

# Experimental Investigation on Internally Strengthened RC Beam with Rectangular Web Opening

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**Abstract:** The present work examines the behaviour of flexure strength of the beam with opening. Total 3 types of beams with dimension (150 X 200 X 1700)mm were casted and tested under two point loading. One beam is solid and other two beams were having transverse rectangular opening. one of the beams with transverse opening is internally strengthened. The beam with opening which is provided during construction at L/3 distance from the support without any internally strengthening (B2 beam) decrease the ultimate load by 8.89% significantly compare to solid beam (B1 beam). The beam with opening which is internally strengthened (B3 beam), increases the ultimate load by 11.2% compare to solid beam and the internally strengthened beam with opening (B3 beam) increase the ultimate load by 21.95 % compared to un-strengthen beam with opening (B2).The theoretical values obtained for all the beams are less than the experimental values like 34.9%, 34.45%, & 18.45% for B1, B2, & B3 beams respectively.

**KEYWORDS:** Internally strengthened, un-strengthened, Flexural strength, transverse opening

## I. INTRODUCTION

In general, pre-stressing is defined as the preloading of a structure, so the performance of a structure is improved, before the service load is applied in specific way. Provision of opening may severely affect the strength of the beams, and may cause excessive cracking and deflection. Beams with openings provide the passage of service ducts in the web reduces the storey height in the building and also save the headroom in buildings. Introducing the openings in the beam is very significant. Very limited data has been reported on design specification of concrete beams with transverse opening. Design of the beam with opening encourages the designers to reduce the required building height, which leads to an economical design. Due to sudden change in cross section of the beams; the nooks of the opening experience more stress and it is possible to produce transverse cracks in the beam. The pipes and service ducts are placed below the beams for aesthetic reasons and are covered by extra ceiling thus create dead load and dead space leads to additional cost. For small structures, the saving in story height is not significant. But for multistorey structures, any saving in the height of story can represent a substantial saving in total height of the building. The height of the pipes or service ducts will range from two centimetre to half a meter. The more number of ducts and depth of service duct added to the overall height of the building is the main reason for additional height for the building, to overcome this problem many investigations is carrying out by many researchers on transverse opening in beams.

**Types of opening:** Web openings in beams have various shapes. Depending on the different shape the most practicable opening used in construction is circular and a rectangular opening. Apart from this many different shape of opening may be used like square, triangular, trapezoidal or any irregular shapes (Fig 1). But these shapes except circular and rectangular are may not be practicable, hence circular and rectangular are most preferred. Preferable opening for service pipes or ducts is circular, like water supply, electrical supply and plumbing. On the other hand, preferable ducts for air-conditioning, is rectangular opening because of their rectangular shape.

Depending upon the opening size, many researchers specified the opening as small and large, but no one define a clear range for size of opening. Square and circular openings are considered as small openings by Mansure and

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Hasant (1979). Some and Corley (1974) considered circular opening as large opening, when the ratio of diameter of opening exceeds 25% of the overall beam depth. Fundamental classification of opening depends on the structural behaviour of beam as either small or large. The behaviour of the beam keeps the same as the solid beam, than the opening is considered as small opening. If the behaviour of beam changes due to the presence of openings, it may be considered as large openings.

With regarding to the size of opening, many researchers use the terms large and small without any standard definition or clear demarcation line. The depth which is less than or equal to  $0.25d$  and the length less than or equal to depth of the beam is considered as small openings.

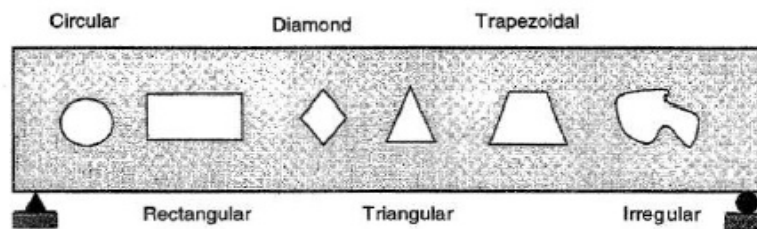


Fig 1: Different shapes of opening

## II. OBJECTIVE OF THE STUDY

An experimental program was planned to achieve the following objectives.

1. Comparing the solid beams (control beams) with the beam provided with rectangular opening without internally strengthened at opening.
2. Comparing the control beam with the beams having rectangular opening with internally strengthened at opening.

