Experimental Study on Flexural Behavior of Reinforced Concrete Beam with Web Openings And Cutouts

Manu Y T[1], Dr. Asha K[2]
[1]Dept of Civil Engineering
[2] Associate Professor, Dept of Civil Engineering
[1, 2]Dayananda Sagar College of Engineering, Bengaluru, Karnataka, India

Abstract- *The investigation is aimed to study the flexural behavior of Reinforced Concrete Beam having circular opening and cutouts of different sizes and located at different location on beam and comparing it with reference beam. The experimental program consists of casting and testing of RC beams of size 750x150x150 mm with and without circular openings and cutouts. In this investigation 7 beams are casted by using M-30 grade concrete consisting 4 beams of circular hole with dia of 25 and 50mm at different locations and 2 beams having cutout of 75x75 mm at different locations are tested. A comparison was made with reference beam. To study the flexural behavior, all beams are tested after 28-days curing by applying loads at 1/3rd points. The performance of Reinforced Concrete Beams with diameter of opening exceeded the 30% of depth of the beam, the reduction of ultimate strength increased and the deflection was observed to be increased. The Reinforced Concrete Beams with cutouts the ultimate flexural behavior of beam decreased drastically and deflection also increased highly and the crack patterns were also observed during experimentation.*

Keywords- Circular openings, Cutouts, Flexural Behavior Deflection

I. INTRODUCTION

For modern construction, the provision of providing transverse openings in the reinforced concrete beam would be a facility to allow the passage of utility pipes and ducts through the structure. This type of design would provoke and promote the structural designers to lower the height of the structure and to make structure better in design and at economical cost. In case of small buildings the savings would not be significant, but in case of high rise building savings in a single storey multiplied by no. of stories would result in substantial savings in total height, length of electrical wires and ducts, air conditioner pipes, plumbing material, partition surfaces and load on foundation. Due to the abrupt change in the cross section of the beam and introduction of opening in the beam the normal beam behavior would change to a complex one. The opening corners would subject to high stress which would lead to cracking of beams. Also reduction in the stiffness of the beam would lead to excessive deflection under the service load. Thus proper detailing with sufficient amount of special reinforcement is to be provided for such beams to avoid the adverse effects on the strength and serviceability of the beam. Presently no design criteria is been mentioned in any of the code which is used for design of concrete building structure.

II. MATERIALS

Ordinary Portland Cement of Birla brand was used and it was conforming to IS 1489-1991. Tests were conducted to find the Specific gravity of cement using Pyconometer and the results are tabulated below. Coarse aggregate was crushed stone which was available locally. Maximum size chosen was 20mm down and 12.5mm size aggregate were chosen. Tests are conducted to find the Specific gravity using Wire basket and Water absorption of coarse aggregate and the results are tabulated below. Locally available river sand was used as fine aggregate. Specific Gravity and Water absorption properties of fine aggregate were determined and test results are tabulated in table 1 below.

Materials	Test	Values Obtained
Cement (53 Grade OPC)	Specific Gravity	3.05
Fine Aggregate	Water Absorption	1%
	Specific Gravity	2.61
Coarse Aggregate (20mm)	Specific Gravity	2.7
	Water Absorption	17.77
Coarse Aggregate (12.5mm)	Specific Gravity	2.68
	Water Absorption	18.45

Table 1: Material Properties

For the present experimental work Fe-500 grade of Tata steel was used for reinforcement. Portable water which is free from organic materials and suspended solids are used, which was available at local site.

