An Experimental Study on Use of Manufactured Sand in Concrete Production

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Abstract: Being cheapest in earlier days the natural sand used in concrete without any alternate even though natural sand containing organic impurities, clay and silt content more than permitted level. Due to excessive mining the river basin environment got affected, the demand for fine aggregate increased and the prevailing market unable to meet the need. Nowadays crushed sand also called as manufactured sand being used as an alternate to natural sand partially or fully. Even though manufactured sand used in normal construction activities, it is not used in high rise structures involving special concretes. Hence it is necessary to study the properties of special concrete with various replacement proportions of fine aggregate by manufactured sand. This will safeguard environment river basin and at the same time unwanted accumulation of crusher dust will put into better use than being used as mere filling material. Experiments conducted on M25, M30, M40 grade concrete with fine aggregate replacement proportion 25%, 50%, 75% and 100%. The properties such as workability, water absorption, compressive strength, split tensile strength and flexural strength are determined from cubes, beams and cylinders cast with manufactured sand.

Keywords: Manufactured Sand, River Sand, Compressive strength,Flexural strength, Split Tensile Strength, Workability.

1. INTRODUCTION

The main cause of concern is the non-renewable nature of natural sand and the corresponding increasing demand of construction industry [1-5]. Therefore looking for an alternative to river sand has become a necessity. The cheapest and easiest alternative to natural sand is manufacturing sand by crushing rocks/stones in desired size and grade by suitable method. Sand produced by such means is known as manufactured/ crusher/artificial sand [6-10].

2. EXPERIMENTAL INVESTIGATIONS

2.1 MATERIALS

- **Cement-** Ordinary Portland cement of 53 Grade conforming to IS 8112 -1989 9, and the specific gravity of cement was found to be 3.15.
- **Natural Sand-** Locally available River sand having bulk density 1.71 Kg/m3 was used and the specific gravity is 2.65. The Fineness modulus of river sand is 5.24.

- **Manufactured Sand-** M-Sand was used as partial replacement of fine aggregate. The bulk density of manufactured sand was 1.75 kg/m3, specific gravity and fineness modulus was found to be 2.73 and 4.66, respectively.
- **Coarse Aggregate-** Crushed angular aggregate with maximum grain size of 20 mm was used and having bulk density 1.38 Kg/m3. The specific gravity and fineness modulus was found to be 2.82 and 8, respectively.
- **Water-** Fresh portable water, which is free from acid and organic substance, was used for mixing the concrete.
- **Superplasticizer**-The sulphonatednapthlene-formaldehyde collected from local supplier Conplast SP430 is used.

2.2 MIX PROPORTIONS AND MIX DETAILS

Mix design is made for M25, M30 and M40 grade concrete accordance with IS 10262-1982. A total of 15 concrete mixes were prepared; one of the mixes was made of 100% ordinary Portland cement (no manufacturing sand content). The remaining 12 mixes were prepared by adding manufacturing sand in various percentages of 25%, 50%, 75% and 100% to the weight of natural sand.

Table 1: Mixture design for M25

Mix	Manufacturing Sand	Quantity (Kg/m^3)					
		Cement	Coarse Aggregate	Natural Sand	Manufacturing Sand	Super Plasticizer	Water
M1	0	320	1356	751	0	1.6	138
M2	25	320	1356	563.25	187.75	1.6	138
M3	50	320	1356	375.5	375.5	1.6	138
M4	75	320	1356	187.75	563.25	1.6	138
M5	100	320	1356	0	751	1.6	138

Table 2: Mixture design for M30

Mix	Manufacturing Sand	Quantity (Kg/m^3)					
		Cement	Coarse Aggregate	Natural Sand	Manufacturing Sand	Super Plasticizer	Water
M1	0	380	1283	711	0	1.9	160
M2	25	380	1283	533.25	177.75	1.9	160
M3	50	380	1283	355.5	355.5	1.9	160
M4	75	380	1283	177.75	533.25	1.9	160
M5	100	380	1283	0	711	1.9	160

Table 3: Mixture design for M40

Mix	Manufacturing Sand	Quantity (Kg/m^3)					
		Cement	Coarse Aggregate	Natural Sand	Manufacturing Sand	Super Plasticizer	Water
M1	0	450	1084.95	623.63	0	1.89	176
M2	25	450	1084.95	467.72	155.90	1.89	176
M3	50	450	1084.95	311.81	311.81	1.89	176
M4	75	450	1084.95	155.90	467.72	1.89	176
M5	100	450	1084.95	0	623.63	1.89	176

2.3 TEST CONDUCTED

2.3.1 WORKABILITY TEST

The slump test which is a field test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measure the settlement i.e., slump.

Fig. 1: Workability test conducted in lab

2.3.2 WATER ABSORPTION TEST

For concrete pavers, the test procedure involves drying a specimen to a constant weight, weighing it, immersing it in water for specified amount of time, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its absorption (in percent).

Fig. 2: Water absorption test conducted in lab

2.3.3 COMPRESSIVE STRENGTH TEST

For compressive strength test, cube specimens of dimensions 150 mm x 150 mm x150 mm were cast for M25, M30 and M40 grade of concrete. The compressive strength test was carried out conforming to IS 516-1959 to obtain compressive strength of concretes. The compressive strength of concrete at the age of 7days, 21 days and 28days are conducted.

