RESEARCHERID
THOMSON REUTERS

[Nagarjuna* *et al.*, 6(12): December, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

AN EXPERIMENTAL ANALYSIS OF STRENGTH PROPERTIES OF HIGH STRENGTH CONCRETE USING STEEL FIBERS

B. Nagarjuna [*1], M. Surya Prakash [2]
[*1]PG Student, ASRCE, Tanuku
[2]Assistant Professor, ASRCE, Tanuku

DOI: 10.5281/zenodo.1116716

ABSTRACT

Concrete is extensively used as a construction material in various types of structures, because of its versatility and durability. Concrete being brittle, is weak in tension and is often subjected to shrinkage and creep. These factors have led to the development of FIBRE REINFORCED CONCRETE. In recent years High strength concrete is gaining importance in the fields of pre-stressed concrete bridges, high rise buildings, machine foundations etc. In this context, an attempt has been made to study the combined effect of high strength concrete and FRC. In the present investigation concrete grades having target strength of 40N/mm^2, 50N/mm^2, 60 N/mm^2 is studied. Steel fibres of circular cross section are used in different volume fractions. The characteristics like compressive strength, split tensile strength, modulus of elasticity, load-deflection and flexural strength are investigated. The test results are analyzed critically and methods for predicting the characteristics of high strength FRC are discussed.

KEYWORDS: Fibre Reinforced concrete, Steel Fibers, Volume fractions, Strength.

I. INTRODUCTION

Concrete is used extensively as a construction material because of its versatility. It is good in compression, but weak in tension. This drawback can be overcome by providing steel in tension zone. This technique called **"**REINFORCED CEMENT CONCRETE**"**, improves the load carrying capacity of concrete members. At the same time durability of concrete is also important. Durability is mainly affected due to cracks developed by creep and shrinkage. This can be avoided by using certain chemical admixtures. But once a crack develops in the member there are no barriers to stop the propagation of such cracks. In RCC it leads the corrosion of the reinforcement slowly and finally it results in the failure of the structure.

In an attempt to control the so formed cracks has led to the development of FIBRE REINCORCED CONCRETE (FRC), obtained by dispersing in concrete, very small sized reinforcement called fibres. The small closely spaced fibres so used act like crack arresters, substantially improve the static and dynamic strengths. That is the properties like toughness, impact resistance and stiffness under different loading conditions are improved. Naturally the properties of fibres influence the properties of FRC composites.

Fibres can be classified into two categories.

A) Natural Fibres
B) Artificial Fibres

The natural fibres like jute, coir, horse hair etc. have got low tensile strength and low elastic modulus. By addition of such fibres static strengths are not improved, while the dynamic properties are improved. Artificial fibres can be of both low or high tensile strength. For ex. Nylon, Polypropylene, polyethylene have got low tensile strength. Steel, Glass, Carbon have got high strength. The earlier three fibres are suitable for the mains structures as they are lease affected by the corrosion. The use of fibres to arrest the propagation of cracks in concrete structures would be of great advantage in improving the quality of structure built in industrial environments. FRC has got wide uses in overlays, precast units such as purlins, girders, trusses and structures requiring resistance to shocks. FRC can also be used in overlays of air field, highway pavements, heavy duty floors, machine bases etc.FRC can be used in thin precast units subjected to flexural loading like piles, fence posts, steps, manhole covers etc. FRC has also got wide potential for application in situation where toughness is important in structures requiring resistance to thermal shocks such as refractory linings, explosive stores. Pads for vertical take off and air craft tank turning pads. High strength concrete is basically a concrete with compressive strength greater than 40N/mm^2, or in general a concrete which possesses compressive strength properties which are difficult of obtain using local materials and practices. Owing to tits various advantages like economy, possibility of smaller cross section and slender members, durability, reduction in weight, low creep and shrinkage, it is gaining more importance nowadays. High strength concrete can be used for various applications like construction of high rise buildings, construction of prestressed bridges, flyovers, railway sleepers.

