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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: Softening behaviour, Normal Strength, Fracture Mechanics

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 120MPa 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 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.

Since the introduction of concrete with a compressive strength of 62 MPa in columns, shear walls and transfer girders of the Water Tower Place in Chicago in 1975, many applications of HSC in projects, ranging from transmission poles to the tallest building (KLCC Twin Tower in Kuala Lumpur, Malaysia) on earth, with concrete strength reaching up to 131 MPa in the Union Square building in Seattle, Washington have been reported.

FRACTURE MECHANICS

Fracture mechanics is the field of mechanics concerned with the study of the propagation of cracks in materials. It uses methods of analytical solid mechanics to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture.

Fracture mechanics plays a central role, as it provides useful tools which allow for an analysis of materials which exhibit cracks. The goal is to predict whether and in which manner failure might occur. Fracture mechanics is generally applied in the field of earth sciences such as petroleum engineering, geological engineering, mining engineering and civil engineering Materials like ceramics, rocks, glasses and concretes behave as brittle and in brittle materials; the crack initiation is determined by using the linear elastic stress field around the crack tip.

The Fracture process in Tension:

The tensile strength of concrete is much like the compressive strength, dependent on the strength of each link in the cracking process, i.e., micro cracks in the cement paste, micro cracks in the bond and macro cracks in the mortar.

Crack Formation:

Fracture mechanics is an energy based method, in which the formation of cracks requires that the material must absorb some amount energy (Bazant and Planas 1998) associated with the resistance of that material (Anderson 2005). This energy requirement is important, because it implies that if it is not met the material will not fracture even after the design strength is met (Bazant and Planas 1998).

FRACTURE BEHAVIOUR

The quasi-brittle behavior of concrete can be best explained by the following five stages.

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 behaviour (Shah et al. 1995).

Damage localization:

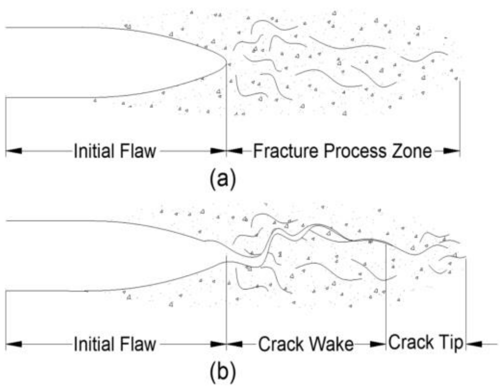
The micro-cracks will localize forming a micro-crack, which occurs at the point of initial crack localization. At which point the material undergoes stable crack growth (crack propagates only when load increases) and a softening behavior occurs (Shah et al. 1995).

Unstable Crack Growth:

Once the ultimate strength is reached at a critical crack length the crack will undergo unstable growth (crack propagates even though load decreases) (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.



II. METHODS AND MATERIAL

- Shape of the item being tested
- Method of gripping the item
- Method of applying the force
- Determination of strength properties other than the maximum force required to fracture the test item.

MATERIALS

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

Cement:

Ordinary Portland cement Of 53 grades 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% .

Tamping rod:

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

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.

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.

III. RESULTS AND DISCUSSION

The specimens were tested on the Universal Testing Machine under deflection rate control. All the specimens were tested under the uniaxial tension test under deflection rate control. To understand the fracture behaviour of plain and fibre reinforced concrete specimen the following graphs were drawn, Load Vs deflection. The stress strain and fracture energy of subjected to tensile test. Calculated by using the graphs and Tables it was observed that, for tensile failure of concrete, It was found that the stress intensity factor and fracture energy increases with the increasing of % of fibres.

TABLE-1

GRADE OF CONCRETE	% OF FIBRES	POST PEAK AREA
M30	0	0.076
	0.5	0.144

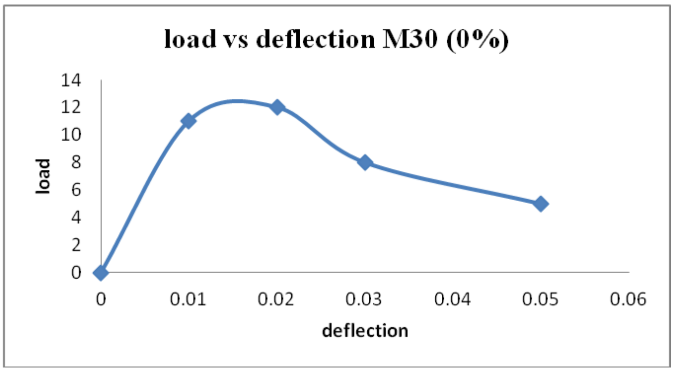
	1	0.455
	1.5	0.828
M70	0	0.274
	0.5	0.502
	1	0.668
	1.5	0.6747
	1.5	0.935

