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EXPERIMENTAL INVESTIGATION ON FIBERS IN COLUMNS SUBJECTED TO COBINED AXIAL LOAD AND UNIAXIAL BENDING

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ABSTRACT

This study primarily explores the experimental study on the effect of fibers in columns subjected to combined axial load and uniaxial bending. In designing of members, concrete being weak in tension its tensile strength in neglected. The present investigation is to incorporate the increase in the tensile strength of concrete due to addition of fibers and thereby reducing the amount of reinforcement. In the present study crimped fibers, a type of steel fibers are used since steel fibers possess some tensile strength and thereby increase the tensile strength of concrete. A symmetrically reinforced C shaped short column is subjected to axial load P at an eccentricity e giving an uniaxial bending moment equivalent to M = P x e. Short column is reinforced with 4 numbers of 10mm diameter of steel bar confined with stirrups of 8mm diameter provided at a spacing of 100mmc/c. C shaped brackets of 10mm diameter is provided at top and bottom in order to get C shaped column. The column is of size 600mmx100mmx100mm.The columns are casted with different percentage of crimped fibers as 0%, 0.5%, 0.75% and 1% to total volume of concrete. The grade of concrete selected is M30 The parameters for all the specimens that are casted are kept constant like shape of columns, reinforcement, types of fibers and grades of concrete. After curing for a period of 28 days the columns are tested on Universal Testing Machine. Roller is provided at an eccentricity of 60mm and the test is performed with gradual increase of loads. The test results show that there has been a considerable increase in the bending stress of column with percentage of fiber ranging from 0.5% to 1% when compared with reinforced concrete i.e. no fiber addition. It is seen that the bending stress of columns has an increase of 25% with fiber addition. The present work is one step towards studying the behavior of elements which are subjected to uniaxial bending and finding the relation between the axial compressive load P, uniaxial moment M and % of fiber added.

I. INTRODUCTION

1.1 Combined Axial Load and Uniaxial Bending

Columns are defined as members that carry loads in compression. Usually they carry bending moment in one or both axes of cross section. The bending action may produce tensile forces over a part of cross section. Despite of the tensile forces that may be produced, columns are generally referred to as Compression members because the compression stresses dominate their behavior A symmetrically reinforced short column is subjected to axial load P at an eccentricity e giving a moment equivalent to M = P x e. Depending on the relative magnitudes of M and P the entire column may be under compression known as compression control region or a part of section may be tension such that the strain in tension steel is greater than the yield point strain when the compressive strain in the concrete reaches 0.0035 known as tension control region. In the compression control region, neutral axis lies outside the region. In the tension control region, neutral axis lies inside the section. When compression axial load is zero, the column section behaves as a doubly reinforced beam and its moment carrying capacity is given as M_0. As compressive axial load increases the moment carrying capacity increases. It is because the compressive stress due to axial load reduces the net tensile stress below the yield level. Consequently, the section can sustain an additional moment such that the net tensile stress in the reinforcement reaches the yield level. The increase in moment carrying capacity continues until the balanced condition is reached, that is, the maximum strain in concrete reaches 0.0035 and the maximum strain in tension steel reaches the first yield point. Moment carrying capacity is reduced as the compressive axial load is further increased beyond the balanced load. IT is because the failure in this region is due to crushing of concrete. As the compressive load increases the margin of additional compressive strain due to bending moment decreases, hence the moment carrying capacity decreases. When the load becomes equal to buckling load, the moment carrying capacity reduces to zero. Concrete being weak in tension, steel fibers are added in order to increase the compressive load carrying resistance along with the reinforcement steel.

1.2 Reinforced Concrete

Reinforced concrete is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength. The reinforcement is usually steel reinforcing bars and is usually embedded passively in the concrete before the concrete sets. Reinforcing schemes are generally designed to resist tensile stresses in particular regions of the concrete that might cause unacceptable cracking and/or structural failure. Modern reinforced concrete can contain varied reinforcing materials made of steel, polymers or alternate composite material in conjunction with rebar.. Reinforced concrete may also be permanently stressed (in compression), so as to improve the behaviour of the final structure under working loads. The weakness in tension can be overcome to some extent by the inclusion of a sufficient volume of certain fibers. The use of fibers also alters the behavior of the Fiber -matrix composite after it has cracked, thereby improving its toughness

1.3Mechanism of Composite Action of Reinforcement and Concrete

The reinforcement in a RC structure, such as a steel bar, has to undergo the same strain or deformation as the surrounding concrete in order to prevent discontinuity, slip or separation of
the two materials under load. Maintaining composite action requires transfer of load between the concrete and steel. The direct stress is transferred from the concrete to the bar interface so as to change the tensile stress in the reinforcing bar along its length. This load transfer is achieved by means of bond (anchorage) and is idealized as a continuous stress field that develops in the vicinity of the steel-concrete interface.

