A STUDY ON GLASS FIBER REINFORCED CONCRETE DEEP BEAMS WITH OPENINGS

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ABSTRACT

This presents the behavior and ultimate strength of Reinforced concrete deep beams with glass fiber with and without openings in the web area. Eleven concrete deep beams were tested to fail by applying two-point loading under simply supported condition. The percentage of glass fiber was varied from zero to one percentage. The effects of glass fiber percentage in concrete deep beams have calculated by measure the deflection and examine the crack profile of deep beams. In addition to that the investigation accounts the influence of glass fiber in reinforced concrete deep beams with and without openings. The theoretical ultimate load calculated by using Ultimate shear strength equation [1] for reinforced concrete deep beams are compared with experimental values. This experimental program includes that the position of openings, web reinforcement and glass fiber content are the important variables that influence the character and strength of deep beams.

Keywords: *Deep beams, Glass fiber, Beam -Web openings, SFRC Beams, Fiber.*

1. INTRODUCTION

Deep beams are often used as structural members in Civil Engineering works. As in required of functional aspects in various situations, web openings are essential to provide for services or for access. Because of the geometric proportions of deep beams, their strength is usually controlled by shear rather than flexure, if normal amounts of reinforcements are provided. A proliferation of new developments in glass fiber reinforced concrete technology has greatly extended the range of applications. The application currently depends on the ingenuity of the designer and builder taking advantage of the improved static and dynamic tensile strength, ductility, energy – absorbing characteristics, abrasion resistance, and fatigue strength of this new material of construction. The uniform dispersion of glass fiber throughout the concrete provided isotropic strength properties which are not exhibited by conventionally reinforced concrete. Previous studies have shown that a significant increase in the shear strength of deep beams with or without openings can be achieved by providing either conventional web reinforcement or glass fibers in the concrete matrix. The inclusion of fibers in a concrete matrix has been found to increase the ultimate strength, increase the first crack load, arrest the crack propagation, and enhance the fracture toughness, post-cracking ductility, and fatigue resistance.

Glass Fiber Reinforced Concrete (GFRC) has gained increased popularity in construction industries in the recent years. Reinforcing plain concrete with glass fibers has been used to improve the performance of structural members such as deep beams and slab, GFRC members can exhibit enhanced shear strength, more ductile behavior and reduced crack widths. For the last two decades, a number of investigations are being carried out on the behavior of fiber reinforced composites. A number of experimental and analytical investigations have been carried out to study the behavior and collapse loads of deep beams with and without web opening. The openings are usually provided in such beams to have an access for utility ducts. As the usage of those beams with or without openings increases, it becomes imperative that the design criteria of such beams is widely tested and established.

In the present investigation, glass fibers were used. This investigation is a bid to study the behavior of deep beams reinforced with glass fibers.

2. REVIEW OF EARLIER WORKS

Kong,F.K et al.(1972) investigated the effect of inclined web reinforcement on deep beams with different span depth ratio. Leonharadt,F. H.A.R.de Paiva et al.(1972) dicussed the strength and behavior of deep beams in shear. Prabhar.K (1976),studied the collapse load of deep beams by using a truss model analysis with a shear -span effective-depth ratios of less than 1.0.Kong,F.K et a.(1973),investigated shear strength of light weight reinforced concrete deep beams with openings. Smith,K.N (1982),studied the effect of vertical and horizontal web reinforcement and shear-span –to- effective depth ratio on inclined cracking shear and ultimate shear strength. Shanmugam,N.E (1984),experimental carried out to study the ultimate load behavior glass fiber reinforced concrete deep beams. Parameshwaran,V.S(1995),introduced to theory, properties and application of fiber reinforced concete.VinuR. Paterl (2010),used polypropylene fiber reinforced concrete in moderate deep beams.

