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AN EXPERIMENTAL STUDY ON STEEL FIBRE REINFORCED CONCRETE DEEP BEAMS WITH AND WITHOUT WEB OPENINGS

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Abstract

A deep beam has wide application in huge structures, offshore structures as a transfer girder, long span structures and where vertical height is limited. The load transfer in this beam get interrupt when the openings are provided, which will decrease the shear carrying capacity and its serviceability. Adequate measures should be taken for the strength in deep beam when such openings are unavoidable. From literature survey it concludes that limited studies reported on deep beam strength with circular openings. Present experimental study the behaviour and strength of the simply supported conditioned steel fibred R C deep beam having dimensions 750mm × 325mm × 75mm (L x D x b) with circular openings and beam without circular openings are tested against two-point loadings. The deflection and crack pattern are studied for RC deep beam containing steel fibre (i.e upto 1 percent). The average of six deep beams for each varying dosage of steel fibre were tested for shear capacity of beam. The experiment outcomes are collated with the theoretical formula for ultimate shear load capacity. Also, this study indicates the effective location of circular shape openings in this deep beams.

Keywords: Deep beam, Web Opening, SFRC.

INTRODUCTION

According to IS 456:2000 code a beam is said to be deep when the effective span of beam with depth ratio of beam is lesser than two for simply supported condition. Deep beams are used as structural elements commonly used in building construction to support heavy loads over large spans. Unlike traditional beams, deep beams have a relatively large depth compared to their span, resulting in higher shear stresses, and often requiring special design considerations. Deep beams transfer loads primarily through flexure and shear, which makes them suitable to carry heavy loads while minimizing the requirements for additional support columns or walls. When openings are provided in this deep beam for various services in the structure which may in any shape (rectangular, circular, etc.,). Due to circular openings the transfer of load get interrupt leading to strength decrease or decrease load carrying capacity and cracks growth develop in deep beam. To overcome this effect steel fibres with required percentage are included in concrete to increase intensity of load resistance capacity and to stop the cracks growth in this deep beams.

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Fig 1: Openings in deep beam

Steel Fibre has high elasticity, strength and help to prevent creep and improves abrasion resistance. Steel fibres are available in different kinds as mentioned below:

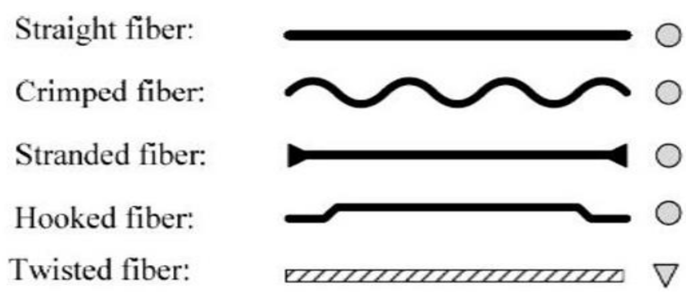

Fig 2: Types of steel fibres

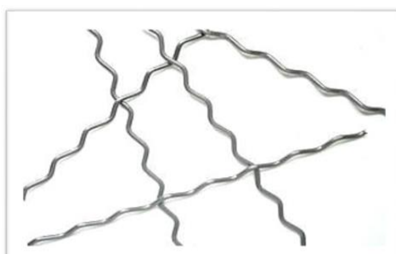

Fig 3: Crimped Steel Fibre

In the present work crimped type steel fibres with varying percentages (0.25, 0.50, 0.75 and 1%) are used with an aspect ratio of 60.

LITERATURE SURVEY

The research work had been limited in reporting strength of deep beam with web openings.

F K Kong [2003]

Prof. Kong gave important information about deep beams and is worth mentioning at this stage. The information related to the failure that occurs in deep beam for various patterns of openings are presented in his work. He observed the first visible inclined cracks normally appear in the support bearing regions and from the opening edges at load varying levels of about 36–55% of the ultimate loads. Also, he identified the flexural cracks

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in these cases of opening (rectangular and circular) flexural cracks are very few and generally occur in a range of ultimate loads of about 60–95%. Finally, he concluded that web opening in deep beam weakens the shear carrying capacity and compared that circular type of opening is more effective than rectangular type.

