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AN EXPERIMENTAL STUDY ON TENSILE BEHAVIOR OF HIGH STRENGTH FIBER REINFORCED CONCRETE

P.Durga Rao[1], K.Sundara Kumar[2]
[1]M.Tech Student,[2]Faculty,
Usha Rama College of Engineering and Technology, Telaprolu, Krishna District.

Abstract: In this work the tensile behaviour of concrete reinforced with steel fibre contents was assessed performing direct tensile tests. In the present work, the steel fibres were added at the volume fraction, being 0%, 0.5%,1%,1.5% to the normal strength concrete in addition to GGBS and Silica fume to prepare high strength concrete. The effects of steel fibbers on the tensile behaviour of high and normal strength are investigated. The fracture energy of conventional SFRC was independent of the specimen size. The fracture energy of SFRC with high strength matrix and normal strength matrix was dependent on the tensile strength of the steel fibres. From the results found that with an increase in % of fibres the tensile softening behaviour increases and fracture energy also increases. According to the results obtained from the uni-axial tensile strength test, the direct tensile strength shows a gradual increase with increase in fibre content and it reached to 3.69N/mm^2 at 1.5% fibre addition for M-30 grade concrete. It was also determined that the uni-axial tensile strength test shows that, the direct tensile strength shows a gradual increase with increase in fibre content and it reached to 4.7N/mm^2 at 1.5% fibre addition for M-70 grade concrete. The ratios of split tensile strength to compressive strength and uni-axial tensile strength to compressive strength increased as compressive strength increased. Form the results it was proved both in high strength concrete and normal strength the post cracking stress increase with an increase in % of fibre replacement. The higher the volume fraction of fibres, the higher the maximum post- cracking Stress. The first crack strength and whole post cracking behaviour were mainly influenced by the amount of fibres. Fracture energy increases with an increase in % of fibre both in high strength concrete and normal strength concrete.

Key Words: Concrete, FRC, Tensile strength, high strength concrete

I. INTRODUCTION

Concrete is very much weak in tension but by addition of randomly oriented short crimped steel fibres will change the behaviour from brittle to ductile. The project aims to study tensile softening behaviour of fibre reinforced concrete. It is an attempt to understand the tensile behaviour of concrete mixed with fibres. Normally split tensile strength and flexural strength tests were used to examine the tensile behaviour of concrete. But in this work an experimental attempt was made to directly test the specially made specimen subjected to tension. This investigation was made on normal and high strength concrete. For this M-30 and M-70 mixes were designed and prepared. In M-70 concrete GGBS and Silica fumes were also added to make it High Strength Concrete(HSC). HSC offers many advantages over conventional concrete. The high compressive strength can be advantageously used in compression members like columns and piles. Higher compressive strength of concrete results reduction in column size and increases available floor space. HSC can also be effectively used in structures such as domes, folded plates, shells and arches where large in-plane compressive stresses exist. The relatively higher compressive strength per unit volume, per unit weight will also reduce the overall dead load on foundation of a structure with HSC. Also, the inherent techniques of producing HSC generate a dense microstructure making ingress of deleterious chemicals from the environment into the concrete core difficult, thus enhancing the long-term durability and performance of the structure.

Fibre reinforced concrete:

Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres. Now, why would we wish to add such fibres to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capcity. The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post- cracking ―ductility‖. If the fibres are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage. When the fibre reinforcement is in the form of short discrete fibres, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel fibre reinforcement cannot therefore be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. However, because of the inherent material properties of fibre concrete, the presence of fibres in the body of the concrete or the provision of a tensile skin of fibre concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions. The fibre reinforcement may be used in the form of three – dimensionally randomly distributed fibres throughout the structural member when the added advantages of the fibre to shear resistance and crack control can be further utilised . On the other hand, the fibre concrete may also be used as a tensile skin to cover the steel reinforcement when a more efficient two – dimensional orientation of the fibres could be obtained.

Structural use and Behaviour of SFRC:
As recommended by ACI Committee 544, ‗when used in structural applications, steel fibre reinforced concrete should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading, and to resist material disintegration. In structural members where flexural or tensile loads will occur the reinforcing steel must be capable of supporting the total tensile load'. Thus, while there are a number of techniques for predicting the strength of beams reinforced only with steel fibres, there are no predictive equations for large SFRC beams, since these would be expected to contain conventional reinforcing bars as well. An extensive guide to design considerations for SFRC has recently been published by the American Concrete Institute. In this section, the use of SFRC will be discussed primarily in structural members which also contain conventional reinforcement.