3. MATERIALS AND MIX USED

OPC of 53 grade with a specific gravity of 3.15 was used for all the specimens cast. The Fine Aggregate used for casting was clean river sand. The specific gravity of fine aggregate was 2.71. The fineness modulus of the fine aggregate was 2.4. The coarse aggregate used was broken granite stone of size 10 mm. The specific gravity of coarse aggregate was 2.84. The bulk density of coarse aggregate was found to be 1640 kg/m3. Bore well water available in the Structural Engineering laboratory was used for casting all specimens of this investigation. The quality of water was found to satisfy the requirements of IS 456 -2000.

Two steel rods of 16mm diameter of 415 N/mm^2 yield strength were used as the main tension reinforcement. The bars were anchored by welding to 6mm thick steel plates at both ends. Each beam contained web reinforcement consisting of two layers of welded wire fabric of

3.3mm diameter and 50mm on centers having yield strength of 300 N/mm^2.Bearing plates and reinforcement cages were provided at supports and loading points to disperse the concentrated forces, thereby avoiding localized distress of concrete.

4. CASTING OF DEEP BEAMS AND ITS COMPANIONS

Concrete mix of 1 (cement) : 1.5(F.A) : 3 (C.A.) with water cement ratio by weight of 0.47 was used for making the standard concrete specimens and for deep beams. Cement and sand were first mixed then coarse aggregate was added and the materials were mixed thoroughly until uniformity was achieved. To this concrete mixture, the fiber of predetermined quantity were added and mixed, taking care to avoid bundling or balling. Then the required quantity of water was added slowly and wet mixing was done. At all stages, hand mixing was adapted and care was taken to ensure random distribution of fibers in the composites. A controlled internal vibration was used for the compaction of the cylinders and prismatic specimens. Eleven deep beams of size 750mm x 325mm x 75mm specimens with and without holes as shown in table.1 were cast flat –wise and compacted on a vibration table in three layers.

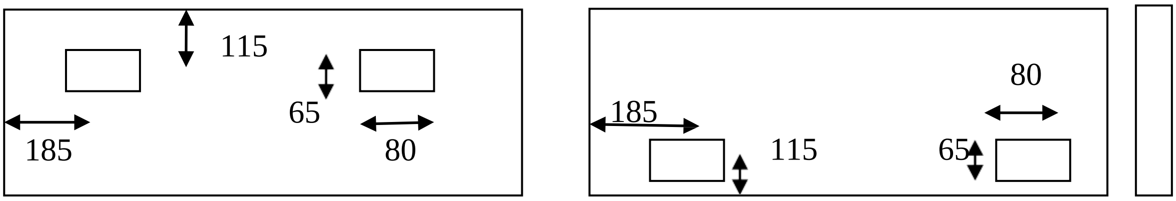

Figure 1: Location of the web opening at top and bottom

Table 1: Deep Beam Designation and Geometric Dimensions

S. No	Beam designation	Beam dimensions(mm)			Opening size(mm)		Detail
		Length	Width	Depth	Width	Depth	
1	DBWWO	750	75	325	-	-	Deep beam without web openings
2	DBWOT	750	75	325	65	80	Deep beam with web openings at position A
3	DBWOB	750	75	325	65	80	Deep beam with web openings at position B

5. EXPERIMENTAL SETUP AND TESTING OF DEEP BEAMS

The deep beams were tested in a 100Tons capacity Universal Testing Machine. All the beams were tested to failure under Two – point loading system. The test set up for the beam is shown in below fig.2.

Each of the beam specimens were mounted on roller supports on the Universal Testing Machine. Three deflectometers were placed at the bottom face of the beam at mid span and under the loading points. Two-point loads were obtained by placing the loading head on the top surface at the centre of the beam and distributing the load through a spreader beam. A small pre load was applied slowly to ensure that the beam was properly seated and the deflectometers were functioning properly. The load was then removed, reapplied and again removed slowly. Successive loads were applied in increments of 10kN. Deflections at the mid-span and under the loading points were recorded at each load increment. During the test, the first –crack load was observed and the crack propagation was carefully marked. All the beams were loaded till failure. Based on the tests results, standard specimens for the various of addition of glass fibers. The optimum fiber content as 0.75% to 1.0%. The main specimens (deep beams) were casted with 0%, 0.75% and 1.0% and were tested to failure.

