"AN EXPERIMENTAL INVESTIGATION ON STEEL FIBER REINFORCED CONCRETE WITH PARTIAL REPLACEMENT OF NATURAL SAND BY M-SAND"

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Abstract - *The term Concrete Mix Design is the methodology of selecting suitable materials of concrete and finding out their relative amounts with an objective of generating a concrete of the required characteristics such as strength, durability, and workability in an economical manner. The required concrete proportioning of ingredient is directed by the performance of concrete in 2 stages i,e the plastic and hardened stage. The plastic concrete cannot be properly placed and compacted if it is not workable. Therefore workability as a property of concrete has a vital importance. In hardened concrete, the compressive strength is generally considered to be an basis of its other properties, depends upon many factors, e.g. quality and quantity of cement , water and aggregates; batching and mixing; placing ,compaction and curing. The aim of this study is to evaluate the mechanical performance of M30 grade concrete containing the manufacturing sand (50% replacement of natural sand) and inducing crimped steel fibers (1%) to enhance the properties of hardened concrete. The test on mechanical properties of concrete i,e compressive , tensile, flexural and shear strength being carried out, even the study of effect of higher temperature on concrete is conducted for 7,14 and 28 days of cured specimen for both the fiber reinforced and the conventional concrete. The study gives clear picture regarding the effect caused by the addition of steel fibers and M-sand compared with that of the conventional concrete.*

Key Words: **Crimped Steel Fibre, M-sand , compressive strength, split tensile strength, flexural strength, shear strength , Thermal Cycle, FRC-MS.**

1.INTRODUCTION

FRC is a composite mixture of cement mortar / concrete with suitable discrete fibers. Fibers are the small size materials that are reinforced which when mixed enhances the properties of the mixture after hardened state. The shape may be flat, circular or crimped. The fibers are defined by the discrete parameter called the "Aspect Ratio". It's represented by l/d ratio where d is diameter and l is the length, usually ranges from 30 to 150. The introduction of fibers is to improvise strength, impact resistance, toughness, enhance other engineering properties and to reduce cracking. The fibers are available in different forms, shapes and sizes. The fiber reinforced concrete properties and characteristics depend upon the amount , type and dimensions of the fibers added, also the cement matrix and bond of fibers to the matrix. In addition, the orientation and suspension of fibers, which affects the toughness and cracking performance of concrete mix . Steel fibers are generally used amongst the different fibers for the structural applications. Thus steel fibers used have a considerable improvement in strength, flexural, impact and fatigue of concrete.

The aim project is to have a study comparison between mechanical performance of crimped SF reinforced concrete (1% maintained constant) with additional replacement of natural sand by Manufacturing sand by 50 % constant for M30 grade concrete mix with that of the normal concrete. The experimental investigation includes the test being carried on fresh and hardened concrete. The test carried out are for the workability of concrete, compressive strength, tensile strength, flexural strength , shear test and concrete subjected to higher temperature.

2. MATERIALS AND METHODS

Cement :

UltraTech -53 grade cement confirming to IS 12269-1987 was been used for the current project to complete the investigation process. The laboratory test conducted on cement are as given be below

Table 1: Properties of Cement

Properties	Result	Permissible limits as per IS 12269-1987
Fineness	3%	≯10%
Specific Gravity	3.15	3.5
Initial Setting Time	30 min	≮ 30 min
Final Setting Time	550min	≯ 600 min

Fine Aggregates

The natural sand was obtained from the local origin. The river sand brought was free from all the silt, clay and other impurities. As per the sieve analysis conducted on the natural fine aggregate (sand) the complied to Zone II IS: 383(1970). Physical properties of fine aggregates are in the tabular column as shown below.

Table 2: Properties of Fine Aggregate

Properties	Result
Shape of aggregates	Angular
Specific gravity	2.67
Fineness Modulus	6.75
Compacted bulk density	1760 kg/m^3

Manufacturing Sand (M-Sand)

The Manufacturing sand used is 50% replacement for the natural sand and was brought from , finely crushed basaltic stone. The lab test conducted on the M-sand confines it to Zone II origin and other properties being tabulated below

Table 3: Properties of M-Sand

Properties	Result
Zone of M-sand	II
Specific Gravity	2.70
Fineness Modulus	2.75
bulk density	1705 kg/m^3

Coarse Aggregates

The locally available coarse aggregate, crushed basalt stone angular in shape with size 20mm down size were utilized for the project work. The test conducted in laboratory on it and their following values are represented below (within Limits of IS:383-1970)

Table 4: Properties of Coarse Aggregate

Properties	Result
Shape of aggregates	Angular
Specific gravity	2.67
Fineness Modulus	6.75
Compacted bulk density	1760 kg/m^3

Water

Portable tap water was used for the preparation of specimens and for the curing of specimens

Steel Fibers

Steel Fibers (crimped) of length 50mm and thickness 1mm with an aspect ratio of 50,is been used in the current project. A constant percentage of fibers i,e 1% is added and is used for the experimental study. They are uniformly dispersed in the concrete while mixing and casting. The Properties of steel fibers is confirmed with the manufacture and it satisfies with ASTM-A820:90 with respect to all characteristics like bend ability, strength and minimum ultimate tensile strength.

