MECHANICAL PROPERTIES OF HIGH STRENGTH CONCRETE BY USING M-SAND AS A FINE AGGREGATE

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ABSTRACT

During the past few decades Common River sand has become expensive due to excessive cost of transport from natural sources. Large scale depletions of these sources have led to many environmental impacts. In order to overcome these impacts an alternative has to be found in order to replace sand. The manufactured sand (M-sand) has found to be economical alternative to the river sand. M-sand is obtained as a crushing of granite stones in required grading to be used for construction purposes as a replacement for river sand. M-sand has been used in large scale in highways as surface finishing materials and also used in the manufacture of hollow blocks and in light weight concrete prefabricated elements. In this, investigations were carried out to study the compressive strength and split tensile strength of concrete using M-sand as fine aggregate instead of river sand. And compare the results obtained from both the river sand and the M-sand. In order to achieve the strength, cement is replaced by silica fume by 15% in weight and also 1.2% weight of binder super plasticizer is added to obtain workability. The present investigations mainly focused on the M-sand properties and the strength obtained from both the river sand and m-sand. In order to solve the problem of the granite powder disposal from the industries and also to solve the raw materials shortage problem for concrete, studies are being made to utilize the M-sand in the manufacture of varieties of building and ceramics products. This investigation is also based on the comparison of the compressive strength and split tensile strength achieved by the cubes and cylinders in normal sand and M-sand.

Keywords: High Strength Concrete;Silica Fume;Compressive And Split Tensile Strengths;Water-Cement Ratio.

I. INTRODUCTION

1.1 High Strength Concrete

HSC is the term used for concrete mixes, which possess invariably high strength, high dimensional stability, reasonable workability and high durability. This type of concrete finds application in heavily reinforced sophisticated structural elements in high rise buildings, off-shore platforms, super span bridges, prestressed concrete members and heavy-duty pavements. High strength concrete has compressive strength of up to100 MPa as against conventional concrete which has compressive strength of less than 50 MPa. High strength concrete are same as those used in conventional concrete with the addition of one or two admixture, (both chemical and minerals).

High strength concrete essentially has a low water-binder ratio. A value of 0.3 is suggested as the boundary between normal strength and high strength concrete. The production of high strength concrete requires more research and more attention of quality control than conventional concrete. High strength concrete (HSC) might be regarded as concrete with strength in excess of 60MPa and such concrete can be produced as relatively normal concrete with a higher cement content and a normal water-reducing admixture. This present investigation evaluates the potential of silica fume and M-sand as filler materials. Measurements of early age properties of fresh concrete including slump test and specific gravity tests and fineness modulus have been examined. Mechanical performances including compressive strength and split tensile strength were evaluated. The aim of the investigation is to investigate the effect of M-sand as a fine aggregate in high strength concrete and compare the results with the River sand. The scope of the present investigation can be summarized as follows:

- To study the effect of workability and the strength of concrete with the replacement of M-sand by river sand, at an addition of silica fume with cement.
- To achieve 28 days characteristic compressive strength of 70MPa.
- To compare the variation of compressive strength at 7 days ,14 days and 28 days strength between M-sand and River sand. In the present investigation more emphasis is given to study the HSC using M-sand replacement by river sand. So as to achieve better concrete composite and to encourage the use of M-sand to overcome the environmental impacts caused due to over depletion of river sand.

1.2 Properties of High Strength Concrete

The properties of high strength concrete are significantly different from those of normal strength concrete. These properties are examined in this section when the concrete is setting and hardening as well as in the hardened state. These properties should be taken into account while designing structures using high-strength concrete.

1.3 Setting and Hardening

When the concrete mixture is in the liquid phase, there are isolated solid grains in a connected structure. Hydration starts from the surfaces of the grain. As the outer crust grows thicker, it retards the hydrations process. The formations of hydrates around each grain change the liquid into a continuous solid. In ordinary concrete, the hydration continuous the anhydrous core remains at the center of the grain for a long time. The post-setting hydration process leads to the internal growth of a skeleton structure and the reduction of the water content in the pores. For high strength concrete with a low water cement ratio, the shrinkage caused by the reduction in the pore water causes internal compression, which is developed due to the surface tension of the pore water at the liquid-vapour interface. The mobility of the fluid state decreases as the water content decreases due to the reaction. High strength concrete with a low water-cement ratio is more sensitive to early drying.

