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STUDY ON HIGH PERFORMANCE CONCRETE WITH REPLACEMENT OF FINE AGGREGATE BY MANUFACTURED SAND

Prasanna K and Anandh K S
Assistant Professor, Department of Civil Engineering, SRM University,
Chennai, Tamilnadu, India

kiruthiga K
Assistant Professor, Department of Civil Engineering, BIHER, Bharath University,
Chennai, Tamilnadu, India

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 M60 grade concrete with fine aggregate replacement proportion 0%. 25%, 50%, 75% and 100%. The properties such as compressive strength, split tensile strength and ultrasonic pulse velocity are determined from cubes and cylinders cast with manufactured sand procured from kundrathur and river sand taken from Araniar basin. The replacement of 75% natural sand by manufactured sand recommended as this proportion gives comparatively better results in special concrete such as high performance concrete. Hence the manufactured can be used in high performance without any doubt which will also improve the environment as well as sustainability of construction industry.

Keywords: High Performance Concrete, Manufactured Sand, River Sand

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1. INTRODUCTION:

Concrete is a structural material formed by the mixture of glue and filler. Portland cement and water represents the glue material and whereas the filler material comprises of coarse aggregate and fine aggregate. When the concrete is fresh it should be workable and cohesive. The hardened concrete should have enough strength to resist permeability, corrosion, abrasion and should possess designated load carrying capacity.

1.1 Definition of Manufactured sand

Manufactured sand is defined as a purpose made crushed fine aggregate produced from a suitable source material like dense rocks in crushers. The production involves crushing, screening to size and washing. The screened and washed material categorized to size and mixed in proportion to suit the purpose related to construction activity. Washing is must when percentage of micro fines present is higher than expected.

2. DIFFERENCE BETWEEN MANUFACTURED SAND AND CRUSHER DUST

In a stone quarry crushed metal above 5 mm designated as coarse aggregate and rest below 5 mm stockpiled as crusher dust. The crusher dust used for road bases due to its less plasticity. Also crusher dust used to fill under slabs as it can be compacted well because of low plasticity due to that this fill pad can be easily trenched for drainage lines and service lines.

Whereas the grains in crusher waste categorized based on size and mixed in proportion to suit the use of fine aggregate i.e., concreting, masonry or plastering is termed as crushed sand or manufactured sand.

3. MATERIALS AND METHODS

The experimental sequences are as follows

- For M60 grade concrete the design to be adopted determined based on trials.
- With natural sand 100% as fine aggregate, cubes and cylinders cast (Identification mark 1)
- With natural sand 75 % and manufactured sand 25 % as fine aggregate, cubes and cylinders cast (Identification mark 2).
- With natural sand and manufactured sand each 50% as fine aggregate, cubes and cylinders cast (Identification mark 3).
- With natural sand 25% and manufactured sand 75% as fine aggregate, cubes and cylinders cast (Identification mark 4).
- With 100% manufactured sand as fine aggregate, cubes and cylinders cast (Identification. mark 5).
- The cube compressive strength and split tensile strength determined after 7 days and 28 days curing to study the influence of different proportions adopted in fine aggregates with natural sand and manufactured sand. The ultrasonic pulse velocity determined on cubes after twenty eight days curing to find the influence on concrete by the alternate material.

2.1. Mix proportions

After trails, the design mix arrived as cement: fine aggregate: coarse aggregate: water: super plasticizer: :1 : 1.35 : 2.19 : 0.29 : 0.8. The quantities of concrete ingredients are tabulated in table 3.6 for casting cubes and cylinders. The cube is of size 150 mm x 150 mm x 150 mm and cylinder is of diameter 150 mm and height 300 mm. Each 30 specimens cast for this study.

Table 1 Mix designed for grade M60

Cement: fine aggregate: Coarse aggregate: water: super plasticizer (1:1.35:2.19:0.29:0.8)					
Material	**Sample 1 100% NS kg**	**Sample 2 75%NS+ 25%MS kg**	**Sample 3 25%NS+ 50%MS kg**	**Sample 4 25%NS+ 75%MS kg**	**Sample 5 100%MS kg**
Cement (OPC Zuari 53 grade)	23.800	23.800	23.800	23.800	23.800
Silica Fume	1.91	1.91	1.91	1.91	1.91
River sand	34.850	26.14	17.40	8.710	-
M – Sand	-	8.710	17.40	26.140	34.850
Coarse aggregate	56.500	56.500	56.500	56.500	56.500
Water	7.25	7.25	7.25	7.25	7.25
Super plasticizer Conplast SP 430	0.23 liter	0.23 liter	0.23 liter	0.23 liter	0.23 liter

2.2 Experiment test procedure

The experimental test procedures of various tests conducted are briefly explained below.

