, 20%, 40%, 60%, 80% and 100% replacement of robosand.

Table – 11

Strength characteristics of M20 grade concrete with different proportions of robosand

Test at the age (days)	*RS-0% (MPa)*	*RS-20% (MPa)*	*RS-40% (MPa)*	*RS-60% (MPa)*	*RS-80% (MPa)*	*RS-100% (MPa)*
	Compressive Strength					
7	*19.07*	*21.17*	*23.51*	*25.46*	*24.43*	*23.47*
28	*28.74*	*30.39*	*32.34*	*34.49*	*33.40*	*32.10*
56	*31.21*	*33.65*	*36.02*	*38.14*	*37.21*	*36.37*
91	*32.06*	*34.52*	*37.38*	*39.91*	*38.10*	*37.43*
	Split Tensile Strength					
7	*2.12*	*2.41*	*2.77*	*2.84*	*2.72*	*2.68*
28	*2.82*	*3.03*	*3.29*	*3.38*	*3.20*	*3.14*
56	*2.98*	*3.17*	*3.31*	*3.46*	*3.32*	*3.26*

91	*3.03*	*3.24*	*3.40*	*3.52*	*3.46*	*3.37*
	Flexural Strength					
7	*4.12*	*4.67*	*4.96*	*5.28*	*5.10*	*4.98*
28	*5.46*	*5.58*	*5.72*	*5.97*	*5.81*	*5.64*
56	*5.73*	*5.98*	*6.32*	*6.41*	*6.10*	*5.94*
91	*5.86*	*6.12*	*6.40*	*6.47*	*6.31*	*6.27*

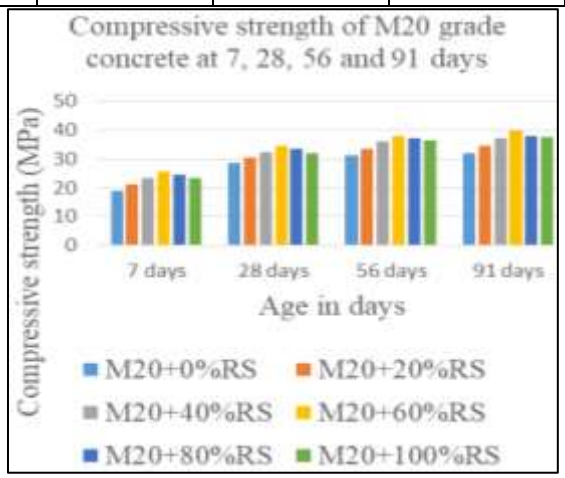

Fig. 7: Variation of compressive strength for M20 grade concrete at 7, 28, 56 and 91 days age with different replacement percentage of fine aggregate by robosand

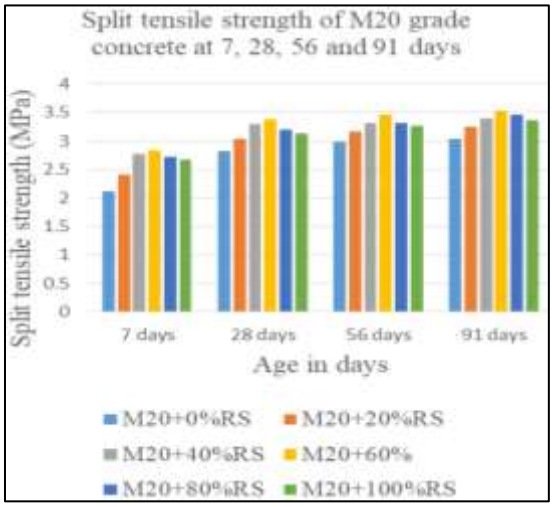

Fig. 8: Variation of split tensile strength for M20 grade concrete at 7, 28, 56 and 91 days age with different replacement percentages of fine aggregate by robosand