Fig. 3: Compressive strength test

2.3.4 FLEXURAL STRENGTH TEST

Flexural strength (MPa) = (P x L) / (b x d) Where, P = Failure load, L = Centre to centre distance between the support = 600 mm, b = width of Specimen=150 mm, d = depth of specimen= 150 mm.

Fig. 4: Flexural strength test

2.3.5 SPLIT TENSILE STRENGTH TEST

Split tensile strength test was conducted on concrete cylinders of 150 mm diameter and 300 mm height. 15 cylinders were prepared for each combination. A control mix was also prepared for the split tensile strength. The cylinders were subjected to compression load along two axial lines which are diametrically opposite. The load was applied continuously at a constant rate. The split tensile strength was found for 28 days.

Fig. 5. Split tensile strength test

3. RESULTS AND DISCUSSIONS

3.1 WORKABILITY TEST RESULTS

Workability reduces significantly with increase in % of manufacturing sand. As the manufacturing sand content workability decreases. As there is a reduction in fineness modulus of cementatious material, quantity of cement paste available is less for providing lubricating effect per unit surface area of aggregate. Therefore, there is a restrain on the mobility. The result obtained for the slump cone test is:-

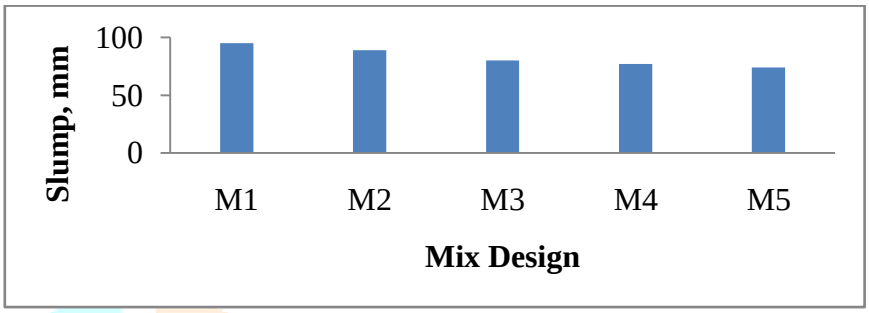

Fig. 6: Workability of Concrete for M 25

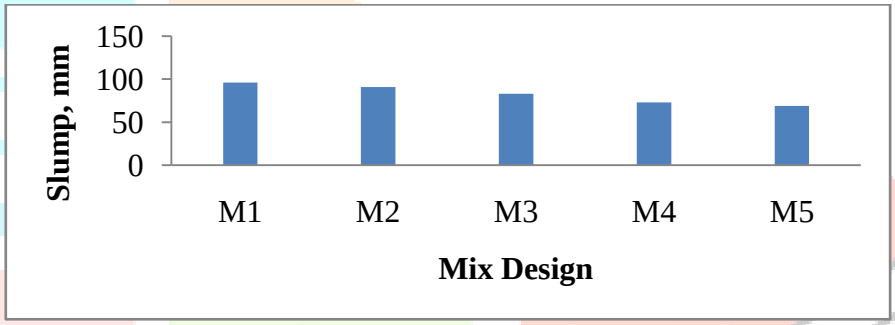

Fig. 7: Workability of Concrete for M 30

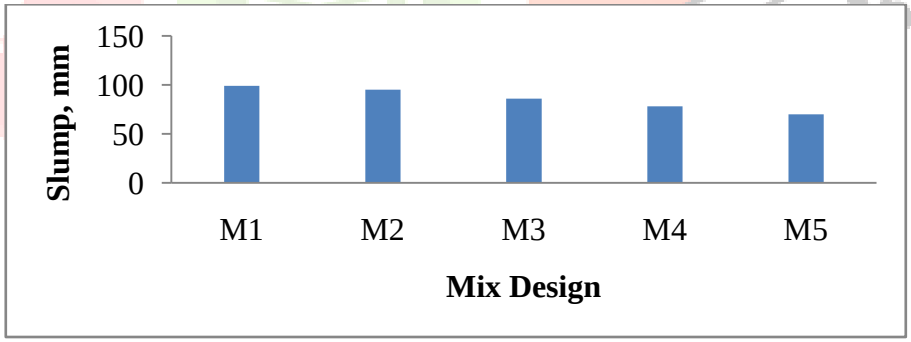

Fig. 8: Workability of Concrete for M 40

3.2 WATER ABSORPTION TEST RESULT FOR M25, M30 AND M40

From table 5.4 – 5.6 it is observed that the manufactured sand content is increased from 0% to 100% water absorption is increasing. But according to IS 15658:2006 the water absorption for concrete is 7%. The water absorption values of specimens are calculated for various mix proportions and the effect of manufactured sand content on water absorption is shown in Fig.3. From the test results, it can be seen that the water absorption values for all the specimens of mix ratios were lower than 7% as per IS: 15658-2006 specifications.

It was also found that, for specimens without manufactured sand, the water absorption values are comparatively lower as compared to that of specimens containing manufactured sand.