2.2.1. Cube compressive strength test

The cube compressive strength is very important due to the fact that clearly exhibits the quality of concrete. Other strengths are expressed in comparison with compressive strength. It helps to achieve higher efficiency of the material that reveal performance of concrete pertaining to strength as well as durability. While carrying out the test care should be taken to apply load only above centroidal axis otherwise it will not exhibit real strength of concrete**.**

The compressive strength for the concrete cubes cast for five different mix ratios as specified in Table 3.6 tested for seventh day and twenty eighth day curing period according to code provisions mentioned in IS : 516(1959), Methods of test for strength of concrete (Reaffirmed 1999) using compression testing machine of capacity 200 T.

2.2.2 Cylinder split tensile strength test

The split tensile strength test is an indirect method to determine the tensile strength of concrete. Tensile strength is the basic and important property of concrete. Hence the concrete is expected to take up tensile stresses along with compressive stresses; the tension is significant with respect to cracking. The cast concrete cylinders of 150mm dia and 300 mm high were tested for split tensile strength after expiry of curing period as per the provisions in IS 5816 (1970) Method of test for splitting tensile strength of concrete cylinders. The test done with compression testing machine until the resistance of specimen to the increasing load breaks down and the load noted. The split tensile strength σsp calculated calculated from the formula

$$\sigma_{sp} = \frac{2P}{\pi dl}$$

Where, σ_{sp} = Split tensile strength in N/mm^2

P = Load at failure in N

D = Diameter of specimen in mm

l = Length of specimen in mm

2.2.3 Ultrasonic Pulse velocity test

It involves measurement of the time of travel of electronically generated mechanical pulses through the concrete**.** In this method time taken by an Ultrasonic pulse to travel across the given specimen termed as path length found out and velocity calculated by dividing the size of specimen by time taken by the ultrasonic pulse.

Generally the measurement of pulse velocity is affected by smoothness of concrete surface, influence of path length on pulse velocity, temperature of concrete, moist condition of concrete and presence of reinforcement. The pulse velocity tests have been used to evaluate quality of concrete and correlate with other properties of concrete. Before testing the specimen, it is assured that it should be kept in dry state after curing period. In this study the direct transmission method is adopted.

3. RESULTS AND DISCUSSIONS

The properties of High performance concrete incorporating manufactured sand as alternative fine aggregate at various proportions were studied by checking cube compressive strength; cylinder split tensile strength and cube ultrasonic pulse velocity.

3.1 Compressive strength

In this study, compressive strength for cubes at various replacement proportions of fine aggregate in the two different curing periods with M60 grade concrete were determined after testing and tabulated in Table 2 and Table 3.The Fig.1 and Fig 2 shows the level of strength variation of M60 grade concrete for different replacement level of manufactured sand.

Table 2 Compressive strength after 7 days curing with replacement of fine aggregate by manufactured sand

Designation of sample	Identification number	Weight	Ultimate load in KN	Compressive strength	Average
Sample 1 100 % Natural sand	1/1	8.500	1140	50.66	51.11
	1/2	8.525	1158	51.47	
	1/3	8.540	1152	51.20	
Sample 2 75% NS + 25% MS	2/1	8.600	1130	50.22	50.53
	2/2	8.540	1138	50.58	
	2/3	8.590	1143	50.80	
Sample 3 50% NS + 50%MS	3/1	8.550	1128	50.13	50.87
	3/2	8.610	1144	50.84	
	3/3	8.625	1162	51.64	
Sample 4 25% NS + 75% MS	4/1	8.600	1246	55.38	54.41
	4/2	8.635	1216	54.38	
	4/3	8.615	1211	53.82	
Sample 5 100% MS	5/1	8.560	1099	48.62	49.21
	5/2	8.610	1118	49.69	
	5/3	8.625	1110	49.33	