III. METHODOLOGY

In this experimental study M-30 grade Concrete was used for the beam specimens using Ordinary Portland Cement, Fine aggregates, Coarse aggregates and potable water were used and mix design was made according to IS:10262:2000 and mix details are tabulated below in Table 2. A Compression test was carried out to know the characteristic Compressive Strength of concrete for 28-days by casting cubes of 150 x150x150mm are tested and tabulated below in Table 3. In this experimental study total of 7 Reinforced Concrete Beams of size 750x150x150mm were casted where a solid beam which is used as reference beam to compare the results with conventional beam. The beam design were carried out according to IS: 456:2000. The Reinforcement was provided using Fe500 steel rods and shear stirrups were provided. For all seven beams bottom reinforcement of 2-16mm Ø and top reinforcement were 2-8mm Ø and for stirrups of 8mm Ø at 225 mm center to center spacing is provided. The capacity of 1000kN Universal Testing Machine was used and the designed ultimate loading carrying capacity of the beams were 128kN and the beam is designed as Balanced Section.

Cement	F.A	C.A	Water
438.14	690	1069	197.16
Kg/m3	Kg/m3	Kg/m3	Kg/m3
1	1.57	2.44	0.45

Table 2: Mix design details.

No of days of curing	Specimen	Load (Kg)	Compressive strength N/mm^2	Average N/mm^2
28 days	1	85	37.06	34.73
	2	72	31.392	
	3	82	35.752	

Table 3: Compression test results.

3.1 Placing of Circular Holes.

For making a transverse hole, frictionless PVC pipe of a predetermined external diameter was tied with the reinforcements in the correct position before casting as shown in the below fig. The holes are made to located at a distance of L/3 of the beam and another hole in another specimen at L/2 and the dia of the hole is varied ie 50mm and 25mm dia holes are used in this research and beam with cutouts are also made ie the opening cuts are placed at two different locations ie L/3 in one specimen and in another specimen it is placed at L/2 the dimension of cutouts is made to be 75mmX75mm.In the case of cutout beams the main reinforcement bar itself is sliced down.

Figure 1: Placing of Openings and Cutouts.

3.2 Casting and Curing.

Concrete of M-30 grade was designed on the guidelines of IS10262-2000 and mix proportion of 1:1.57:2.44 was selected. The entire beam mould was thoroughly lubricated with grease/old for easy removal of mould after 24 hours of concreting on beam and clear cover or spacers of 25 mm was provided to beam for uniform spacing of bar. As per design calculation, concrete mix was poured in layer and compacted using tamping rod. The compaction is carried out until mould is completely filled and there was no visible presence of air voids. After 24hrs of setting the moulds are removed and kept for curing in curing tank for 28 days.

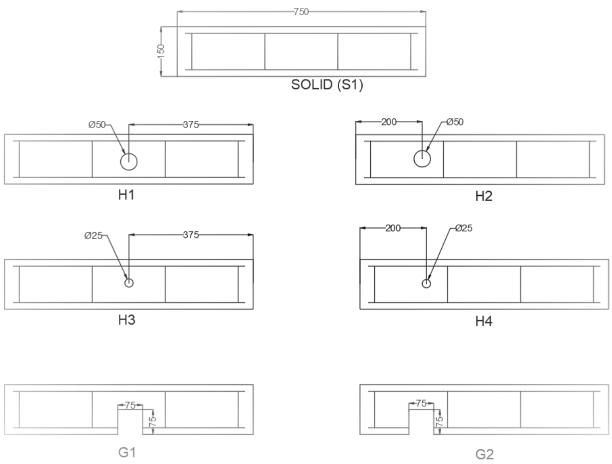


Figure 2: Beam Layout.

Sl.No	Beam Name	Shape of Opening	Size of Opening	Distance of Opening from Support
1	S1	---	---	---
2	H1	CIRCULAR	50	325
3	H2	CIRCULAR	50	200
4	H3	CIRCULAR	25	325
5	H4	CIRCULAR	25	200
6	G1	SQUARE	75*75	325
7	G2	SQUARE	75*75	200

Table 4: Beam designation details.

3.3 Test Procedure.

The specimens were tested using a 1000 kN Universal Testing Machine; a dial gauge having a travel of 25 mm was used to record the vertical deflection at the bottom of the mid-span of the beam. The behavior of the beams was keenly observed from beginning to failure. The appearance of the first crack, the development and the propagation of cracks due to the increase of load were observed. The loading was continued after the initial cracking load and was stopped when the beam was just on the verge of collapse.