3.MIX DESIGN :

As per IS 10262 – 2009 code and using the above test results. The mix design producer was carried out for M30 grade of concrete. A Trail mix for M30 grade was obtained by mix design and the mix proportion obtained for M 30 grade concrete is given in the Table below

Table 5: Mix Proportion

Cement	Sand	Coarse Aggregate	W/C Ratio
438 Kg/m^3	638.4 Kg/m^3	1081.35 Kg/m^3	0.45
1	1.46	2.47	0.45

4. DETAILS OF PRESENT INVESTIGATION

The Investigation programme involves casting, curing and testing of a total 102 specimen, it includes casting and testing of 48 nos cubes, 18 nos cylinders, 18 nos prisms and 18 nos L-shaped specimen. All the test were carried for 7, 14 and 28 days of curing except the cube specimen subjected to higher temperatures. Among the 48 cubes casted, 18 cubes were subjected for carrying the compressive test for 7,14 and 28 days after curing, 9 cubes for normal M30 grade concrete and 9 cubes for the Steel fiber reinforced concrete (FRC-MS*). Cubes were of the dimension 150mm x 150 mm x 150 mm casted in the steel cubical moulds. Testing being carried out in the compression testing machine.*Steel (crimped ,1% constant) fiber reinforced concrete with 50% natural sand replaced with M-sand.

For split tensile strength 18 nos of cylinders were made and curing carried out for 7,14 and 28 days, 9 were for the normal concrete and 9 for the FRC-MS. The cylinder were of the 150mm dia and 300mm height casted in steel cylindrical moulds, testing being done in the CTM. The flexural test were carried for the prism 18 nos of size 100mm x 100mm x 500mm casted in the steel prism moulds and cured for the period of 7,14 and 28 days and testing was done on the UTM machine with three point loading.

The shear specimen casted were of L-shaped, casted in the cube moulds totally 18 nos , 9 for the normal concrete and 9 for FRC-MS testing. The testing being carried out after 7,14 and 28 days in the UTM machine. For the testing of concrete subjected to higher temperatures, cubes of about 30 numbers being casted and being cured for 28 days. The loss in mass and compressive strength of each cube which is tested for different temperatures i,e 50^{o},100^{o},150^{o},200^{o} and 300^{o}. Three cubes for each temperature

5. RESULT AND DISCUSSION

5.1 Compressive Strength Test

The Compressive-strength of concrete depends on various factors, quality of the aggregate, water-cement ratio, quality of cement, temperature conditions etc. Compressive test is done either on cylinder or cube specimen.

For the cube test carried out , a mould of 15cm X 15cm X 15cm was been used. All the concrete is thoroughly mixed to impart uniformity. Now the concrete is poured in layers and compacted using the tamping bar to avoid the pore space in the specimen. After the required 7, 14 and 28 days of cured specimen, the specimen is then put into the CTM machine and where gradual load of 140 kg/cm^2 per minute applied, till it cracks or breaks. Failure- load to the Area provides the Comp-strength.