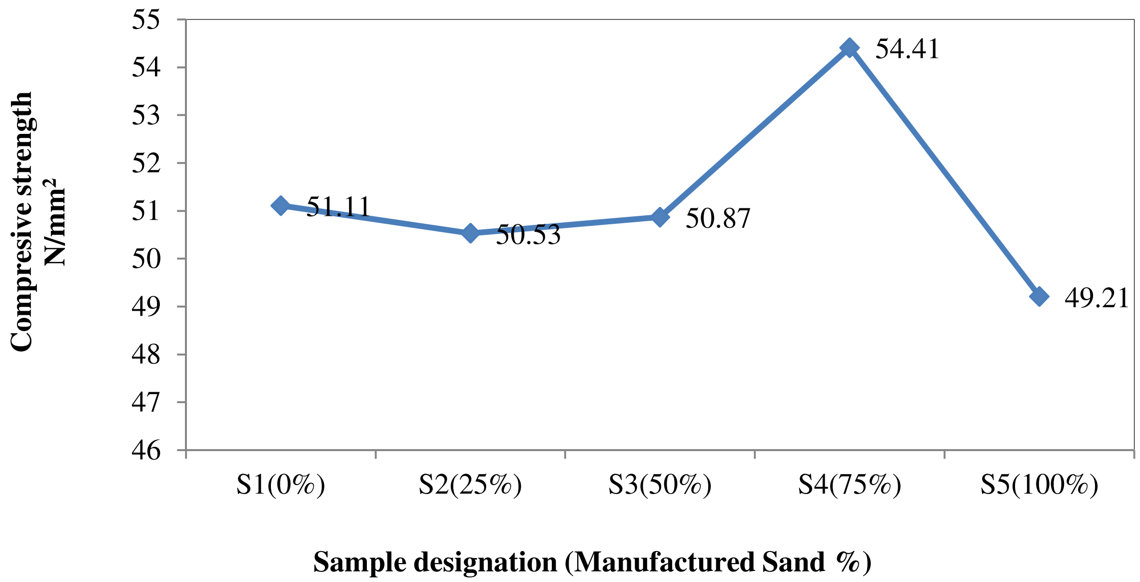


Figure 1 Compressive strength after 7 days curing with replacement of fine Aggregate by manufactured sand

In the above Figure 1 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 4 with 25% natural sand and 75% manufactured sand shows 6.45% increase in strength over sample 1 with 100% natural sand, whereas other samples shows slightly lesser strength compared to sample 1.

Table 3 Compressive strength after 28 days curing with replacement of fine aggregate by manufactured sand

Designation of Sample	Identification Number	Weight	Ultimate load KN	Compressive strength N/mm^2	Average
Sample 1 100% (NS)	1/4	8.520	1555	69.11	69.63
	1/5	8.510	1570	69.77	
	1/6	8.540	1575	70.00	
Sample 2 75% NS + 25% MS	2/4	8.45	1540	68.44	68.74
	2/5	8.49	1549	68.44	
	2/6	8.50	1551	68.22	
Sample 3 50% NS + 50% MS	3/4	8.520	1535	68.22	68.65
	3/5	8.560	1539	68.40	
	3/6	8.490	1560	69.33	
Sample 4 25% NS + 75% MS	4/4	8.525	1594	70.85	70.90
	4/5	8.530	1600	71.11	
	4/6	8.540	1592	70.76	
Sample 5 100% MS	5/4	8.350	1566	69.60	69.36
	5/5	8.335	1559	69.29	
	5/6	8.200	1557	6920	

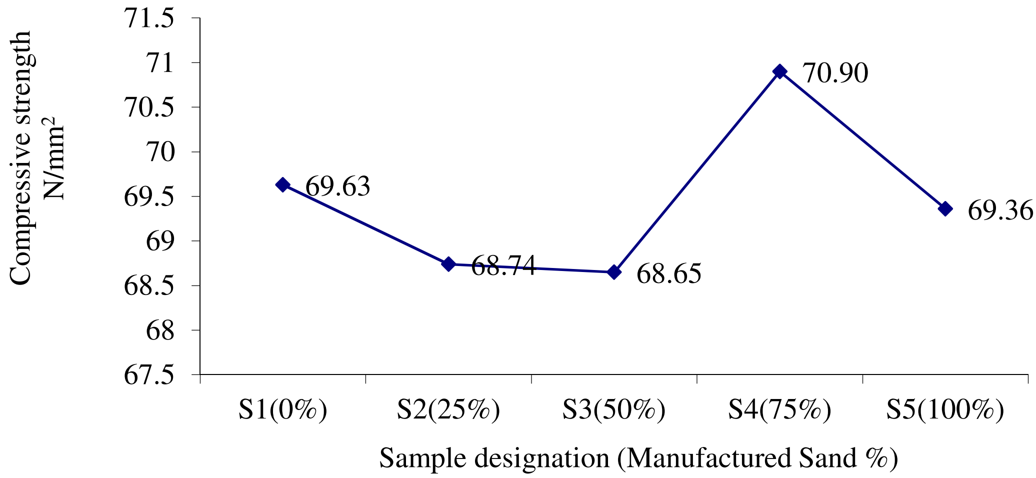


Figure 2: Compressive strength after 28 days curing with replacement of fine aggregate by manufactured sand