1.4 Fiber Reinforced Concrete

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop provides some post- cracking "ductility". If the fibers 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. There are, of course, other (and probably cheaper) ways of increasing the strength of concrete. The real contribution of the fibers is to increase the toughness of the concrete (defined as some function of the area under the load vs. deflection curve), under any type of loading. That is, the fibers tend to increase the strain at peak load, and provide a great deal of energy absorption in post-peak portion of the load vs. deflection curve.

1.5 Effect of Fibers in Concrete

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact–, abrasion–, and shatter–resistance in concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is higher than the matrix they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems. The most important contribution of fiber reinforcement in concrete is not to strength but to the flexural toughness of the material. When flexural strength is the main consideration, fiber reinforcement of concrete is not a substitute for conventional reinforcement. The greatest advantage of fiber reinforcement of concrete is the improvement in flexural toughness.

1.6 Bridging Action

Pullout resistance of steel fibers (dowel action) is important for efficiency. Pullout strength of steel fibers significantly improves the post- cracking tensile strength of concrete. As an SFRC beam or other structural element is loaded, steel fibers bridge the cracks, as shown in Figure1. Such bridging action provides the SFRC specimen with greater ultimate tensile strength and, more importantly, larger toughness and better energy absorption.

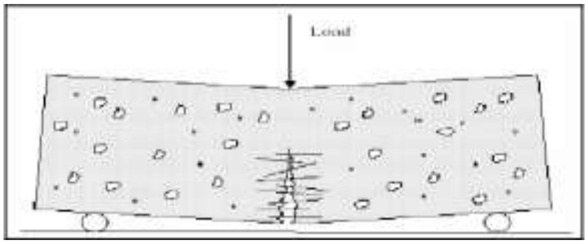

Figure 1: Fiber Pull-Out

1.7 Need for the Present work

Fiber reinforced concrete is widely used in beams and slabs which are subjected to flexural stresses but now a days it finds its application even in structures where a member is subjected to axial compression and bending (uniaxial bending). In such cases it will be economical to incorporate the increase in tensile strength of concrete due to the addition of fibers. The present work is one step towards studying the behavior of such elements which are subjected to uniaxial bending and find the relation between the axial compressive load P, uniaxial moment M and % of crimped fibers added.

1.8 Workability

We know that it is usually wrong to add water to concrete for workability. The main problem with workability of steel fiber reinforced concrete is in getting proper distribution of the fibers so that they don't ball up.This difficulty is usually overcome by slow, continuous and uniform feeding of the fibers into the wet or dry mix by means of vibratory feeders. Sometimes the fibers are passed through screens as they are introduced. Proper feeding can virtually eliminate the problem of balling. On the other hand, addition of water to improve workability can reduce the flexural strength significantly; a critical matter when one considers that one of the main reasons for using steel fibers is to improve the flexural strength. In such cases use of suitable admixture probably would improve the workability to certain extent and may not to the extent that you require

II. LITERATURE REVIEW

Jin-Keun Kim a,*, Sang-Soon Lee b, Yusong, Taejon and Yusong, Taejon (3) in September 1999 has worked for a numerical method for predicting the behavior of reinforced concrete columns subjected to axial force and biaxial bending considering curvature localization because When stress is beyond elastic limit or cracking occurs in a reinforced concrete member subjected to axial force and biaxial bending, curvature about each principal axis of gross section may be influenced by axial force and bending moments about both major and minor principal axes. It is mainly due to the translation and rotation of principal axes of the cross section after cracking.
L. Pallar´es_, J.L. Bonet, P.F. Miguel, M.A. Fern´andez Prada (4) accepted 6 December 2007- presented an experimental research on high strength concrete columns subjected to compression and biaxial bending forces. The aims of the experimental program were to provide experimental tests of high strength concrete columns under the loads and to contribute to the knowledge regarding the behaviour of columns.