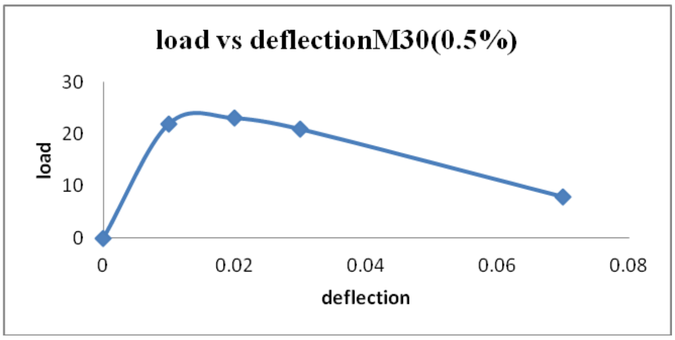
TABLE-2

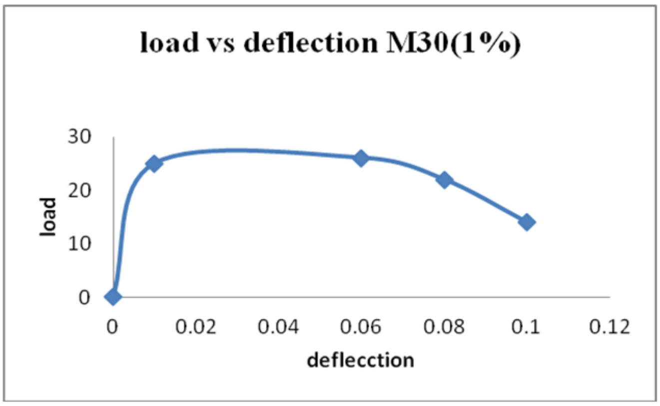
GRADE OF	**SPECIMEN**	**F_{CK}(N/MM^2)**	**F_T(N/MM^2)**	**DIRECT TENSILE STRENGTH (N/mm^2**
CONCRETE	**TYPE**			
M70		78.17	5.3	3.24
	0			2.61
	0.5	80.4	5.8	2.94
				3.6
	1	84.53	6.3	3.52
				3.26
	1.5	91.9	7.1	3.59
				4.7

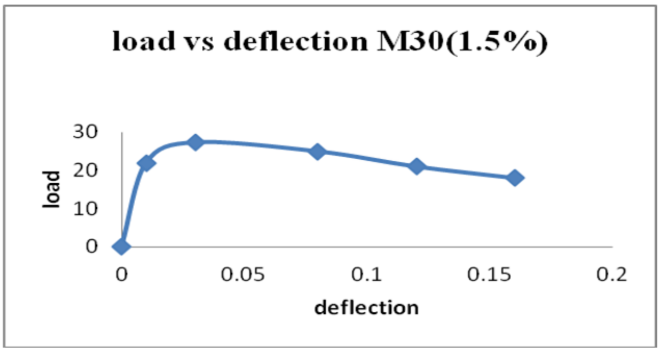
TABLE-3

GRADE OF	**SPECIMEN**	**F_{CK}(N/MM^2)**	**F_T(N/MM^2)**	**DIRECT TENSILE STRENGTH (N/mm^2)**
CONCRETE	**TYPE**			
M30		44.3	2.3	1.59
	0			1.36
	0.5	52.04	3.67	3.26
				3.07
	1	56	5.63	3.47
				3.24
	1.5	60.5	6.1	3.69
				3.41

