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INFLUENCE OF TRANSVERSE HOLE ON FLEXURAL STRENGTH OF RC BEAM

Boorla Tharun[1] & Sreenu Ramavath[2]

[1]Research Scholar, Department of Civil Engineering, Anurag Group of Institutions, Hyderabad, India

[2]Assistant Professor, Department of Civil Engineering, Anurag Group of Institutions, Hyderabad, India

ABSTRACT

Height limitations are not uncommon in multi-storey buildings due to economic requirements and esthetical considerations. Substantial spaces are normally required to enable the passage of large pipes and ducts beneath RC beams leading to uneconomic floor heights. The most adopted solution for this issue is the use of RC beam with openings to provide the required space for services. These openings could lead to a significant decrease in the beam load carrying capacity depending on the adopted openings shape, and location. These aspects motivated the present study based on FE simulations calibrated against numerical results. In this study, a solid RC beam, beam with a circular hole and beam with a square hole, totally 3 beams were considered. The modeling & analysis is carried by using ANSYS software. The models are compared for their flexural strength to find out the best suitable shape of the opening and also the optimum position of the opening.

An study shows that the beam with a circular opening having more flexural strength than a beam with a square opening. This is because of smooth stress flow around the circular opening and stress flow lines at sharp edges of the square opening are crowded, leads to an increase in stress concentration and decrease in flexure strength. The opening should be placed nearer to the supports to have the more flexural strength than at the middle of the beam. The flexural strength of a beam with a circular opening is same as that of the solid beam if we increase the depth of beam by 6%.

KEYWORDS: *ANSYS, A Circular Opening, Four Point Loading, RC Beam and Square Opening*

Article History

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INTRODUCTION

In most buildings, utility ducts and pipes are accommodated in the space within the floor-ceiling sandwich. The need for services in all types of buildings has greatly increased, new regulations and demands, such as for more efficient methods of cooling, local temperature control, effective ventilation, more efficient methods of heat recovery, combined heat, power and cooling systems, information technology and communication systems and new forms of renewable energy technologies, have also focused attention on how to locate and distribute these services effectively within buildings and to facilitate future maintenance and adaptability. The integration of services within the structural elements of buildings leads to economies in the construction by reducing the floor-to-floor height.

Modern buildings require many different types of services for the comfort, health and safety and rapid movement of the users. Building services can be grouped under the following categories. Air-conditioning equipment and vertical distribution of air to floors

- Heating and cooling, including local control for each part of the floor.
- Fire protection systems, including active measures, such as sprinklers and automatic detection.
- Electrical and data communication systems.
- Water and sanitary distributions and facilities.

Passing these service ducts through transverse openings in the floor beams saves a significant amount of headroom, economic construction, and they have a scene of beauty as well and results in a more compact design. These openings could lead to savings in construction material leads to a decrease in dead weight of structure on the foundation which ultimately results in savings in construction cost.

The present work is aimed at evaluating the effect of transverse circular and square openings on its flexural strength of RC beams with the following objectives.

- To find out the best shape of the opening.
- To find out the optimum location of the opening.
- To find out the increased depth of beam having an opening to get the flexural strength same as that of the solid beam.

METHODOLOGY

In the present study, the RC members are modeled using ANSYS software. Explicit dynamicmethod of analysis is adopted for the analysis of RC beams with and without opening.

- In the first stage, modeling of a solid RC beam and beam with circular and square openings at the center is to be done and the analysis is carried out.
- In the second stage, results are compared and the best shape of the opening has to be suggested.
- In the third stage, the position of openings is changed nearer to the supports and analysis is carried out.
- In the fourth stage, results are compared to find out the optimum location of the opening.
- In the final stage, the depth of beam having an opening is increased to get the flexural strength same as that of the solid beam.

MODELING AND ANALYSIS

Geometry

The geometry of the model considered is a rectangular RC beam. The length of the beam is 1700mm, breadth is 150mm and depth is 250mm. The beam is reinforced with structural steel of grade Fe 415, 3 No’s 12mm diameter bars at the bottom and 2 No’s 10mm diameter bars at the top. Stirrups of 8mm diameter provided at 150mm spacing.