V. Vengatachalapathy and Dr. R. Ilangovan [2012]

They have measured the resulting shear strength of steel fibre RC deep beams with and beam without rectangular openings in subjected to two- point loading system, seven deep beams having measurements 750mm x 350mm x 75 mm thick are tested to applied load. Finally, they conclude that rectangular openings provided away from zone of shear area of the deep beams is effective and fibre content of 0.75% may be included to get improved strength of structure.

Vinu R Patel and I. I. Pandya [2012]

They measured the shear strength of Polypropylene Fibre Reinforced Concrete (PPFRC) moderate deep beams without stirrups having span and depth ratio 2.0, 2.4, 3.0, 4.0. Finally, they concluded that adding steel fibres (Circular Corrugated type) in the reinforced concrete beam improves the shear strength of R.C.C. beams without using stirrups. Steel fibers can be used to replace stirrup partially with proper design of concrete.

Dipti R. Sahoo, Carlos A. Flores, etal. [2012]

They conducted experiment on 2 RC deep beam with large openings under point loading. They identified the ultimate strength and failure modes of these beams and compared the same with design STM. They conclude that design STMs significantly underestimate the ultimate strengths of the test beam. The crushing of concrete that occurred in the highly stressed region over the supports determined and is primarily due to the lack of sudden release of the concrete under high axial stress.

Critical Observations:

The important observations which are noticed from the existing literature are mentioned below:

- Limited research work on deep beam with circular shaped web openings.
- Less research work done on crimped type steel fibres.

OBJECTIVES

Following are the objectives of present study:

1) To understand the shear behavior of normal reinforced RC deep beam with no openings for the following circumstances:
    a) With stirrups
    b) Without stirrups
    c) Without stirrups but with steel fibre reinforcement.

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2) To observe the shear behavior of normal reinforced RC deep beam having circular shaped web openings under the following conditions:
    a) Beams provided with stirrups
    b) Beams provided without any stirrups
    c) Beams without stirrups, but with the provision of steel fibre reinforcement
3) To investigate occurrence crack growth with respect to loading and measurement of final crack at failure for objective 1 and 2.

MATERIALS & METHODOLOGY

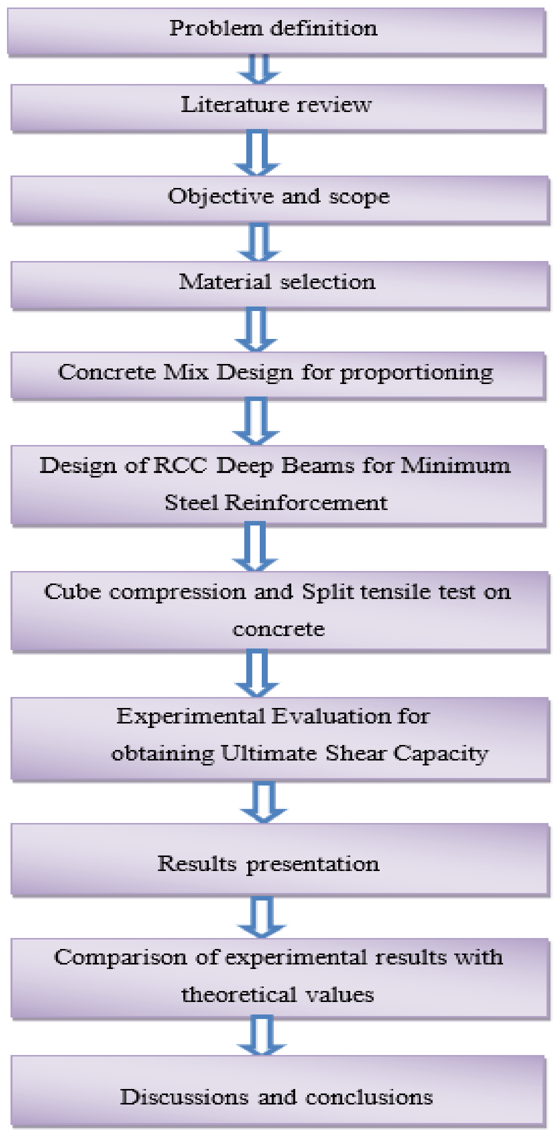

Fig 4: Methodology flow chart

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The materials that are used for present experiment work and their properties are:

1) **Cement:** 53 Grade OPC conforming to IS:12269 having a Sg. of 3.11 was used for mix design.