For beams containing both fibres and continuous reinforcing bars, the situation is complex, since the fibres act in two ways: They permit the tensile strength of the SFRC to be used in design, because the matrix will no longer lose its load-carrying capacity at first crack; and They improve the bond between the matrix and the reinforcing bars by inhibiting the growth of cracks emanating form the deformations (lugs) on the bars.

Uni-Axial Tensile Test:
The tension test is one of the most commonly used tests for evaluating materials. In its simplest form, the tension test is accomplished by gripping opposite ends of a test item within the load frame of a test machine. A tensile force is applied by the machine, resulting in the gradual elongation and eventual fracture of the test item. During this process, force-extension data, a quantitative measure of how the test item deforms under the applied tensile force, usually are monitored and recorded. When properly conducted, the tension test provides force-extension data that can quantify several important mechanical properties of a material.

These mechanical properties determined from tension tests include, but are not limited to, the following:
1.Elastic deformation properties such as the modulus of elasticity(Young's modulus) and Poisson's ratio.
2.Yield strength and Ultimate tensile strength
3.Ductility properties, such as elongation and reduction in area
4.Strain hardening charecteristics
These material characteristics from tension tests are used for quality control in production, for ranking performance of structural materials, for evaluation of newly developed alloys, and for dealing with the static-strength requirement of design. The basic principle of the tension test is quite simple, but numerous variables affect results. General sources of variation in mechanical-test results include several factors involving materials, namely, methodology, human factors, equipment, and ambient. methodology of the tension test and the effect of some of the variables on the tensile properties determined.

II. EXPERIMENTAL PROGRAM

The experimental program is designed to understand whether the addition of fibers in high strength concrete and normal strength concrete favours strain hardening and increase of amount of fibers produces identical enhancement of tensile properties.

Materials :
The main ingredients used were cement, fine aggregate, coarse aggregate, water, super plasticizer and steel fibres.
Ordinary Portland Cement of 53 grade conforming to IS: 12269-1987 was used for the study. The cement content can be 350 – 450 kg/m3. Some amount of cement replaced by adding add-mixtures to increase strength and durability
Water: Potable water supplied by the college was used in the work
Fine Aggregate: River sand passing through 4.75 mm sieve and conforming to grading zone II of IS: 383-1970 was used as the fine aggregate. Normal river sands are suitable for high strength concrete. Both crushed and rounded sands can be used. Siliceous and calcareous sands can be used for production of HSC
Coarse Aggregate: Crushed granite stone with a maximum size of 20 mm was used as the coarse aggregate. The properties of aggregates used
Super Plasticizer: Conplast SP430 a product of Fosroc was used as the super plasticizer.
Steel Fibre: Crimped steel fibres with 0.35 mean diameter was used at a volume fraction of 0%, 0.5%,1%,1.5%

Mould shape:

Fig 1: Specimen mould shape

Casting: The moulds were tightly fitted and all the joints were sealed by bolts and nut order to prevent leakage of cement slurry through the joints. The inner side of the moulds was thoroughly oiled . The mix proportions were put in miller and thorough While casting the specimen , most of the concrete required was poured in the middle of the mould and allowed to spread to the ends; few scoops of concrete were placed at the ends to top of the mould. This method was followed so as to avoid any weak planes in the zone where failure is expected to occur during testing.
Curing: The specimens were removed from the moulds after 24 hours of casting and the specimens were placed in water for curing
Preparing of Notch: The notch was prepared with steel plates with different a/w ratio sizes.

Mix Proportioning
The normal strength concrete mix M30 was proportioned as

per Indian Standard for a target mean strength 30MPa. After various trial mixes, the optimum mix proportion was selected as 0.45:1:1.562:2.902 with cement content of 405.81 kg/m3. The different constituents in the order of water: cement: fine aggregate: coarse aggregate were proportioned as 60.32:134.11:209.53:389.11 for making 1m3 of mix.