Solid RC Beam Model

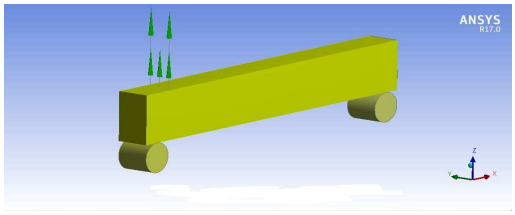

Figure 1: RC Solid Beam Model

The figure 1 shows a 3D solid RC beam model is developed using ANSYS. The beam model is assigned with a concrete grade of M35 and structural steel of grade Fe 415 materials.

Table 1: Properties of Solid RC Beam

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415

The table 1 shows properties of solid RC beam. The size of the beam is 1700mm x 150mm x 250mm. M35 grade of concrete and Fe 415 grade of steel is used in the beam.

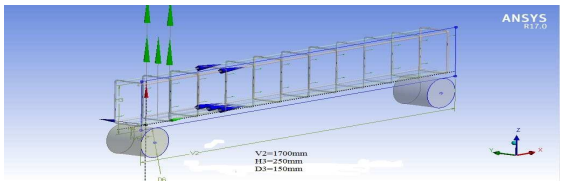

Figure 2: Reinforcement Detailing of Solid RC Beam Model

The figure 2 shows reinforcement details of 3D solid RC beam model developed using ANSYS. Fe 415 grade steel is used. 3 No's 12 mm diameter bars at the bottom and 2 No's 10mm diameter bars on top and stirrups of 8mm diameter used.

Loading

As we know that the four-point bending flexural test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress-strain response of the material. Hence here we use four-point loading mechanism to finding out the flexural strength of the RC beam.

Figure 3 shows the RC beam loaded with four-point loading. In flexure test, the beam is simply supported and loaded with 2 point loads at a distance of d between the loads, where d is the depth of the beam.

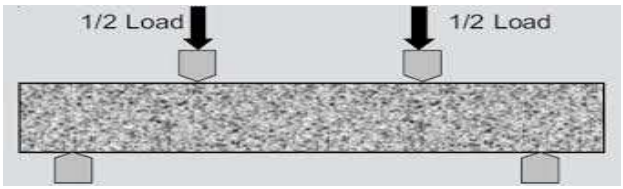

Figure 3: Four Point Loading-Flexure Test

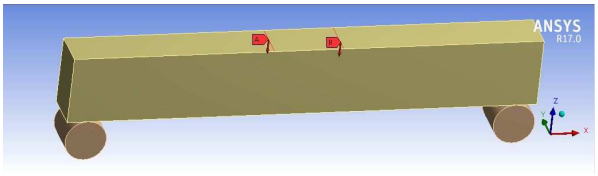

Figure 4: Four Point Loading-Flexure Test

Figure 4 shows the RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm. All the models were loaded symmetrically by four-point loading, where the positions of the applied load were kept constant.

RC Beam with a Central Circular Opening

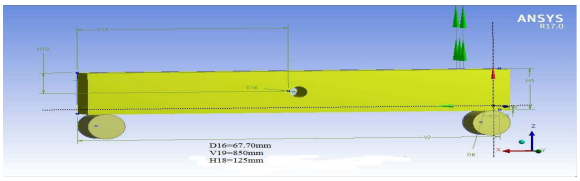

Figure 5: RC Beam with Central Circular Opening

Figure 5 shows the 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a circular opening at its center. The size of the opening is 67.70 mm diameter the distance between the center of the opening to top / bottom edges of the beam is 125mm.

Table 2 shows properties of RC beam with a central circular opening. The size of the beam is 1700mm x 150mm x 250mm provided with a circular opening at its Center. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 67.70 mm diameter.

Table 2: Properties of RC Beam with a Central Circular Opening

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415
Load	25 kN/m^2
Opening shape	Circular
Opening size	67.70 mm diameter
Opening position	Center

RC Beam with a Circular Opening near Left Support

Figure 6: RC Beam with a Circular Opening near Left Support

Figure 6 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a circular opening near left support. The size of the opening is 67.70 mm diameter the

distance between the center of the opening to top / bottom edges of the beam is 125mm.

Table 3 shows properties of RC beam with a circular opening near left support. The size of the beam is 1700mm x 150mm x 250mm provided with a circular opening near left support. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 67.70 mm diameter.