$$fc = P/A \ \text{N/mm}^2$$

Where P= Load applied in N,
A= Area of specimen in m^2

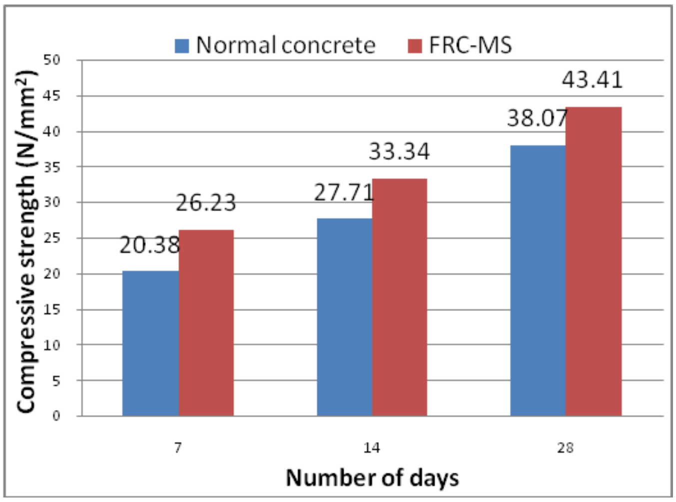
$$Tsp = 2P/\pi DL \ \text{ in N/mm}^2$$

Table 5.1: Compressive Strength Test Results

Grade	No.of Days	Compressive Strength in N/mm^2			
		Normal	Avg.	FRC-MS*	Avg.
M30	7	20.00 20.45 20.67	20.38	26.67 26.23 25.78	26.23
	14	27.62 27.56 28.45	27.71	33.34 33.56 33.12	33.34
	28	37.75 38.23 38.23	38.07	43.12 43.56 43.56	43.41

*FRC-MS : Steel (crimped) Fiber Reinforced Concrete

Graph 5.1 : Difference in the Compressive Strength of Normal Concrete Vs FRC-MS.



5.2 Split Tensile Strength Test

The split Tensile Test determines the tensile strength parameter of concrete which is the important basic property. The concrete is good in compression and weak in tension, it develops cracks when subjected to direct tension. Thus, by inducing certain fibers such as steel, the tensile property of the concrete can be enhanced.

For the testing process cylinders are been casted in the metal cylindrical moulds of 3mm thick. The arrangement of it is made such that it can be opened longitudinally after casting. The mould internal dia is 150mm and height 300mm. The bottom consists of a firm metal base plate.

The specimen is placed on the compression testing machine along longitudinal direction, two metal strips or wooden plank is kept at top and bottom and load applied

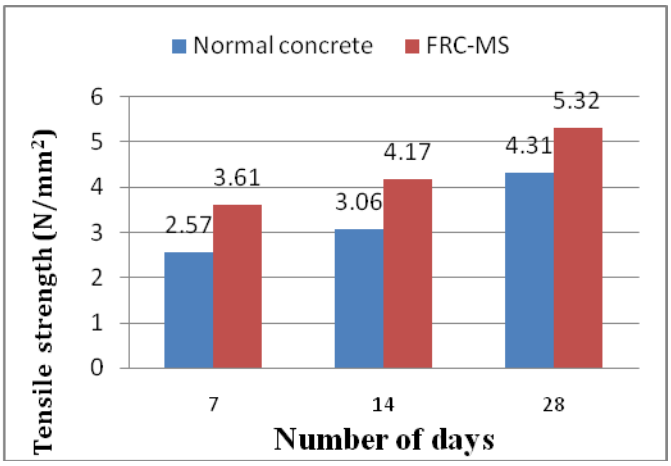
continuously at 14.0-20.0 kg/cm² per min, till specimen breaks or cracks. Applied load at failure is noted.
The tensile strength of concrete is given as

Where P= Applied Load in N,
D= Diameter of the Cylinder in mm,
L= Length of the Specimen in mm.

Table 5.2: Split Tensile Strength Test Results

Grade	No.of Days	Split Tensile Strength in N/mm²			
		Normal	Avg.	FRC-MS	Avg.
M30	7	2.55 2.62 2.55	2.57	3.54 3.68 3.61	3.61
	14	2.97 3.18 3.04	3.06	4.10 4.24 4.17	4.17
	28	4.26 4.38 4.30	4.31	5.26 5.32 5.37	5.32

Graph 5.2: Difference in the Split Tensile Strength of Normal Concrete Vs FRC-MS.



5.3 Flexure Strength Test

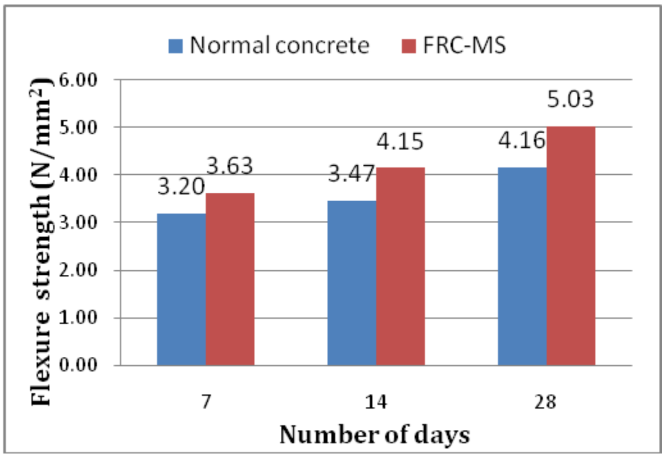
The flexural strength of concrete is an important property to be determined especially for changes in the volume of concrete due to temperature variation or shrinkage, for the road slab performed on to the vehicular loads. The specimen for the above test is casted in size of prism 10.0cm x 10.0cm x 50.0 cm (size < 20 mm). The bottom of the testing machine (UTM) is provided with steel rollers of 38mm dia so placed that the centre to centre distance of the specimen placed upon it is 40 cm. At top of the specimen two similar rollers are placed centre to centre at the third point from the supporting span. The axial load then applied is equally distributed between the top two rollers without any torsional stresses acting on specimen. The load applied is at 180 kg/min for 10 cm specimen, and the maximum load at which the specimens fails or breaks is noted.