II. EXPERIMENTAL INVESTIGATIONS

2.1 Introduction

This chapter presents the details of the experimental investigations carried out on the test specimens to study the workability and mechanical properties of HSC using silica fume as a constant percentage replacement with cement and to correlate the results between the normal sand and the m-sand. In addition the performance of silica fume in concrete also required to ensure. In present investigation, a specified mix design procedure for HSC using silica fume and m-sand and super plasticizer which was formulated. Based on the above procedure, a concrete mixture property with a characteristics target compressive strength of 70 MPa is designed with 15% replacement of silica fume with cement and full replacement of normal sand with m-sand and correlates the results obtained in both the sand conditions. Experimental investigation have been carried out on the HSC specimen to ascertain the workability such as slump test and mechanical properties such as compressive strength and split tensile strength of the M70 grade mixes. Minimum three specimens were tested for each trial mix for normal water. All the tests were conducted as per codal specifications.

2.2 Preparation before Tests

The test specimens where cast in cast iron moulds. The inside of the mould were applied with oil to facilitate the easy removal of specimens. For obtaining the binder content, the cement and silica fume were thoroughly mixed with one another in dry condition. The fine aggregate and the binder content should be mixed with in dry condition. The coarse aggregate, fine aggregate and the binder content were placed in a concrete mixer machine and then mixed thoroughly in dry condition. For addition of water initially 75% of the mix water is added to the dry mix and mixed thoroughly. The super plasticizer was added to the remaining 25% of the mix water and added to the mix and then mixing was carried out about 2 to 3 minutes. The concrete was then placed in the moulds in three layers of equal thickness and each layer was vibrator. For each series of test specimens, specimens were cast to study the strength and shear related properties of the HSC mixes. After 24 hours, the test specimens were de-molded and set of specimens was placed in normal water curing, till the age of test.

2.3 Workability Properties

Measurements on workability of HSC are done by slump cone test and compaction factor test. The tests on fresh concrete of all trial mixes were carried out.

2.4 Slump Cone Test

This test is used to determine the workability of concrete. The apparatus is a cone of 10cm top diameter, 20cm bottom diameter and 30 cm height. It has two handles for lifting purposes. Initially, the con is cleaned and oil is applied on the inner surface. Then, the concrete to be tested is placed into the cone in three layers. Each layer is compacted 20 times by a standard tamping rod. After filling the cone, it is lifted slowly and carefully in the vertical direction. Concrete is allowed to subside and this subsidence is called slump. If the slump is even, then it is termed as true slump. If one half of cone slides, it is called shear. If entire concrete slides, it is called as collapse. Shear slump indicates that concrete is non-cohesive and shows a tendency for segregation. Generally, the slump value is measured as the difference between the height of the mould and the average height after subsidence. Slump test is found to be the simple test and is widely used.

2.5 Strength Related Properties

The strength related tests were carried out on hardened conventional cement concrete for 28 days to ascertain the strength related properties such as cube compressive, cylinder compressive strength.

2.6 Compression Tests for Cubes

For cube compression tests on concrete, cube of size 150mm were employed. All the cubes were tested in saturated condition after wiping out the surface moisture from the specimen. For each trial mix, three cubes were tested at the age of 7, 14 and 28 days of carrying 400 tons capacity HELICO compression testing machine referred to BIS: 516-1959. The tests were carried out at a uniform stress after the specimen has been centered in the testing machine. Loading was continued till the dial gauge needle just reverses its direction of motion. The reversal in the directions of motion of the needle indicates that the specimen has failed. The dial reading at the instant was noted, which is the ultimate load. The ultimate load divided by the cross section area of the specimen is equal to the ultimate cube compressive strength. The test setup for the compressive strength and typical failure pattern is shown in figures.