The universal testing machine consists of a set up for testing the two point at the distance of L/3 from supports for bending set up facilities. For performing flexural test to achieve pure bending an additional fixture was made using an iron block and load is applied manually using hydraulic cylinder. The values of load applied and deflection are noted directly and further the plot of load vs. deflection is performed which is taken as the output. The load in kN is applied with uniformly increasing the value of the load and the deflection under the different applied loads is noted down.
Figure 3: UTM test setup for 2-point flexure.

IV. RESULTS AND DISCUSSIONS

All beams were tested under two point loading condition in the Universal Testing Machine of 1000kN capacity. Load was applied by hydraulic jack, then these beams were loaded up to the first flexural cracking and all the beams were loaded up to the ultimate load.

4.1 Flexural Behavior.

The universal testing machine consists of a set up for testing the two point at the distance of L/3 from supports for bending. The first crack loading and ultimate loading on solid beam and beams with openings and cutouts at different locations as been discussed follow.

4.1.1 Solid Beam (S1).

The first hair crack was visible in the shear span at a load of 55 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 105 kN exhibiting a wider crack.

Figure 4: First cracking in S1 Specimen.

4.1.2 Beam of 50Ø hole at Mid Span (H1):

Figure 5: UTM test setup for H1 Specimen

The first hair crack was visible in the shear span at a load of 25 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 37 kN exhibiting cracks around the hole. Due to the presence of hole in the midspan the load carrying capacity of the beam decreases when it is compared with solid beam the first crack loading is decreased by 55% and ultimate load decreased by 64% due to the presence of 50mm dia hole at the mid span of the beam.

4.1.3 Beam of 50Ø hole near Support (H2):

The first hair crack was visible in the shear span at a load of 45 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 66kN exhibiting a cracks around the hole. Due to the presence of hole nearer to the support the load carrying capacity of the beam decreases and the beam failure in shear failure mode. When it is compared with solid beam the first crack loading is decreased by 18% and ultimate load decreased by 37% due to the presence of 50mm dia hole nearer to the support beam.

Figure 6: Crack Pattern observed in H2 Specimen

4.1.4 Beam of 25Ø hole at Mid Span (H3):

The first hair crack was visible in the shear span at a load of 40 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 78 kN. Due to the presence of hole in the midspan the load carrying capacity of the beam decreases when it is compared with solid beam the first crack loading is decreased by 27% and ultimate load decreased by 25% due to the presence of 25mm dia hole at the mid span of the beam.

4.1.5 Beam of 25Ø hole near Support (H4):

The first hair crack was visible in the shear span at a load of 55 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 92kN exhibiting a wider crack. Due to the presence of hole nearer to the support the load carrying capacity of the beam decreases and the beam failure in shear failure mode. When it is compared with solid beam the first crack loading was same as that of solid beam and ultimate load decreased by 10% due to the presence of 25mm dia hole nearer to the support beam

Figure 6: UTM test setup for H4 Specimen.

4.1.6 Beam of 75mm square Cutout at Mid Span (G1):

The first hair crack was visible in the shear span at a load of 10 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 15kN exhibiting a wider crack. Due to the presence of cutout in the midspan the load carrying capacity of the beam decreases when it is compared with solid beam the first crack loading is decreased by 80% and ultimate load decreased by 85% due to the presence of cutout at the mid span of the beam. The longitudinal reinforcement of the beam is shortened at the cutout region hence the tensile strength of the beam decreases drastically and that can be observed. In crack propagation it starts from the corner edge of the cutout and it propagates towards the other surface.