## III. EXPERIMENTAL PROGRAM

Nine rectangular cross section reinforced concrete beams were prepared with a dimension of 150mm X 200mm X 1700mm. First three beams are solid beams without any opening. These beams are used as reference beams to compare with other two types of beams. Rest six beams have rectangular opening in transverse direction, with opening size of 180mm length and 80mm height at a distance of  $L/3$  from the support. The rest of six beams are hollow beams in transverse direction with and without internal strengthening. In six beams three beams are casted without any internal strengthening. Compare to solid beams one longitudinal stirrup is reduced at the hollow portion. And the remaining three beams are casted with internal strengthening. Compare to solid and without internal strengthened beams, extra 4 numbers of 8mm dia bars were given to increase the strength in hollow portion.

## IV. MATERIALS AND METHODOLOGY

**Cement:** Ordinary Portland Cement of 43grade is used for all the concrete mixes. The cement used is free from the lumps and fresh. The test results are confirming to IS 8112-1989. The specific gravity of cement is 3.06.

**Coarse aggregate:** Locally available aggregate had been used throughout the work. 60% of 20mm passing aggregate and retained on 12.5mm IS sieve and 40% of 12.5mm passing aggregate and retained on 4.75mm IS sieve was used in preparation of the specimen to obtain a reasonably good grading. The sieve analysis of combined aggregate confirms to the specification of IS: 383-1970 for graded aggregate. The specific gravity of coarse aggregate is 2.67.

**Fine aggregate:** Locally available clean Tungabhadra River sand comes under zone II confirming to IS 383-1970 is used throughout the experimental work. The specific gravity of sand is 2.61. The zoning of fine aggregate is shown in logarithmic graph (Fig 2).

**Water:** To prepare concrete mix and for curing the beam clean portable water was used throughout the project work.

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*Reinforcement:* Un-tensioned high yield strength deformed (HYSD) bars of size 10mm dia were used as main bars at tension phase and 8mm dia bars were used for top reinforcement and for stirrups. The properties of reinforcement are shown in Table 1.

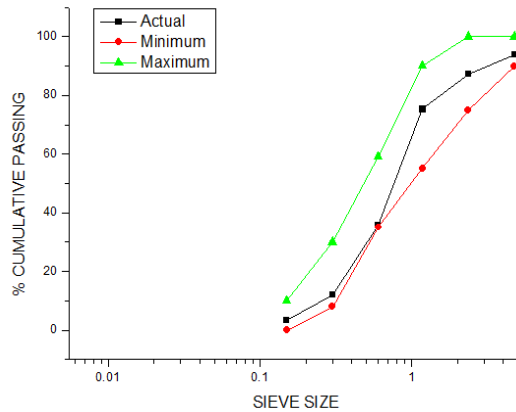


Fig 2 : Graph showing Sieve Analysis of fine aggregate

Table 1: Properties of the steel bars

SL. NO	Diameter of bar	Yield Strength	Ultimate Strength	Percentage Elongation
1	10mm	487 N/mm <sup>2</sup>	601.6 N/mm <sup>2</sup>	10.83 %
2	8mm	430 N/mm <sup>2</sup>	644.5 N/mm <sup>2</sup>	13.3 %
Average value		458.5 N/mm <sup>2</sup>	623 N/mm <sup>2</sup>	

*Test set up:* The complete test set up showing all the parts is shown in the Fig 3. All the beams are tested under two point loading.

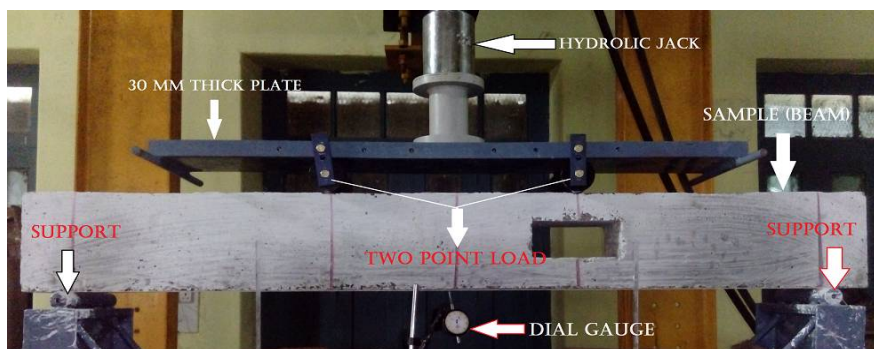
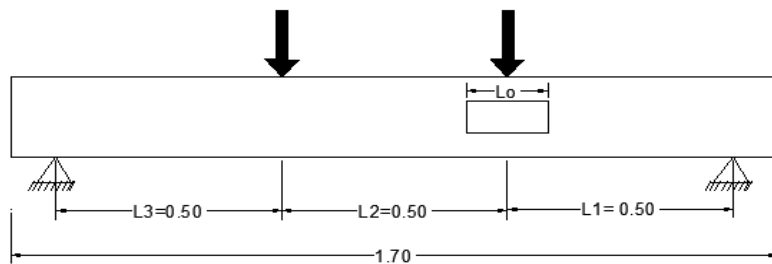


