PERFORMANCE EVALUATION OF POST-TENSIONED BEAM WITH OPENING USING DIFFERENT SHAPES AND LOCATIONS

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Abstract: In case of building, openings are provided in web of beam to accommodate utility ducts and pipes. It also provides substantial economic saving in the construction of Multi-storey building. However it is important to study the effect of opening on structure. This paper includes the study behavior of Post-tensioned Beam with opening. A various Aspects has been discussed including the effect of different opening shapes and location.The main objective of this paper is to suggest the best suitable location and shape of the opening. The complete analysis work has done by using Finite Element software ANSYS Workbench v18. Comparison of results based on static analysis of Post-tension beam.

***Index terms* –Post-tensioned beam, web opening, shear and flexure behavior, Finite element analysis, ANSYS.**

1. INTRODUCTION

In building and other structures various concrete structural components exists in different forms. Understanding the behavior of these components under the action of loading is important to construct the overall economical and safe structure. In prestressed concrete to nullify the effect of stresses resulting from applied external loads the internal stresses of suitable magnitude and distribution are introduced by tensioning the high strength tendons. Post-tensioning is a method of prestressed concrete by tensioning the tendons against the hardened concrete. In this method prestress is transmitted to concrete by bearing.

In the construction of building it is necessary to provide ducts and pipes to occupy essential services like the air-conditioning, heating, sewage, water supply systems, electricity and internet cables. Generally these pipes and ducts are placed below the soffit of the beam and for the aesthetic reasons these are covered by a suspended ceiling thus creates a dead space which reduce the effective floor height. This dead space in each floor adds to the overall building height. Therefore an alternative arrangement is used to pass these ducts through the transverse opening in the beam. For the small building the saving achieved by this may not be significant as compared to the overall cost. But for multi-storey building any saving in storey height multiplied by the number of stories a substantial saving in total height.

Several investigation has been carried out on reinforced concrete beam with opening (Flexural Behaviour of RC beam with regular square or circular web openings, 2013). Comparatively little attention has been directed toward the behavior of prestressed beams with opening. It should be noted that the design of prestressed concrete beams with an opening is more critical than the design in reinforced concrete beams. In the reinforced concrete beams the opening are usually provided in the zone below the neutral axis where the concrete is assumed to be cracked and therefore flexurally inactive. On the other hand in prestressed concrete construction the whole cross section is fully utilized and hence presence of opening will reduce the strength of such beams. In pretension beams, web openings should placed away from the regions required for the development of full tendon force. (M.A.Mansur, et al., 1999). Also beams in which opening are placed in high shear regions do not perform as well as beams in which openings are located in predominant flexural stresses (M.A.Mansur, et al., 1999). The aim of the study is to investigate the effect of opening on deflection, shear stress and flexural stresses.

2. PROGRAM OF STUDY

In this paper work has done to analyze the behavior of post-tension beam with circular and square opening at different locations. The Post-tensioned beam is designed by using the IS:1343-2012. Analysis has done for different models of post-tension beam in ANSYS Workbench v18.

2.1 Geometry of Beam

Total span of beam = 6m	Loading =35 kN/m
Width of beam = 250 mm	Eccentricity of tendon = 120 mm
Depth of beam = 500 mm	Prestressing force = 905 kN

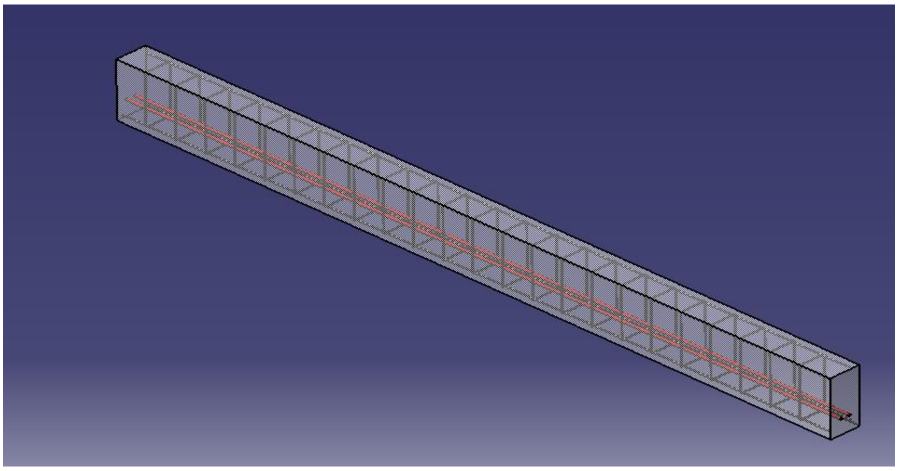

Figure 1. Modeling of Beam

2.2 **Structural Model Configuration**

Three dimensional modelling of Beam has been done in ANSYS Workbench v18 Figure 1. shows the model of beam.Following table gives information regarding material and sectional properties used for modelling.