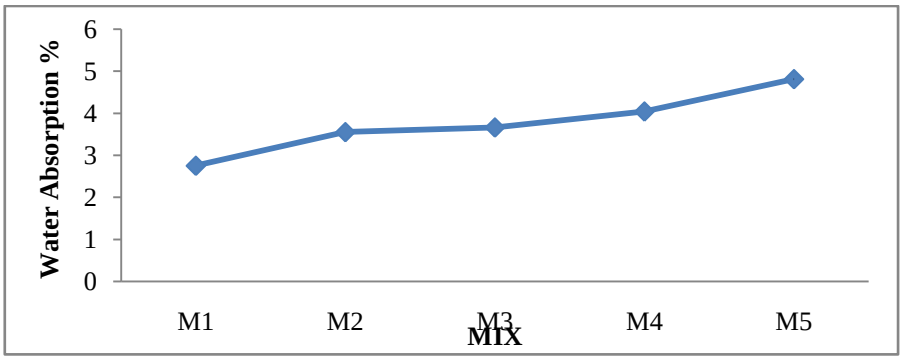

Fig. 9: Water Absorption for M25

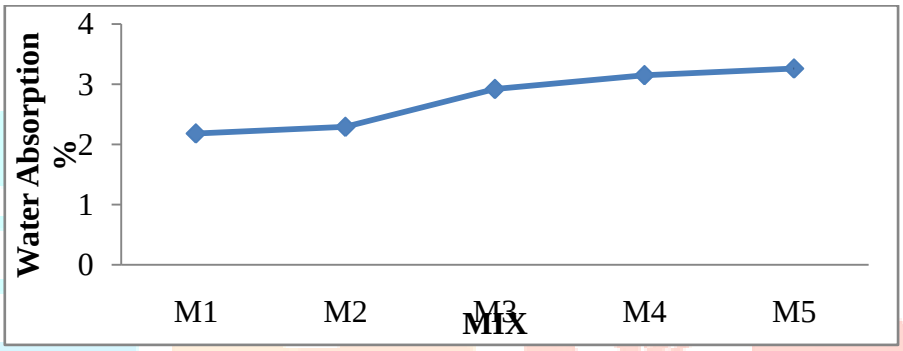

Fig. 10: Water absorption for M30

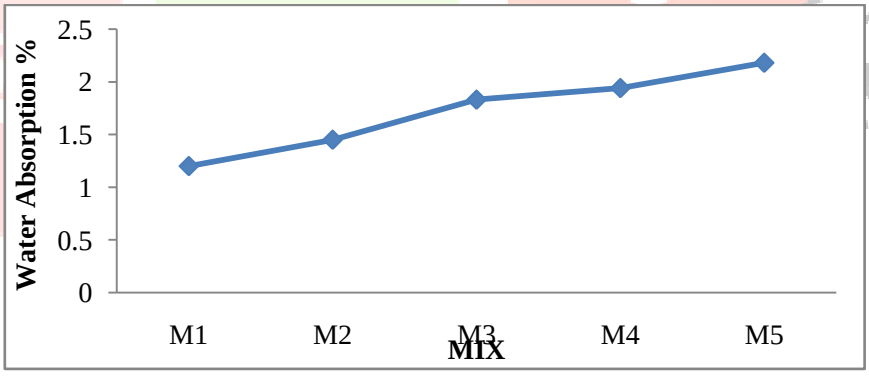

Fig. 11: Water Absorption for M40

3.3 COMPRESSIVE STRENGTH TEST RESULTS

3.3.1 COMPRESSIVE STRENGTH TEST RESULT FOR M25

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 7 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 29.25 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 15.7 %, 20.22 % and 6.44 % slightly lesser strength compared to sample 1.

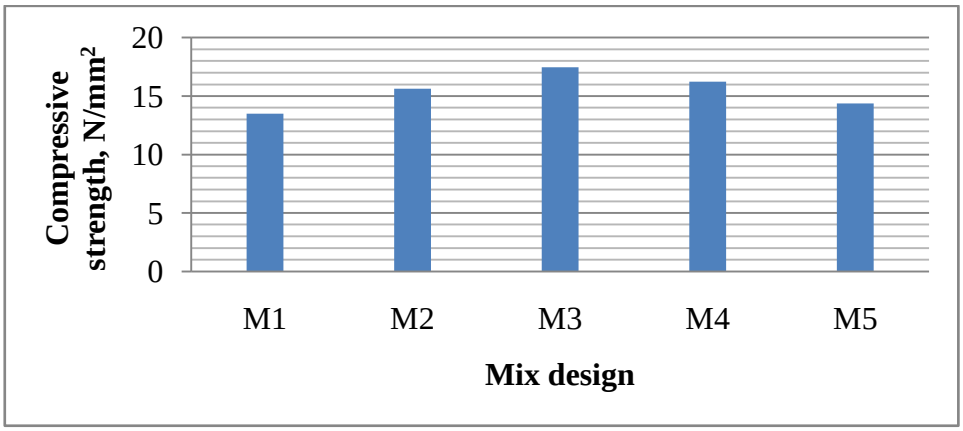

Fig. 12: Variation of compressive strength after 7 days curing for M25

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 21 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 15.38 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 5.62 %, 9.66 % and 3.89 % slightly lesser strength compared to sample 1.