Cubes of size 150mm which had been cast along with the slabs were tested on the same day on which the respective slabs were tested to ascertain the compressive strength of the concrete used in the slabs. The cube tests were carried out in a Compression Testing machine of 200 T capacity and these tests were carried out as per the recommendations of Indian Standard Codes of Practice.

Prisms of size 100mm x 100mm x 500mm were used for the determination of the flexural tensile strength of reinforced concrete. The tests were conducted in the Universal Testing Machine. Each prism was supported over a span of 400mm. The two point loads applied at each of the third span points, i.e., 133.33 mm from each of the two supports, were gradually increased until the specimen failed. The failure load was noted down.

The modulus of elasticity of glass fiber reinforced concrete deep beam was determined by conducting compression tests on SFR Cylinders that had been cast along with the deep beams. The test was conducted in a UTM and the deformations corresponding to the various loads were measured by a dial gauge. These tests were carried out as per IS-code recommendation.

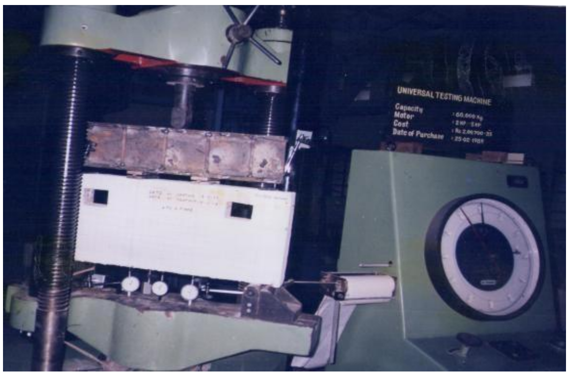

Figure 2: Test setup for deep beams

DISCUSSION OF TEST RESULTS

Formation of cracks

All deep beam specimens were tested and all of them failed in shear. All beams were loaded to failure. The beams collapsed due to excessive destruction of concrete in the shear span. The crack patterns and failure of test specimens are shown in fig.3. No cracking was observed in any beam up to about 32% of ultimate load. The first vertical flexural cracks were formed in the region of maximum bending moment between 40 % to 55% of the ultimate load a sudden major inclined crack was formed almost in the middle of the shear span. The initial crack was usually a sudden inclined shear crack originating from the bottom corner of the opening. With further increase of load, cracks propagated towards the support while crack originating at the top inner corner of the opening propagated upward towards the load bearing plate. Other flexural and flexural shear cracks were subsequently formed and propagated upwards. At higher loads, diagonal cracks were developed and propagated until the beam failed in diagonal shear mode. This is verified by the test results.

All existing cracks were observed between 55 to 68% of ultimate load. At about 72 to 78 % of ultimate load, new inclined cracks were formed parallel to the line joining the load edge and support blocks. Also at about the same load level a tension vertical cracks appeared over the supports. This is the results of the thrust's eccentricity which essentially acts along the inclined crack. Finally, beam failure occurred by concrete destroyed in either the reduced compression zone at the head of the inclined crack and the region adjacent to the loading block or by fracture of the concrete along the inclined cracks.