FIG 3 : TEST SET UP IN LOADING FRAME

**V. THEORETICAL EVALUATION**

*Design Specification of Beam with Opening*

In their paper entitled “A review of design specification of opening in the web for simply supported RC beams”, SoroushAmiri, Reza Masoudnia and Mohammad Amin Ameri represent the procedure for calculation of formula for bending moment at opening. Usually beams are subjected to combined shear and bending. Fig 4 shows the simply supported RC beam with an opening which is subjected to two point loading at L/3 distance from the support.



**FIG 4 : RC BEAM WITH OPENING UNDER TWO POINT LOADING**

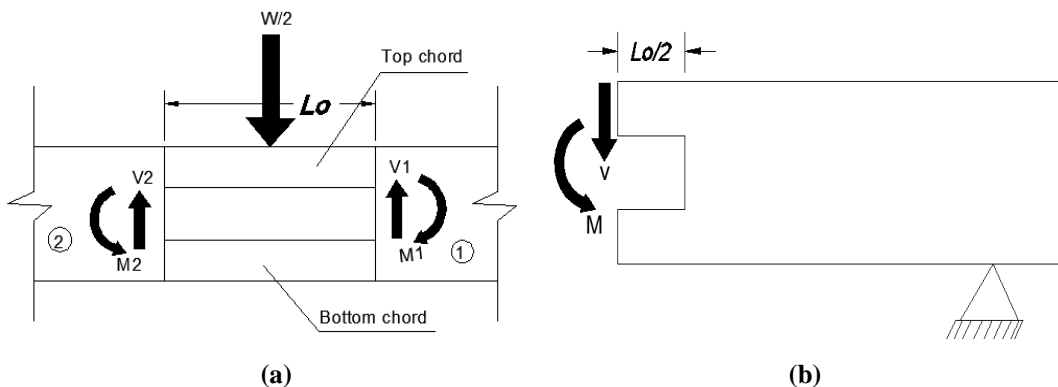
$$M_u = 0.87 f_y A_{st} d \left[ 1 - \frac{A_{st} X f_y}{b \times d \times f_{ck}} \right]$$

*Moment at the ends of chord members*

The solid portion of the beam is designed in usual method by considering the shear force and bending moment. The moment at the ends of chord members are calculated. The free body diagram which shows the bending moment and shear force action of the beam at the centre of the opening and at the edge of the chord member is shown in Fig 5.

$$M_1 = - \frac{WL_1}{2} - \frac{V_1L_0}{2}$$

$$M_2 = - \frac{WL_2}{2} - \frac{V_2L_0}{2}$$



**Fig 5 Beam with opening under shear and bending (a) free-body diagram at the center of opening (b) Free-body diagram at the ends of chord**