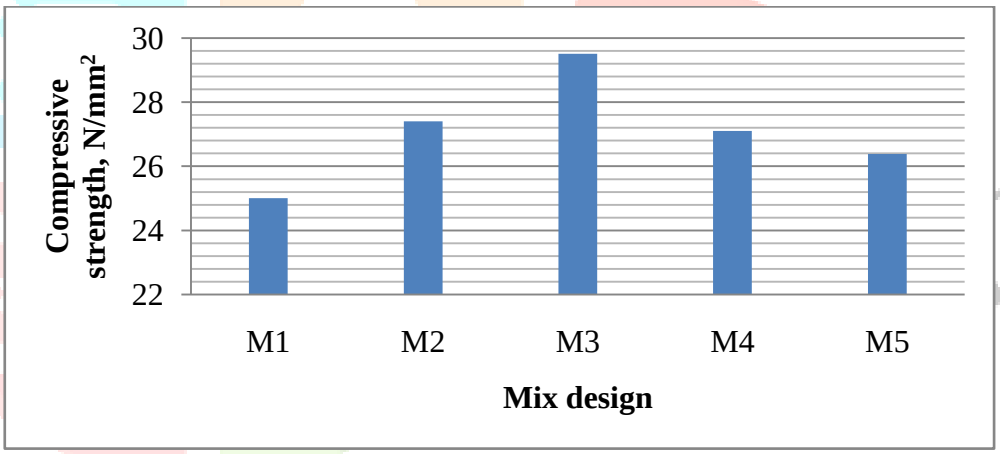

Fig. 13: Variation of compressive strength after 28 days curing for M25

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 28 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 17.9 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 9.55 %, 8.35 % and 5.47 % slightly lesser strength compared to sample 1.

3.3.2 COMPRESSIVE STRENGTH TEST RESULT FOR M30

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 7 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 14.67 % increase in strength over sample 1

with 100% natural sand, whereas other samples shows 6.77 %, 8.52 % and 5.90 % slightly lesser strength compared to sample 1.

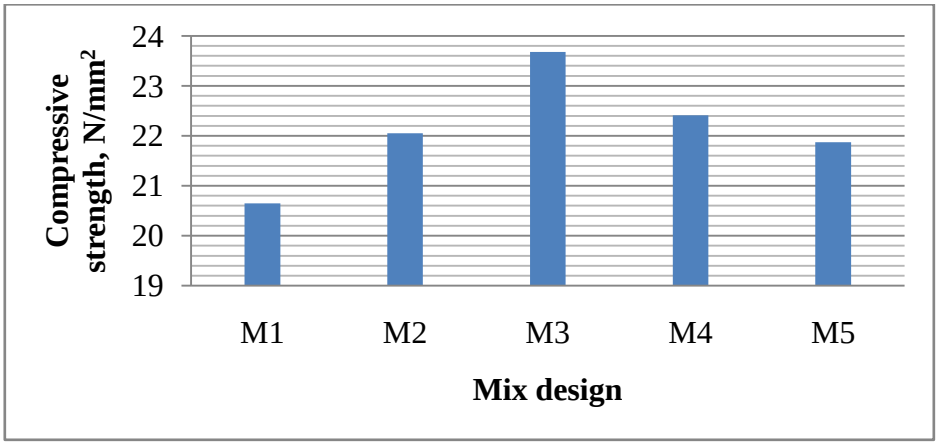

Fig. 14: Variation of compressive strength after 7 days curing for M30

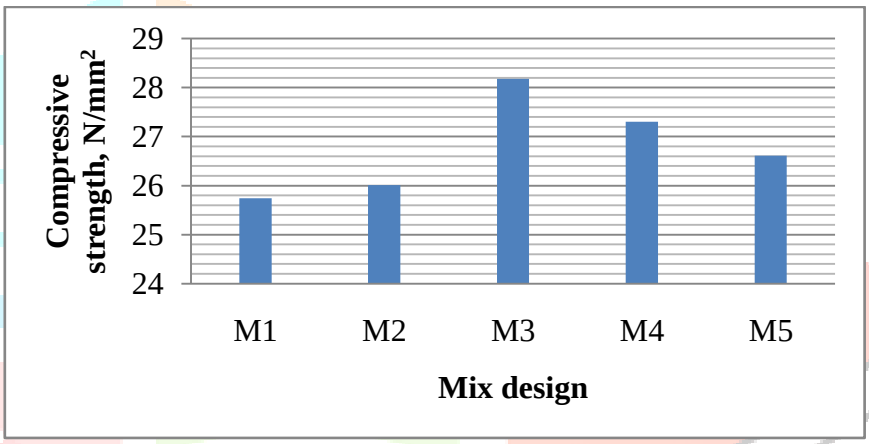

Fig. 15: Variation of compressive strength after 21 days curing for M30

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 21 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 9.47 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 1.04 %, 6.06 % and 3.37 % slightly lesser strength compared to sample 1. The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced.

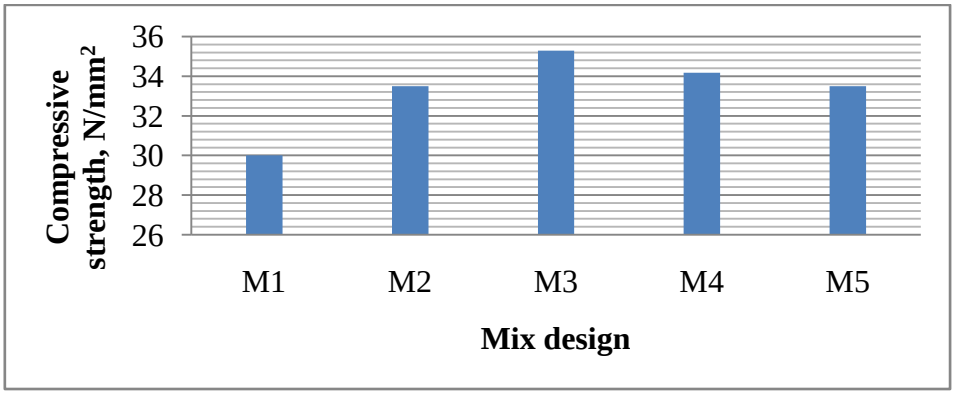

Fig. 16: Variation of compressive strength after 30 days curing for M30

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 28 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 17.63 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 11.66 %, 13.93 % and 12.63 % slightly lesser strength compared to sample 1.