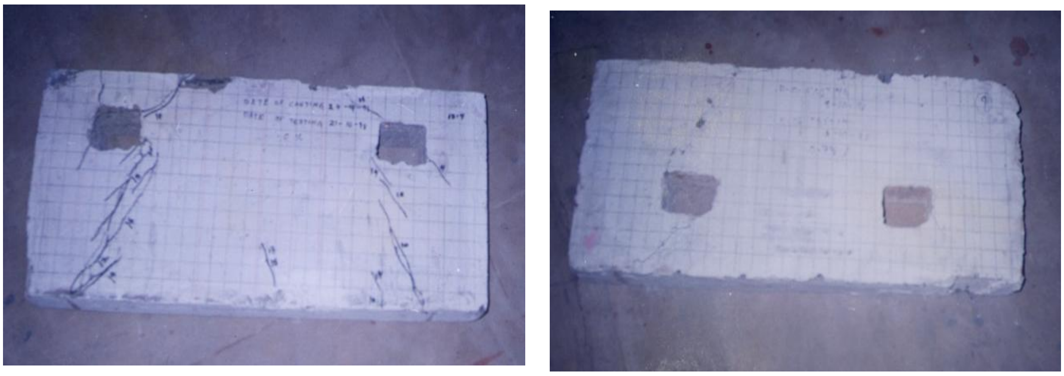

Figure 3: Deep beams a) DBBOT b) DBWOB

Inclined Cracking and Ultimate Loads

Inclined cracking load is defined as the load at which the first major inclined crack appears in the shear span. This was sudden cracks that usually originated in the middle of the shear span and propagated towards the support and loading joint from a subsequent increase in applied load. The crack widths tends to increase with load, especially at loads higher than inclined cracking loads. Maximum crack width along the major inclined crack in the shear span occurred almost at mid depth of the beam.

Load Vs Deflections

A load deflection curve for all the beams tested are shown in fig.4.The variation at the earlier stage is linear until the first crack is reached. As more cracks were formed and propagated, there was a reduction in the stiffness of the beams resulting in higher rate of deflection. It is also observed that the stiffness of the beam depend largely on the extent to which the openings interrupt the vertical load path.

