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AN EXPERIMENTAL STUDY ON TENSION SOFTENING BEHAVIOR OF FIBER REINFORCED CONCRETE

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ABSTRACT
The project aims to study tensile softening behavior of fiber reinforced concrete .Concrete is very much weak in tension but by addition of randomly oriented short crimped steel fibers will change the behavior from brittle to ductile. In the present work, the steel fibers were added at the volume fraction, being 0%, 0.5%, 1%, 1.5% to the normal strength concrete and high strength concrete. The effects of steel fibbers on the tensile behavior of high and normal strength are investigated. In the project work the tensile behavior of concrete reinforced with steel fiber contents was assessed performing direct tensile tests .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 fibers. From the results found that with an increase in % of fibers the tensile softening behavior increases and fracture energy also increases.

KEYWORDS: Fiber Reinforced Concrete, Softening behavior, Normal Strength, Deflection

I. INTRODUCTION
Concrete, a composite consisting of aggregates enclosed in a matrix of cement paste including possible pozzolans, has two major components – cement paste and aggregates. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface . With most natural aggregates, it is possible to make concretes upto 120 MPa compressive strength by improving the strength of the cement paste, which can be controlled through the choice of water-content
ratio and type and dosage of admixtures . However, with the recent advancement in concrete technology and the availability of various types of mineral and chemical admixtures, and special super plasticizer, concrete with a compressive strength of up to 100 MPa can now be produced commercially with an acceptable level of variability using ordinary aggregates.These developments have led to increased applications of high-strength concrete (HSC) all around the globe.

The high compressive strength can beadvantageously used in compression members like columns and piles. Higher compressive strength of concrete results redu ction in column size and increases available floor space. Since the introduction of concrete with a compressive strength of 62 MPa in columns, shear walls and trans f er girders of the Water Tower Place in Chicago in 1975

1. Fiber reinforced concrete
Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous Fibers. Now, why would we wish to add suchFibers to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes disconti nuous 1.1Fibers is to bridge across the cracks that develop provides some post- cracking ductility‖. If the 1.1Fibers 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 Fiber reinforcement is in the form of short discrete Fibers, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel Fiber

reinforcement cannot therefore be regarded as a direct replacement of longitudinal reinforcementin reinforced and prestressed structural members.
However, because of the inherent material properties of Fiber concrete, the presence of Fibers in the body of the concrete or the provision of a tensile skin of Fiber concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions

2. Static Mechanical Properties Of Fibers

- ***Compressive Strength***

Fiber do little to enhance the static compressive strength of concrete, with increases in strength ranging from essentially nil to perhaps 25%. Even in members which contain conventional reinforcement in addition to the steel Fiber, the Fiber have little effect on compressive strength. However, the Fiber do substantially increase the post-cracking ductility, or energy absorption of the material.

- ***Tensile Strength***

Fiber aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight steel Fiber. However, for more or less randomly dist ribu ted Fiber, the increase in strength is much small er, ranging from as little as no increase in some inst ances to perhaps 60%, with many investigations ind ca ting intermediate values .Splitting-tension test of SFRC show similar result. Thus, adding Fiber smer e ly to increase the direct tensile strength is probably not worthwhile. However, as in compression, steel Fiber do lead to major increases in the post-cracking behavior or toughness of the composites

- ***1.2.3 Flexural Strength***

Steel Fiber are generally found to have aggregate much greater effect on the flexural strength of SFRC than on either the compressive or tensile strength, with increases of more than 100% having been reported. The increases in flexural strength is particularly sensitive, not only to the Fiber volume, but also to the aspect ratio of the Fiber, with higher aspect ratio leading to larger strength increases. the Fiber effect in terms of the combined parameter Wl/d, where l/d is the aspect ratio and W is the weight percent of Fiber. It should be noted that for $Wl/d > 600$, the mix characteristics tended to be quite unsatisfactory. Deformed Fiber show the same types of increases at lower volumes, because of their improved bond characteristics

3. Structural Use And Behaviour Of Sfrc

As recommended by ACI Committee 544, when used in structural applications, steel Fiber 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 Fiber, 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

- ***Flexure***

The use of Fiber in reinforced concrete flexure members increases ductility, tensile strength, moment capacity, and stiffness. The Fiber improve crack control and preserve post cracking structural integrity of members.