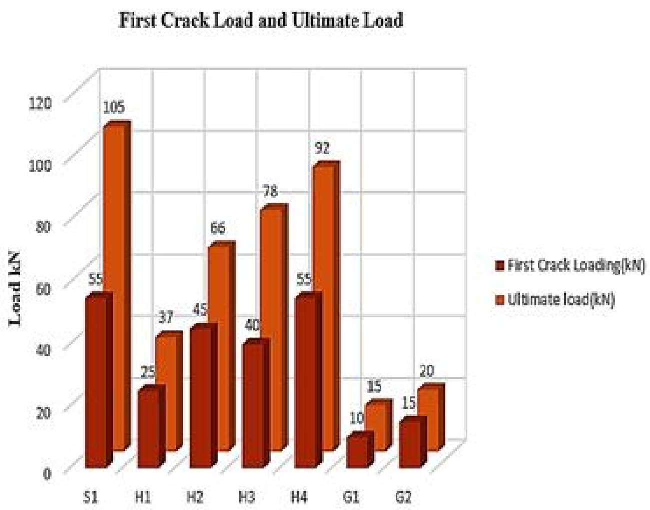
Figure 7: UTM test setup for G1 specimen.

4.1.7 Beam of 75mm square Cutout near Support (G2):

Figure 8: UTM test setup for G2 specimen

The first hair crack was visible in the shear span at a load of 15 kN. As the load increased beyond the first crack load, many inclined cracks were also developed and the first visible crack started widening. With further increase in load, the beam finally failed at a load of 20kN exhibiting a wider crack. Due to the presence of cutout in shear zone the load carrying capacity of the beam decreases when it is compared with solid beam the first crack loading is decreased by 70% and ultimate load decreased by 80% due to the presence of cutout at the mid span of the beam. The longitudinal reinforcement of the beam is shortened at the cutout region hence the tensile strength of the beam decreases drastically and that can be observed. In crack propagation it starts from the corner edge of the cutout and it propagates towards the other surface.

.

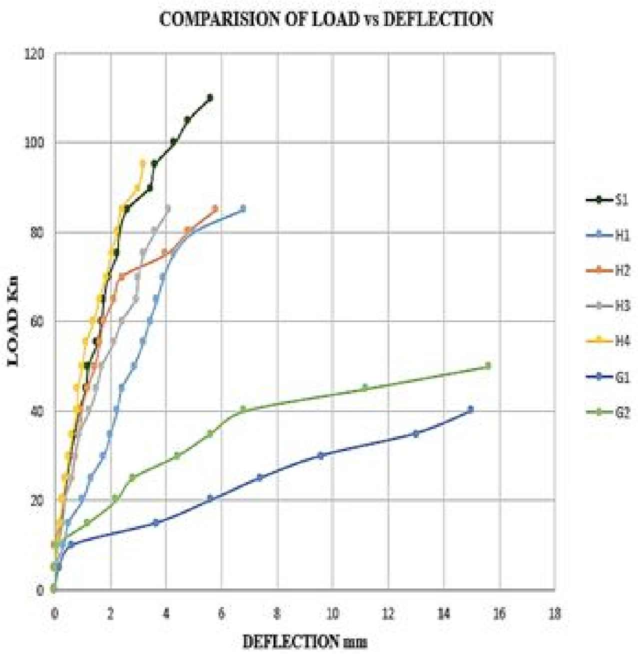


Graph 1: First crack load and ultimate load vs. Load for various beam specimens

Examining the results presented in the Graph 1, it is clear that the presence of an opening not only reduces the load carrying capacity of the beam but also reduce the stiffness of the beam. The presence of hole in the flexural region decreases more loading carrying capacity of the beam when it is compared when the hole is nearer to the support and also as the diameter of the hole increases the flexural strength of the beam decrease. And it can also be observed that in the specimens G1 and G2 the loading carrying capacity of the beam has decreased more than 70% which is due to the cutting the longitudinal reinforcement.

4.2 Load vs. Deflection Behavior.

The specimens were tested under monotonically increasing load until failure. As the load increased, beam started to deflect and flexural cracks developed along the span of the beams.