In the Fig 2 the cube compressive strength for sample 1 to 5 for different replacement level of manufactured sand (0%, 25%, 50%, 75%, and 100%) at the end of 28 days curing period shown. Sample 4 with 25% natural sand and 75% manufactured sand shows 1.82% increase in strength over sample 1 with 100% natural sand, all other samples strength found slightly lesser compared to sample 1.

The below Table 4 shows that at the end of 7 days compressive strength of sample designation S2, S3 and S5 decreased by 1.13%, 0.47% and 3.72 respectively. But S4 increased by 6.46%

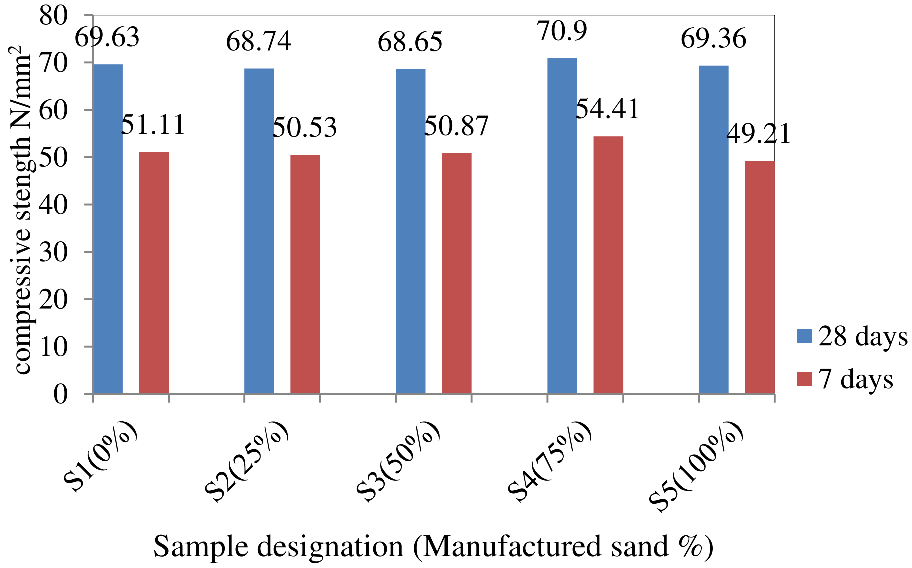
The below Table 4 also shows that at the end of 28 days compressive strength of sample designation S2, S3 and S5 decreased by 1.28% , 1.41% and 0.39% respectively. But S4 increased by 1.82%.

This shows that since ordinary portland cement and high performance concrete design mix used , the compressive strength at seventh day attained more than the requirement guide lines. At twenty eighth day the cubes attained just above the target strength

Even though fine aggregate alternate used the strength of concrete seems to be not reduced. The fine aggregate alternate does not show adverse effect on strength requirements of designed concrete. At the same time the variation between the strength is between +1.82 % and -1.41 % with an overall variation of 3.23 %.

Table 4 Average compressive strength of M60 grade concrete with replacement of fine aggregate by manufactured sand

Manufacture sand content in %	Designation of Sample	Compressive strength N/mm^2	
		7 days	28 days
0	S1	51.11	69.63
25	S2	50.53	68.74
50	S3	50.87	68.65
75	S4	54.41	70.90
100	S5	49.21	69.36



