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Behaviour of Fibre Reinforced Concrete Beams in Pure Torsion, Combined Bending and Torsion

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ABSTRACT

In structures where equilibrium torsion occurs, in addition to shear and flexure, torsion should be calculated and designed for torsional strength of sections. The sections made with homogeneous materials can be estimated quite accurately using theory of elasticity. But it is very difficult to assess the torsional strength of heterogeneous reinforced concrete sections. The problem becomes more acute because such members are seldom under pure torsional; rather they are subjected to bending shear and torsion. Many theories have been proposed to explain the phenomenon of torsion in reinforced concrete, such as skew bending theory and space truss analogy. A large amount of experimental research has also been devoted to the subject.

It has been observed that a plain concrete member when subjected to cracking torque fails along a spiral inclined at 45^0 to the axis of the member. It is obvious that reinforcement in the form of 45^0 rectangular spirals will be most effective in resisting torque in case of a member of rectangular section. Provision of only longitudinal bars without stirrups increases torsional strength to the extent of 15%, the most appropriate system of torsional reinforcement consists of longitudinal bars together with closed transverse stirrups.

In view of above observations, an attempt is made to study the following aspects:

a) Behaviour of reinforced concrete beam under pure torsional, combined bending and torsional
   (i) Without glass fibres
   (ii) With glass fibres
b) The effect of increase of fibre percentage on torsional resistance of beam.
c) To develop torque. Vs. twist relation of the beams.
d) To study the cracking pattern in each case.

The experimental program consists of casting 8 reinforced concrete beams of size 150mm X150 mm and length 2m. Two of them were cast without fibres to make a comparative study with the remaining 6 beams; two beams are cast with 0.5% fibre by weight, two beams 1.0% fibre by weight in the rest two beams 1.5% fibre by weight added. The longitudinal reinforcement, spacing of shear stirrups is kept constant.

INTRODUCTION

Torque or twisting moment is one of the six internal forces at any section of a member of a skeleton structure. Similarly it is one of the five internal forces commonly occurring at any cross sectional face of an element of plate or shell (membrane normal and shear forces, transverse shear force, bending moment and twisting moment.).

Twisting moments, which are essential to maintain equilibrium of the structure, give rise to equilibrium torsion. Equilibrium torsion assumes much greater importance in the concrete structure. Twisting moments which are not essential for equilibrium but are present only to establish compatibility of deformation give rise to compatibility torsion while the neglect of compatibility torsion may lead to undesirable cracking and inadequate serviceability, the neglect of equilibrium torsion may lead to disastrous collapse of the structure

LITERATURE REVIEW

In the plain concrete and similar brittle materials, structural cracks develop even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these cracks seldom exceeds a few microns, but their other two dimensions maybe of higher magnitude.

Definition:

It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is kwon as fibre reinforced concrete.

ADVANTAGES OF FRP

Some of the main advantages of FRP can be listed below:

Low weight: The FRP is much less dense and therefore lighter than the equivalent volume of steel. The lower weight of FRP makes installation and handling significantly easier than steel. These properties are particularly important when installation is done in cramped locations. Other works like works on soffits of bridges and building floor slabs are carried out from man-access platforms rather than from full scaffolding.

REVIEW OF PREVIOUS WORK

Torsion occurs specially in beams curved in plan, balcony girders, supporting cantilevers slabs, spiral stairs and spandrel beams, where torsional reinforcement is to be specially designed and provided for. Yet torsion is considered secondary till now in many structures. The safety factor provided for flexure takes care of torsion indirectly

PURE TORSION

Plain concrete members under torsion fail abruptly at the formation of first crack. Providing reinforcement either longitudinally or transversely alone does not result in any appreciable increase in strength beyond cracking. It has been observed that the longitudinal bars alone both at top and bottom, hardly increase the tensional strength an improvement of at most 15%, was shown by the tests conducted by Young et al [2], Marshall and Tembe [1],Hsu [3], Pandit [4]. This increased strength has been attributed to the dowel action of the longitudinal steel at the points where cracks transverse the longitudinal steel. Experiments conducted by Venkateshwerlu et al [1] have shown that stirrup reinforcement along with bottom longitudinal bars only, without top longitudinal bars will not contribute to the tensional capacity. The strength of a reinforced concrete beam with longitudinal reinforcement only, or with stirrup reinforcement and longitudinal steel at top or bottom alone is almost equal to the torsional capacity of a similar plain concrete beam. However by providing reinforcement longitudinally at top and bottom transversely as well , the tensional strength can be increased substantially after cracking. The torsional stiffness reduces quit significantly after cracking. The ductility beyond cracking increases.