Scope of the present investigation

The adequate and economic application of any material to field problems demands extensive knowledge of its performance under different loads. An extensive application of FRC can be seen in both industrial structures and civil engineering fields. Therefore, the thorough knowledge of the properties of FRC is quite essential. A lot of work has been carried out on FRC using low strength concrete like M20, M30 etc. A little work has been done on FRC high strength concrete. Here in this work an attempt has been made to bring out certain characteristics of high strength FRC using M40, M50, M60 grades of concrete. The characteristics studied are compressive strength (cube strength and cylinder strength), flexural strength, modulus of elasticity, split tensile strength and load-deflection curve.

II. LITERATURE REVIEW

Steel fibre reinforced concrete is emerging as a superior construction of material than plain cement concrete due to its better engineering properties. The research and development in FRC has been going on since last three decades. Romuldi.J.P. and Batson G.B. are the pioneers who stressed the importance of FRC as a construction material, since then extensive research has been done on various aspects of FRC. A brief review of the important investigations concerned with FRC is presented in the following articles.

K.S. Prebhakumari, P. Jayakumar(2013) This experimental investigation on the fracture behaviour of high strength concrete and steel Fiber reinforced high strength concrete with particular emphasis on the size effect method. Fracture study was carried out by conducting three point bending tests on series of geometrically similar single edge notched beams the influence of notch size on the fracture properties of steel Fiber reinforced high strength concrete was also investigated. Various fracture parameters like the fracture energy, length of fracture process zone, critical crack tip opening displacement and the fracture toughness were determined as per RILEM procedure. The test results showed that the fracture parameters are sensitive to the Fiber addition and the notch size. With the experimental parameters an attempt has been made to predict the nominal strength of steel Fiber reinforced high strength concrete structures.

V.Mechtcherine and H.S. Miiller(1976),did an investigation the effect of the testset-up on fracture mechanical parameters of concrete was studied experimentally and numerically. In the first step a series of deformation controlled uniaxial tension tests on dog-bone shaped specimens and notched specimens. with rotatable and non-rotatable boundaries as well as three-point bend tests were performed. As a result, the experiments with rotatable loading platens provided lower values of the fracture energy Gp than the tests with nonrotatable boundaries, but slightly higher GF-values than those obtained from the bend tests. In the second step, these experiments were analyzed numerically within the frame of a smeared crack concept. The analysis showed, that the GF-values obtained from the uniaxial tension tests with non-rotatable loading platens are the most realistic ones.

III. PREPARATION OF THE SPECIMENS

General:

In the present investigation, locally available materials have been used as ingredients for the preparation of concrete specimens. The concrete mixes are designed for strengths 40 N/mm^2, 50 N/mm^2, 60 N/mm^2 as per IS:10262-1982.

Material Selection:

The results of various physical tests are reported in APPENDIX-I. ordinary Portland cement of grade 53, Birla super brand is used in the preparation af al the specimens. The fact that this cement confirms to specifications of IS:12269-1987 standards has been checked as per the results of physical tests recommended by IS:4031-1988.
The locally available river sand belonging to zone II of IS:383-1963 has been used as the fine aggregate. For coarse aggregate, 10 mm and downsized granite metal of angular shape is utilized. Keeping in the view the restrictions on the size of the coarse aggregate as recommended in the literature. Ordinary portable tap water is used in the preparation of the concrete. The galvanized round type steel wire cut to required size is used as fibers.

Fixing up of the Aspect Ratio:

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

To know the diameter of the wire being used as fibers, a known length of wire is taken and its density is determined. Knowing the density and the length, the equivalent diameter is calculated. The steel wire used is found to have equivalent diameter of 0.091 mm. This is also checked by taking the measurements by screw guage (micrometer). It is recommended that the length of the fibres should be kept less than the minimum dimension of the specimen to be casted. With an aspect ratio of 55 it is found that the length of the fibers is well within the minimum dimension of the specimen used (100mm).This aspect ratio of 55 has been adopted in the preparation of the specimens used in the present in investigation.