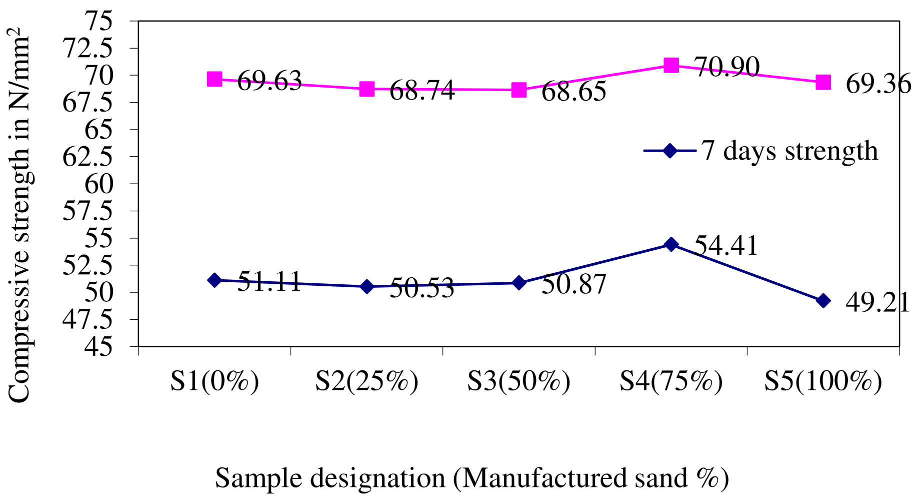


Figure 3 Average compressive strength of M60 grade concrete with Replacement of fine aggregate by manufactured sand

3.2 Split tensile strength

The split tensile strength for cylinders at various replacement proportions of fine aggregates in two different curing periods with M60 grade concrete were determined after testing and tabulated in Table 5 and Table 6. The Fig 4 and Fig 5 shows the level of tensile strength variations of M60 grade concrete

Table 5 Split tensile strength after 7 days curing with replacement of fine aggregate by manufactured sand

Cylinder tensile strength – 7th day					
Designation of Sample	**Identification Number**	**Weight**	**Ultimate load in KN**	**Tensile Strength**	**Average**
Sample 1 100% NS	1/1	13.685	285	4.03	3.99
	1/2	13.600	286	4.04	
	1/3	13.660	275	3.89	
Sample 2	2/1	13.700	271	3.83	3.80

75% NS + 25% MS	2/2	13.720	273	3.86	
	2/3	13.690	263	3.72	
Sample 3 50% NS+ 50% MS	3/1	13.750	263	3.72	3.73
	3/2	13.750	262	3.71	
	3/3	13.800	266	3.76	
Sample 4 25% NS + 75% MS	4/1	13.740	285	4.03	4.06
	4/2	13.695	283	4.00	
	4/3	13.735	293	4.14	
Sample 5 100% MS	5/1	13.740	270	3.82	3.87
	5/2	13.760	275	3.89	
	5/3	13.800	276	3.90	

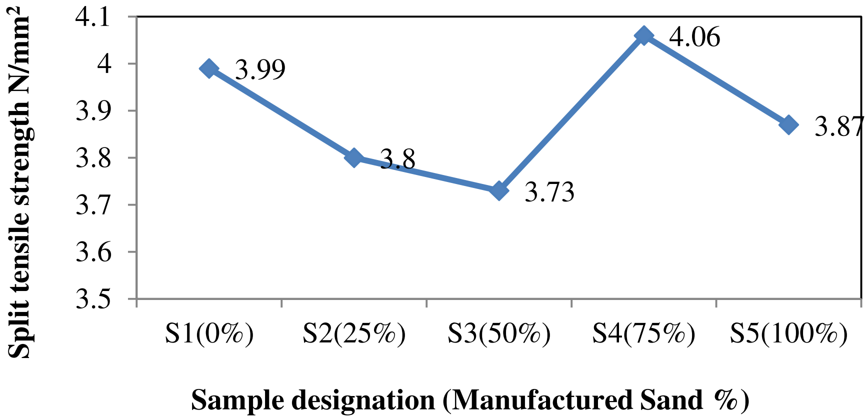


Figure 4 Split tensile strength after 7 days curing with replacement of fine aggregate by manufactured sand

The Fig 4 shows the value of split tensile strength at various replacement proportion of natural sand by manufactured sand (0%, 25%, 50%, 75%, and 100%)at the end of 7 days curing period. For sample designation S4 the split tensile strength increases by 1.75% over sample designation S1 which contain 100% natural sand.75% over sample designation S1 which contain 100% natural sand.