ULTIMATE TORSIONAL STRENGTH

Based on the general premise the torsional strength of a fully reinforced beam is composed of the sum of the strengths contributed by concrete and reinforcement, the approach of the earlier investigators and ACI for predicting the ultimate pure torsional strength of reinforced rectangular concrete beams can be expressed in a general form.

$$T_u = K\, T_{uc} + (\Omega)\, (a_s\, f_{sy}\, b_s\, d_s\,)/\, S$$

T_u = ultimate torsional strength of a reinforced rectangular concrete beam

T_{uc} = torsional strength contributed by concrete

K = a non dimensional.factor,

F_{sy} = yield stress of stirrup steel

Ω = a function of d_s, b_s and m, the volume ratio of longitudinal and stirrup steel

b_s, d_s = smaller and longer center line dimension of the stirrup

a_s = cross sectional are of stirrup leg,

s = spacing of stirrups

Table – 1 Values of K and Ω

Torsional sriffness

Torsional stiffness of the beam is defined, as the twisting moment required to produce a unit angle of twist per unit length.

COMBINED BENDING, TORSION AND SHEAR

Assumption: In developing the epressions for predicting the cracking torque of reinforced concrete rectangular beams the following assumptions are mode.

1) The torsional shear stresses are distributed on the cross section according to the plastic theory.
2) The flexural shear stresses and flexural normal stresses are distributed according to the elastic theory.
3) Cracking initiates when the maximum principle tensile stress equals the tensile strength of concrete.
4) The transformed area of steel is taken in to account in the calculation of section properties.
5) The stresses in the steel due to applied loads are negligible prior to the formation of initial crack.

EXPERIMENTAL PROGRAM

Pure torsion

The experimental program consists of casting and testing of 4 RCC beams out of which one beam was without glass fibres and the remaining 3 beams were cast by adding glass fibres, among these 3 beams one beam containing glass fibres of 0.5% by weight, 2nd beams of 1.0% by weight and the 3rd one with 1.5% by weight.

Concrete mix used is M20 grade and is constant for all beams. Spacing of stirrups is constant for all beams i.e. 180mm.details of beams as shown in table (2). All the beams were tested to study the effect of the ultimate torque and cracking torque in pure torsion.

Materials used

Cement:

Fine aggregate:

Coarse aggregate:

Water:

Concrete mix:

Reinforcement:

Fibres:

Glass fibres of aspect ratio of 865.27 was used, whose diameter is 0.01386 mm and length 12 mm.

Aspect ratio is defined as the ratio of length to its diam

Moulds:

Moulds consist of rolled steel channels and bottom plate, which are joined by means of bolts and nuts. These moulds are used for casting of beams. Size of mould is 2m x15cmx15cm. Standard cast iron cube is used for casting cubes.

Casting of test beams:

Glass fibre added while mixing Mixing of concrete

Compaction and casting

Test set up and testing procedure for pure torsion

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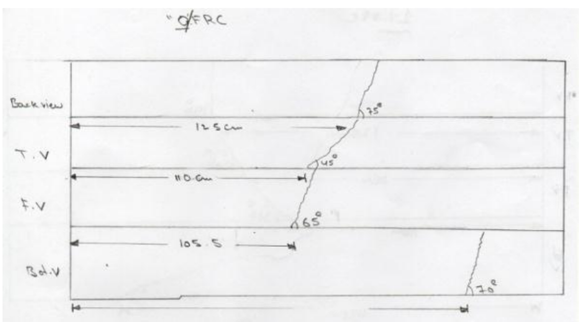
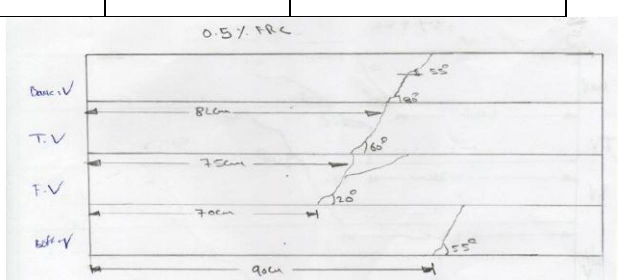
Reinforced concrete beams