Table 3: Properties of RC Beam with a Circular Opening Near Left Support

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415
Load	25 kN/m^2
Opening shape	Circular
Opening size	67.70 mm diameter
Opening position	Near left support

RC Beam with a Circular Opening Near Right Support

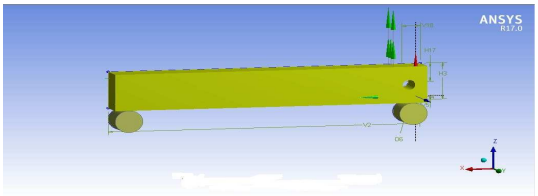

Figure 7: RC Beam with Circular Opening Near Right Support

Figure 7 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a circular opening near right support. The size of the opening is 67.70 mm diameter the distance between the centerof the opening to top / bottom edges of the beam is 125mm.

The table 4 shows properties of RC beam with a circular opening near right support. The size of the beam is 1700mm x 150mm x 250mm provided with a circular opening near right support. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 67.70 mm diameter.

Table 4: Properties of RC Beam with a Circular Opening Near Right Support

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415
Load	25 kN/m^2
Opening shape	Circular
Opening size	67.70 mm diameter
Opening position	Near right support

RC Beam with a Central Square Opening

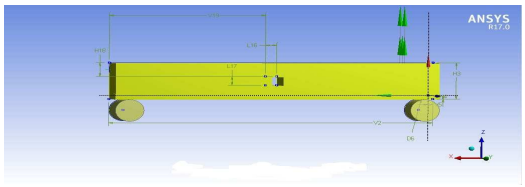

Figure 8: RC Beam with Central Square Opening

The figure 8 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a square opening at its center. The size of the opening is 60 mm x 60mm, the distance between the center of the opening to top / bottom edges of the beam is 125mm.

The table 5 shows properties of RC beam with a central square opening. The size of the beam is 1700mm x 150mm x 250mm provided with a Square opening at its Center. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 60 mm x 60mm (L x B).

Table 5: Properties of RC Beam with a Central Square Opening

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415
Load	25 kN/m^2
Opening shape	Square
Opening size	60 mm x 60 mm (L x B)
Opening position	Center

RC Beam with a Square Opening near Left Support

Figure 9: RC Beam with a Square Opening Near Left Support

Figure 9 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a square opening near left support. The size of the opening is 60 mm x 60mm, the distance between the center of the opening to top/bottom edges of the beam is 125mm.

The table 6 shows properties of RC beam with a square opening near left support. The size of the beam is 1700mm x 150mm x 250mm provided with a square opening near left support. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 60 mm x 60mm (L x B).

Table 6: Properties of RC Beam with a Square Opening Near Left Support

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415

Table 6: Contd.,	
Load	25 kN/m^2
Opening shape	Square
Opening size	60 mm x 60 mm (L x B)
Opening position	Near left support

RC Beam with a Square Opening Near Right Support

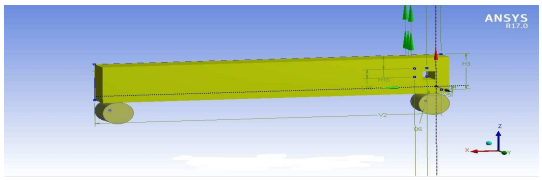

Figure 10: RC Beam with a Square Opening Near Right Support

The figure 10 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a square opening near right support. The size of the opening is 60 mm x 60mm, the distance between the center of the opening to top / bottom edges of the beam is 125mm.

The table 7 shows properties of RC beam with a square opening near right support. The size of the beam is 1700mm x 150mm x 250mm, provided with a square opening near right support. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 60 mm x 60mm (L x B).

The figure 11 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 265mm provided with a circular opening at its center. The size of the opening is 67.70 mm in diameter the distance between the centerof the opening to bottom edge of the beam is 125mm.