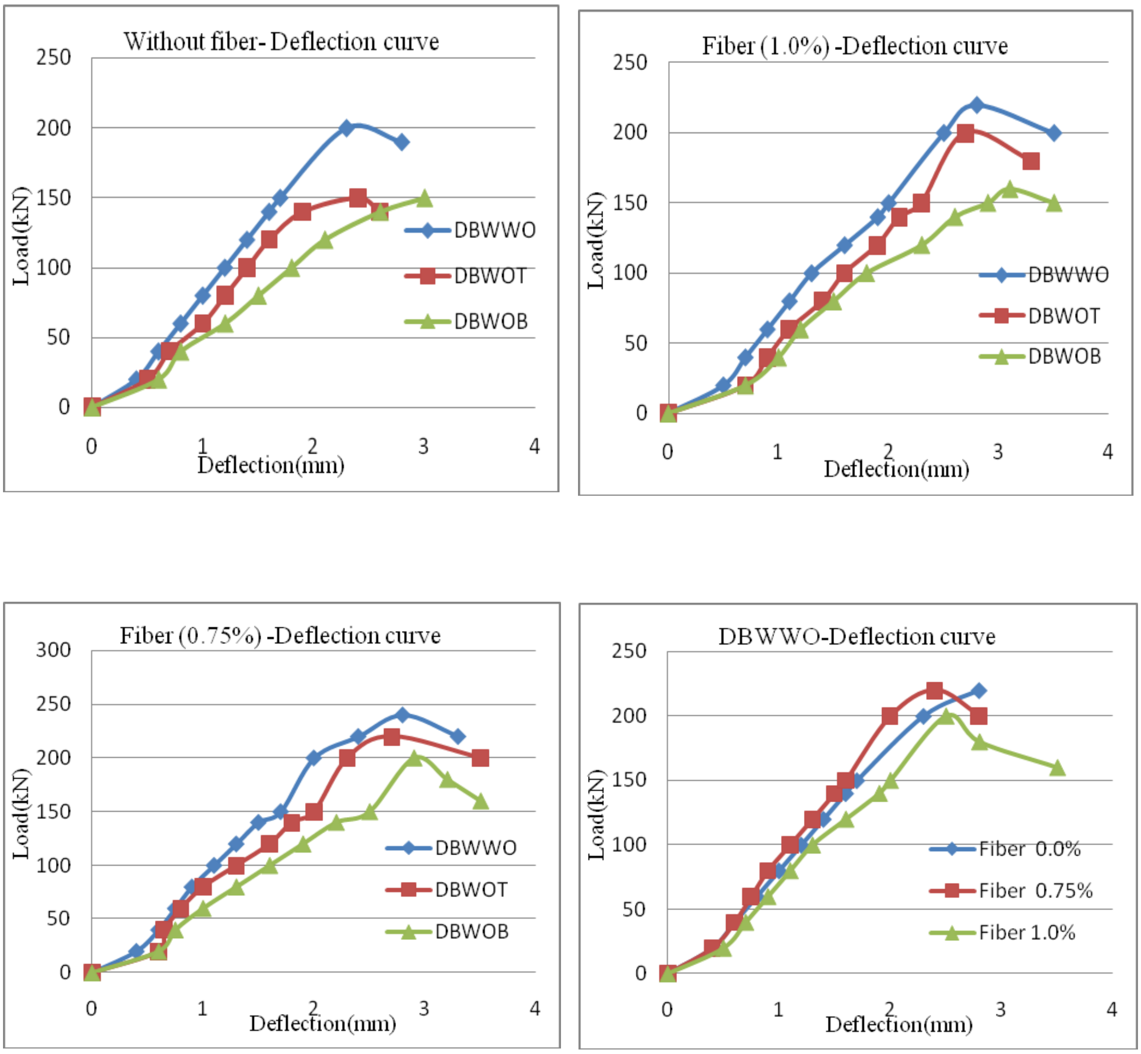

Figure 4 Load vs. Deflection Curve

First crack and ultimate load

The initial cracks for the reinforced concrete beams without fiber were observed at 40% of the ultimate load where, for glass fiber reinforced beam the first crack load was found to be between 40% to 50% the ultimate load. There is a 5% to 10% increase in ultimate load for fiber reinforced concrete beams when compared with beams without fiber reinforcement. Thus the experimental results show that there is increase in the ultimate load and the first crack load for the fiber reinforced concrete deep beams.

The test results discussion

The proposed equation(modified Kong and Sharp's formula) is suggested by Swaddiwudhipong et al [7] for reinforced concrete deep beams with openings to calculate the theoretical shear capacity and it is incorporate the effect of glass fibers that develop an additional shear capacity, toughness and crack resistant.

$Pu/2 = C_1 f_1 f_2 (1\text{-}0.36\ X / d)\ f_t^n\ b\ D + \sum \lambda C_2\ A(y/D) \sin^2\alpha$

P_u = Ultimate capacity) of fiber RC deep beams with openings

C_1 = 1.0

C_2 = 300N/mm^2 for deformed bars

f_1 = $(1\text{-}\ a_1)(1\text{-}1.667\ a_2)$.

f_2 = $h+2(k_2)^r\ X(((k_1\text{-}\ k_2)^2/((a_1x)^2 + (a_2D)^2))^{1/2} \leq 1.0$,

the N =1.1

λ =1.5 for web bar and 1.0 for main bar

h =$0.6\text{-}2k \geq 0.2$

r unloaded quadrant=1.0 and loaded quadrant =2.0

b is width, X is clear span, D is over all depth, y is the depth due to intersects a diagonal crack to steel bars, α is the intersection angle, A is the steel area, f_t is the concrete split tensile strength and a_1, a_2 , k, & k_1 the coefficients for size and position.

The calculated theoretical ultimate capacity as given in the table.3 by using above formula.

The comparison of the experimental failure load with theoretical results in table.3 shows that the modified Kong and Sharp's formula, provides theoretical predication and it is matching with experimental values. The observation of the failure load listed in Table.3 in conjunction with the beam geometry confirms that the effect of web opening on the load-carrying capacity of deep beams depends largely on the percentage of fiber interrupt the load pat. The greater degree of interruption, the greater is the reduction in ultimate strength.