2) **Fine Aggregates:** M-sand used for casting having Sg. 2.60. Fineness modulus of fine aggregate is 3.20. The OMC was found to be 4%.

3) **Coarse Aggregates:** The coarse aggregates which are used are from broken granite stone of size 10 mm and down size. The Sg. of coarse aggregate was 2.72. The γ_b of coarse aggregates was found to be 1640 kg/m^3.

4) **Water:** Water from bore well which was available in the testing laboratory was used for casting all beam specimens for the investigation. The quality of water is considered as per the requirements of IS 456:2000.

5) **Admixture**: Since steel fibre is added to concrete superplastisizer is included as admixture to overcome balling effect and also to improve overall workability of mix

6) **HYSD Steel Bars:** Two HYSD bars having 16mm diameter of Fe 500 N/mm^2 grade were used as the main tension steel. All beams having reinforcement consisting of 6 # 6mm in 3 layers.

7) **Steel Fibres:** Crimped type steel fibres are considered as replacement of shear reinforcement which is having aspect ratio (A_r) of 60.

MIX DESIGN

1. 0% Steel fibre:

Trial mix = cement: sand: jelly: w/c ratio

= 1: 1.86: 3.05: 0.45

2. 0.5% Steel fibre:

Trial mix = cement: sand: jelly: w/c ratio

= 1: 1.85: 3.02: 0.45

3. 0.75% Steel fibre:

Trial mix = cement: sand: jelly: w/c ratio

= 1: 1.844: 3.017: 0.45

4. 1% Steel fibre:

Trial mix = cement: sand: jelly: w/c ratio

= 1: 1.837: 3.005: 0.45

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Design of Deep Beam

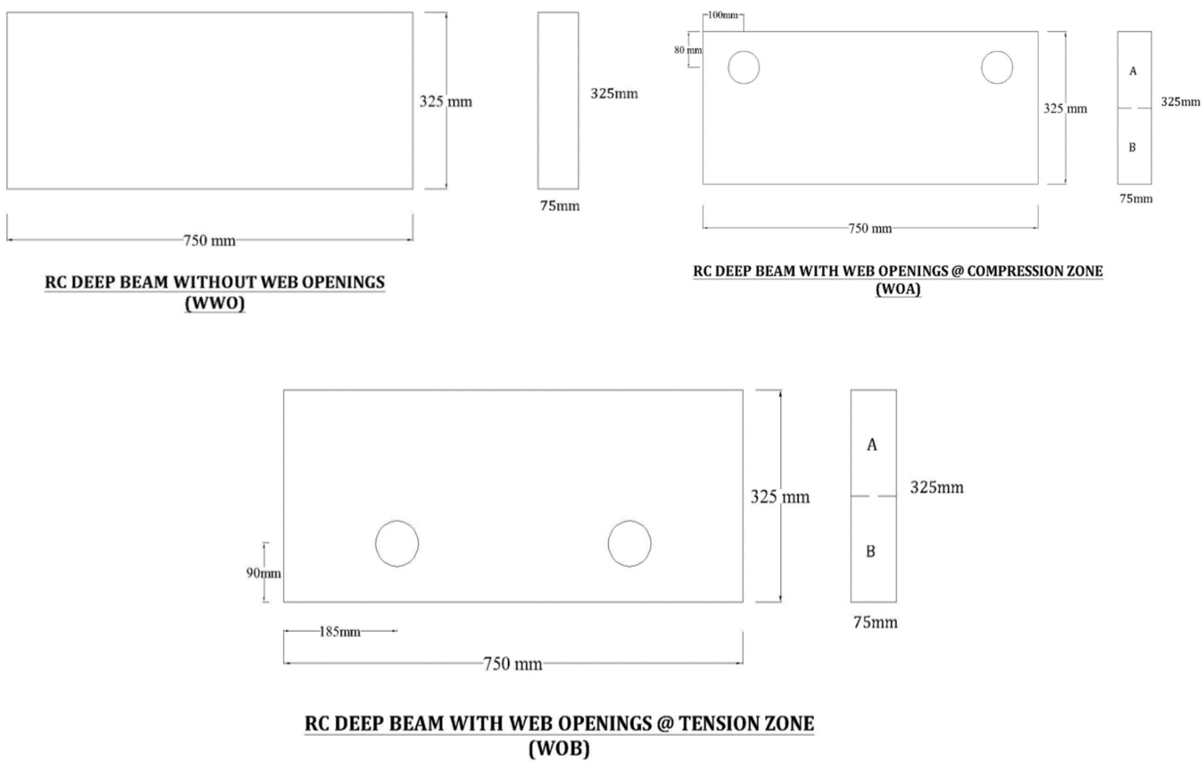

Fig 5: Deep beam with openings

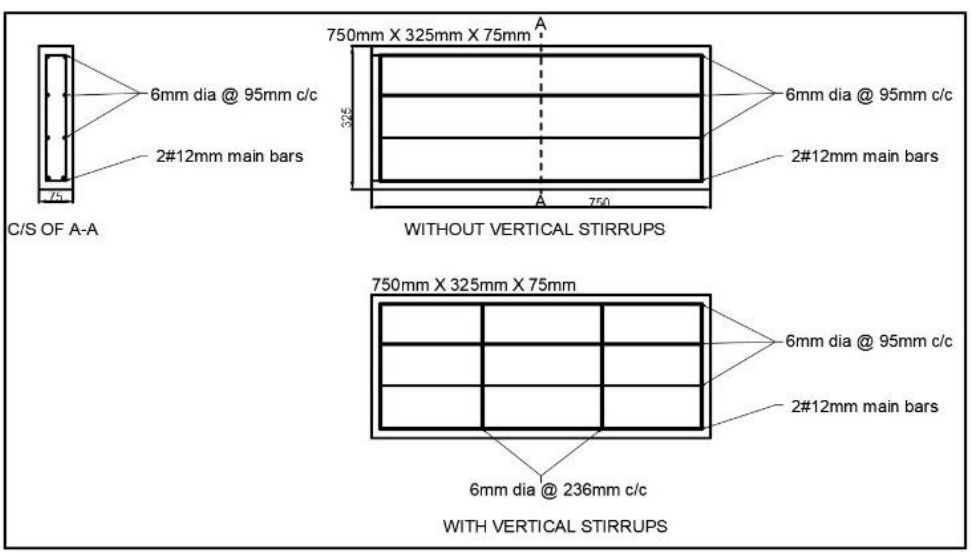

Fig 6: Reinforcement details

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EXPERIMENTAL STUDY AND RESULT DISCUSSION

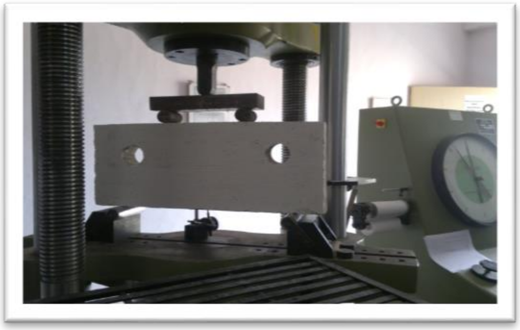


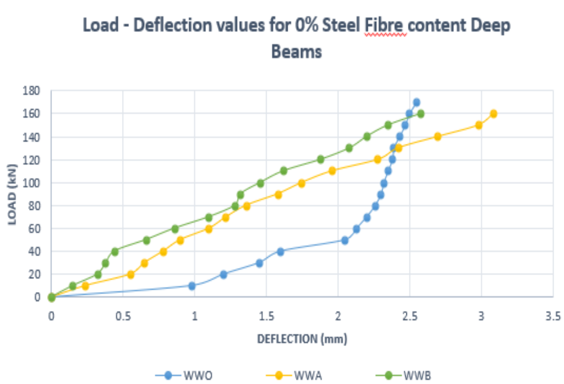
Fig 7: Experimental set up

UTM of 2000kN capacity with dial gauge is used for testing. The average of three specimen readings is recorded while testing for various dosage of steel fibre (0%, 0.5%, 0.75% and 1%) for the following types of deep beams:

- Deep beam with no openings in web (WWO)
- Deep beam having web openings (circular shaped) at position A or opening in compression zone or opening above the centroidal axis (WWA)
- Deep beam having opening (circular shaped) at position A or opening in compression zone or opening above the centroidal axis (WWA)

For 0% Steel Fibre:

%age of Steel Fibre	0.%		
	Without opening	With opening @ A	With opening @ B
First Crack Load (kN)	74	68	62
Ultimate Load (kN)	164	160	152
Max. Deflection (mm)	2.50	3.08	2.58



- The deep beam without any openings deflects significantly in comparison to deep beam having openings in circular shape.
- In other words, deep beam with no web openings appears to be weaker in resisting deflection for loads varying from 0 – 80 kN.
- In contract to this the deflection are observed to be constant even though considerable amount of load applied beyond 80 kN.