- ***Torsion***

The use of Fiber eliminate the sudden failure characteristic of plain concrete beams. It increases stiffness, torsional strength, ductility, rotational capacity, and the number of cracks with less crack width.

- ***High Strength Concrete***

Fiber increases the ductility of high strength concrete. Fiber addition will help in controlling cracks and deflections.

- ***Shear***

Addition of Fiber increases shear capacity of reinforced concrete beams up to 100 percent. Addition of randomly distributed Fiber increases shear-friction strength and ultimate strength.

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- ***Cracking and Deflection***

Tests have shown that Fiber reinforcement effectively controls cracking and deflection, in addition to strength improvement. In conventionally reinforced concrete beams, Fiber addition increases stiffness, and reduces deflection.

4. Effects Of Fiber In Concrete

Fiber are usually used in concrete to controlcracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of Fiber produced greater impact, abrasion and shatter resista nce in concrete. Generally Fiber do not increase the flexural strength of concrete Indeed, some Fiber actu ally reduce the strength of concrete. The amount of Fiber added to the concrete mix is expressed as aperc entage of total volume of the composite (concrete and Fiber), termed volume fraction (Vf). Vf typicallyrang es from 0.1 to 3%. Aspect ratio (l/d) is calculated by divi ding fiber length (l) by its diameter (d). . This finding is very important since traditionally, people think that the ductility increases when concrete is reinforced with Fiber. The results also indicated out that the use of micro Fiber offers better impact esistance compared with the longer Fiber.

5. Fracture behavior

The quasi-brittle behavior of concrete can be best explained by the following five stages (Shah et al. 1995) as depicted graphically in figure 1.9.1 and with the use of figure1.9.2.

- ***Elastic***

The material exhibits elastic behavior until the proportional elastic limit (PEL) is reached. The PEL in concrete is typically assumed to be the point of first crack (Shah et al. 1995).

- ***Micro Cracking***

Random micro – cracking occurs ahead of a flaw leading to a toughening behavior (Shah et al. 1995).

- ***Damage Localization***

The micro-cracks will localize forming a micro-crack, which occurs at the point of initial crack localization. At which point the material undergoes stable crack growth (crack propagates only when load increases) and a softening behavior occurs (Shah et al. 1995).

- ***Failure***

The crack will continue to propagate until failure, which occurs when the stress is equal to zero (Shah et al. 1995).

The region ahead of the initial flaw location is termed the fracture process zone (Shah et al. 1995). This zone can be separated into the crack wake process zone and the crack tip process zone. As shown in Figure 3b, the crack tip process zone is the region ahead of the crack where micro-cracking occurs during the fracture process and the crack wake process zone is the region in which the macro-crack resides (Shah et al.1995).

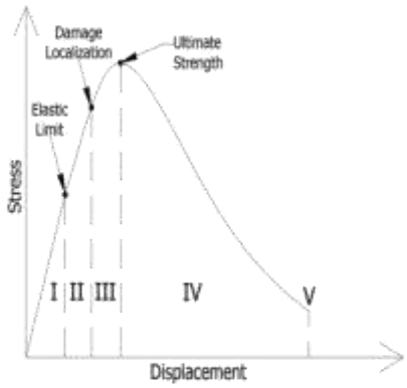

Fig. 1.5.1 Stages of quasi-brittle behavior

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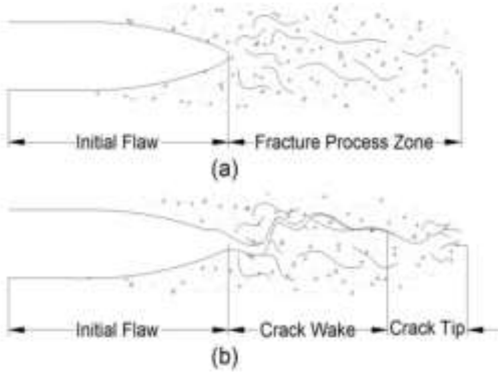

Fig1.5.2 Fracture process zone: stage II (a) and (b)

For analysis purposes it is commonly assumed that a crack propagates in a linear fashion. However, concrete is a composite material so cracks tend to propagate along non-linear or chaotic crack paths due to the heterogeneity of the material. This can be associated with several toughening mechanisms that occur within the Fracture Process Zone (FPZ) as pointed out by Shah et al. (1995).