The observation shows that the first crack load was found to increase 5% to 10% for the fiber reinforced beams and the beams did not crumble and fell down. The observation also shows that for an optimum percentage of 0.75% by volume, gives maximum ultimate load for the deep beams.

Hence the results presented here in support the postulates that ultimate strength of deep beams depends greatly on the degree of interruption of the opening on the natural load path and also the percentage of fiber content present in the beam and openings in the tension zone weaken the beam. The modified Kong and Sharp's formula provides the accurate prediction of the ultimate strength of fiber reinforced concrete deep beams with and without web openings.

Table 2: Deflection at mid span

S.No	Loads (kN)	Without fiber			Fiber 0.75%			Fiber1.0%		
		DBWWO	DBWOT	DBWOB	DBWWO	DBWOT	DBWOB	DBWWO	DBWOT	DBWOB
1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	20	0.4	0.5	0.6	0.4	0.6	0.6	0.5	0.7	0.7
3	40	0.6	0.7	0.8	0.6	0.65	0.75	0.7	0.9	1.0
4	60	0.8	1.0	1.2	0.75	0.8	1	0.9	1.1	1.2
5	80	1.0	1.2	1.5	0.9	1.0	1.3	1.1	1.4	1.5
6	100	1.2	1.4	1.8	1.1	1.3	1.6	1.3	1.6	1.8
7	120	1.4	1.6	2.1	1.3	1.6	1.9	1.6	1.9	2.3
8	140	1.6	1.9	2.5	1.5	1.7	2.2	1.9	2.1	2.6
9	150	1.9	2.4	2.8	1.8	2.0	2.6	2.1	2.4	2.9
10	200	2.3			2.0	2.3	3.3	2.5	2.7	3.1
	220				2.4	2.7		2.8		
	240				2.8					
First crack Load(kN)		85.0	80.0	75.0	105.0	91.0	81.0	102.0	90.5	89.0
Ultimate Load(kN)		201	175	165	230.0	221	174	215.0	209.0	163.2

Table 3: Experimental Analytical results for deep beams

Opening Position	Fiber -0%		Fiber -0.75%		Fiber -1.0%	
	Experimental load(kN)	Theoretical load(kN)	Experimental load(kN)	Theoretical load(kN)	Experimental load(kN)	Theoretical load(kN)
Without web opening (DBWWO)	201	208	230	221	215	212
Web opening at A (DBWOT)	175	176	221	188	209	180
Web opening position at B (DBWOB)	165	168	174	161	163.2	158

7. CONCLUSION

The following conclusions can be drawn from the experimental results:

- The effect of an opening on the ultimate shear strength of a deep beam depends primarily on the extent to which it intercepts the load path joining the load bearing block at the loading point and the support reaction point, and on the location at which this interception occurs.
- The observation shows that the first crack load was found to increases 5to 10% for the fiber reinforced beams.
- Web openings may be provided in the compression zone of the beams and fiber content of 0.75% by volume may be added to improve the strength of the structure.
- The opening in the tension zone weaken the beam.
- Fiber content of 0.75%by volume of the beam improves the ultimate load and the first crack load of the beam.
- Additional of glass fibers increase the tensile strength of concrete matrix and also increase in the flexural rigidity of the beam.

- Modified kong and sharp's formula provides almost accurate prediction of the ultimate strength of fiber-reinforced concrete deep beams with or without opening.

8. SUGGESTION FOR FURTHER WORK

- The experimental investigation may be carried out for fiber with different aspect ratio.
- Different location of openings in the web may be tried with the same fiber for a bigger size specimen.
- Experimental investigation may be carried out to study the long term behavior of the structure by conducting accelerated test.
- Size of openings may be varied and percentage if saving of material which will not affect ultimate load carrying capacity of the beams may be studied.
- Experimental investigation may be conducted with plastic fibers such as polypropylene, high density polyethylene fibers and corrugated glass fibers.
- The openings may be stiffened with stirrups and behavior of beams may be studied.

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