Compressive strength = load / area (N/mm^2)

2.7 Split Tensile Strength for Cylinders

This is an indirect test to determine the tensile strength of the specimen, splitting tensile tests were carried out on 150mm*300mm sized cylinder specimens at an age of 7, 14 and 28 days, using 400 ton capacity heico compression testing machine as per IS 5816-1970. The load was applied till the specimen split and readings were noted. The splitting tensile strength has been calculated using the following formula.

$$\text{Split tensile strength} = \frac{2*P}{\pi D*L} \ N/mm^2$$

Where,

P – Maximum load in "N" applies to the specimen

D – Measured diameter in "mm" of the specimen

L – Measured length "mm" of the specimen

III. MIX DESIGN-M70

3.1 Design Stipulations

Characteristic compressive strength required in the field of 28 days	=	$70N/mm^2$
Type of coarse aggregate	=	Rock
Typical shape of coarse aggregate particles	=	Angular
Specific gravity of the cement	=	3.15
Specific gravity of silica fume	=	2.20
Specific gravity of fine aggregate	=	2.60
Specific gravity of coarse aggregate	=	2.70
Bulk density of coarse aggregate	=	1560 kg/m^3
Bulk density of fine aggregate	=	1570 kg/m^3
Water absorption of coarse aggregate	=	0.4
Moisture content of coarse aggregate	=	NIL
Water absorption of fine aggregate	=	1.48%
Moisture content of fine aggregate	=	NIL

3.2 Mix Design

1) Target mean compressive strength of concrete

The target mean compressive strength for the specified characteristic cube strength = 70+9.7

= 79.7 N/mm^2

2) Selection of maximum size of coarse aggregate

The maximum size of coarse aggregate selected as 12.5 mm as per table 4.2

3) Estimation of free water content

Since the saturation point of super plasticizer is not known the minimum free water content is selected as 199 l/m^3 as per table 4.3

4) Super plasticizer dosage

The super plasticizer dosage is taken as 1.2%

5) Estimation of air content

The entrapped air content is estimated as 2.0%

6) Selection of coarse aggregate content

Since the coarse aggregate particle shape is angular, the coarse aggregate content is taken as 880 kg/m^3 as per table 4.5

7) Selection of w/b ratio

The water binder ratio is chosen as 0.26 for the target mean compressive strength of 79.7 MPa from fig 4.1 of the proposed w/b ratio Vs compressive strength relationship.

8) Calculations of binder content

Binder content required per unit volume of concrete is

= free water content / (W/B ratio)

= 199/0.26

= 765.38 kg

Let the % replacement of cement by the silica fume is 15%

Silica fume content = (15*765.38)/100

= 114.80 kg

Mass of cement = 765.38-114.80

= 650.58 kg

9) Super plasticizer content

Mass of solids in super plasticizer

M_{sol} = (c*d)/100

Where

'c' is the mass of the cementitious materials in kg

'd' is the dosage expressed as the % of its solid cement

M_{sol} = (1.2*765.38)/100

M_{sol} = 9.18 kg

Volume of the liquid super plasticizer,

V_{liq} = $_{Msol}$*100/(S*Ss)

Where

S is the solid content of the super plasticizer in %

Ss is the specific gravity of the liquid super plasticizer

V_{liq} = (9.18*100)/(40*1.22)

= 18.81 l/m^3

Volume of water in super plasticizer

V_w = V_{liq}*S_s[(100-S)/100]

= 18.81*1.22[(100-40)/100]

= 13.764 l/m^3

Volume of solids in liquid super plasticizer,

V_{sol} = V_{liq}-V_w

= 18.81-13.764

= 5.046 l/m^3

10) Estimation of fine aggregate content

Absolute volume of sand = Vfa

$$Vfa = 1000 - [\left(Vw + \left(\frac{Mc}{Sc}\right) + \left(\frac{Msf}{Ssf}\right) + \left(\frac{Mca}{Sca}\right) + Vsol + Vea\right)]$$

Where,

$Vsol$ is the absolute volume of sand in litres per unit volume of the concrete (m^3)

Vw is the volume of water (litres) per unit volume of concrete

Mc is the mass of cement (kg) per m^3 of concrete

Sc is the specific gravity of cement

Msf, Mca are the total mass of the silica fume and coarse aggregates (kg) per m^3 of concrete respectively.