The table 8 shows properties of RC beam with a circular opening at its center. The size of the beam is 1700mm x 150mm x 265mm provided with a circular opening at its center. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 67.70mm diameter

Table 7: Properties of RC Beam with a Square Opening Near Right Support

Beam dimensions	1700mm x 150mm x 250mm
Grade of concrete	M35
Grade of reinforcement	Fe 415
Load	25 kN/m^2
Opening shape	Square
Opening size	60 mm x 60 mm (L x B)
Opening position	Near right support

RC Beam Having 265mm Depth with a Central Circular Opening

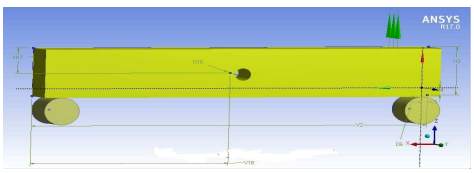

Figure 11: RC Beam Having 265mm Depth with a Central Circular Opening

The figure 10 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 250mm provided with a square opening near right support. The size of the opening is 60 mm x 60mm, the distance between the center of the opening to top / bottom edges of the beam is 125mm.

The table 7 shows properties of RC beam with a square opening near right support. The size of the beam is 1700mm x 150mm x 250mm, provided with a square opening near right support. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 60 mm x 60mm (L x B).

The figure 11 shows 3D RC beam model developed using ANSYS software. The size of the beam is 1700mm x 150mm x 265mm provided with a circular opening at its center. The size of the opening is 67.70 mm in diameter the distance between the center of the opening to bottom edge of the beam is 125mm.

The table 8 shows properties of RC beam with a circular opening at its center. The size of the beam is 1700mm x 150mm x 265mm provided with a circular opening at its center. M35 grade of concrete and Fe 415 grade of steel is used in the beam. The size of the opening is 67.70mm diameter

Table 8: Properties of RC Beam Having 265mm Depth with a Central Circular Opening

Beam dimensions	1700mm x 150mm x 265mm
Grade of concrete	M35
Grade of reinforcement	Fe 415
load	25 kN/m^2
Opening shape	Circle
Opening size	67.70 mm diameter
Opening position	Center

RESULTS AND DISCUSSIONS

Flexural Strength of Solid RC Beam

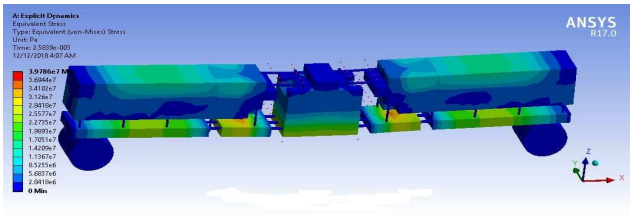

Figure 12: Stress Diagram for Solid RC Beam

The above figure 12 shown is a stress diagram for 3D solid RC beam. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of solid RC beam obtained is 1642.97 N/m^2.

Flexural Strength of RC Beam Having a Central Circular Opening

The figure 13 shown is a stress diagram for 3D RC beam having a central circular opening. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having a central circular opening is 1272.31 N/m^2.

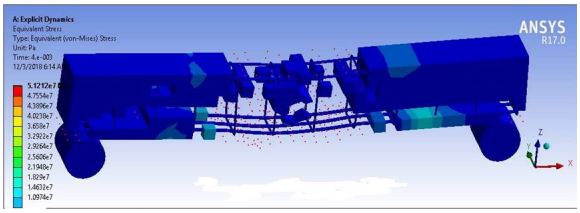

Figure 13: Stress Diagram for RC Beam Having a Central Circular Opening

Flexural Strength of RC Beam Having a Circular Opening near Left Support

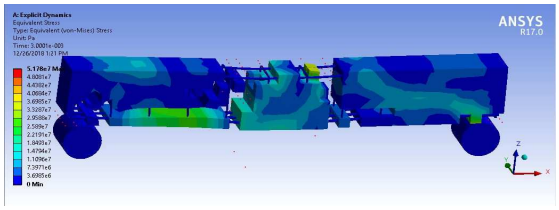

Figure 14: Stress Diagram for RC Beam Having a Circular Opening near Left Support

The above figure 14 shown is stress diagram for 3D RC beam having a circular opening near left support. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having a circular opening near left support is 1492.21 N/m^2.

Flexural Strength of RC Beam Having a Circular Opening near Right Support

The figure 15 shown is stress diagram for 3D RC circular opening near right support. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having a circular opening near right support is 1492.21 N/m^2.