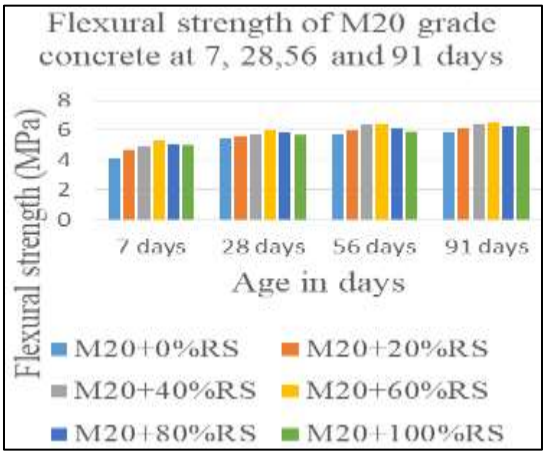

Fig. 9: Variation of flexural strength for M20 grade concrete at 7, 28, 56 and 91 days age with different replacement percentages of fine aggregate by robosand

E. Effect of addition of robosand for M30 Mix

The compressive strength, split tensile strength and flexural strength are increasing from 0% to 60% and decreasing from 80% to 100% replacement of robosand. For M30 grade concrete the compressive strength is of order 0%, 8.2%, 17.21%, 24.8%, 20.69%, 17.98%, the split tensile strength is of order 0%, 8.52%, 19.36%, 24.44%, 21.90%, 17.97% and the flexural strength is of order 0%, 6.48%, 9.16%, 13.93%, 10.87%, 8.25% for 0%, 20%, 40%, 60%, 80% and 100% replacement of robosand.

Table – 12
Strength characteristics of M30 grade concrete with different proportions of robosand

Test at the age (days)	*RS-0% (MPa)*	*RS-20% (MPa)*	*RS-40% (MPa)*	*RS-60% (MPa)*	*RS-80% (MPa)*	*RS-100% (MPa)*
	Compressive Strength					
7	*27.04*	*28.73*	*30.86*	*33.24*	*31.62*	*30.78*
28	*40.15*	*43.45*	*47.06*	*50.11*	*48.46*	*47.37*
56	*43.35*	*45.87*	*48.65*	*51.61*	*49.92*	*48.27*
91	*43.90*	*46.24*	*48.92*	*52.15*	*51.04*	*49.10*
	Split Tensile Strength					
7	*2.16*	*2.75*	*3.19*	*3.27*	*3.18*	*3.07*
28	*3.15*	*3.42*	*3.76*	*3.92*	*3.84*	*3.71*
56	*3.34*	*3.83*	*3.98*	*4.17*	*3.94*	*3.90*
91	*3.41*	*3.90*	*4.04*	*4.28*	*4.13*	*4.06*
	Flexural Strength					
7	*5.25*	*5.55*	*5.76*	*5.89*	*5.72*	*5.64*
28	*6.13*	*6.46*	*6.79*	*7.19*	*7.02*	*6.93*
56	*6.48*	*6.98*	*7.33*	*7.47*	*7.31*	*7.29*
91	*6.76*	*7.11*	*7.48*	*7.65*	*7.43*	*7.34*

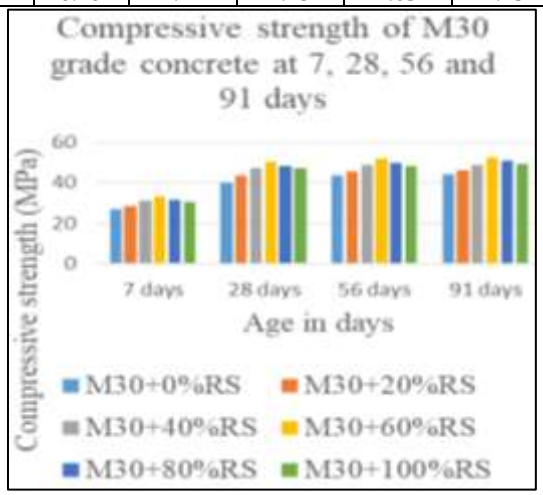

Fig. 10: Variation of compressive strength for M30 grade concrete at 7, 28, 56 and 91 days age with different replacement percentages of fine aggregate by robosand