3.3.3 COMPRESSIVE STRENGTH TEST RESULT FOR M40

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 7 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 10.23 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 2.58 %, 7.65 % and 4.18 % slightly lesser strength compared to sample 1.

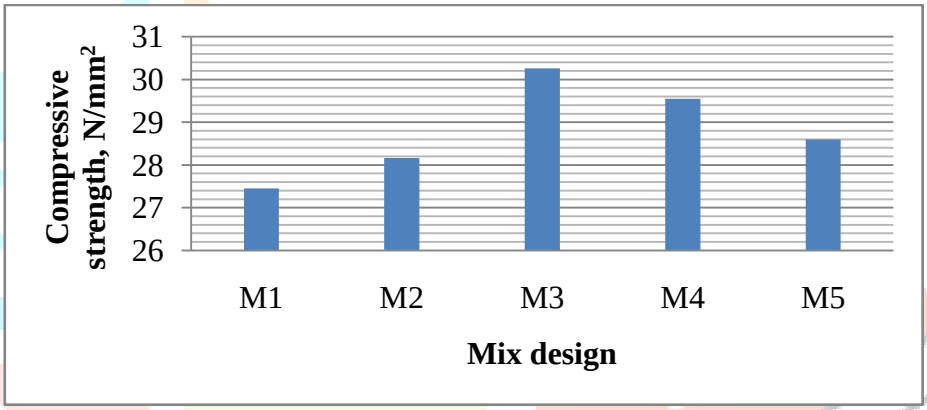

Fig 17: Variation of compressive strength after 7 days curing for M40

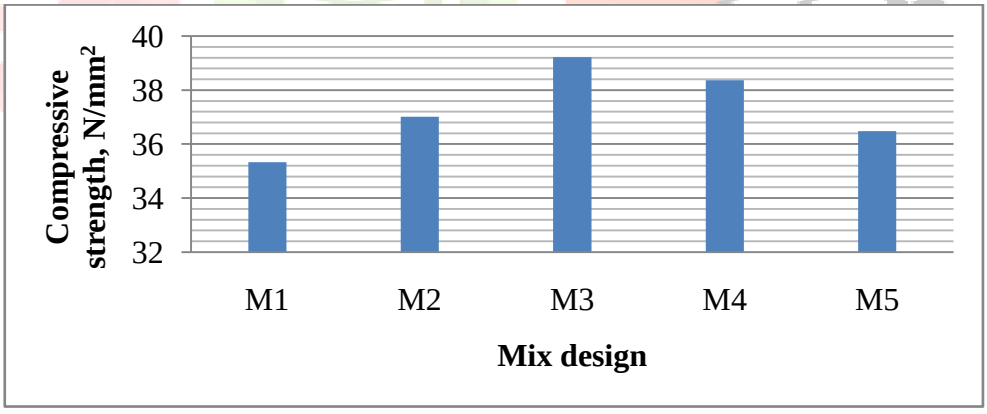

Fig. 18: Variation of compressive strength after 21 days curing for M40

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 21 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 11.01 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 4.75 %, 8.60 % and 3.25 % slightly lesser strength compared to sample 1.

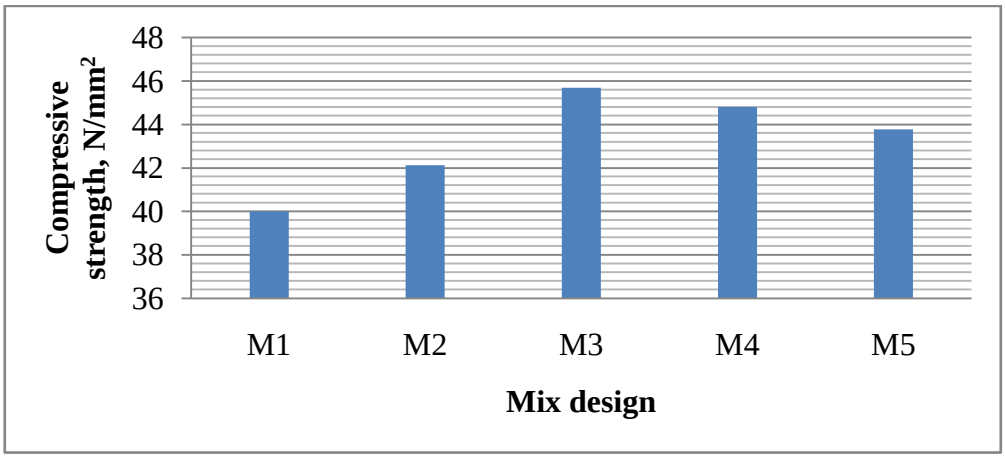

Fig. 19: Variation of compressive strength after 28 days curing for M40

The cube compressive strength for sample 1 to sample 5 for different replacement level of fine aggregate with manufactured sand (0%, 25%, 50%, 75% and 100%) at the end of 28 days curing period shown. Sample 3 with 50% natural sand and 50% manufactured sand shows 11.01 % increase in strength over sample 1 with 100% natural sand, whereas other samples shows 5.29 %, 11.99 % and 9.39 % slightly lesser strength compared to sample 1.