6. Modes Of Fracture Failure

A crack front in a structural component is a line usual ly of varying curvature. Thus, the state of stress in the vicinity of the crack front varies from one point toano ther. A segment of the crack front can be divided into 3 basic modes as shown in fig1.6

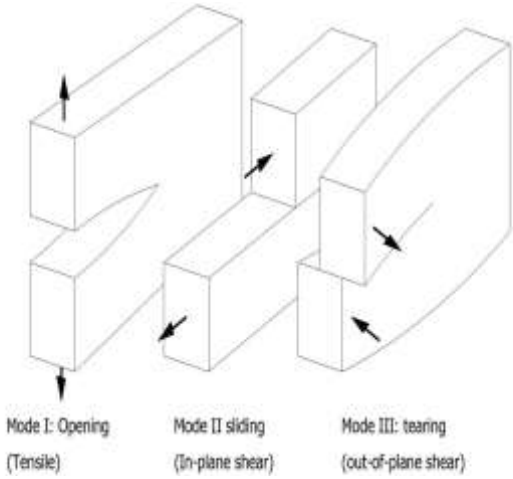

Fig1.6 Three modes of fracture

MODE I –it is the opening mode and the displacement is normal to the crack surface.
MODE II –it is the sliding mode and the displacement is in plane of the plate (these paration is anti symmetric and the relative displacement is normal to the crack front).
MODE III –it is the tearing mode and the displacement is parallel to the crack front

II. LITERATURE REVIEW

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

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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.

Milind V. Mohod(2012) *studied on* ***Performance of Steel Fiber Reinforced Concrete*****.** In this modern age, civil engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory. It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of Steel Fiber Reinforced Concrete (SFRC) is its superior resistance to cracking and crack propagation. In this paper effect of fibers on the strength of concrete for M 30 grade have been studied by varying the percentage of fibers in concrete. Fiber content were varied by 0.25%, 0.50%, 0.75%, 1%, 1.5% and 2% by volume of cement. Cubes of size 150mmX150mmX150mm to check the compressive strength and beams of size 500mmX100mmX100mm for checking flexural strength were casted. All the specimens were cured for the period of 3, 7 and 28 days before crushing. The results of fiber reinforced concrete for 3days, 7days and 28days curing with varied percentage of fiber were studied and it has been found that there is significant strength improvement in steel fiber reinforced concrete.

Dario Redaelli *studied on* ***TESTING OF REINFORCED HIGH PERFORMANCE FIBER CONCRETE MEMBERS IN TENSION(2006)***
A test series has been carried out on UHPFC reinforced with two types of ordinary steel reinforcement.
At the serviceability limit state, the behaviour of tensile members is very positively affected by the interaction between UHPFC and steel. Up to significant load levels, cracks are very thin and closely spaced. Moreover, tension stiffening is much more effective than in ordinary concrete, leading to a substantial increase in stiffness.

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.

III. MATERIALS AND METHODS

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

1. Materials

The main ingredients used were cement, fine aggregate, coarse aggregate, water, super plasticizer and steel Fiber.

- ***Cement***

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

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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 Forsook was used as the super plasticizer.

- ***Steel Fiber***

Crimped steel Fiber with 0.35 mean diameter was used at a volume fraction of 0%, 0.5%,1%,1.5%

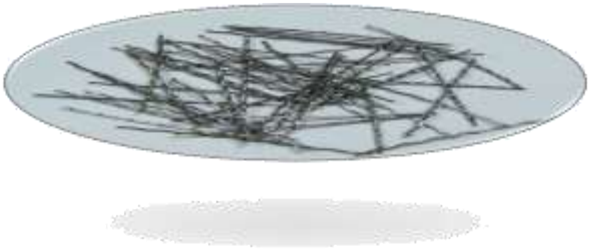

Fig3.1.7 steel crimped fibers

- ***Tamping Rod***

Tamping rod was used for compacting the test specimens, beams.

- ***Specimen mould***

Fig 3.1.9 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.

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- ***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 ratiosizes.