The high strength concrete mix M70 was proportioned as per indian standards for target mean strength 70MPa. After various trial mixes, the optimum mix proportion was selected as 0.24:1:1.346:1.103 with cement content of 650.58kg/m3. The different constituents in the order of water: cement: fine aggregate: coarse aggregate were proportioned as 60.32:134.11:209.53:389.11 for making 1m3 of mix.

Specimen preparation:
A operated miller of sixty litre capacity was used to prepare the cement mixture. Cement, water, coarse aggregate, sand ,ground granulated blast furnace slag, crimped fibre and super plasticizer were used. Cement sand silica fume, GGBS were first dry mixed for about 10 min. water pre mixed with conplast sp430 was added gradually and mixed for another 5-10 min
.when the mortar show enough flow ability for workability and viscosity for uniform fiber distribution , the crimped fiber were dispersed carefully by hand into the mortar mixture added .the cement mixture with fibers was then placed in mould .the specimen s were placed in the water curing for 2 days after remoulding was carried out .all specimens were tested in dry condition for 28 days.

Table 1: Details of materials for 1 cubic meter of concrete for M30

Grade of concrete	Mix Proportion	Water wt. (kg)	Cement wt.(kg)	Weight of FA (kg)	Weight of CA (kg)
M30	0.45:1:1.562:2.902	183.0	406.81	635.4	1180.56

Table 2: Details of materials for 1 cubic meter of concrete for M70

Grade of concrete	Mix Proportion	Water wt. (kg)	Cement wt.(kg)	Weight of FA (kg)	Weight of CA (kg)
M70	0.24:1:1.36:1.103	156.13	650.58	875.68	717.5

Test setup and specimen
The dimensions of the test specimen were chosen to be representative of actual structural Element and to provide a cross section large enough to place various types and amounts of Fiber .The load introduction system was designed to prevent the development of eccentricities or unexpected end rotations. Rigid end conditions were chosen as the best solution from a constructive point of view.

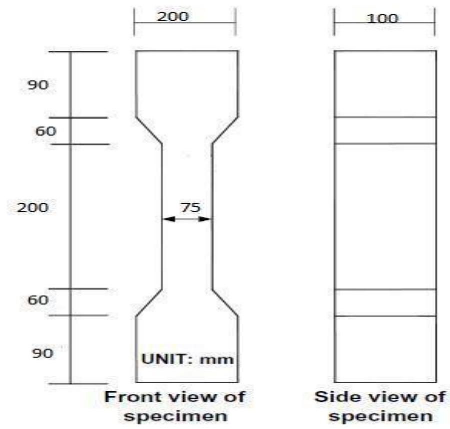

Fig 2: Dimensions of specimen

Tensile Test:
To obtain increased understanding about normal strength steel fiber reinforced concrete and high strength steel fiber reinforced concrete behavior program, under direct-tensile load, a conventional dogbone shape specimen was selected to detect elongation occurring during the test. The notch was provided at the center .At the centre at equal distance dail gauge was fixed to detect the elongation The top and bottom ends of the specimens were held by specially designed grips attachedof rod size 25 mm diametre was fixed inoder to fit into the machine The average elongation was obtained from dial guage. this process was carried on universal testing machine.

Fig 3: Test set up of specimen

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III. RESULTS AND DISCUSSIONS

The objective of the present study is to understand the tensile behaviour of concrete when fibres are added. For this first the optimum percentage of the fibres that can be added to this particular concrete mixes was to be established. Hence workability test using compaction factor test has been conducted and found that beyond 1.5% addition of fibres, concretes workability got reduced. Hence the tests on concrete were confined to 1.5 % addition of fibres.

In order to assess the normal compressive strength and split tensile strengths were estimated by testing cubes and cylinders, and the test results were presented below. Later to estimate the direct tensile strengths of different specimens with different percentages of fibres were carried out by testing the specially prepared specimens under UTM. The specimens were tested on the Universal Testing Machine under deflection rate control. To understand the fracture behaviour of plain and fibre reinforced concrete specimens the following graphs were drawn like Load Vs deflection, and Stress Vs Strain. From the graphs and tables it was observed that, for tensile failure of concrete, the stress intensity factor and fracture energy increases with the increasing % of fibres. Based on the tests on specimen can be observed that, in the case of centred notched specimen, the first crack appeared in the tension zone at notch tip. The deflection were measured only up to the ultimate load and failed suddenly in to two pieces. The tensile stress-strain curves (where the strain is valid up to the peak stress only) for the test series and are given in the graph and discussed below. The load increased with increased displacement.