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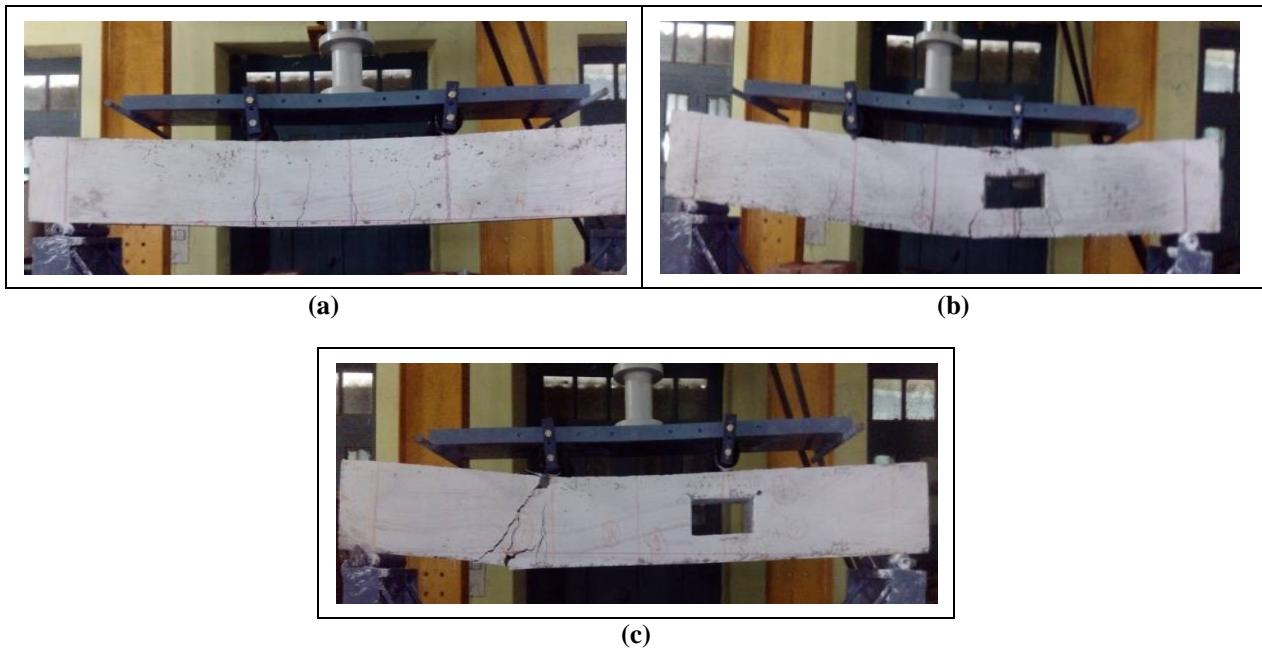
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## Reinforcement at the chords

The longitudinal reinforcement designed at the bottom and top of the solid portion adjacent to the rectangular opening should continue throughout the opening segment. To resist the axial force and combined moment additional reinforcement is required at the chord member. Hence in our experimental work, additional reinforcement is provided at the opening to increase the ultimate load carrying capacity of the beam.