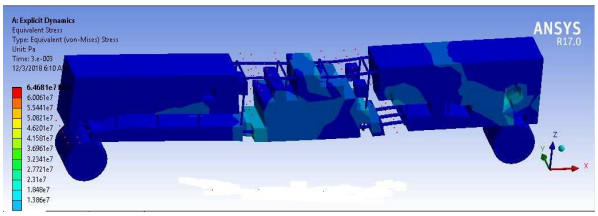

Figure 15: Stress Diagram for RC Beam Having a Circular Opening near Right Support

Flexural Strength of RC Beam Having a Central Square Opening

The figure 16 shown is a stress diagram for 3D RC beam having a central square opening. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having a central square opening is 1175.37 N/m^2.

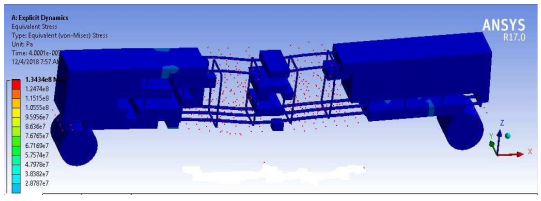

Figure 16: Stress Diagram for RC Beam Having a Central Square Opening

Flexural Strength of RC Beam Having a Square Opening near Left Support

The figure 17 shown is stress diagram for 3D RC beam having a square opening near left support. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having a square opening near left support is 1222.74 N/m^2.

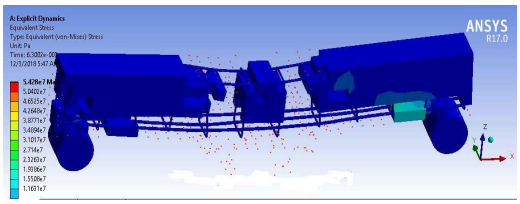

Figure 17: Stress Diagram for RC Beam Having a Square Opening near Left Support

Flexural Strength of RC Beam Having a Square Opening near Right Support

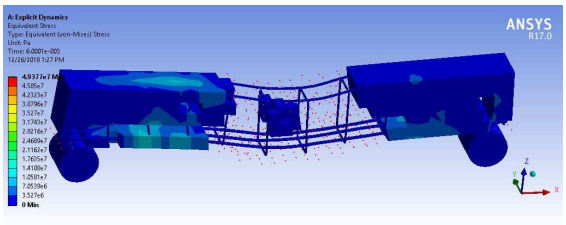

Figure 18: Stress Diagram for RC Beam Having A Square Opening near Right Support

The above figure 18 shown is a stress diagram for 3D RC beam having a square opening near right support. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having a square opening near right support is 1222.74 N/m^2.

Flexural Strength of RC Beam Having 265mm Depth with a Central Circular Opening

The figure 19 shown is a stress diagram for 3D RC beam having depth 265mm with a central circular opening. The stress diagram is obtained from the explicit dynamic analysis in ANSYS. The maximum flexural strength of RC beam having depth 265mm with a central circular opening is 1522.67 N/m^2.

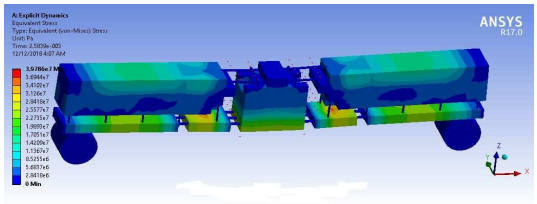

Figure 19: Stress Diagram for RC Beam Having Depth 265mm with a Central Circular Opening

Comparison of Results

Table 9: Comparison of Results

Sl. No	Beam	Flexural strength N/m^2
1	Solid RC beam	1642.97
2	RC beam with central circular opening	1272.31
3	RC beam with circular opening near left support	1492.21
4	RC beam with circular opening near right support	1492.21

Table 9: Contd.,		
5	RC beam with central square opening	1175.37
6	RC beam with a square opening near left support	1222.74
7	RC beam with a square opening near right support	1222.74
8	RC beam having 265mm depth with central circular opening	1522.67

Table 9 shows the comparison of flexural strengths of different models analyzed. The flexural strength for square opening from ANSYS analysis was 1175.37 N/m^2 and circular opening from ANSYS analysis was 1272.31 N/m^2. While the corresponding value for the solid beam (without opening) obtained from ANSYS were 1642.97 N/m^2. The difference in the flexural strength between the solid beam and a central circular opening is about 22.5% and equivalent square opening (w = 60 mm) it is about 28.4%. It shows that square opening reduces the flexural strength more than the equivalent circular opening because stress concentration occurs at the existing orthogonal corners in square opening. If we increase the depth of beam having a central circular opening by 6% i.e. 15mm then it behaves similarly to the solid beam.