3.4. FLEXURAL STRENGTH TEST RESULTS

3.4.1 FLEXURAL STRENGTH TEST RESULT FOR M25

The Figure 5.19 shows the value of flexural strength at various replacement proportion of natural sand by manufactured sand at the end of 28 days curing period. For sample designation M3 with 50% natural sand and 50% manufactured sand, the flexural strength increase by 9.91 % over sample designation M1 which is of 100% natural sand as fine aggregate.

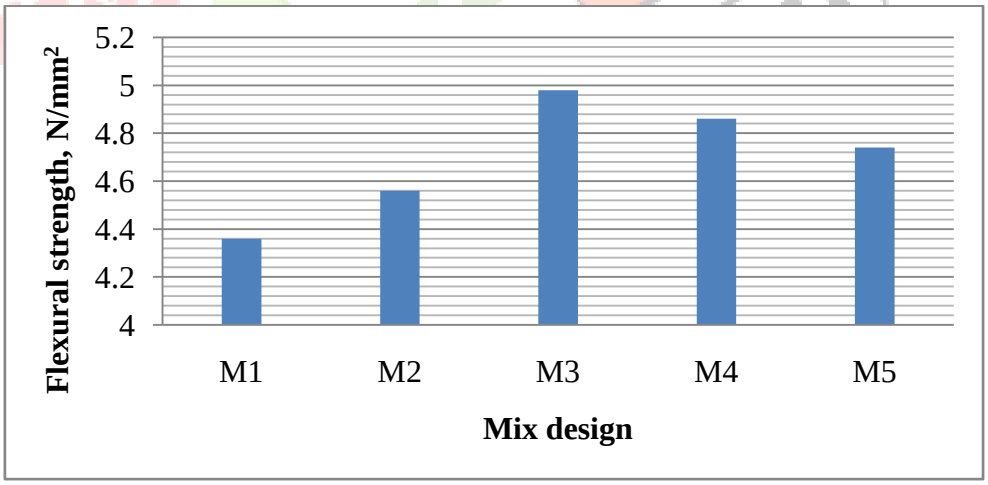

Fig. 20: Flexural strength after 28 days curing for M25

3.4.2 FLEXURAL STRENGTH TEST RESULT FOR M30

The Figure 5.20 shows the value of flexural strength at various replacement proportion of natural sand by manufactured sand at the end of 28 days curing period. For sample designation M3 with 50% natural sand

and 50% manufactured sand, the flexural strength increase by 14.22 % over sample designation M1 which is of 100% natural sand as fine aggregate.

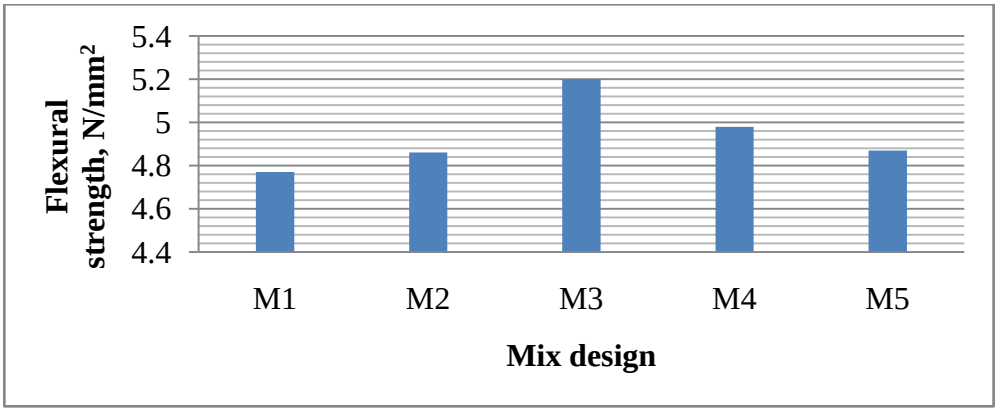

Fig. 21: Flexural strength after 28 days curing for M30

3.4.3 FLEXURAL STRENGTH TEST RESULT FOR M40

The Figure 5.21 shows the value of flexural strength at various replacement proportion of natural sand by manufactured sand at the end of 28 days curing period. For sample designation M3 with 50% natural sand and 50% manufactured sand, the flexural strength increase by 9.01 % over sample designation M1 which is of 100% natural sand as fine aggregate.