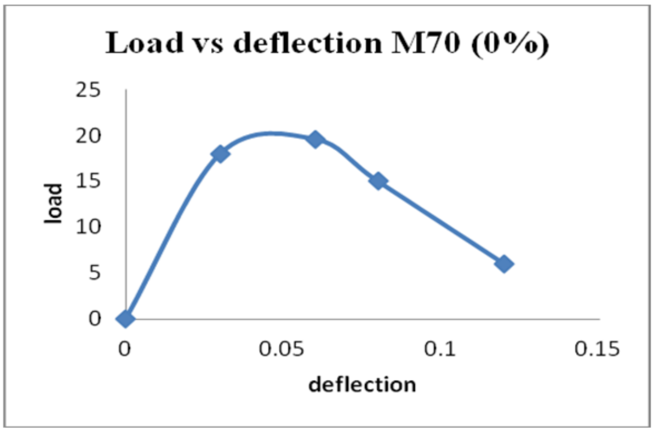


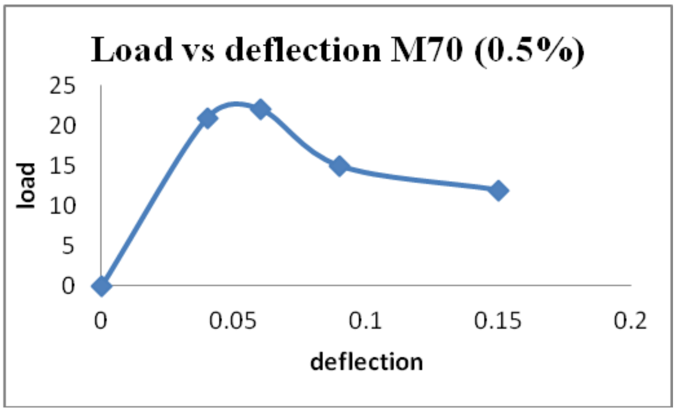


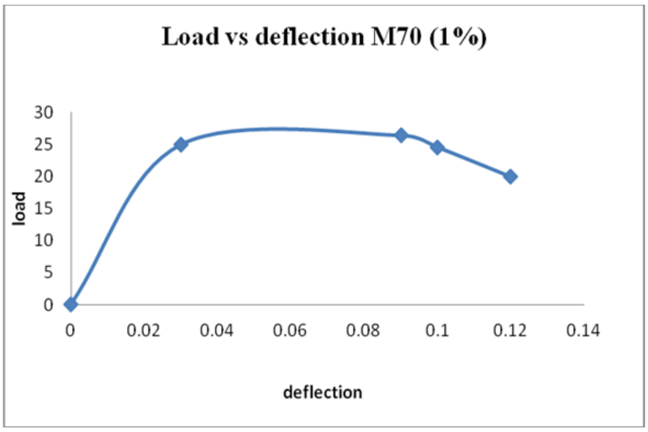


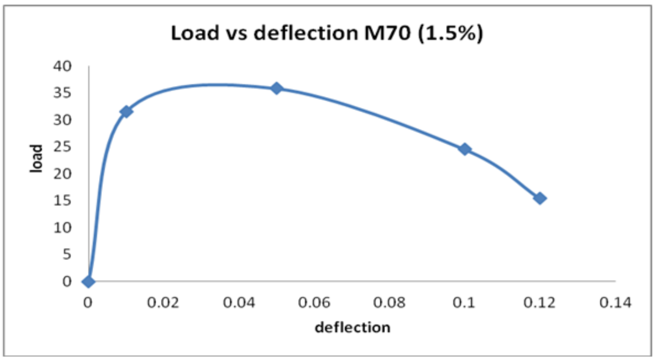


load vs deflection for M30(0%,0.5%,1%,1.5%)