Table.3 Test Results for M 30 Concrete

Grade of concrete	% of Fibre	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Direct Tensile stress (N/mm^2)
M30	0	39.24	3.2	3.07
	0.5	42.59	4.6	3.24
	1.0	44.51	5.6	3.47
	1.5	46.73	6.1	3.69

Table.4 Test Results for M 70 Concrete

Grade of concrete	% of Fibre	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Direct Tensile stress (N/mm^2)
M70	0	78.17	5.3	3.24
	0.5	80.40	5.8	3.52
	1.0	83.53	6.3	4.1
	1.5	84.90	7.1	4.70

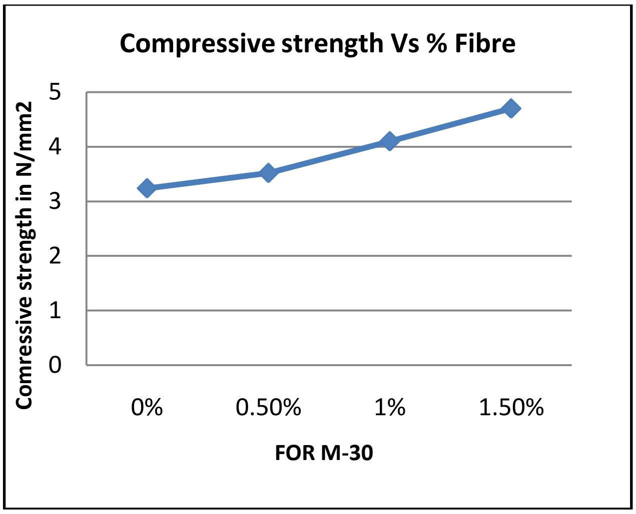

Fig.4: Compressive strength Vs % Fibre for M30

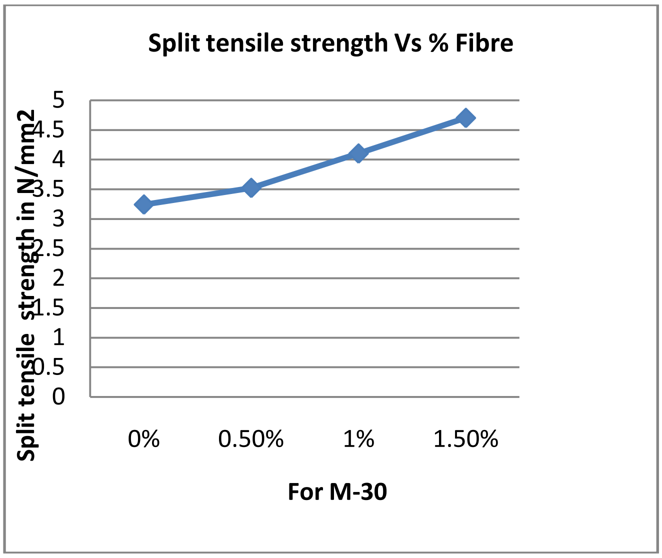

Fig.5: Split tensile strength Vs % Fibre for M30

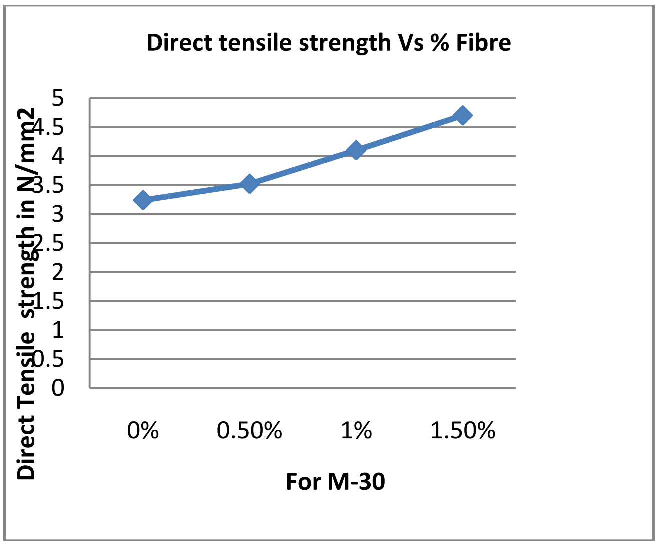

Fig.6: Direct tensile strength Vs % Fibre for M30

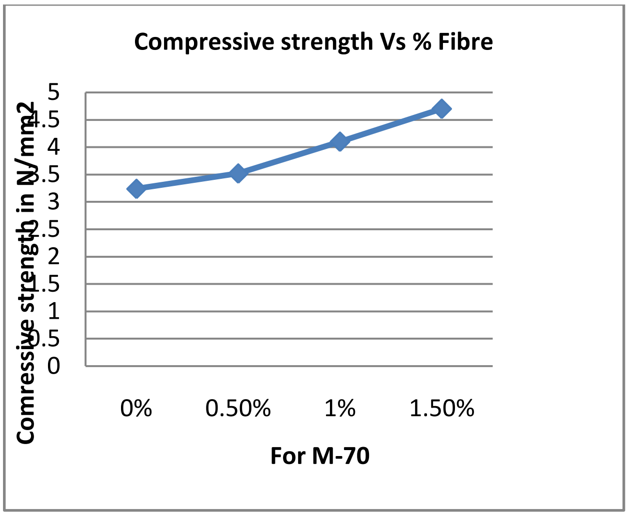

Fig.7: Compressive strength Vs % Fibre for M70