Details of the Specimen:

In the present work three different grades of concrete mix i.e. mixes with target strength 40 N/mm^2, 50 N/mm^2, 60 N/mm^2 are used. For each grade four different fiber contents are used (0% -1.2% @ intervals of 0.4%). With each percentage of fiber volume fraction, three cube specimens, six cylinders and three beams are casted. The specimen dimensions are fixed as per the IS code recommendations.

Workability Of Concrete:

Workability is defined as the amount of useful internal work necessary to produce full compaction. Water cement ratio is an important factor which influences the workability. However with increased workability other properties of concrete are reduced. High strength concrete can be achieved using a lower water cement ratio but at the same time workability more water shouls be added at constant water cement ratio i.e. cement should be added in extra to achieve the required workability. To get the required workability without increasing either of cement or water content, one may have to use proper admixtures. These are of water reducing type and are added to improve the desirable properties of concrete. Water reducing agents may be used in three different ways in concrete:

a) Concrete can be made having greater workability facilitating easier placement with no reduction of cement content and no significance change in strength.

b) The workability can be kept same, the water content reduced, the cement content left the same, and higher strength obtained.

c) The workability and strength can be kept the same while the cement content reduced, thus resulting in a saving in the cost of cement.

The high range water reducing admixture may be of melamine formaldehyde condensate, Sulphanated naphthalene formaldehyde condensate, modified lignosulphates, acrylic copolymers, amino aromatic sulphonic aid or phenol formaldehyde condensate. In general they do not alter the properties of the hardened concrete like the tensile strength, flexural strength and Young's modulus of elasiticity (Rixon M.R.1978).

Superplasticizers:

The superplasticizers are improved water reducing admixtures. They are free from side effects like high air entertainment and excessive retardation exhibited by concrete with ordinary water reducing admixture at high dosages. When they are added to the concrete mix along with a water, the dispersion of cement particles takes place and hence larger surface area is exposed to hydration process. They are generally recommended for the production of high workability concrete at low water cement ratio.The superplasticizer used is concrete Master manufactured by M/s ROFF Chemicals, confirming to IS:9103-1979 (real firmed 1990).

Mixing of FRCT:

The mixing operation is carried out in the following steps:

a) The cement and fine aggregate are mixed dry thoroughly and uniformly in specified proportions.

b) The required quantity of coarse aggregates are added to the above mix uniformly.

c) The above mix is spread out. Over this mix the fibers is required quantity are sprinkled randomly and mixed thoroughly.

d) Water, premixed with required dosage of superplasticizer, is then added to the ingredients and mixed till the mix achieves uniformity. The process take about ten minutes. The time required for the entire mixing process is about twenty minutes. After the mixing process the concrete is placed in the moulds kept ready with mould releasing agent applied on the surfaces of the moulds as per the IS specifications. These moulds are then vibrated using a table vibrator. After vibrating, the top surface is smoothened off to get a clean and smooth surface. All the specimens are kept in the moulds for a duration of 24 hours for drying. They are then fully immersed in portable tap water in a tank for curing of twenty eight days.

Table 3.1 Specimen details for various tests:

Sl. No.	Type of test	Specimen type	Specimen dimensions	IS code Reference
1	Cube Compressive Strength	Cubes	150 x 150 x150mm	IS:516-1959
2	Split Tensile Strength	Cylinders	150 dia x 300mm depth	IS:5816-1970
3	Static Elastic Modulus	Cylinders	150 dia x 300mm depth	IS:516-1959
4	Third-point Flexure test	Beams	100 x 100 x500mm	IS:516-1959

Table 3.2 Specimens tested for different tests:

Mix	Cubes	Cylinders	Beams	Total
M40	12	24	12	48
M50	12	24	12	48
M60	12	24	12	48
			TOTAL	144

IV. MATERIALS AND METHODS

Size of Aggregate:

The problem is more complicated when the fibres are introduced into a concrete rather than a mortar matrix because they are separated not by a fine grained material which can move easily between them, which may lead to bunching of fibres. The uniform fibre distribution is more difficult to achieve as the aggregate size increases from 5mm to 10 mm to 20mm. In a normal concrete mix the particle finer than 5 mm occupy about 54% of the volume. Thus only about 54% of real volume is available for the fibre movement during compaction.(6)

Water Cement Ratio:

Experience has shown that for a satisfactory for fibre concrete it should contain a mortar volume of above 20% consisting of particles between 5mm to 10mm.(6). The strength of FRC achieved will be maximum when it is cast without any segregation at the maximum water cement ratio. It is found that FRC cast under good control will achieve its maximum strength at water cement ratio around 0.3 to0.35. But due to the problem of balling at low water cement ratio it is advised to use either increased water cement ratio or to use a good quality water reducing admixture as an additive to achieve the required workability, without balling of fibres.(15)

Grade of Mix:

The grade of mix influences the properties of the Fibre reinforced concrete properties like compressive strength, flexural strength and split tensile strength etc. are increased using high grade of concrete.(15)

Properties of Steel Fibre Reinforced Concrete:

The properties which are influenced by including the discrete discontinuous fibres are compressive strength, flexural strength, split tensile strength and other properties like dynamic strength and fatigue strength are also influenced. They are discussed in the following paragraphs.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

High Strength Concrete:

High strength concrete is basically a concrete with compressive strength greater than $40Nmm^2$ or in a concrete which possesses compressive strength properties which are difficult to obtain using locally available conventional materials and practices. The high strength concrete has the properties like low creep, low shrinkage, finer microstructure i.e. lesser porosity and permeability, higher modulus of elasticity and tensile strength. High early gain of strength and bond at the hydrated cement paste-aggregate is more.(21)

TESTING:

Testing on Fresh Concrete:

The tests on fresh concrete are done to know the workability levels of the concrete. Workability is defined as the amount of useful internal work necessary to achieve the full compaction. The size of aggregates, water cement ratio and the fiber content are important variables affecting the level of workability of FRC. The use of bigger sized aggregates and higher water-cement ratio provide concrete with good workability, but lead to poor quality in hardened state. Such a hardened concrete exhibits highly inadequate durability characteristics due to its porosity.

The variation of compaction factor with different dosages of superplasticizer added to the mix are shown in the figures 4.1 to 4.3 for different volume of fibers added for M40, M50, M60 grades respectively. As the fiber content increases workability decreases. So more dosage of superplasticizer is required with increase in fiber content. This is observed from graphs. The final dosages used for the different mixes are tabulated in tables 4.1, 4.2 and 4.3 respectively for M40, M50, M60. Grades.

Testing of Hardened Concrete:

In the present investigation specimens are tested in wet condition after twenty eight days of wet curing. The tests are carried out as per recommendations of relevant IS code specifications. In all subsequent discussions the FRC mixes in the present investigation are designated by notations as indicated in table 4.4.

Tests for Compressive Strength:

The cubes are removed from the curing tank and the surfaces are cleaned with cotton waste. They are tested in wet condition in a 2000KN compression testing machine. The rate of load is maintained at 140kg/cm2/minute as per the IS:516-1959 code provisions. Three cubes of 150mm size are tested and the average value of cube compressive strength is computed. The results of this compression test are presented in Tables 4.5, 4.6 and 4.7 for M40, M50, M60 grades respectively. Plate 1 displays the required arrangement for the above tests. Three of the cylindrical specimens in each set after being tested for static elastic modulus were subjected to compressive loading up to failure and the results are tabulated I tables 4.8, 4.9 and 4.10.

Split Tensile Strength:

The split tensile tests are carried out for all the three mixes for the specified variations in fibre volume fraction, in a 2000KN compression testing machine as per IS:5816-1970. The results are tabulated in tables 4.11,4.12 and 4.13. plate 2 displays split tensile test of a SFRC cylindrical specimen.

