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Experimental Study of Cracking Behaviour for SFRC Beams without Stirrups with Varying A/D Ratio

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***Abstract*—**Paper describes an experimental study for behavior of crack and modes of failure of SFRC (Steel Fiber Reinforced Concrete) deep beams & Moderate deep beams without stirrups having various shear span (a) to overall depth ratio (D). Eight nos. of SFRC simply supported beams having different depths of 300 mm, 400 mm, 500 mm and 600 mm were tested. We have used CCT (circular corrugated type) fibers in four beams and FCT (fibrillated corrugated type) fibers in another four beams. The span (overall span of 1300 mm, effective span of 1200 mm) and width (150mm) of all the beams were kept constant. Three cubes & three cylinders were cast as control specimen. Initiation or appearance and proportion of behavior of crack and mode of failure of beams were noted. We conclude that SFRC moderate deep beams with a/D ratio<1and were failed in shear mode so they are shear predominant members which is brittle in nature. The beams having a/D ratio ranging from 1to2.5 were failed in both shear and flexure. The beams having a/D ratio more than 2.5 failed in pure flexure.

***Keywords*—**Moderate deep beam ; Crack patterns; crack width; shear mode failure.

I. INTRODUCTION

Remarkable improvements in elastic modulus, tensile strength, crack resistance, crack control, durability, fatigue resistance, impact resistance, abrasion resistance etc., resulted in FRC (Fiber Reinforced Concrete) material, which arrived as a boon to overcome the drawbacks of steel-reinforced concrete. Over this short time-span, FRC has proved its worth as an economic and useful construction material for its ease of application. Varied types of synthetic fibers, acrylic, carbon, nylon, polyester, polyethylene, and polypropylene fibers apart from steel have found their way in forming FRC.

Also, the fibers can prevent excessive diagonal tensile cracking and localization of the tensile crack damage. Therefore, the fibers can increase the effective stiffness of the beam after diagonal tensile cracking occurs and can decrease the deflection of the beam. Concrete has the disadvantage that it fails in a brittle manner. The fibers can make the failure mode more ductile by increasing the tensile strength of concrete. As a result, the structural performance of concrete can be maximized.

The fiber reinforced concrete has found many interesting field applications such as bridge decks, highways, pavements for air fields, slope stabilizing in mining and tunneling, industrial flooring etc. The application of fibers to reinforced concrete structural members would be one of the major areas of use in structural engineering. The fibers to reinforced concrete have got an exciting future in construction in days ahead.

IS 456: 2000[1], along with other various codes of different countries, classifies the beam into three categories; namely normal beam, moderate deep beam, and deep beam, according to their span to depth ratios. In general, it can be classified as,

1) Deep beams ($a/D < 1.0$)
2) Moderate deep beams ($1.0 < a/D < 2.5$)
3) Shallow beams ($a/D > 2.5$).

Looking to the wide use of moderate deep beam in various important structures such as nuclear reactors, water tanks, halls, hotels, complex foundations, offshore structures, corbels etc. An attempt has been made through the study to understand cracking behavior of such beams under fibrous matrix.

II. OBJECTIVES

Increasing use of Fiber based composites in engineering construction has made it important to understand the behavior of these structural materials. The fibers to reinforced concrete have got an exciting future in construction in days ahead. The objective of the present experimental investigation was to provide a systematic and comprehensive comparative study on the first Crack load, ultimate load, as well as modes of failure of SFRC moderate deep beam for varying a/D ratio.

EXPERIMENTAL PROGRAMME:

Test materials:

Pozzolona Portland Cement of 53 grade, natural river sand having fineness modulus of 2.8 and maximum size of 4.75 mm as a fine aggregate, and natural basalt gravel of maximum size 20mm as coarse aggregate were used. The concrete mix proportion was 1:1.5:3.0 (cement: fine aggregate: coarse aggregate) by weight with water cement ratio of 0.45 kept constant for all beams. While in SFRC beams, Circular corrugated steel fibers of length 50 mm, aspect ratio 80, equivalent diameter 0.625 mm, and 1% by volume of concrete were used. Two types of fibers namely CCT (Circular corrugated type) and FCT (Flat corrugated type) were used in SFRC beams. All beams were provided with anchor bars along with nominal HYSD bars of 0.3% as main longitudinal tension reinforcement (Table 1). In this experiment we didn't provide the web reinforcement. There were series of beams and for each series three cubes (150mm diameter) and three cylinders (150 mm diameter and 300 mm height) were cast as control specimens. All specimens were cured at least for 28 days.