$Vsol$, Vea are the volume of solids in the super plasticizer and entrapped air (litres) per m^3 of concrete respectively.

Vfa =1000[199+(650.58/3.15)+(114.80/2.2)+(880/2.7)+5.0461+20]

= 216.17 l/m^3

Mass of the sand = 216.17*2.6 = 562.05 kg

11) Moisture adjustment

The actual quantity of the coarse aggregate = 880 kg/m^3

Actual quantity of the fine aggregate = 562.05 kg

The actual quantity of the water content required after deducting the volume of water included in the liquid super plasticizer is

= 199-Vw

= 199-13.764

= 185.23 litres

12) Unit mass of concrete

=185+650.58+114.80+880+309.6+9.18

=2344.16 kg/m^3

The actual quantities of different ingredients required for 1m^3 of the concrete are

Mixing water = (WC-Vw)

= 185 litres taken as 199 liters itself.

Cement = 650.58 kg

Silica fume = 114.80 kg

Fine aggregate = 562.05 kg

Coarse aggregate = 880 kg

Super plasticizer = 18.81litres the mix proportion then becomes,

The mix proportion then becomes,

Water	:	(cement+SF)	:	FA	:	CA
199	:	**765.38**	:	**562.05**	:	**880**
0.26	:	**1**	:	**0.734**	:	**1.15**

Test Results and Discussions

Compression test results for river sand (Curing period – 7 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Compressive strength (N/mm^2)	Average Compressive strength (N/mm^2)
1	0.26	7	A1	8.45	1019	45.3	45.7
2			A2	8.57	1035	46	
3			A3	8.38	1030	45.8	
4	0.28	7	B1	8.62	954	42.4	42.8
5			B2	7.98	981	43.6	
6			B3	8.65	958	42.6	
7	0.30	7	C1	8.29	893	39.7	39.3
8			C2	8.54	900	40	
9			C3	7.65	859	38.2	

Compression test results for river sand (curing period – 14 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Compressive strength (N/mm²)	Average Compressive strength (N/mm²)
1	0.26	14	A4	8.32	1282	57	56.1
2			A5	8.54	1271	56.5	
3			A6	8.36	1237	55	
4	0.28	14	B4	7.95	1219	54.2	53
5			B5	8.12	1170	52	
6			B6	7.45	1192	53	
7	0.30	14	C4	8.62	1120	49.8	49
8			C5	9.3	1035	46	
9			C6	8.21	1147	51	

Compression test results for river sand (curing period – 28 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Compressive strength (N/mm²)	Average Compressive strength (N/mm²)
1	0.26	28	A7	9.32	1545	68.7	68
2			A8	9.21	1552	69	
3			A9	8.98	1496	66.5	
4	0.28	28	B7	8.45	1473	65.5	65
5			B8	7.65	1435	63.8	
6			B9	8.51	1480	65.8	
7	0.30	28	C7	8.26	1395	62	62
8			C8	9.21	1422	63.2	
9			C9	9.12	1361	60.5	

Compression test results for m- sand (curing period – 7 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Compressive strength (N/mm²)	Average Compressive strength (N/mm²)
1	0.26	7	A1’	8.12	916	40.7	40.5
2			A2’	7.54	952	42.3	
3			A3’	7.12	866	38.5	
4	0.28	7	B1’	7.65	864	38.4	38
5			B2’	8.24	810	36	
6			B3’	7.69	891	39.6	
7	0.30	7	C1’	8.15	769	34.2	34.4
8			C2’	8.23	810	36	
9			C3’	8.54	738	32.8	

Compression test results for m- sand (curing period – 14 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Compressive strength (N/mm^2)	Average Compressive strength (N/mm^2)
1	0.26	14	A4’	7.45	1137	50.57	50.5
2			A5’	8.15	1158	51.5	
3			A6’	8.94	1113	49.5	
4	0.28	14	B4’	8.12	1095	48.7	48
5			B5’	8.51	1035	46	
6			B6’	7.45	1102	49	
7	0.30	14	C4’	7.91	1044	46.4	44.2
8			C5’	8.45	945	42	
9			C6’	8.95	990	44	