Static Elastic Modulus:

Static elastic modulus (compression) is found in accordance with the code of practice IS:516-1959. The mean value of results with three cylindrical specimens is reported as the static elastic modulus for particular mix. The testing is carried out for all the three mixes with different percentage of volume fractions. The values are recorded to nearest 50 MPa. The results are tabulated in the tables 4.14, 4.15 and 4.16. Plate 3 displays the arrangements for the above tests.

Third-point Flexure test on Beams:

The tests are conducted on beams in wet condition on a 100KN capacity flexure testing machine. The beams are subjected to third-point bending on a span of 400mm. all the specimens are initially preloaded to approximately 100kg which is well below the cracking load for the specimens, to eliminate initial seating problems. The rate of straining is maintained at 0.1 mm/minute till first crack. After the first crack the load is applied approximately at the rate of 180 kg/minute continuously, which is stipulated in (IS:516-1959). The load deflection graphs are drawn which are shown in figures. plate 4 displays the arrangements for the flexural tests. The results of first-crack load, ultimate load, flexural strength are tabulated in tables.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table 4.4. Mix Designations:

Sl.No	Mix Grade	Fibre volume fraction (%)	designation
1	M40	0.0	400
2	M40	0.4	4004
3	M40	0.8	4008
4	M40	1.2	4012
5	M50	0.0	5000
6	M50	0.4	5004
7	M50	0.8	5008
8	M50	1.2	5012
9	M60	0.0	6000
10	M60	0.4	6004
11	M60	0.8	6008
12	M60	1.2	6012