III. EXPERIMENTAL INVESTIGATION

In this chapter, the details of the material that have been used in the study are mentioned. The details regarding the properties of cement, aggregate, and the super plasticizer used are described. The casting and cuing method and the test procedures have also been discussed. In the present experimental programme C shaped concrete columns of length 600mm and cross section 100mm x 100mm, standard cubes of (150x150x150mm) size and cylinders with fiber addition as percentages of 0%, 0.5%, 0.75% and 1% to total volume of concrete are casted. For each percentage 3 specimens were casted and tested for finding the axial compressive resistance of steel fiber reinforced concrete

3.1 Concrete Mix Design

Using the properties of cement, fine aggregate and coarse aggregate, M30 grade of concrete was designed as per IS 10262 mix design procedure The following proportions by weight were obtained.

Table 3.7: Mix Design Ratios

Cement	Fine Aggregate	Coarse Aggregate
1	1.18	2.2

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Water Cement ratio = 0.39. And also to get the required workability Cornplast chemical is added in proportion of 17ml / 5kg of cement. The same proportion of mix was used throughout the experimental programmed.

Table 3.8 Quantities of Material Required for Casting of 1 Specimen of Concrete Column

s.no	Quantity of Cement in kgs	Quantity of Fine Aggregate in kgs	Quantity of Coarse Aggregate in kgs	Percentage of Fiber	Quantity of Fibers in kgs
1	5.000	5.900	11.000	0.500	0.109
2	5.000	5.900	11.000	0.750	0.164
3	5.000	5.900	11.000	1.000	0.219

3.3 Preparation of Test Specimens

3.3.1 Description of Test Specimens

Columns The size of the column is 600mm in length and 100mm x 100mm in cross section. For columns, steel reinforcement of four numbers of 10mm diameter bar of length 6oomm and C shaped steel rod links are provided at both ends and confined with 8mm diameter stirrups at 100mm spacing are provided keeping 20mm cover all-round. Cubes The cast iron moulds of size 150mm x 150mm x 1500 mm are used for casting of cubes.

3.3.2 Mixing

Initially the ingredients of concrete viz., coarse aggregate, fine aggregate, cement and Admixture were mixed, to which the fine aggregate and coarse aggregate were added and thoroughly mixed. And then water is measured exactly satisfying w/c ratio of mix design and is added gradually with addition of Conplast chemical. By thorough mixing, crimped fibers are sprinkled over the concrete without getting balling effect in percentages of 0.5%, 0.75% and 1% to total volume of concrete and it was thoroughly mixed until a mixture of uniform color and consistency were achieved which is then ready for casting. Prior to casting of specimens, workability is measured in accordance IS 1199-1959[28] and is determined by slump test and compaction factor test. Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the objective of producing Concrete of certain minimum strength and durability as economically as possible. The design of concrete mix is not a simple task on account of widely varying properties of the constituent materials, the condition that prevail at the work and the condition that are demanded for a particular work for which mix is designed. Design of concrete mix requires complete knowledge of various properties of the constituent materials, the complications, in case of changes on these conditions at the site. The design of concrete mix needs not only the knowledge of material properties of concrete in plastic condition, it also needs wider knowledge and experience of concerning. Even then the proportions of the material of the concrete found out at the laboratory require modifications and readjustments to suit the field Condit. Firstly dry mixing of cement, sand and coarse aggregate is done. And then water is added gradually with addition of Conplast chemical. By thorough mixing, crimped fibers are sprinkled over the concrete without getting balling effect in percentages of 0.5%, 0.75% and 1% to total volume of concrete. The mixed concrete is ready for casting of specimen

3.3.3 Casting of Specimens

The cast iron moulds are cleaned of dust particles and applied with mineral oil on all sides before concrete is poured in the moulds. The moulds are placed on a level platform. The concrete with different percentage as 0% , 0.5%, 0.75% and 1% is filled into the C shaped moulds for casting of C shaped columns and cubes by vibrating with needle vibrator to avoid honey combing and voids. Excess concrete was removed with trowel and top surface is finished level and smooth. Three specimens for different percentage of fibers are casted to total of 12 C shaped columns and 12 cubes.