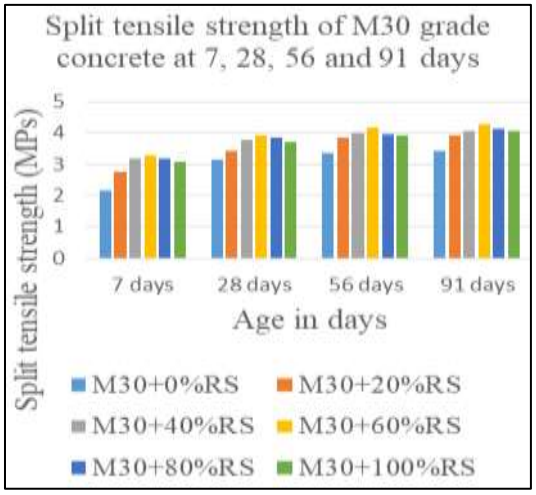

Fig. 11: Variation of split tensile strength for M30 grade concrete at 7, 28, 56 and 91 days age with different replacement percentages of fine aggregate by robosand

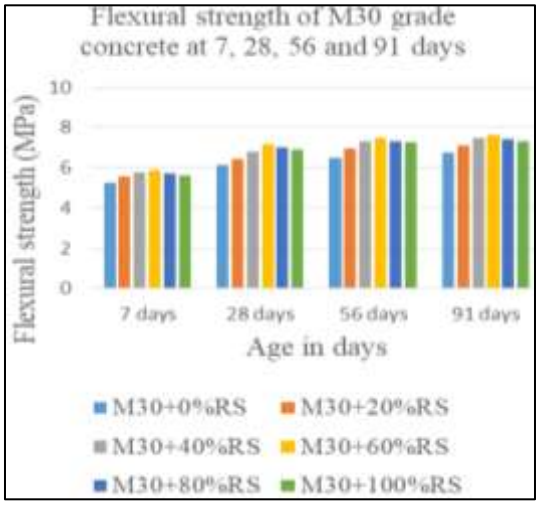

Fig. 12: Variation of flexural strength for M30 grade concrete at 7, 28, 56 and 91 days age with different replacement percentages of fine aggregate by robosand

V. CONCLUSIONS

Results were analyzed to derive useful conclusions regarding the workability, strength characteristics of concrete with replacement of natural sand with robosand in different proportions for M20 and M30 grade concrete. The following conclusions were drawn from the study

- The robosand can be used as a best alternative material for partial replacement of natural sand as fine aggregate and gives more compressive strength in order of 5.74% to 20% for M20 grade concrete and 8.2% to 24.8% for M30 grade concrete than conventional concrete.
- The slump values of concrete with robosand were observed to be relatively less when compared to conventional concrete. As robosand had more water absorption capacity compared to the river sand. Therefore, workability of concrete decreases significantly with the increase of robosand percentage in concrete.
- As the percentage of replacement of robosand increases slump and compaction factor decreases which shows decrease in workability.
- The slump in terms of vee-bee time increases with increase in percentage replacement of robosand
- It is observed that 60% replacement of natural sand by robosand is giving better compressive strength, for M20 and M30 grade concrete compared to other proportions of mixes.
- It is observed that 60% replacement of natural sand by robosand is giving better split tensile strength, for M20 and M30 grade concrete compared to other proportions of mixes.
- It is observed that 60% replacement of natural sand by robosand is giving better flexural strength, for M20 and M30 grade concrete compared to other proportions of mixes.
- The increase in compressive strength for M20 grade concrete is of order 0%, 5.74%, 12.52%, 20%, 16.21%, 11.69% for 0%, 20%, 40%, 60%, 80%, 100% replacement of robosand and for M30 grade concrete is of order 0%, 8.2%, 17.21%, 24.8%, 20.69%, 17.98% for 0%, 20%, 40%, 60%, 80%, 100% replacement of robosand.
- The increase in split tensile strength for M20 grade concrete is of order 0%, 7.44%,
- 16.66%, 19.85%, 13.47%, 11.34% for 0%, 20%, 40%, 60%, 80%, 100% replacement of robosand and for M30 grade concrete is of order 0%, 8.52%, 19.36%, 24.44%, 21.90%, 17.77% for 0%, 20%, 40%, 60%, 80%, 100% replacement of robosand.
- The increase in flexural strength for M20 grade concrete is of order 0%, 6.48%, 9.16%, 13.93%, 10.87%, 8.25% for 0%, 20%, 40%, 60%, 80%, 100% replacement of robosand and for M30 grade concrete is of order 0%, 5.38%, 10.76%, 17.29%, 14.51%, 13.05% for 0%, 20%, 40%, 60%, 80%, 100% replacement of robosand.

NOTATIONS

- RS-Robosand

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