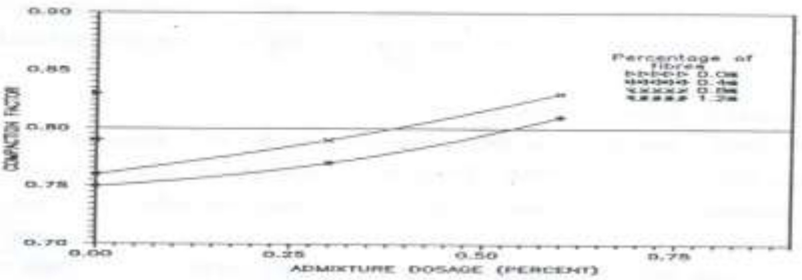

Fig. 4.1 Variation in compaction factor with admixture dosage for M40 grade

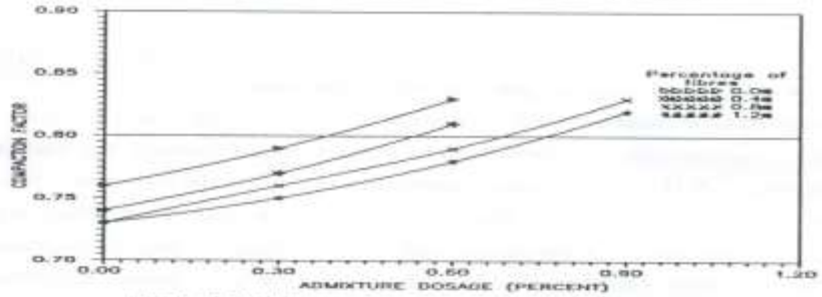

Fig.4.2 Variation in compaction factor with admixture dosage for M50 grade

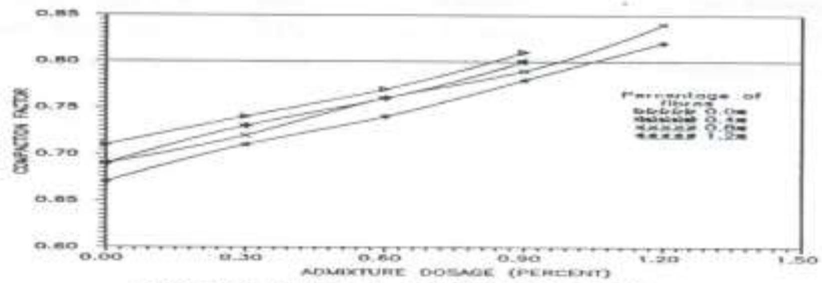

Fig.4.3 Variation in compaction factor with admixture dosage for M60 grade

V. RESULTS AND DISCUSSION

Tabl : Variation in Split Tensile strength of SFRC with fibre content—M50 grade

Sl.No.	Mix	Specimen number	Split Tensile strength in N/mm^2	Average Split Tensile strength N/mm^2	Percent deviation	Present deviation from plain concrete
1	5000	1 2 3	2.97 2.97 2.83	2.92	1.6 1.6 3.2	--
2	5004	1 2 3	3.39 3.32 3.11	3.27	3.6 1.53 4.89	11.87
3	5008	1 2 3	3.32 3.53 3.46	3.44	3.48 2.61 0.58	17.68
4	5012	1 2 3	3.68 3.82 3.75	3.75	1.86 1.86 0.07	28.3

Table 4.8 Variation in Cylinder compressive strength of SFRC with fibre content—M40 grade:

Sl.No.	Mix	Specimen number	Cylinder Compressive strength in N/mm^2	Average compressive strength N/mm^2	Percent deviation from PCC	Ratio of Cylinder cube Strength
1	4000	1 2 3	29.99 32.82 32.25	31.68	---	0.78
2	4004	1 2 3	32.43 32.99 34.12	33.18	4.74	0.768
3	4008	1 2 3	34.96 33.00 34.40	34.12	7.70	0.766
4	4012	1 2 3	32.98 36.36 35.23	34.86	10.03	0.77

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table 5.3 Analysis of theoretical and experimental values of Static Modulus of Elasticity of SFRC

Sl. No.	Mix	Experimental Value N/mm²	As per Equation 1		As per Equation 2	
			Theoretical	Ratio(Exp/The)	Theoretical	Ratio(Exp/The)
1	4004	41333	36288	1.14	37466	1.10
2	4008	51940	36216	1.43	38036	1.36
3	4012	43333	36205	1.19	36205	1.13
			Average	1.25	Average	1.20
1	5004	44800	38997	1.15	42486	1.05
2	5008	56800	38954	1.38	43260	1.24
3	5012	44625	38932	1.14	43510	1.02
			Average	1.22	Average	1.106
1	6004	50330	43260	1.16	44273	1.14
2	6008	59300	43220	1.37	45656	1.30
3	6012	52000	43180	1.20	46331	1.12

VI. CONCLUSION

1) The inclusion of fiber has decreased the workability of the mixes (the effect is more pronounced at high fiber content) and the super plasticizer 'ROFF concrete master' was found to be effective in maintaining the constant workability of 0.8CF for all the mixes.
2) The cube and cylinder compressive strength of SFRC have increased with reference to plain concrete. The range of increase is 7% to 15%, which is not significant. But the ductility imparted can be advantageous factor. With higher grades the percentage increase is more and the difference between cube and cylinder strength is not significant.
3) An increase of about 30%% is achieved in split tensile strength with the inclusion of fibres to plain concrete, which indicates a better performance of SFRC in tensile loading.
4) Static modulus of elasticity of SFRC specimens have shown a remarkable increase irrespective of the grade. At 1.2% fibre content there is a decrease in rate of percentage increase. The trend is observed in all mixes.
6) There is a appreciable increase of about 60% in the modulus of rupture due to the addition of fibres in plain concrete. The brittle mode of failure of the beam specimen has changed to ductile mode. Thus fibers have imparted a well defined post-crack behavior.
7) At higher fibre content, the flexure strength is not affected by the strength of the mix.
8) The shape of load-defection curve is mostly dependent on fibre content and its distribution across the cross section of the specimen at the point of first-crack. When the position of first-crack was not in the centre, the ultimate central deflection is relatively lesser.
9) The mathematical models established already for predicting
   a) The cube strength of SFRC
   b) The split tensile strength of SFRC
   c) Modulus of elasticity of SFRC are found to be satisfactory.
10) The proposed formula for predicting flexure strength also gave satisfactory results.