SPECIMEN DETAILS:

The test specimens consist of 8 nos. moderate deep beams & deep beams divided in series having different depths of 300 mm, 400 mm, 500 mm and 600 mm with three beams in each series. The span and width of all the beams were kept constant having overall span of 1300 mm, effective span of 1200 mm and width of 150 mm. All the beams were kept simply supported and tested under two equal points loading each at a distance of ⅓ of effective span (i.e. 400 mm) from the support, so that each beam is divided into three equal zones having center zone subjected to constant flexure and two outer zones subjected to constant shear throughout the zone. And also tested under center point load effective span (i.e. 600mm) from support, so each beam is divided into two equal zones. Centre part subjected to flexure and end parts subjected to shear.

After the completion of curing period; surface of specimen was made smooth by removing projections if any. All the beams were white washed to easily visualize the marking on the surface of beam and the cracks on the surface of beam during testing. Notations of beams and a/D ratios were written on the surface of the beam at right corners for identification.

To avoid stress concentration, and to keep bearing stresses within permissible limit to avoid crushing of concrete at the points of load application and at the points of support, 6 mm thick steel plates having dimensions 150 mm × 100 mm were provided in beams. Looking to the wide use of moderate deep beam in various important structures such as nuclear reactors, water tanks, halls, hotels, complex foundations, offshore structures, corbels etc. An attempt has been made through the study to understand cracking behavior of such beams under fibrous matrix as they predominantly fail under shear.

OBJECTIVES:

Increasing use of Fiber based composites in engineering construction has made it important to understand the behavior of these structural materials. The fibers to reinforced concrete have got an exciting future in construction in days ahead. The objective of the present experimental investigation was to provide a systematic and comprehensive comparative study on the first Crack load, ultimate load, as well as modes of failure of SFRC moderate deep beam for varying a/D ratio.

III. DISCUSSION OF TEST RESULTS

Behavior of Cracks, their Patterns, Propagation, and Modes of Failure

In all the beam specimens, initiation of flexure cracks was from the bottom of the beams. In most of the cases, all the flexure cracks were almost vertical, while most of the shear cracks were inclined and their direction of propagation was towards the nearest load point irrespective of its place of origin.

Beams with a/D ratio greater than 2.5 failed in pure flexure failure by yielding of longitudinal tensilereinforcement. Size and propagation of the flexure cracks were noticeable, while shear cracks were few and very fine. Majority of flexure cracks propagated beyond ¾ height of the beam and were considerably wide at the bottom.
Beams having a/D ratio between 1 to 2.5 are failing due to both flexure and shearmode. The phenomenon of all of a sudden formation of major diagonal shear cracks emerging from D/3 toD/4 height of the beam from bottom and its rapid propagation towards the nearest load and support point; was firstly seen in beams of a/D ratio varying from 1 to 2.5.Although, the shear cracks were comparable to flexure cracks .The ultimate failure of all the beams was due to the yielding of the longitudinal tensile reinforcement.

Beams with a/D ratio less than 1failed in pure shear failure. Flexure cracks were few and very fine, and hardly reached up to the mid height of the beam, while shear cracks were noticeable in size and its propagation covered more than ¾ height of the beam. After sudden formation of major diagonal shear cracks beam sustained some more load before ultimate failure, which shows its reserve strength.

The mechanism of shear cracking in moderate deep beams is conceived as resulting from a modification of the internal force system, accompanied by associated deformations consistent with the altered geometry of the members after flexural cracks form.

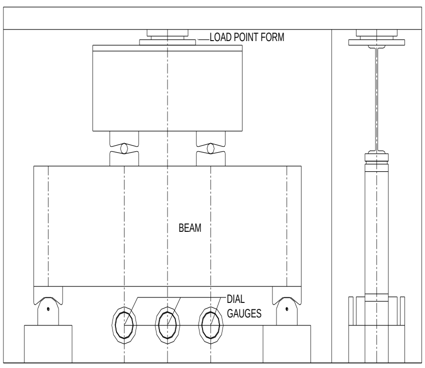
Table: - 1 Reinforcement Details

BEAM	TOP STEEL	BOTTOM STEEL	GRADE
D30	2-10 mm	2-10 mm	HYSD Fe 415
D40	2-12 mm	2-12 mm	HYSD Fe 415
D50	2-12 mm	2-12 mm	HYSD Fe 415
D60	2-12 mm	3-12 mm	HYSD Fe 415

Table 2: COMPARISOCOMPARISON TABLE FOR MAXIMUM CRACKWIDTH BY VARYING a/D RATIO.