Table 6 Split tensile strength after 28 days curing with replacement of fine aggregate by manufactured sand

Cylinder split tensile strength – 28th day					
Designation of sample	**Designation of sample**	**Designation of sample**	**Designation of sample**	**Designation of sample**	**Designation of sample**
Sample 1 100% Natural Sand (NS)	1/4	13.470	347.76	4.92	4.97
	1/5	13.610	353.65	5.01	
	1/6	13.700	352.18	4.98	
Sample 2 75% NS + 50% MS	2/4	13.750	328.14	4.64	4.69
	2/5	13.710	333.54	4.72	
	2/6	13.685	333.05	4.71	

Sample 3 50% NS + 50% MS	3/4	13.840	313.92	4.44	4.58
	3/5	13.870	327.65	4.64	
	3/6	13.800	330.11	4.67	
Sample 25% NS + 75% MS	4/4	13.650	361.99	5.12	5.15
	4/5	13.510	364.44	5.16	
	4/6	13.490	365.42	5.17	
Sample 5 100% MS	5/4	13.450	365.71	4.51	4.56
	5/5	13.560	324.24	4.60	
	5/6	13.515	323.24	4.58	

The Figure 5 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 S4 with 25% natural sand and 75% manufactured sand75% manufactured sand, the split tensile strength increase by 3 .62% over sample designation SI which is of 100% natural sand as fine aggregate.

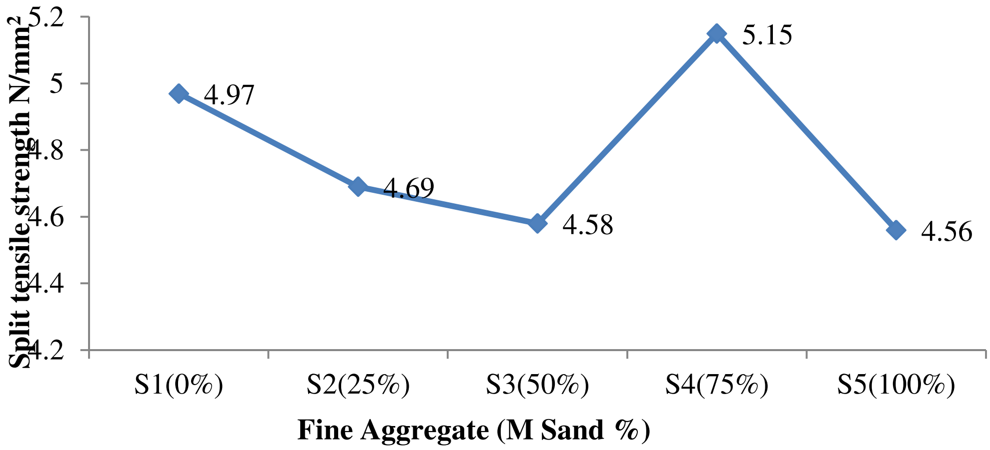


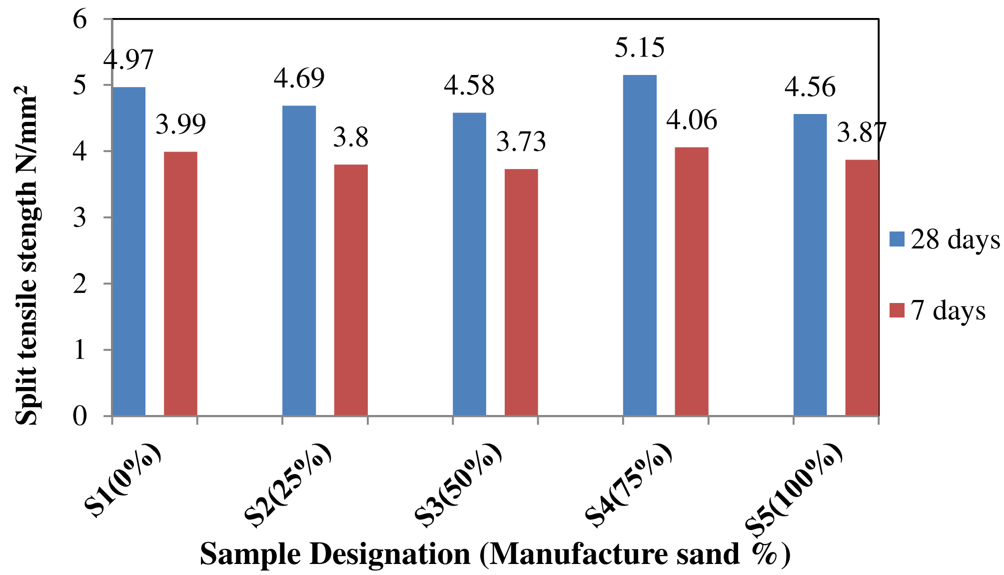
Figure 5 Split tensile strength after 28 days curing with replacement of fine aggregate by manufactured sand

The below Table 7 shows that at the end of 7 days tensile strength of specimen designation type S2 S3 and S5 decrease by 4.76%, 6.52% and 3.00% respectively whereas S4 increase by 1.75% compared to S1, sample made with natural sand. In all the cases the strength is achieved and alternate materials not induce any adverse effect on mix by strength reduction.