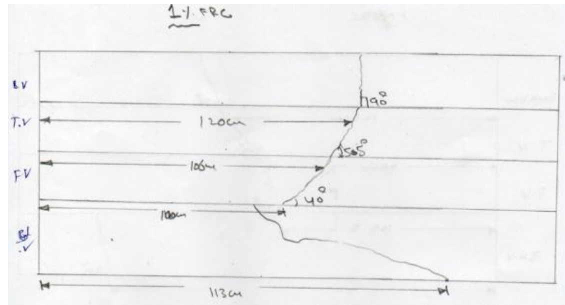
There is a steady increase in the angle of twist per unit length for the applied torque up to the initial crack was formed. After the first crack has been formed, increase in the angle of twist with constant torque has been observed. Angle of twist increases more rapidly after the first crack formed with a steady applied torque. Even after the beam reached its ultimate torque the values of the angle of twist of the beam was still increasing.

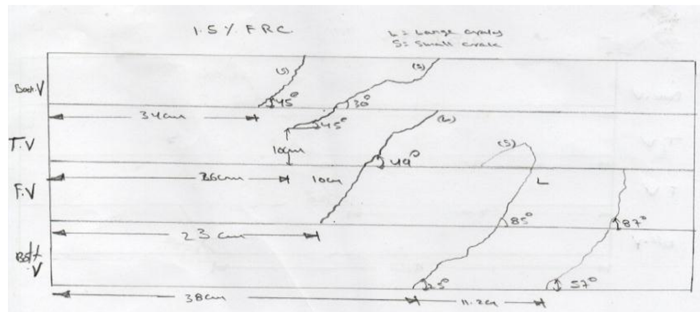
CRACK PATTERN IN PURE BENDING



Beam	Cracking torque (kN-M)	Ultimate Torque
FR 0	2.916	4.116
FR 0.5	3.516	5.316
FR 1	4.116	5.916
FR 1.5	4.716	6.516

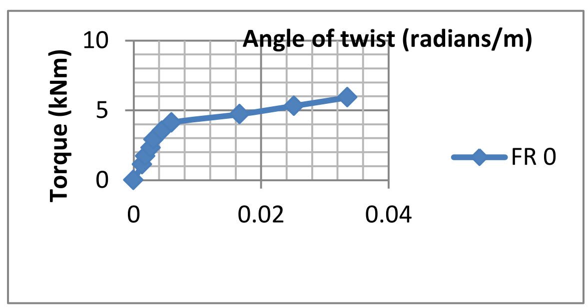






Above diagrams shows the pattern of cracks formed on four sides of the beam after testing of the beams. All distances are shown from left end of the beams. Angle of cracks are measured with protector and drawn on paper. Original cracks on the beam are shown in plate below.

GRAPHS IN PURE BENDING



Comparison Values of Cracking torque and ultimate torque:

CONCLUSIONS

1. From the **Torque-Twist curves,** derived from the thesis work, it is observed that, the steepness of the Torque –Twist curve increases with increase of percentage of glass fibres by weight.

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From this observation it is concluded that, both cracking torsional strength and ultimate torsional strength increases with the addition of glass fibres.

2. From the Torque-Twist tables, derived from the thesis work, it is observed that the angle of twist at the cracking stage is increasing with the increase of percentage of glass fibre.

From this observation it is concluded that, the ductility property of the reinforced concrete beams can be increased by adding glass fibres. That is decreasing the brittleness of the concrete by adding glass fibers.

3. From the cracking pattern diagrams of beams subjected to both pure torsion and combined bending and torsion, it is observed that the inclination of cracks to their respective longitudinal axis increase with the increase of fiber content, hence it is concluded that the increase in fiber content of beams improves the rotational capacity.

4. From the above said points it can be concluded that this thesis work helps in finding the amount of addition of glass fibre to the area of the given structure where concrete is to bear some part of the tensile stress.

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