TYPE	BEAM	a/D RATIO	FIRST CRACK LOAD (FCL)	ULTIMATE LOAD (UL)	MAXIMUM CRACK WIDTH	MODE OF FAILURE
	S 0.0		(t)	(t)	Wcr(mm)	
SFRC(CCT) (1P)	D30	2	19.4	53.2	7.2	Flexure
	D40	1.5	11.5	23.5	7.5	Flexure-shear
	D50	1.2	15	39.75	7	Flexure-shear
	D60	1	17.6	53.9	7.38	Shear
SFRC(FCT) (2P)	D30	1.33	5	10.9	6.88	Flexure
	D40	1	8.5	16.9	7.3	Flexure-shear
	D50	0.8	8.9	27.3	5.98	Flexure-shear
	D60	0.66	20.5	43.7	6.2	Shear

Fig. 1 TEST SETUP FOR 2 POINT LOADING.



FCL: - 19.4 UL: - 53.20T a/D=1.33

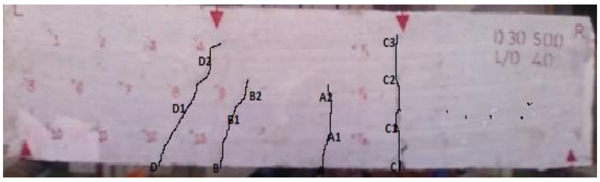


***Fig:-2* D 30-S 0.0-SFRC(FCT)-2P**

FCL: - 11.5T UL: - 23.5T a/D=1

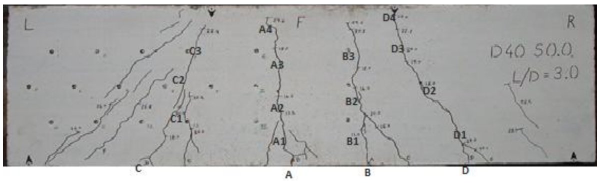


***Fig:-3* D 40-S 0.0-SFRC(FCT)-2P**

FCL: -15T UL: - 39.75a/D=0.8

***Fig:-4* D 50-S 0.0-SFRC(FCT)-2P**

FCL: - 17.60TUL: - 53.90 a/D=0.66

***Fig:-5* D 60-S 0.0-SFRC(FCT)-2P**

FCL: -5.0TUL: - 10.90 a/D=2.0

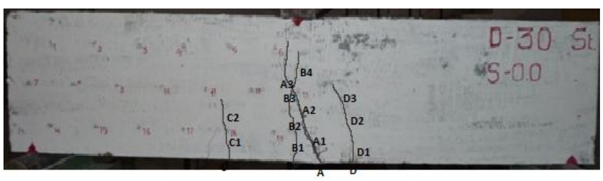


***Fig:-6* D 30-S 0.0-SFRC(CCT)-1P**

FCL: -8.5TUL: - 16.90 a/D=1.50

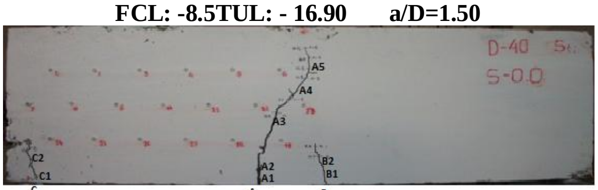


***Fig:-7* D 40-S 0.0-SFRC(CCT)-1P**

FCL: -8.90 TUL: - 27.30a/D=1.20

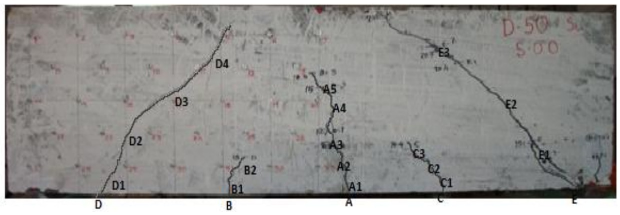


Fig:-8 **D 50-S 0.0-SFRC(CCT)-1P**

FCL: -20.50TUL: - 43.7 a/D=1.0

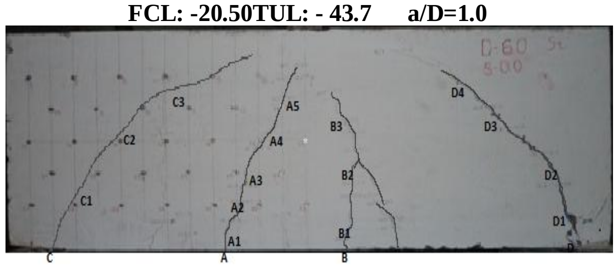


Fig:-9 **D 60-S 0.0-SFRC(CCT)-1P**

FIGURES OF BEAMS SHOWING CRACKS WITH VYRING a/D RATIO

IV. CONCLUSIONS

Based on the results of this study, the following conclusions were drawn:

The evaluation indicated that SFRC beams with a/D ratio less than 1 are shear predominant members and generally fails in shear mode which is brittle in nature and having a/D ratio between 1 to 2.5 are failing due to both flexure and shear. SFRC Beams with a/D ratio greater than 1 are flexure predominant member and fails in flexure mode.

V. ACKNOWLEDGEMENTS

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