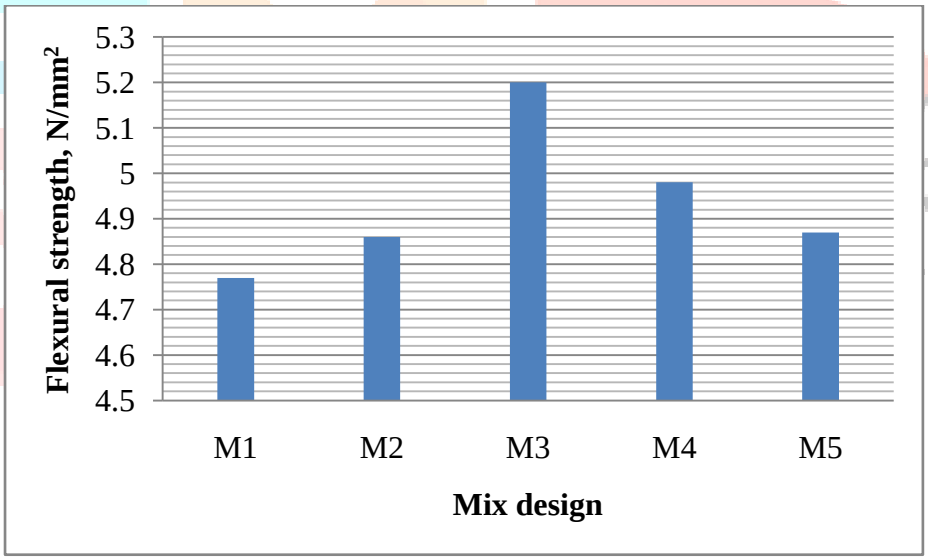

Fig. 5.22: Flexural strength after 28 days curing for M40

3.5 SPLIT TENSILE STRENGTH TEST RESULT

3.5.1 SPLIT TENSILE STRENGTH TEST RESULT FOR M25

The Figure 5.22 shows the value of split tensile strength at various replacement proportion of natural sand by manufactured sand at the end of 28 days curing period. For sample designation M3 with 50% natural sand and 50% manufactured sand, the split tensile strength increase by 16.47 % over sample designation M1 which is of 100% natural sand as fine aggregate.

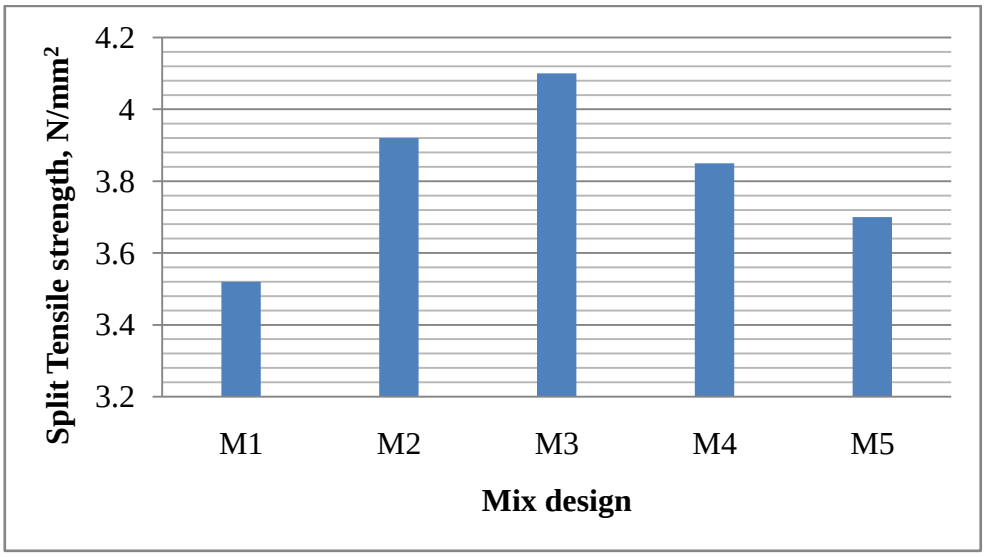

Fig. 23: Split tensile strength after 28 days curing for M25

3.5.2 SPLIT TENSILE STRENGTH TEST RESULT FOR M30

The Figure 5.23 shows the value of split tensile strength at various replacement proportion of natural sand by manufactured sand at the end of 28 days curing period. For sample designation M3 with 50% natural sand and 50% manufactured sand, the split tensile strength increase by 26.45 % over sample designation M1 which is of 100% natural sand as fine aggregate.

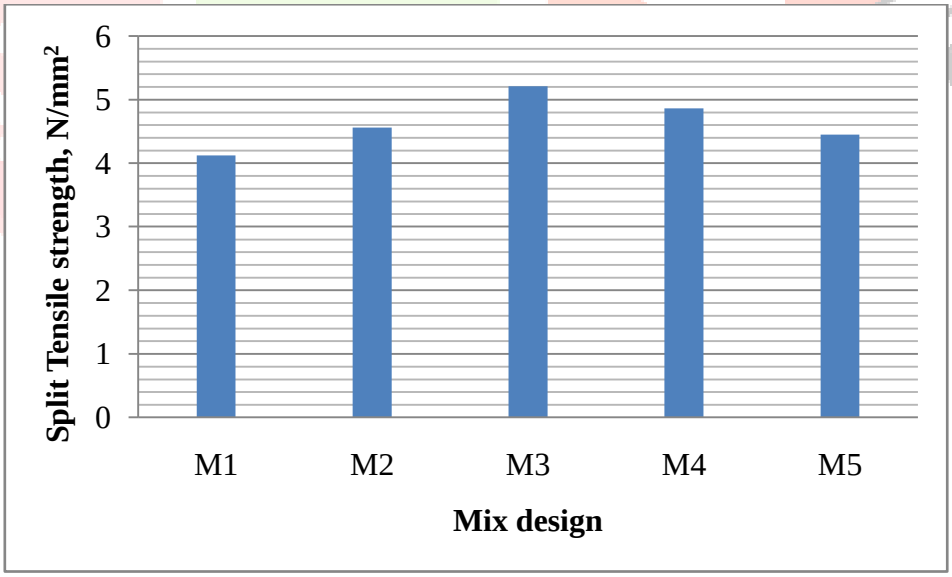

Fig. 24: Split tensile strength after 28 days curing for M30

3.5.3 SPLIT TENSILE STRENGTH TEST RESULT FOR M40

The Figure 5.24 shows the value of split tensile strength at various replacement proportion of natural sand by manufactured sand at the end of 28 days curing period. For sample designation M3 with 50% natural

sand and 50% manufactured sand, the split tensile strength increase by 17.76 % over sample designation M1 which is of 100% natural sand as fine aggregate.