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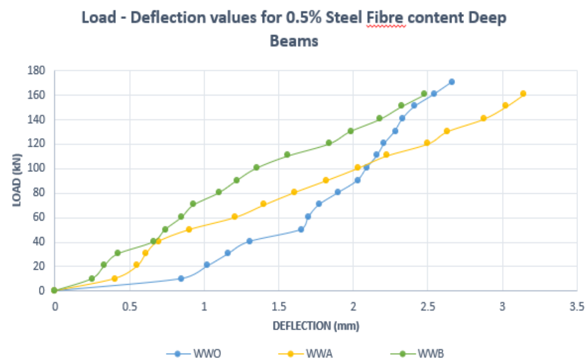
For 0.5% Steel Fibre:

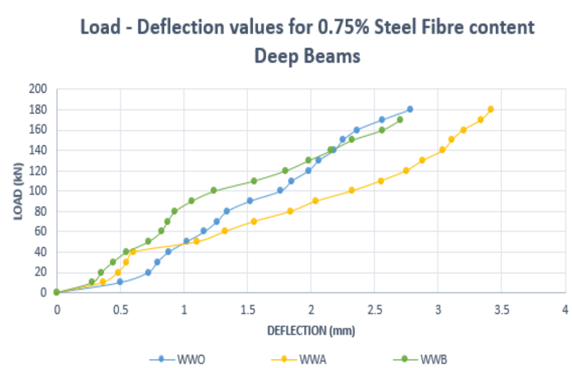
%age of Steel Fibre	0.5%		
	Without opening	With opening @ A	With opening @ B
First Crack Load (kN)	85	77	72
Ultimate Load (kN)	170	164	158
Max. Deflection (mm)	2.54	3.14	2.48



- The deep beam without web opening deflects significantly when it is compared with beam having circular shaped openings in web.
- In other words, deep beams without web opening appear to be weaker in resisting deflection for loads varying from 0 – 100 kN.
- In contract to this the deflection are observed to be constant even though considerable amount of load was applied beyond 100 kN.

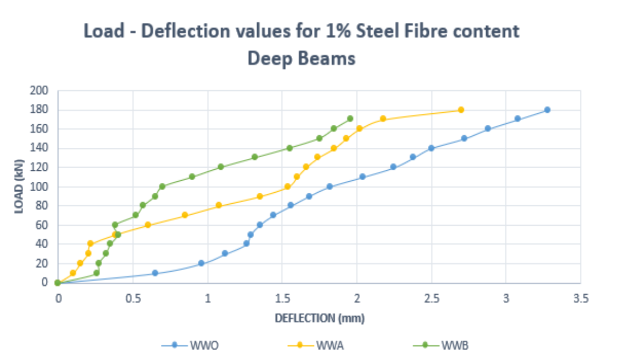
For 0.75% Steel Fibre:

%age of Steel Fibre	0.75%		
	Without opening	With opening @ A	With opening @ B
First Crack Load (kN)	98	89	82
Ultimate Load (kN)	178	174	166
Max. Deflection (mm)	2.78	3.42	2.70



For 1% Steel Fibre:

%age of Steel Fibre	1%		
	Without opening	With opening @ A	With opening @ B
First Crack Load (kN)	100	96	88
Ultimate Load (kN)	180	174	168
Max. Deflection (mm)	3.28	2.70	1.96