Compression test results for m- sand (curing period – 28 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Compressive strength (N/mm^2)	Average Compressive strength (N/mm^2)
1	0.26	28	A7’	8.65	1525	67.8	69
2			A8’	8.15	1552	69	
3			A9’	9.21	1575	70	
4	0.28	28	B7’	8.45	1467	65.2	67.2
5			B8’	7.15	1530	68	
6			B9’	8.59	1541	68.5	
7	0.30	28	C7’	8.65	1402	62.35	63.3
8			C8’	8.24	1451	64.5	
9			C9’	7.98	1417	63	

Split tensile strength results for river sand (curing period-28 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Split strength (N/mm^2)	Average split strength (N/mm^2)

1	0.26	28	A1	13.59	381	5.40	5.5
2			A2	13.54	396	5.6	
4	0.28	28	B1	12.98	339	4.8	4.701
5			B2	13.48	325	4.602	
7	0.30	28	C1	13.98	333	4.706	4.7
8			C2	13.47	329	4.66	

Split tensile strength results for m- sand (curing period-28 days)

S. No.	W/C Ratio	Age at testing (days)	Specimen	Weight (kg)	Load (kN)	Split strength (N/mm^2)	Average split strength (N/mm^2)
1	0.26	28	A1’	12.57	403	5.7	5.67
2			A2’	12.98	399	5.64	
4	0.28	28	B1’	12.51	346	4.9	5.05
5			B2’	12.53	368	5.2	
7	0.30	28	C1’	12.48	329	4.65	4.785
8			C2’	13.57	348	4.92	

Tensile strength is one of the basic and important properties of concrete. The results are required for the design of concrete structural elements subject to transverse shear, torsion, shrinkage and temperature effects. Its value is also used in the design of prestressed concrete structures, liquid retaining structures, roadways and runway slabs. The split tensile strength is generally greater than the direct tensile strength and lower than flexural strength (modulus of rupture). It is used to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement. The split tensile strength of HSC of the tested specimens is presented in the table.

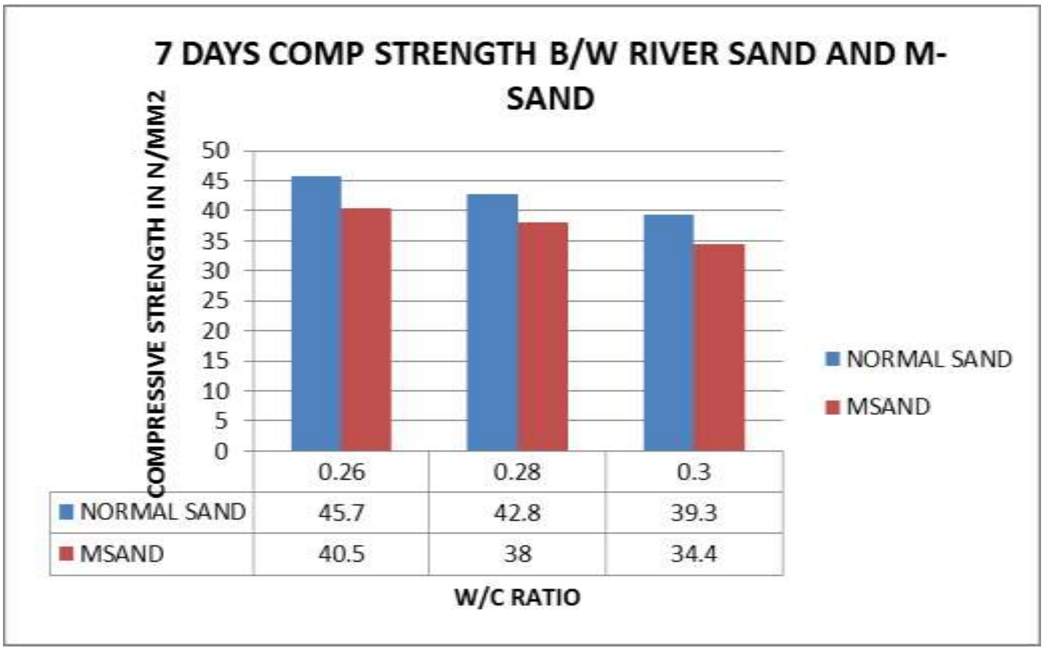
Average compressive strength results for both river sand and m-sand