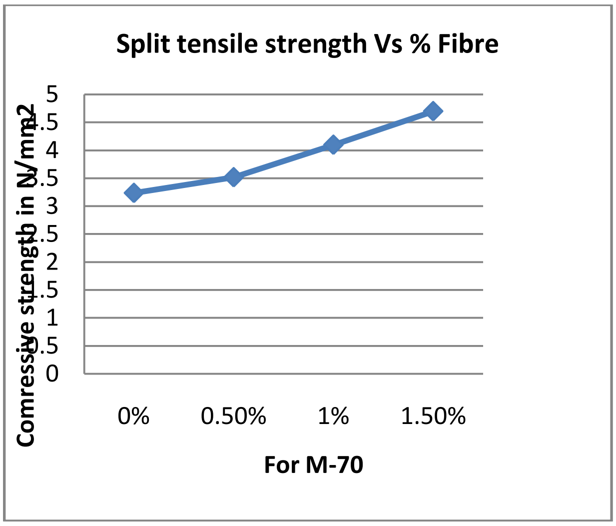

Fig.8: Split tensile strength Vs % Fibre for M70

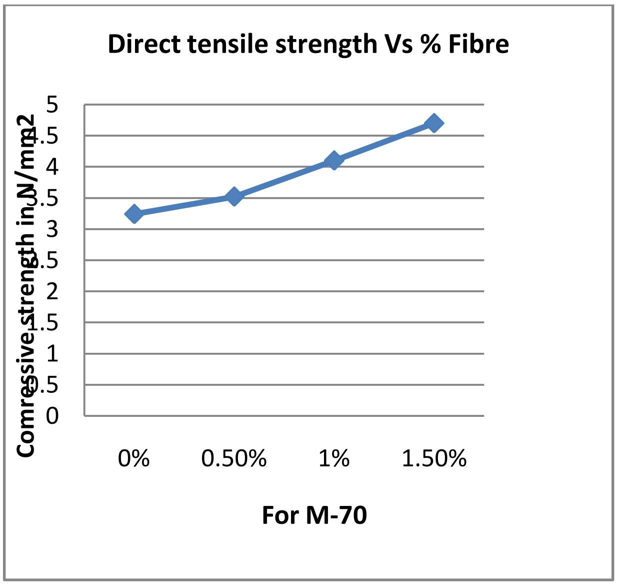

Fig.9: Direct tensile strength Vs % Fibre for M70

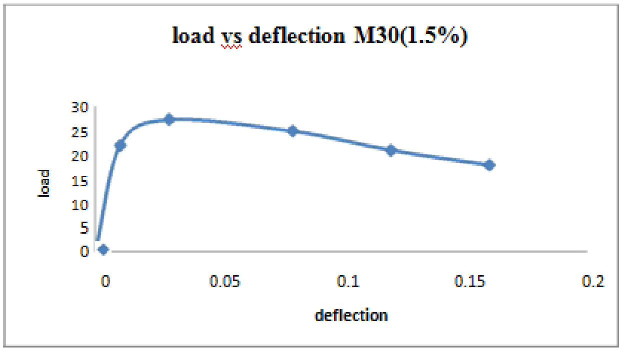

Fig.10: Load Vs % Deflection for M30

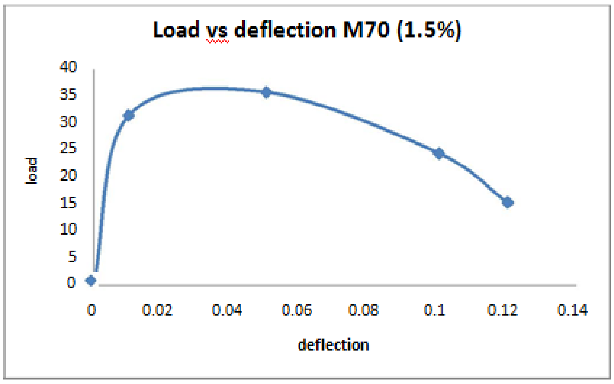

Fig.11: Load Vs % Deflection for M70

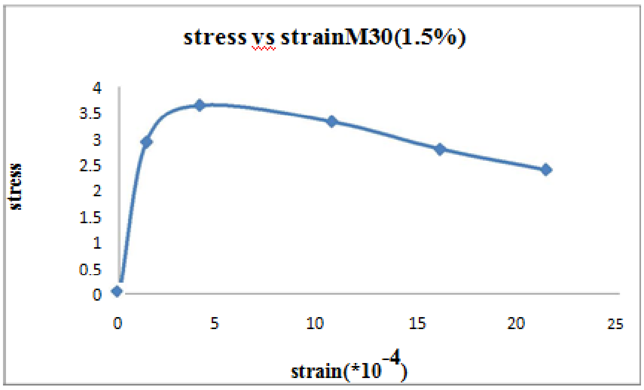

Fig.12: Stress Vs % Strain for M30

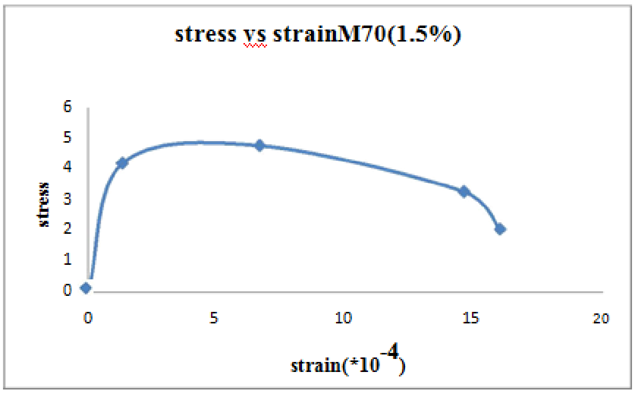

Fig.13: Stress Vs % Strain for M70

Fig.14: Failure of specimens 1% fibre

Fig.15: Failure of specimens 1.5% fibre

IV. CONCLUSIONS

An experimental investigation was made to study the tensile behaviour of concrete mixed with fibres under direct tensile loading. For this a test specimen was prepared and test setup was arranged in UTM. The proposed test method for measuring direct tensile strength minimized the eccentricity during loading. Workability of the concrete with addition of fibres was satisfactory up to 1.5% of fibres. The concretes normal behaviour under direct compression and split tension were also tested using standard test procedures. The testing was carried out for both normal (M-30)and high strength(M-70) concrete mixes. The maximum compressive strength 46.73 N/mm^2 reached at 1.5% fibres for M-30 concrete. The maximum Split tensile strength 6.1 N/mm^2 reached at 1.5% fibres for M-30 concrete. The maximum compressive strength 84.9 N /mm^2 reached at 1.5% fibres for M-70 concrete. The maximum Split tensile strength 7.1 N/mm^2 reached at 1.5% fibres for M-70 concrete.

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