Graph 2: Deflection vs. Load for various beam specimens

Examining the results presented in the Graph 2, it is clear that the presence of an opening reduces the stiffness of the beam. And hence increases the deflection of the beam. The presence of hole in the flexural region increases deflection of the beam when it is compared when the hole is nearer to the support and also as the diameter of the hole increases the deflection of the beam also increases. And it can also be observed that in the specimens G1 and G2 due to the presence of cutouts in the tension of the beam the deflection is very high compare to the solid and other beams with opening which is due to the cutting the longitudinal reinforcement.

V. CONCLUSION

Based on the results of this experimental investigation, it could be concluded that:

- The location of openings has a large effect, where this effect is large when openings location is at midspan as small effect when openings location is nearer to support.
- In RC beams with large opening at flexure zone, excessive flexural cracks were found at the tension zone around the openings. The failure mode was in flexure. Providing large opening in RC beam decreased the ultimate load carrying capacity. However, in terms of deflection, the beam deflection increased more than the control beam.
- Beam of circular opening with diameter less than or equal to 30% of the depth of the beam behave similar to the beams without opening, However the ultimate loading carrying capacity may decreased very less but when it is comparatively low.
- Beam circular opening with diameter more than 30% of the depth of the beam reduces the ultimate load capacity of the RC rectangular beams by at least 45%, and the deflection also increases due to lack of stiffness in the beam.
- From Load vs. Deflection curve it can be observed that beams with cutout the deflection is very high and the load carrying capacity is decreased drastically. Hence cutout openings are highly not recommended.

VI. ACKNOWLEDGMENT

I show my inertness and gratitude to the valuable guidance given by my Guide **Dr. Asha K**, Associate Professor, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru for her initiative and motivation during the course of this work.

I express my sincere thanks and gratitude to **Mr. Arjun K** Assistant Professor, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru for his initiative and motivation during the course of this work.

Finally last but not least I thank my friends for constantly helping in completing this work and I thank my parents for their blessings. Finally we devote our thanks to the almighty that helped us in making our ideas into actions and into success.

REFERENCES

[1] Prof. P.G.patel, Nilesh H. Saksena. “Experimental study of reinforced concrete beam with web openings” International Journal of Advanced Engineering Research and Studies (IJAERS)/Vol. II/ Issue III (2013).

[2] J.Jebasingh Daniel, Dr. J. Revathy, “Experimental Investigation on flexural strength of Beams with Opening”, International Journal of Research in Management & Technology (IJRMT), Vol. 4, No.2 (2014).

[3] Reza Masoudnia, Soroush Amiri, and Mohammad Amin Ameri, “A review of design specifications of opening in the web for simply supported RC beams”, Journal of Civil Engineering and Construction Technology Vol. 2(4), pp. 82-89 (2011).

[4] C-C. Chen, C.-Y. Li and M.-C. Kuo, “Experimental study of steel reinforced concrete beams with web openings”, The 14th World Conference on Earthquake Engineering, Beijing, China (2008).

[5] Hawraz Karim M. Amin, V.C. Agarwal, Omar Q. Aziz, “Effect of Opening Size and Location on the Shear Strength Behavior of R.C Deep Beams without Web Reinforcement”, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-3, Issue-7 (2013).

[6] Rezwana Binte Hafiz, Shaibal Ahmed, SaikatBarua, Sharmin Reza Chowdhury, “Effects of Opening on the Behavior of Reinforced Concrete

[7] Beam”, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 11, Issue 2 Ver. VII (2014).

[8] M.A. Mansur, “Design of reinforced concrete beams with web openings”, Asia-Pacific Structural Engineering and Construction Conference (2006).

[9] T.M. Yoo, J.H. Doh, H. Guan, “Experimental work on Reinforced and Prestressed Concrete Deep Beams with Various Web Openings”, S. Fragomeni Victoria University, Australia

[10] Lee JK, Li CG, Lee YT (2008) Experimental Study on Shear Strength on Reinforced Concrete Continuous Deep Beams with Web Opening. The 14th World Conference on Earthquake Engineering, Beijing, china.

[11] Mansur MA, Tan KH (2013) Concrete Beams with Openings: Analysis and Design. CRC Press, Florida, USA.