S.NO	W/C RATIO	RIVER SAND (N/mm^2)			M-SAND (N/mm^2)		
		7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS
1	0.26	45.7	56.1	68	40.5	50.5	69
2	0.28	42.8	53	65	38	48	67.2
3	0.30	39.3	49	62	34.4	44.2	63.3

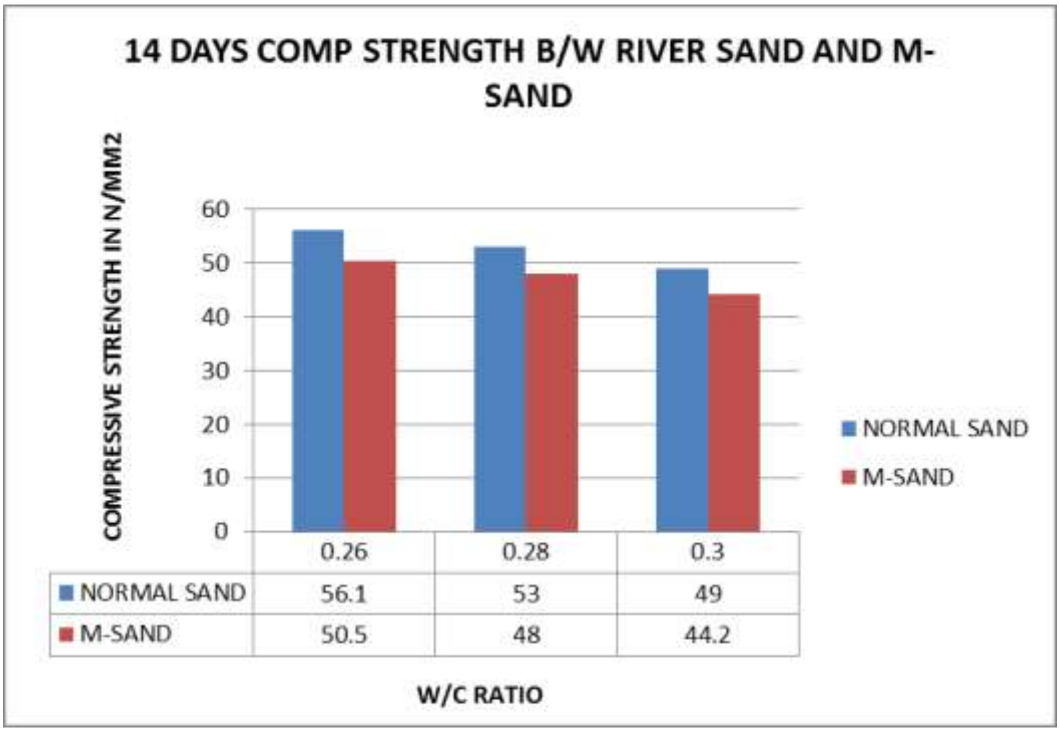
Average split tensile strength results for both river sand and m-sand