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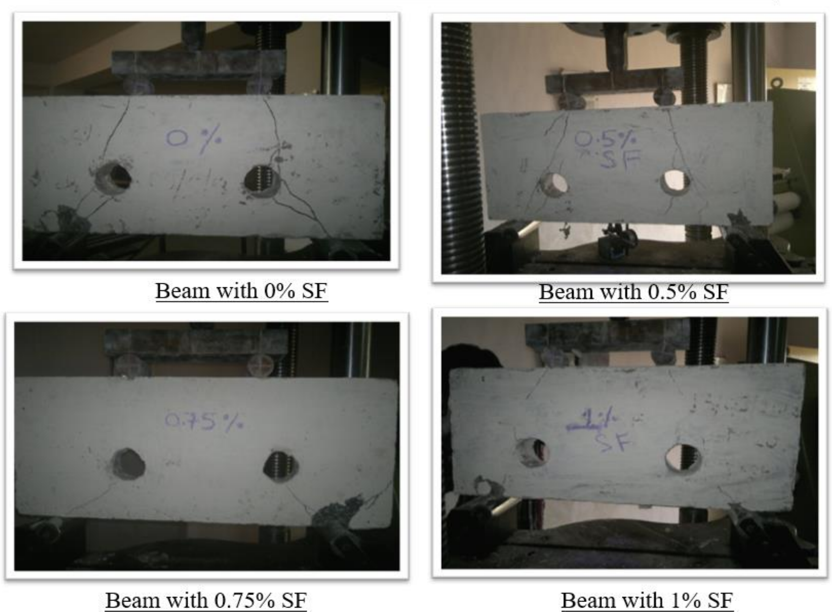
Fibre content of 0.75% and 1% by volume provides almost the same ultimate shear strength values of beam showing improved strength of beam having much close values.

Beam with 0% SF
Beam with 0.5% SF
Beam with 0.75% SF
Beam with 1% SF

Fig 8: Failure of deep beam having opening at position A



Beam with 0% SF
Beam with 0.5% SF
Beam with 0.75% SF
Beam with 1% SF

Fig 9: Failure of deep beam having opening at position B

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Theoretical Expression to find Ultimate Shear Strength of the deep beams

Prof. F. K. Kong [10] provided the following expression for determination of factored shear carrying capacity of deep beam as shown below:

$$Q_u/bD = (P_u/2bD) = 0.1\ f_c\ (\lambda_1)\ (\lambda_2)\ (\lambda_3) + 0.0085\ \Psi_s\ p_s\ f_{sy} + 0.01\ \Psi_w\ K_w\ r_w\ f_{wy}$$

Where:

- Q_u = *ultimate shear strength for single point load* = $P_u/2$ *for 2-point load*
- *b* = *width / thickness of beam*
- *D* = *Overall Thickness of beam*
- f_c = *cylinder (150 mm dia.×300 mm height) compressive strength of concrete*
- f_{cu} = *cube (150 mm) compressive strength of concrete.*
- λ_1 , λ_2 , λ_3 = *empirical co-efficient*

Table I: Comparison of Ultimate Shear Capacity b/w experimental & theoretical values

Opening position	Ultimate Shear Load (kN)									
	Fibre – 0%		Fibre – 0.25%		Fibre – 0.5%		Fibre – 075%		Fibre – 1%	
	Exp. value	The. value	Exp. value	The. value	Exp. value	The. value	Exp. value	The. value	Exp. value	The. value
Without web opening (WWO)	164	183.87	167	188.10	170	192.32	178	205	180	206.41
Web opening at position A (WWA)	160	159.42	162	166.22	164	165.11	174	173.64	174	174.59
Web opening position at B (WWB)	152	145.20	155	147.24	158	149.28	166	155.40	168	156.07

CONCLUSIONS

The following conclusions are made from the experimental investigation:

1) The shear carrying capacity get reduced if openings are provided for the deep beams.
2) From result analysis it is clear that web openings provided in the compression zone (i.e. web opening provided at position – A) of a beam improve the Shear Load Carrying Capacity of Beam when compared with web openings which are provided at tension zone (i.e. web opening provided at position – B).
3) The opening in the tension zone of beam reduces the strength of beam about 10 % compared with openings which are provided at compression zone.
4) 0.75% and 1% addition of crimped steel fibre provides almost the same strength results of beam where 0.75% dosage can be considered as optimum.
5) Fiber content of 0.75% and 1% shows the reduction in growth of shear cracks.
6) It has been observed that the Experimental agree with the corresponding values for shear strength of the deep beam obtained from available published materials.

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