The Flexural-Strength (f_b) : $f_b = pl/bd^2$ N/mm²

Table 5.3: Flexure Strength Test Results

Grade	No.of Days	Flexure Strength in N/mm²			
		Normal	Avg.	FRC-MS	Avg.
M30	7	3.08 3.28 3.24	3.20	3.56 3.68 3.64	3.63
	14	3.48 3.44 3.50	3.47	4.08 4.16 4.20	4.15
	28	4.04 4.20 4.24	4.16	4.96 5.04 5.08	5.03

Graph 5.3 : Difference in the Flexure Strength of Normal Concrete Vs FRC-MS



5.4: Shear Strength Test

Shear strength of a component or a composite material like concrete is the structural failure or yield at which it fails under the shear. The loading of shear exhibits the material to fail due to sliding along its plane which is parallel to the direction of load or force applied. The purpose of providing stirrups in the concrete beam is to resist the shear and increase its structural ability.

The Specimen for the shear test were of L-shape casted, the dimension are been shown in the figure 1. The cubical moulds were utilized for the casting purpose and wooden block of 60mmx90mmx150mm were being placed in the cubical moulds before filling of the concrete mixture. After subsequent curing of specimen, they were centrally placed in the UTM with detail arrangement as provided in diagram. The load was applied uniformly and the maximum load at which the specimen starts to crack or fails is noted.

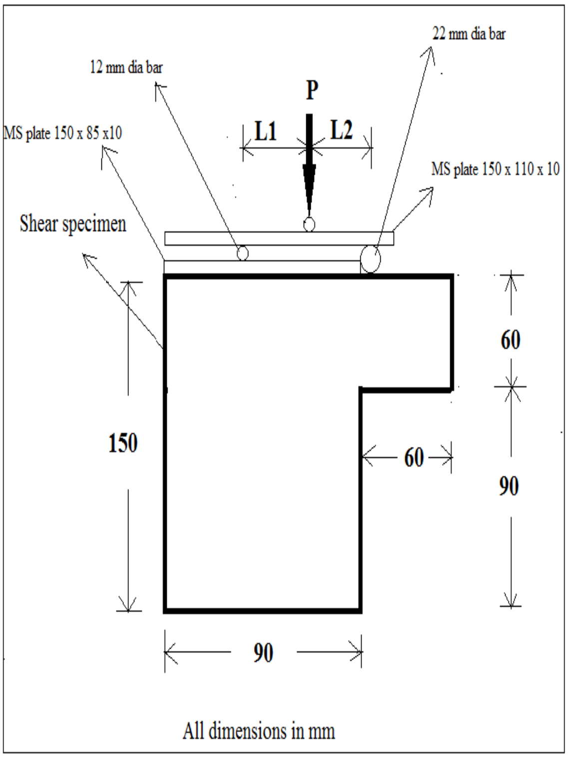


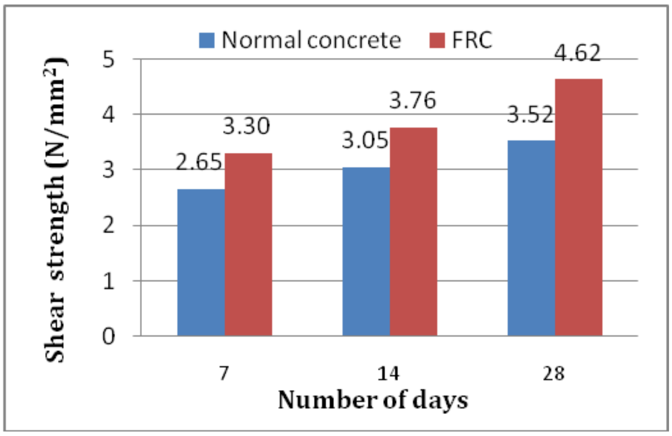
Figure 1: Experimental Set Up for Shear Test Specimen