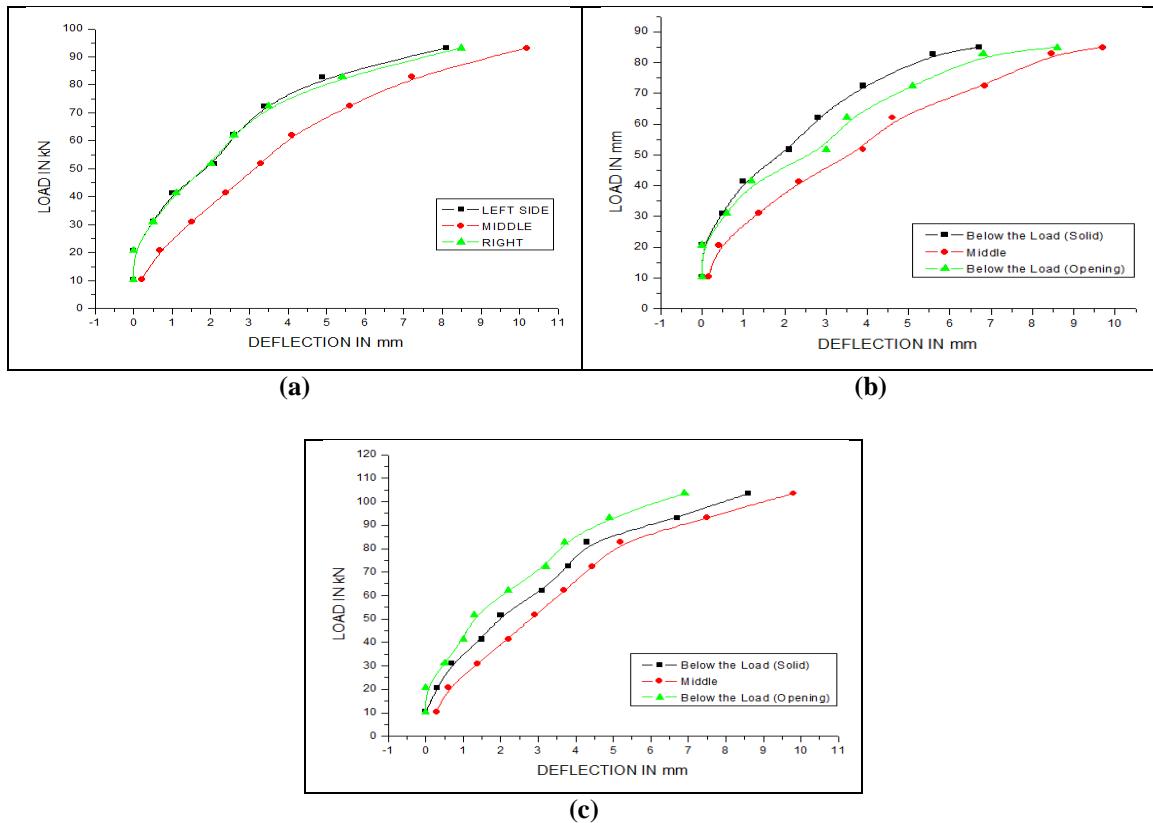
## VI. EXPERIMENTAL RESULTS

*Compression strength:* The compressive strength test was carried out for harden concrete to know the initial compressive strength of the concrete. The 7 and 28 days compressive strength results were tabulated in the Table 2. *Experimental results:* In design of concrete structures deflection is the main serviceability criteria to be satisfied. The span to effective depth ratio equal to or less than 20 is sufficient to restrict the deflection to allowable value of 20mm or span/250 as per the clause 23.2 (IS-456 : 2000). In the experimental study, the deflection was compared at centre and below the loads for all the beams.



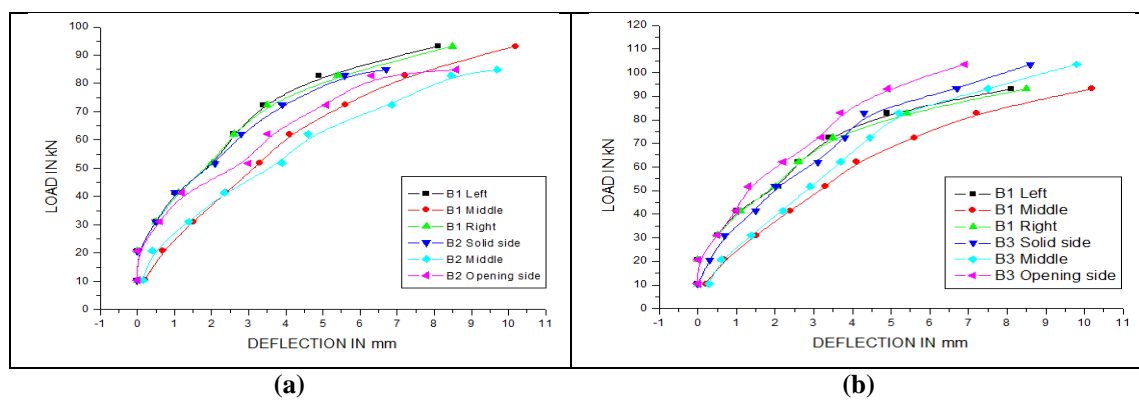
**Fig 6: Failure pattern of a) Solid Beam b) Un-strengthened hollow beam c) Internally Strengthened hollow beam**

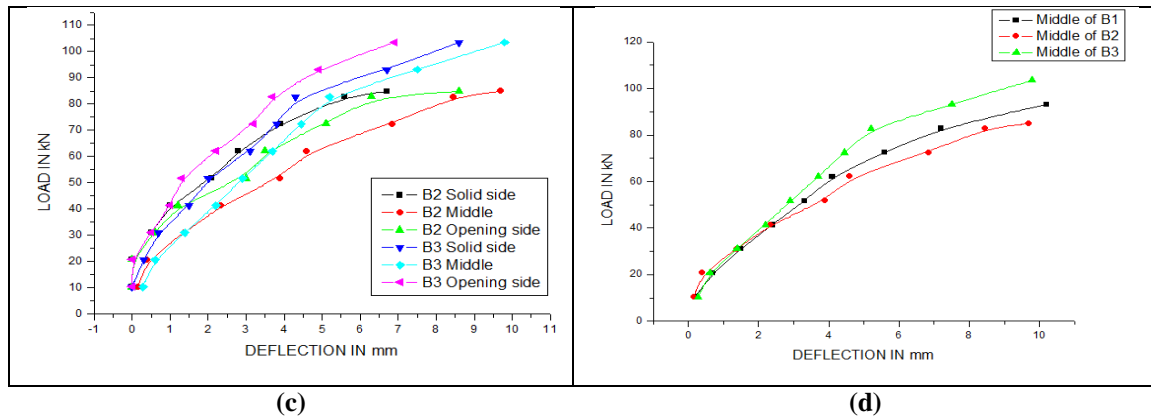
The crack pattern and position of failure for solid beam, un-strengthened hollow beam and internally strengthened hollow beam is shown in the Fig 6. B1 beam fails at the centre of the beam, B2 beam fails at the opening side of the beam and B3 beams fails below the load (other than opening side).