FUTURE SCOPE:

1) The present study can be continued for higher grades of concrete and for higher volume fractions.
2) Studies with different aspect ratios and different type of fibers can be carried out.
3) Toughness investigations can be carried out in detail using various other methods.
4) Studies can also be made by partially replacing the cement with fly ash.

This fragment should obviously state the foremost conclusions of the exploration and give a coherent explanation of their significance and consequence.

VII. ACKNOWLEDGEMENTS

The Author would like to thank all the persons who helped in the completion of his experimental work. Also thanks are extended to ASR College of Engineering, Tanuku, INDIA for support throughout the execution of the experimental work

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

VIII. REFERENCES

1. ACI Committee 544 report., "State-of-the-art-Report on Fibre Reinforced Concrete," ACI Journal, V.70, November,(1973), PP.729-744.
2. ACI Committee 544 report., " Guide for specifying, Mixing, Placing and Finishing of Steel Fibre Reincorced concrete," ACI Journal, V.81, Mar-Apr 1984,pp 140-147.
3. ACI Committee 544 report., " Measurement of Properties of Fibre Reinforced concrete beams," ACI Journal, proceedings, V.75, No.7, July (1978). Pp.283 -289.
4. Anbu, Selvam .t, " Experimental Study on the toughness characteristics of Steel Fibre Concrete Beama," M.Tech Thesis Submitted to Manglore University, April 1994.
5. Gopalratnam,V.S.: Shah,S.P.: Batson, G.B: Criswell,M.E.,; Ramakrishna,V., and Wecharatanna,M., "France Toughness of Fibre Reinforced Concrete." Materials Journal, Title No. 88-M41, V.88, No.4, July-August. 1991,pp.393-353.
6. Hannant,D.J., " Fibre cements and Fibre Concrete," John Wiley and Sons Ltd., Toronto, New York, 1978,pp.1-79.
7. Kar,J.N.; Pal,A.K., "Strength of Fibre Reinforced concrete," Journal of the Structural Division, Proceedings, ASCE.V.98, NoST5, May 1972, pp.1053-1068.
8. Karthikeyan,O.H,; V,;Singahl.D,; and NAutiyal,B.D. " fibres for FRC. Their Properties Applications and Mixing A review report," Indian concrete Institute Bulletin, No.34, March 1991,pp 37-49.
9. Kong, F.K., Evas,R.H.,Cohan,E.,R. " Handbook of Sturctural concrete," 1983,pp.20-28 to 20-30.
10. Kulkarni, S.B., " The Use of 53 Grade Cement for Production of high Quality Concrete," Civil Engineering and Construction Review, May 1994, pp.17-23.
11. Lin, T.Y and Ned,H.Burns., "Design of Prestressed of Concrete Structures," Jhon Wiely and Sons, 1992.
12. Mangath,P.S.; and Swamy,R.N., "compactibility of Steel fibre Reinforced Concrete," concrete journal, May 1974,pp.34-35.
13. Mahadevappa,P., "Fibre Reinforced Concrete," KREC Surathkal Summer School on Ferrocement and Fibre Reinforced Concrete in Rural Applications. July 1985, pp.PM1 to PM12.
14. Nagarkar,P.K,; Tambe,S.K,; and Pazare,D.G, "Study of Fibre Reinforced Concrete," Proceedings of the international Symosium of Fibre Reinforced Concrete, Dec 1987,pp.2.131-21.141.
15. Narayanan,R., and Kareem-Palanjian, A.S., " Effect of Fibre addition on concrete Strengths," Indian Concrete Journal, Apr-1984,pp.100-103.
16. Prasad,B.B.N., "Studies on Flexural Toughness of Fibre Reinforced Concrete Beams," M.Tech Thesis submitted to Manglore University, March.

CITE AN ARTICLE

Nagarjuna , B., & Prakash, M. S. (n.d.). AN EXPERIMENTAL ANALYSIS OF STRENGTH PROPERTIES OF HIGH STRENGTH CONCRETE USING STEEL FIBERS. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *6*(12), 308-316.