CONCLUSIONS

In this study, RC Beam model deals with the procedure of analysis within the ANSYS software and obtaining certain results from the analysis. The RC beam was subjected to four-point bending test i.e. flexure test. The RC beam has been analyzed and comparative results have been developed using explicit dynamic analysis. Using these results the conclusion on research is obtained by subsequent discussion.

- With the provision of different shapes of openings, the flexural strength of the RC beam gets reduced.
- The circular shape of the opening is found to be more efficient as the stress distribution around the circular opening is smooth.
- Square shaped opening is found less efficient when compared to the circular opening due to increase in stress concentration around sharp edges of the square opening.
- We will get the same flexural strength as that of the solid beam by increasing the depth of beam with an opening by 6%.
- Flexural strength of the beam is more when the opening is placed nearer to the supports than at a center of the beam.

REFERENCES

1. *Abdalla Hany and Kennedy,B.John., (1995), ''Design of Prestressed Concrete Beams with openings.'' Journal of Structural Engineering, Vol. 121, No. 5, 1995, pp 890-898.*
2. *Abdalla Hany and Kennedy,B.John., (1995), ''Dynamic analysis of prestressed concrete beams with openings.'',Journal of Structural Engineering,Vol.121, No.7, 1995, pp 1058-1068.*
3. *Borney, B.G.,Gene Corley,w.,Hanson John,M and Parmelee,A.R., (1977), "Prestressed concrete beams with large web openings.", PCI Journal, 1977, pp 32-61.*

4. *Darwin,D., (2000), "Design of composite beams with web openings.", Prog. Struct. Engng Mater, 2000, 2, pp 157-163.*

5. *Fahmy,E.H., (1996), "Analysis of Composite Beams with Rectangular web Openings.",Journel of Structural Engineering, Vol. 37,No.1, 1991, pp 47-62.*

6. *Hasnat Abul,Akhtaruzzaman ali A. and Wafa faizal F., (1993), "Prestressed beams with openings and no stirrups under torsion and bending.", Journal of Structural Engineering, Vol. 119, No.10, 1993, pp 2883-2895.*

7. *Mansur,M.A., (1998), "Effect of Openings on the behavior and Strength of R/C Beams in Shear.", Journel of Elsevier Science Ltd.,Vol.20, 1998, pp 477-486.*

8. *Mansur,M.A.,Lee,Y.F.,Tan,K.H. and Lee,S.L., (1991), "Tests on RC continuous beams with openings.", Journel of Structural Engineering, Vol. 117, No. 6, June,1991, pp 1593-1606.*

9. *Mansur,M.A.,Tan,K.H and Lee,S.L., (1991), "Piecewise Linear Behaviour of RC Beams with Openings.", Journel of Structural Engineering, Vol. 117, No. 6, June,1991, pp 1607-1621.*

10. *Mansur,M.A.,Ting,S.K and Lee,S.K., (1983), "Torsion tests of RC beams with large openings.", Journal of Structural Engineering, Vol.109,No. 8, 1983, pp 1780-1791.*

11. *Morkhade,S.G. and Gupta,L.M., (2015), "Analysis of steel I beams with rectangular web openings:experimental and finite element investigation.", Engineering Structures and Technologies, August,2015, pp 13-23.*

12. *Redwood,R.G. and Poumbouras,G., (1984), "Analysis of composite beams with web openings.", Journel of Structural Engineering, vol. 110,No.9, Sepetmber,1984, pp 1949-1958.*

13. *Rodrigues,F., Vellasco,P.C.G.Das., Lima,L.R.De. and Andrade,S.A.L.De., (2014), "Finite element modelling of steel beams with web openings.", Scientific Research Publishing Inc.,No.6, December,2014, pp 886-913.*

14. *Sharma S.Dharmendra., (2011), "Stress concentration around Circular / Elliptical / Triangular cutouts in Infinite Composite Plate. ",Proceedings of WCE, Vol III,2011.*

15. *Soon Ho Cho and Redwood,R.G., (1992), "Slab behavior in composite beams at opening I Analysis.",Journal of Structural Engineering, Vol.118, No.9, 1992, pp 2287-2303.*