Table 7 Average split tensile strength of M60 grade concrete

Manufactured sand content in%	Type of Sample	Split tensile strength N/mm^2	
		7 days	28 days
0	S1	3.99	4.97
25	S2	3.80	4.69
50	S3	3.73	4.58
75	S4	4.06	5.15
100	S5	3.7	4.56

At the end of 28 days the tensile strength of specimen type S2, S3 and S5 decrease by 5.63%, 7.85%, and 8.24% respectively whereas S4 increase by 3.62 % . This shows S4 sample better than all other combination sample and natural sand sample. The result also shown in Figure 6



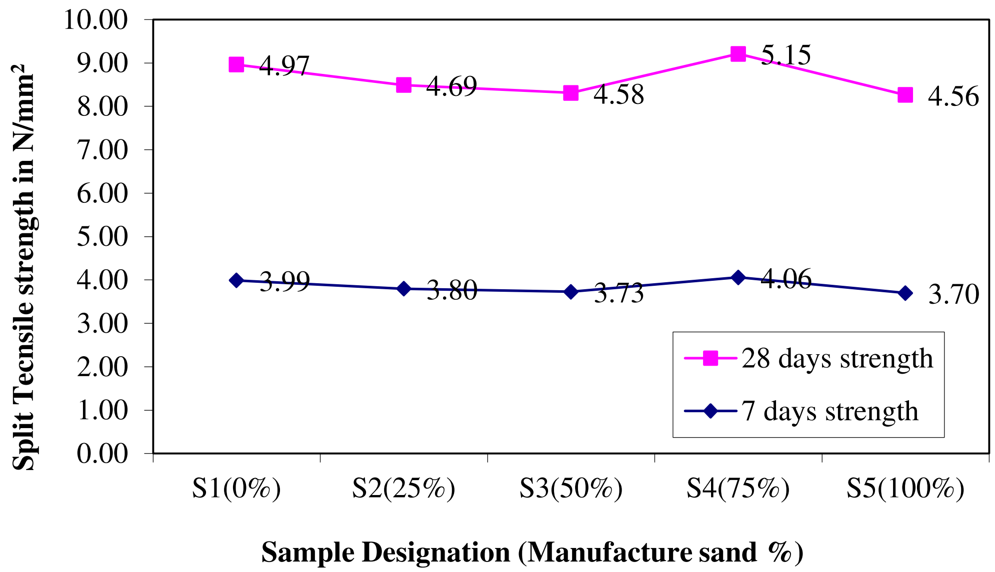


Figure 6 Average split tensile strength of M60 grade concrete with replacement of fine aggregate by manufactured sand

3.3 Ultrasonic pulse velocity

The M60 grade concrete with various proportion of manufactured sand were tested for passing ultrasonic pulse by pulse generator on cubes cast by direct transmission method and to arrive ultrasonic pulse velocity to ensure durability of concrete, which is a guideline to check closely packed dense concrete. The pulses measured electronically and the path length between transducer divided by time taken gives velocity of wave propagation. The specimen comprises of 150mm size cubes after 28 days curing period. The results were shown in Table 8.

Table 8 Ultrasonic pulse velocity on 28 days cube

Designation of sample	Cube Identification number	Length	Time taken X10-6 Micro see	Pulse velocity in M/see	Average pulse velocity in Km/see
Sample 1 100% NS	1/4	0.15	28.00	5357	5.313
	1/5	0.15	28.40	5282	
	1/6	0.15	28.30	5300	
Sample 2 75% NS + 25% MS	2/4	0.15	29.20	5085	5.075
	2/5	0.15	29.0	5137	
	2/6	0.15	30.00	5000	
Sample 3 50% NS + 50% MS	3/4	0.15	30.60	4902	4.809
	3/5	0.15	31.00	4839	
	3/5	0.15	32.00	4688	
Sample 4 245% NS + 75% MS	4/4	0.15	28.10	5338	5.389
	4/5	0.15	27.60	5434	
	4/6	0.15	27.80	5396	
Sample 5 100%MS	5/4	0.15	30.40	4934	4.881
	5/5	0.15	31.00	4839	
	5/6	0.15	30.80	4870	

As per the Bureau of Indian standards the pulse velocity is less than 3 km/second, the concrete is designated as poor. If it is between 3 to 3.5 , the concrete is medium and between 3.5 to 4.5, the concrete is good. When the results more than 4.5 km/sec, the concrete is excellent

From the results it is ascertained that the pulse velocity for all types of combination fine aggregate more than 4.80 km/sec. It shows that concrete quality is excellent due to close packing of concrete ingredients.