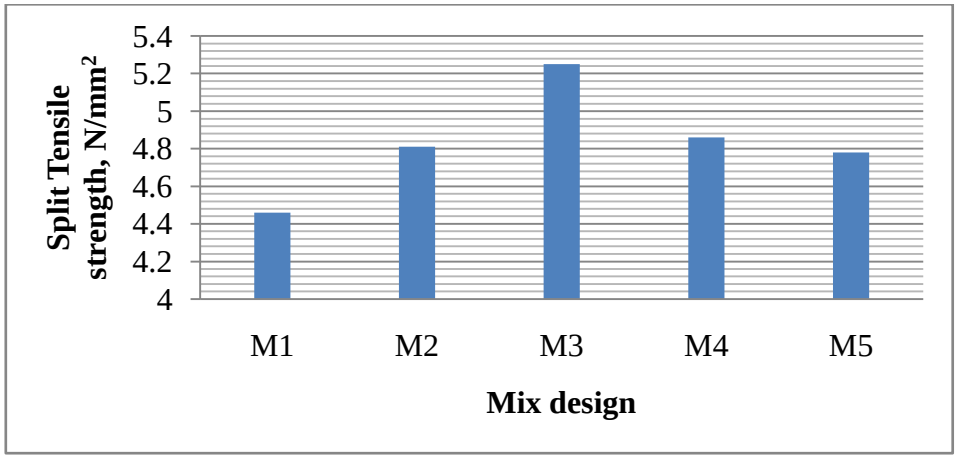

Fig. 25: Split tensile strength after 28 days curing for M40

4. CONCLUSION

4.1 FOR WORKABILITY

Workability reduces significantly with increase in % of manufacturing sand. As the manufacturing sand content workability decreases. As there is a reduction in fineness modulus of cementatious material, quantity of cement paste available is less for providing lubricating effect per unit surface area of aggregate. Therefore, there is a restrain on the mobility.

4.2 FOR WATER ABSORPTION

From table 5.4 – 5.6 it is observed that the manufactured sand content is increased from 0% to 100% water absorption is increasing. But according to IS 15658:2006 the water absorption for concrete is 7%. The water absorption values of specimens are calculated for various mix proportions and the effect of manufactured sand content on water absorption is shown in Fig.3. From the test results, it can be seen that the water absorption values for all the specimens of mix ratios were lower than 7% as per IS: 15658-2006 specifications.

4.3 FOR COMPRESSIVE STRENGTH

4.3.1 COMPRESSIVE STRENGTH TEST FOR M25

- The compressive strength of concrete with manufactured sand has been increased upto 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 18.45 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50% when OPC is used.

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 24.6 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50% when OPC is used.

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 29.51 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50% when OPC is used.

4.3.2 COMPRESSIVE STRENGTH TEST FOR M30

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 23.68 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50 %.

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 28.18 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50 %.

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 35.29 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50 %.

4.3.3 COMPRESSIVE STRENGTH TEST FOR M40

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 30.26 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50 %.

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 39.22 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50 %.

- The compressive strength of concrete with manufactured sand has been increased up to 50% and after 50% of the replacement the strengths are gradually reduced. The maximum values of compressive strength at 50% Natural sand and 50 % Manufactured sand are 45.69 N/mm^2. The maximum percentage of the natural sand and manufactured sand on the natural sand replacement must therefore be 50 % and 50 %.

4.4 FOR FLEXURAL STRENGTH

4.4.1 FLEXURAL STRENGTH TEST FOR M25

The maximum 28 days flexural strength of M25 grade of concretes with replacement of natural sand by manufactured sand was 4.10 N/mm^2. Hence the optimum mix for achieving higher tensile strength is 50 % natural sand 50 % manufactured sand.

4.4.2 FLEXURAL STRENGTH TEST FOR M30

The maximum 28 days flexural strength of M30 grade of concretes with replacement of natural sand by manufactured sand was 4.98 N/mm^2. Hence the optimum mix for achieving higher tensile strength is 50 % natural sand 50 % manufactured sand.

4.4.3 FLEXURAL STRENGTH TEST FOR M40

The maximum 28 days flexural strength of M40 grade of concretes with replacement of natural sand by manufactured sand was 5.2 N/mm^2. Hence the optimum mix for achieving higher tensile strength is 50 % natural sand 50 % manufactured sand.

4.5SPLIT TENSILE STRENGTH

4.5.1 SPLIT TENSILE STRENGTH TEST FOR M25

The maximum 28 days split tensile strength of M25 grade of concretes with replacement of natural sand by manufactured sand was 4.10 N/mm2. Hence the optimum mix for achieving higher tensile strength is 50 % natural sand 50 % manufactured sand.

4.5.2 SPLIT TENSILE STRENGTH TEST FOR M30

The maximum 28 days split tensile strength of M40 grade of concretes with replacement of natural sand by manufactured sand was 5.21 MPa. Hence the optimum mix for achieving higher tensile strength is 50 % natural sand 50 % manufactured sand.

4.5.3 SPLIT TENSILE STRENGTH TEST FOR M40

The maximum 28 days split tensile strength of M40 grade of concretes with replacement of natural sand by manufactured sand was 5.25 MPa. Hence the optimum mix for achieving higher tensile strength is 50 % natural sand 50 % manufactured sand.

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