3.3.4 Curing of Specimens The specimens are left in the moulds undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the moulds Marking has been done
on the specimens to identify the optimum Percentage and steel fibers to maintain the constant moisture on the surface of the specimens they were placed in water tank for curing of 28 days. All the specimens have been cured for the desired age.
After 28 days of curing all the specimens are removed from the pond and left to dry for some time. The casted specimens are now tested as per standard procedures.

3.3.5.1 Testing of Cubes Cubes and cylinders are tested on Compression testing machine. The oil level is checked, the MS plates are cleaned and the machine is kept ready for testing specimens.The specimen is kept and the load is applied and the machine is started. The max load readings shown on dial gauge are noted. The test is repeated for the three specimens and the average value is taken as mean strength.
The compressive strength is taken as load applied on the specimen divided by the area of the load bearing surface of specimen (P/A). The results are tabulated.

Figure 3.2 Testing of Cubes

3.3.5.2 Testing of Columns
The columns are tested on the Universal Testing Machine. The columns are placed on the machine and the loading gauge is placed at an eccentricity of 60mm from the axis. Rollers are provided at top below the loading gauge and at the bottom of specimen at the same eccentricity on the machine. Then slowly the dial gauge is brought into contact with the specimen and made fixed. Then loading is performed gradually with increasing loads until the specimen fails. The maximum load resisting capacities of specimen for different percentages of fibers added are tabulated. Then the moments are calculated by multiplying the load and eccentricity. (M = P x e)

Figure 3.3 Testing of Columns

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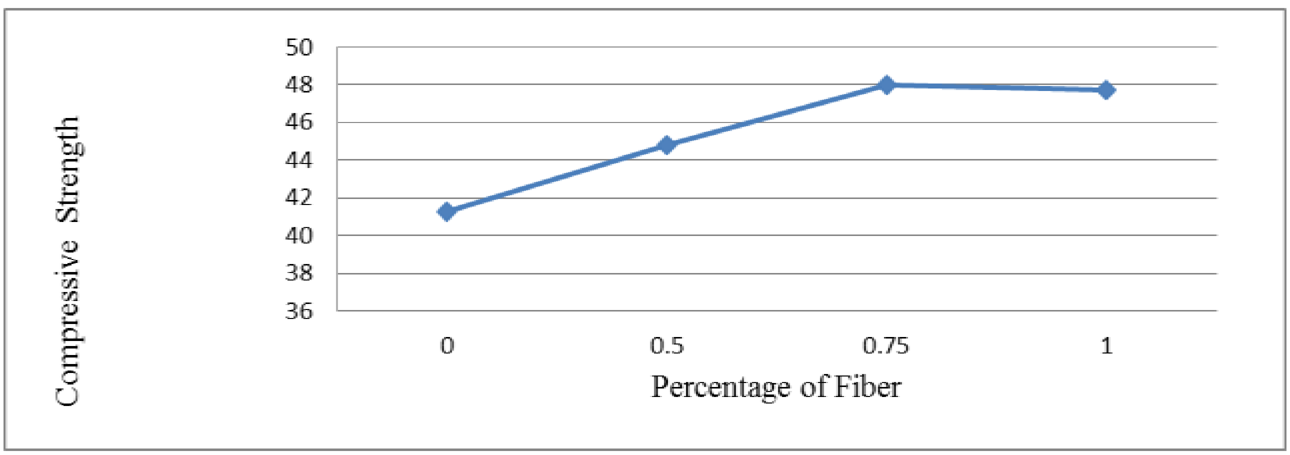
Table 4.1 Compressive Strength

S.No	Percentage of Fibers	Compressive Load in kN	Compressive Strength in N/mm^2	Average Compressive Strength in N/mm^2
1	0%	910.00	40.44	41.26
2	0%	930.00	41.33	
3	0%	945.00	42.00	
4	0.50%	980.00	43.56	44.81
5	0.50%	1005.00	44.67	
6	0.50%	1040.00	46.22	
7	0.75%	1065	47.33	48.00
8	0.75%	1080	48.00	
9	0.75%	1095	48.67	
10	1%	1020	45.33	47.70
11	1%	1050	46.67	
12	1%	1150	51.11	