In this case the other durability factors such as permeability, impact strength etc also will yield good results if tested for a specific duration. The alternate material does not cause any hindrance to the formation of homogeneous concrete. The Fig 7 below shows that the sample S4 is showing a higher ultrasonic pulse velocity rate.

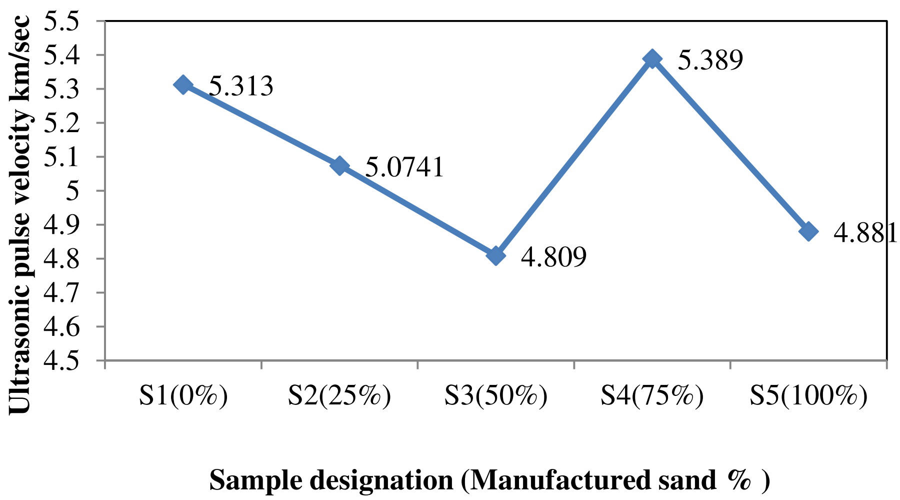


Figure 7 Ultrasonic pulse velocity on 28 days cube

4. CONCLUSION

- Various experiments were carried out on M 60 grade high performance concrete with replacement of fine aggregate by manufactured sand also called as crushed sand in different proportions ie, 0%, 25%, 50%, 75%, and 100%. By analyzing the results the following conclusions arrived at.
- Due to heavy demand and scarcity, natural sand dug well below the permitted levels which contain organic impurities, more silt and clay content. Hence the usage of natural sand must be reduced to the possible extent. The manufactured sand from the quarry graded according to the requirement of usage to suit the purpose ie., concreting, masonry and plastering.
- This is free form organic impurities, silt and clay. Hence this can be chosen as good alternative to natural sand. If manufactured sand is used in structural concrete, the usage of natural sand gets reduced and manufactured sand also put into better use instead of using it to filling purpose only. This will improve the environmental atmosphere of both river basin and store crusher area.
- Results obtained from the carefully performed experiments shows that M60 grade concrete with 25% natural sand and 75% manufactured sand show higher compressive strength of 6.46% over concrete with natural sand 100% on seventh day. On twenty eighth day the same mix show 1.82% increase. All other mix proportion S2, S3 and S5 are shown lesser strength of 1.13%, 0.47% and 3.72 compared to S1 on seventh day and 1.28%, 1.41% and 0.39%, compared to S1 on twenty eighth day of cube compressive strength.
- It shows that S4 mix with 25% natural sand and 75% manufactured sand may be used in high performance concrete to get higher strength over standard mix with 100% natural sand.
- Test on split tensile strength also confirms the results discussed earlier. S4 mixes attain a higher strength of 1.75% on seventh day and 4.08% on twenty eighth day over standard mix S1 with 100% natural sand. Both compressive strength and split tensile strength increases with age of concrete in all cases.
- The ultrasonic pulse velocity for
- Cubes pertaining to S4 mix ie, concrete with 75% manufactured sand found higher than standard S1 mix. The result shows S4 mix found homogeneous, dense and more durable than other mixes.

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