Shear Strength is calculated as follows:-
Failure load = $PL1/(L1 + L2)$ in kN
Shear strength = (Failure load / A)× 1000 N / mm²
Where, P = Load in kN,
A = shear surface Area in mm²,
L_1 = 25.0 mm, L_2 = 25.0 mm

Table 5.4 : Shear Strength Test Results

Grade	No.of Days	Shear Strength in N/mm²			
		Normal	Avg.	FRC-MS	Avg.
M30	7	2.50 2.67 2.78	2.65	3.54 3.68 3.61	3.30
	14	2.88 3.11 3.17	3.05	4.10 4.24 4.17	3.76
	28	3.44 3.62 3.50	3.52	5.26 5.32 5.37	4.62

Graph 5.4: Difference in the Shear Strength of Normal Concrete Vs FRC-MS



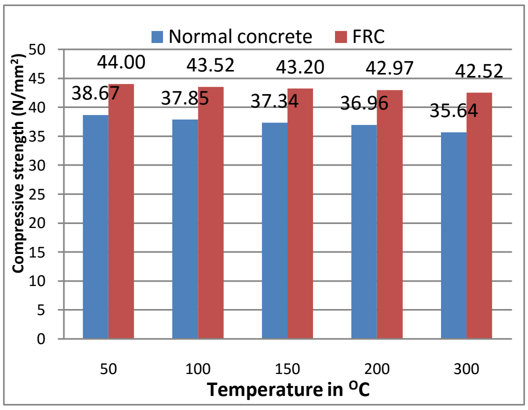
5.5 : Thermal Cycle

The basic idea of this test is to investigate the concrete specimen subjected to the higher temperature and their strength parameters to be evaluated. The investigation was carried out for both the specimen of normal and FRC-MS M30 design mix concrete. Overall 30 specimen where casted in the cube moulds for temperature variations of 50°, 100°, 150°, 200° and 300°C. After the 24hrs of casting, the moulds were removed and the specimens were cured for 28 days. weight of it was taken after removal from the curing tank. It was placed in the hot oven for the temperature required say 50°C for 24 hrs. After this it is allowed to cool for 30 minutes and again its weight is taken. The specimen is then tested for the compressive strength. The same step is followed for each of the temperature mentioned above. The result of the same is tabulated.

Table 5.5 : Compressive strength Test Results for specimen subjected to variable Temperatures.

Temp. in °C	Compressive Strength in N/mm² (28days Curing)			
	Normal	Avg.	FRC-MS	Avg.
50	38.22 39.12 38.67	38.67	43.56 44.45 44.00	44.00
100	37.78 38.00 37.78	37.85	43.56 43.50 43.56	43.52
150	37.56 37.34 37.11	37.34	43.34 43.12 43.12	43.20
200	37.34 36.88 36.67	36.96	42.89 43.12 42.89	42.97
300	35.78 35.56 35.56	35.64	42.67 42.44 42.44	42.52

Graph 5.5: Comparison of Compressive strength, specimen subjected to thermal variations.



6. CONCLUSION

The comparison was between normal and FRC-MS (with 1% steel fibers and 50% replacement of natural sand to that of Manufacturing sand) and the test results proved that the inducing of the fibers of crimped steel and natural sand replaced by M-Sand has a greater values on all the aspect of the study made compared to the normal M30 grade design mix concrete.

- The compressive test results shows a 14.2% increase in strength for 28 days curing by the FRC-MS concrete compared to the normal concrete.
- The split tensile test conducted has a 23.7 % increment of strength for 28 days curing by the FRC-MS. This increment specifies due to SF addition, helps the concrete to resist tensile load since the concrete is weak in tension. Same case in the flexural part of the concrete that the involvement of Steel Fibre has an impact of gaining additional strength of about 18 % after 28 days of curing.
- The shear test conducted on the L-shape specimen also shows good resistance to load carrying capacity and there is an increment in shear of FRC-MS with that of normal concrete. Due to the presence of the fibers in the specimen the breaking pattern is of wedge shape in the cantilever portion of FRC-MS, where as the specimen break exactly at the cantilever portion with less resistance to load shown by the normal concrete.
- The Test conducted on higher temperature for both the concrete specimens shows that there is marginal effect of higher temperature on the FRC-MS concrete compared with that of the normal concrete which has rapid reduction the strength due to varying temperature.

Thus , the overall results implicate that the usage of FRC-MS with replacement of natural sand by M-sand(50%) have a significant growth in strength and durability compared to that of the normal concrete.

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