Graph 4.1: Compressive Strength for Different Percentages of Fibers

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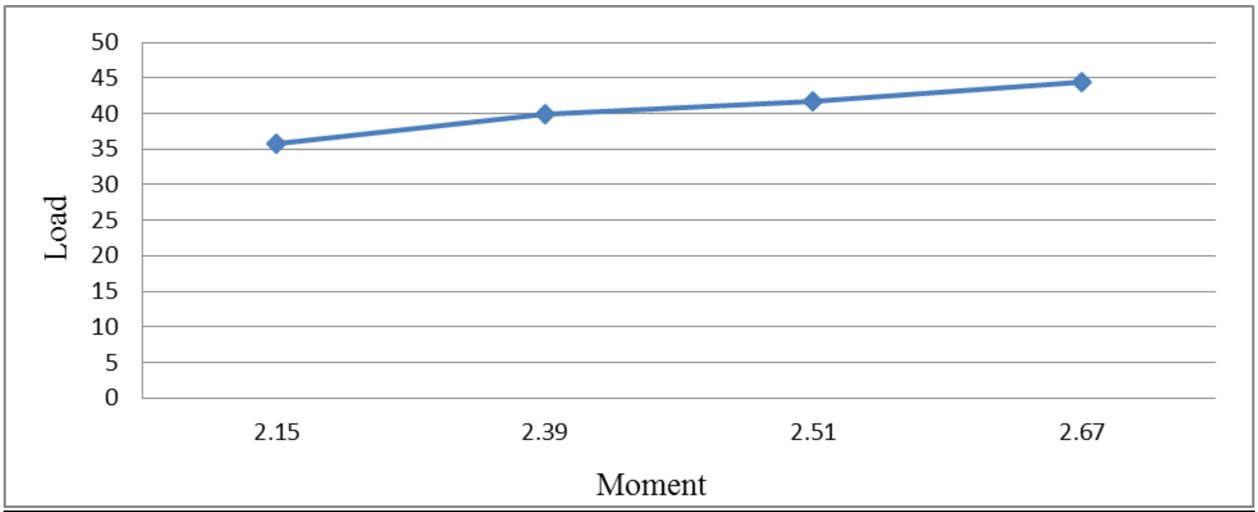
Table 4.3 Axial and Bending Stresses

S.No	% of Fiber	Load in kN	Eccentricity e in m	Bending Moment in kNm	Axial Stress MPa	Bending Stress in MPa
1	0%	33.50	0.06	2.01	3.35	12.06
2	0%	34.68	0.06	2.08	3.47	12.48
3	0%	35.81	0.06	2.15	3.58	12.89
4	0.50%	37.56	0.06	2.25	3.76	13.52
5	0.50%	38.87	0.06	2.33	3.89	13.99
6	0.50%	39.86	0.06	2.39	3.99	14.35
7	0.75%	40.25	0.06	2.42	4.03	14.49
8	0.75%	40.65	0.06	2.44	4.07	14.63
9	0.75%	41.75	0.06	2.51	4.18	15.03
10	1%	42.90	0.06	2.57	4.29	15.44
11	1%	43.68	0.06	2.62	4.37	15.72
12	1%	44.50	0.06	2.67	4.45	16.02



Graph 4.2: Load vs Moment Curve for Different Percentage of Fiber

4.2 Calculation of Axial Stress

Cross section column = 100mm x 100mm

Crushing load = 35.81 kN

Crushing Strength $= \frac{P}{A}$

$= \frac{35.81 \times 10^3}{100 \times 100} = 3.58$ MPa

4.3 Calculation of Bending Stress

Cross section column = 10mm x 100mm

Crushing load = 35.81 kN

Bending moment = 35.81×10^3 x 60mm = 2.15 x 10^6 Nmm

Bending Stress $= \frac{M}{Z}$

$Z = \frac{bd^2}{6}$

$Z = \frac{100 \times 100^2}{6}$ = 1.66 x 10^5 mm^4

Bending Stress $= \frac{2.15 \times 10^6}{1.66 \times 10^5}$ = 12.95MP

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IV. CONCLUSION

The bending stress of fiber reinforced concrete columns is larger than that of reinforced concrete columns. Addition of steel fibers ranging from 0% to 1.0% by volume of concrete has shown that bending stress of columns has increased from 12.89 to 16.02 i. e an increase of about 25% when compared to reinforced concrete columns As the axial compressive strength increases the bending moment carrying capacity also increases. As a result axial and bending stress capacities of columns also increase .Further increase in the percentage of fiber is affected by balling effect, decrease in the workability and creating mixing problem for the selected cross section.

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