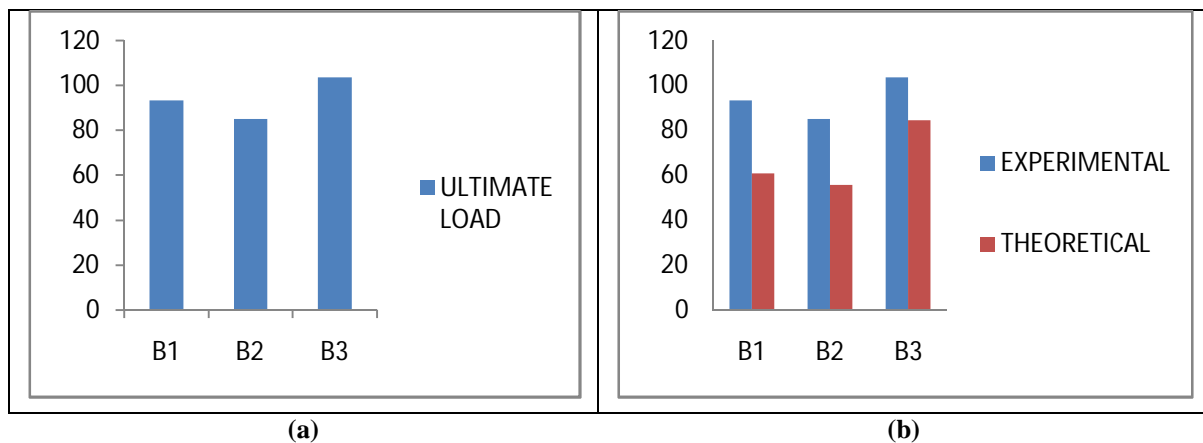
**Fig 7: Load V/S Deflection curve for a) solid beam b) Un-strengthened beam & c) Internally strengthened beam.**

The deflection at below the loads is almost same for solid beam, for B2 beam the deflection is more below the load at the opening side were as less at the other side and vies versa for B3 beam. Load V/S deflection for B1, B2 and B3 is shown in the Fig 7.





**Fig 8: Comparison for a) B1 & B2 Beam b) B1 & B3 Beam c) B2 & B3 Beam and d) B1, B2 & B3 Beam.**



**Fig 9: Ultimate load comparison of a) B1, B2 & B3 b) experimental and theoretical values**

The ultimate load for B3 beam is maximum compare to B1 and B2 beam because of extra reinforcement is provided above and below the opening to strengthen the opening zone. The comparison of experimental and theoretical value for all the beams is shown in the graph (Fig 9b).

**VII. CONCLUSION**

- 1) The ultimate strength of un-strengthened beam (B2) was significantly decreased by 8.89% compare to solid beam (B1). The cracks were formed around the corners of opening. Diagonal cracks are formed around the opening and cause for sudden failure.
- 2) The ultimate strength of internally strengthened beam (B3) significantly increases by 11.2% compare to solid beam(B1). The failure of the beam is formed below the one concentrated load which is away from the opening. Only small hair cracks were formed around the opening, all stress concentration was carried by extra reinforcement provided at the opening.
- 3) The ultimate strength of B3 beam was significantly increase by 21.95 % compared to B2 beam. The crack pattern was same for both beams but the failure of B2 beam is at opening side were as for B3 beam failure is in opposite direction.
- 4) The deflection of the transverse hollow beam which is internally strengthened was controlled and the ultimate load was increased compare to solid beam and un-strengthen beam.
- 5) The deflection of the internally strengthened beam (B3) was less, compare to solid beam.

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- 6) The deflection of the un-strengthened beam (B2) was more, compare to solid beam.
- 7) The theoretical values obtained for all the beams are less than the experimental values like 34.9%, 34.45%, & 18.45% for B1, B2, & B3 beams respectively.

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- v. IS 516: 1959 (Specification for compressive strength)
- vi. IS 8112: 1989 (Specification for 43grade ordinary Portland cement)