2. 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/m^3. 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 1m^3 of mix

The high strength concrete mix M70 was prop rtio ned as per Indian standards for target mean strength 70MPa. After various trial mixes, the optimu m mix proportion was selected as 0.24:1:1.346 :1.103 with cement content of 650.58kg/m^3. The different constit uents in the order of water: cement: fineaggregate coarse aggregate were proportioned as 60.32:134 .11 :209.53:389.11 for making 1m^3 of mix

3. 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 Fiber 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 re moulding was carried out .all specimens were tested in dry condition for 28 days

Table 1: details of materials for M30

S.NO	MATERIALS	QUANTITY
1	Grade of Concrete	M30
2	Water	3.204
3	Cement	7.12
4	Fine aggregate	11.12
5	Coarse aggregate	20.66
6	% of Fiber added	00
		0.5
		1.0
		1.5
7	% of fibers	0.000
		0.344
		0.688
		1.033

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Table 2: details of materials for M70

S.NO	MATERIALS	QUANTITY
1	Grade of Concrete	M70
2	Water	2.73
3	Cement	11.41
4	Fine aggregate	15.36
5	Coarse aggregate	12.58
6	% of Fiber added	00
		0.5
		1.0
		1.5
7	% of fibers	0.000
		0.344
		0.688
		1.033

IV. EXPERIMENTAL SETUP AND TESTING PROCEDURE

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.

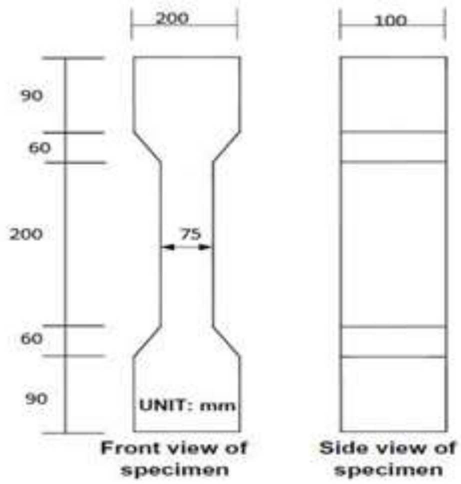

Fig 4. Dimensions of specimen

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 dog bone shape specimen was selected to detect elon gation 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 attached of rod size 25 mm diametre was fixed in order to fit into the machine The average elongation was obtained from dial guage. this process was carried on universal testing machine.

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Fig 4.1 Specimen testing on UTM

V. RESULTS AND DISCUSSIONS

The specimens were tested on the Universal Testing Machine under deflection rate control. All the speci mens were tested under the uniaxial tension testunder deflection rate control. To understand the fracture be ha viour of plain and fiber reinforced concrete specim en the following graphs were drawn, Load Vs deflect tion. The stress strain and fracture energy of subject ted to tensile test.calculated by using the graphs and Tables it was observed that, for tensile failure of concrete

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

Table 3 : details of peak Area of M30&M70 Grade of concrete

S.No	Grade of Concrete	% of fibers	Post peak area
1	M30	00	0.076
		0.5	0.144
		1.0	0.455
		1.5	0.828
2	M70	00	0.274
		0.5	0.502
		1.0	0.668
		1.5	0.935

Table 4: Details of Tensile strength test

M30 Grade of concrete			
Type of specimen	**F_{CK} (N/MM^2)**	**F_T (N/MM)2**	**Tensile Strength (N/MM^2)**
00	78.17	5.3	3.24
0.5	80.4	5.8	2.94
1.0	84.53	6.3	3.52
1.5	91.9	7.1	3.59

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Table 5: Details of Tensile strength test

M70 Grade of concrete			
Type of specimen	**F_{CK} (N/MM^2)**	**F_T (N/MM)2**	**Tensile Strength (N/MM^2)**
00	44.3	2.3	1.59
0.5	52.04	3.67	3.26
1.0	56	5.63	3.47
1.5	60.5	6.1	3.69

Fig 5.1 Failed specimen and fractured surface

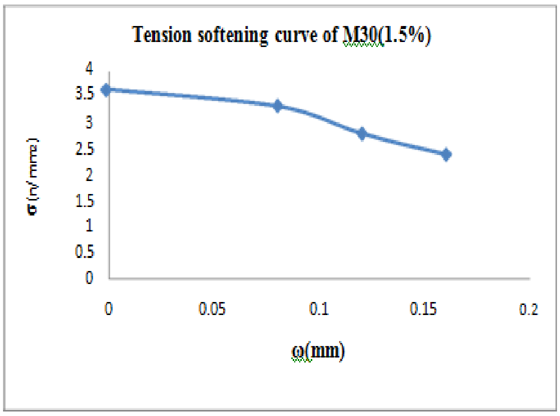

Fig 5.2 Tension softening curves of M30(0%,0.5%,1%,1.5%)