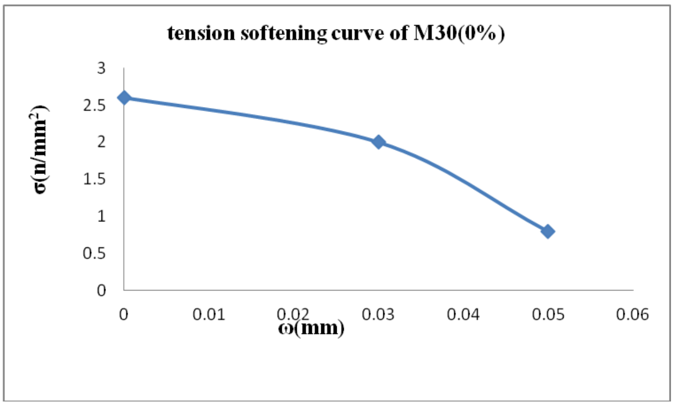


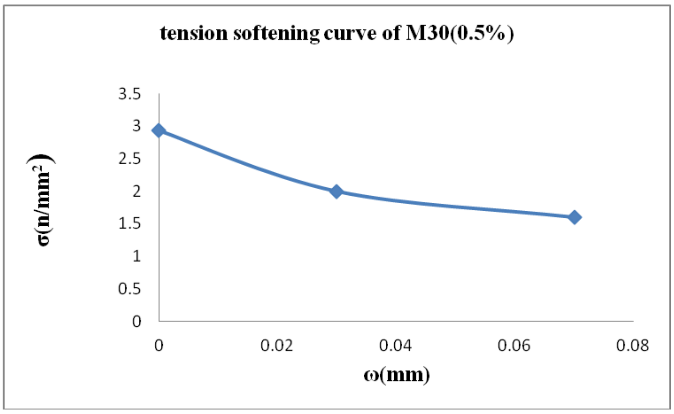


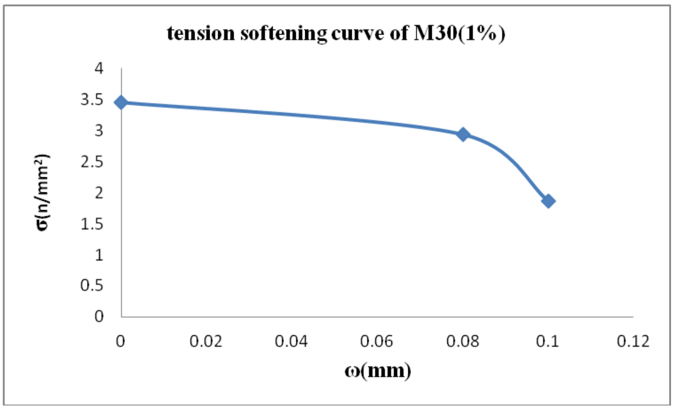


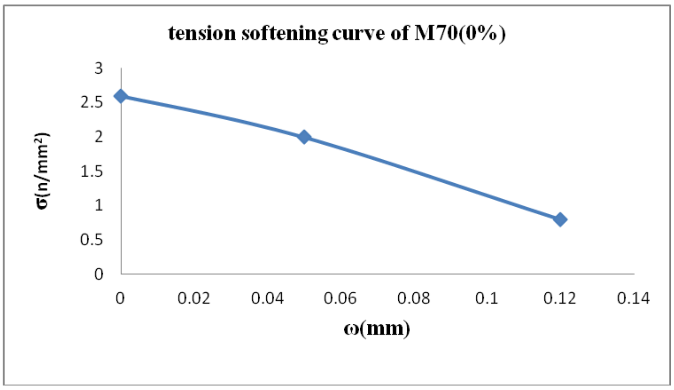


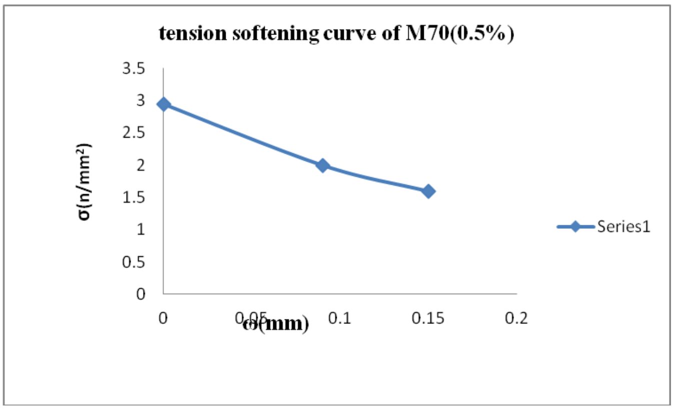
load vs deflection M70(0%,0.5%,1%,1.5%)

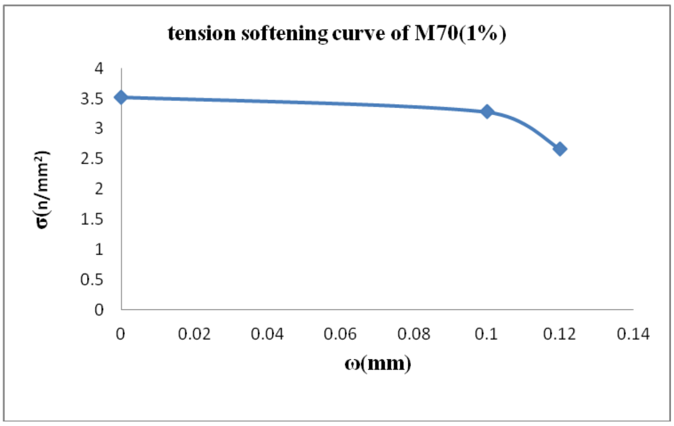


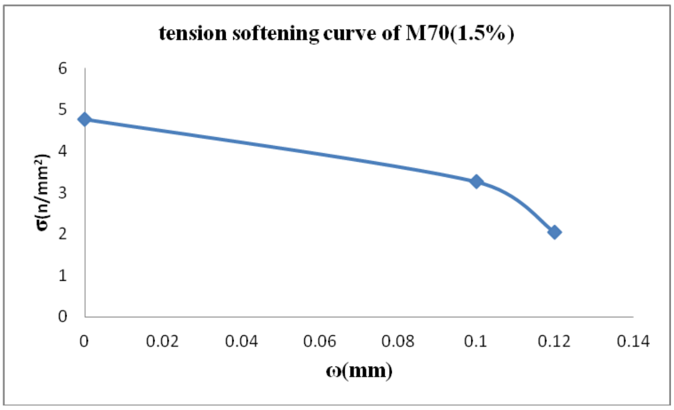












Tension softening of M70(0%,0.5%,1%,1.5%)

IV. 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 ratios of split tensile strength to compressive strength and uniaxial tensile strength to compressive strength increased as compressive strength increased.
- 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.
- It was determined that the uniaxial tensile strength was 66.52% smaller than split tensile strength for 0% replacement and 88.82% smaller for 0.5%replacement and 61.32% smaller for 1% replacement and 60.4% smaller for 1.5% replacement these for 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.

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