S.NO	W/C RATIO	RIVER SAND (N/mm^2)	M-SAND (N/mm^2)
1	0.26	5.5	5.67
2	0.28	4.701	5.05
3	0.30	4.7	4.785

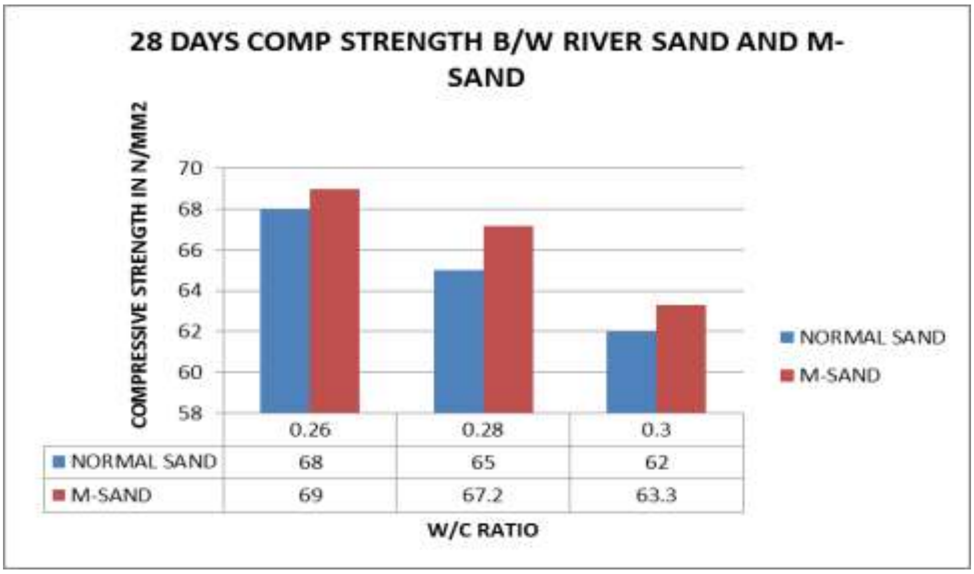
Comparison between the river sand and m-sand (compressive strength for 7 days curing period)



Comparison between the river sand and m-sand (compressive strength for 14 days curing period)

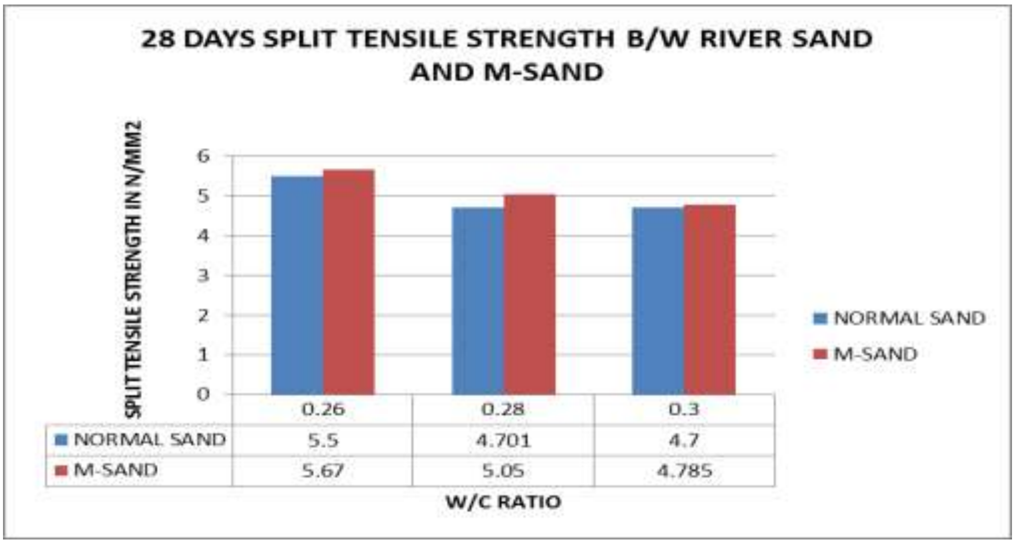


Comparison between the river sand and m-sand (compressive strength for 28 days curing period)



	0.26	0.28	0.3
NORMAL SAND	68	65	62
M-SAND	69	67.2	63.3

Comparison between the river sand and m-sand (split tensile strength for 28 days curing period)



	0.26	0.28	0.3
NORMAL SAND	5.5	4.701	4.7
M-SAND	5.67	5.05	4.785

IV. CONCLUSIONS

Cubes and cylinders of M-70 grade concrete have been cast with river sand as fine aggregate and tested for cube compressive strength and split tensile strength. Cubes and cylinders of M-70 grade concrete have been cast with M-sand as fine aggregate and tested for cube compressive strength and split tensile strength.

Based on the experimental investigation, the following results have been found,

i) 7 days and 14 days strength of concrete with River sand is higher when compared with the strength of concrete with M-sand.

ii) 28 days strength of concrete with M-sand is higher than that of with River sand.

iii) Also, due to the superior gradation of M-sand gave good plasticity to mortar providing excellent workability.

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