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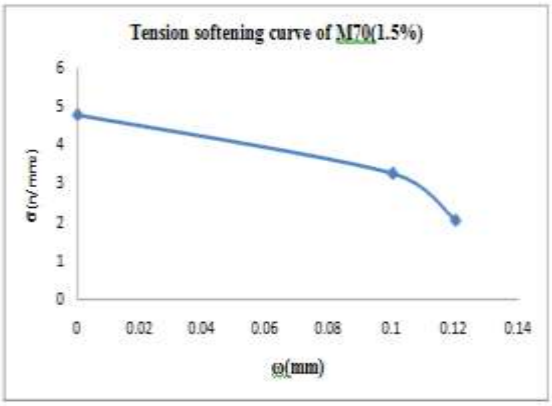

Fig 5.3 Tension softening curves of M70(0%,0.5%,1%,1.5%)

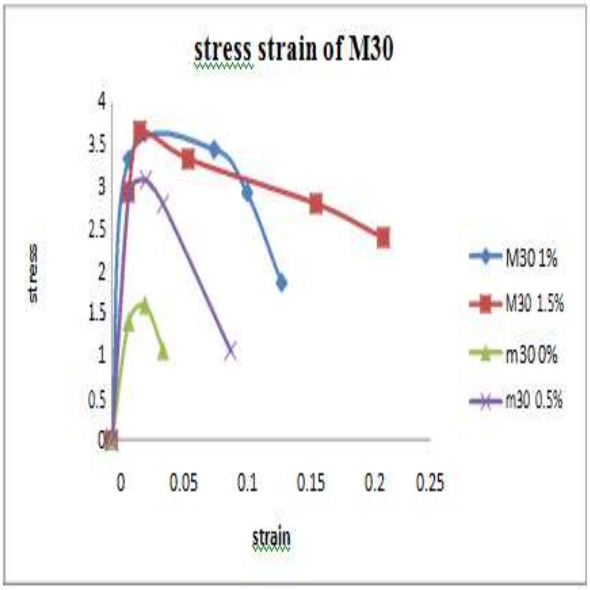

Fig 5.4 : stress strain curves of different % of fibers(M30)

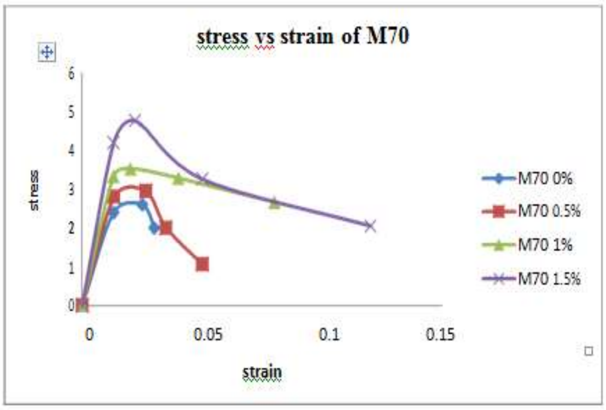

Fig 5.5 : stress strain curves of different % of fibers(M70)

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VI. CONCLUSION

The proposed test method for measuring direct tensile strength minimized the eccentricity during loading.

- According to the results obtained the uniaxial tensile strength in high strength concrete having 78.17-91.7MPa and 44.5-60.5MPa in normal strength concrete compressive strength.
- It was determined that the uniaxial tensile strength was 61.13% smaller than split tensile strength for 0% replacement and 56.20% smaller for 0.5%replacement and 55.95% smaller for 1% replacement and 66.22% smaller for 1.5% replacement these for high strength concrete .
- The higher the volume fraction of fibers, the higher the maximum post-cracking Stress
  Fracture energy increases with an increase in
  % of steel fiber both in high strength concrete and normal strength concrete.
- From the results it was proved both in high strength concrete and normal strength the post cracking increase with an increase in % of fiber replacement.
- Form the results it was proved both in high strength concrete and normal strength the post cracking increase with an increase in % of fiber replacement

VII. ACKNOWLEDGEMENT

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