Table 1: Material properties

Material Name	Strength (MPa)	Young's Modulus (MPa)	Poisson's Ratio
Concrete	35	3.0E+04	0.18
Main bars	415	2.0E+05	0.3
Stirrups	250	2.0E+05	0.3
Tendon	1500	1.95E+05	0.3

Table 2: Details of beams

Beam ID	Type of Opening	Size of Opening (mm)	Opening Distance from Support (m)
S1	Square	150 x 150	1.00
S2			1.50
S3			2.00
S4			2.50
S5			3.00
C1	Circular	Ø = 150	1.00
C2			1.50
C3			2.00
C4			2.50
C5			3.00

3. RESULTS

Using solid elements, Three dimensional elastic finite element (FE) analysis of the beams is done. The main variables were opening shape and locations. A finite Element model using ANSYS Workbench v18 was developed and used to:

1. Predict the behavior of the beams and identify areas of stress concentrations.
2. Perform a parametric study to optimize the opening geometry and locations.

3.1 **Beam without Opening**

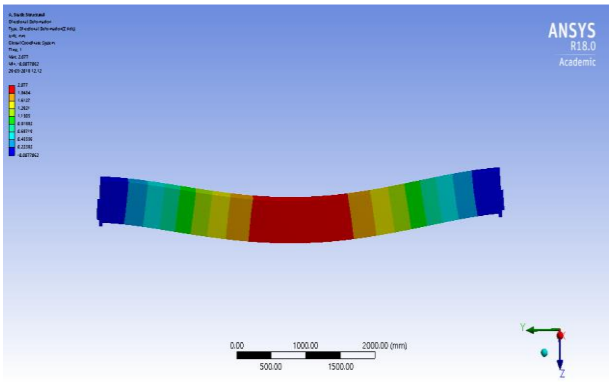

Figure 2. Deflection

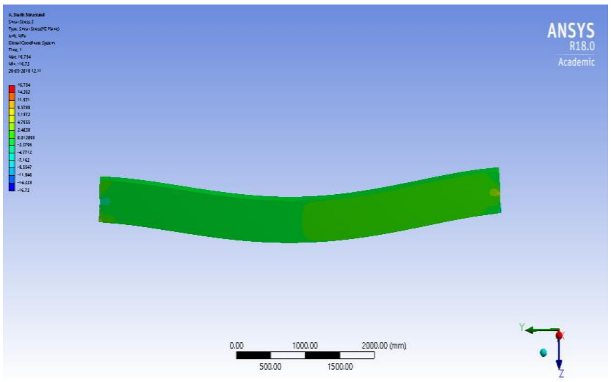

Figure 3. shear stress

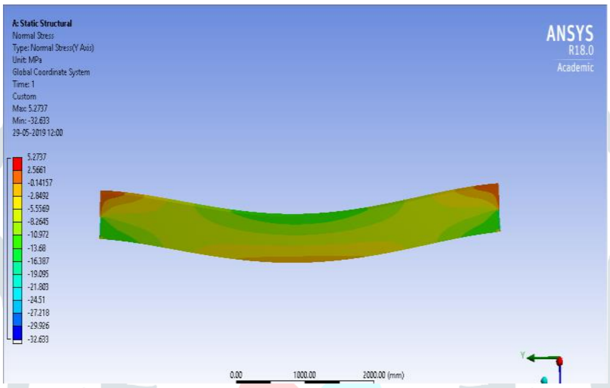

Figure 4. Normal stress

4.2 Beam with Opening

i) Deflection

Following table gives the deflection of beam in mm for square and circular opening;

Table 3: Deflection of beam

Opening Location from Support (m)	Square Opening (mm)	Circular Opening (mm)
1.00	2.11	2.08
1.50	2.13	2.10
2.00	2.14	2.12
2.50	2.16	2.13
3.00	2.18	2.16

ii) Shear stress

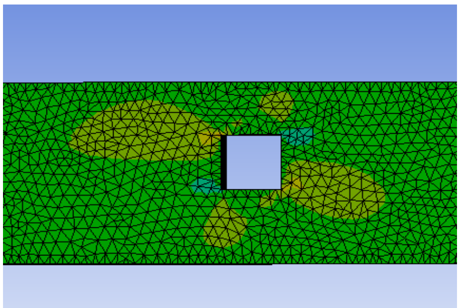

Figure 5. Shear stress around square opening

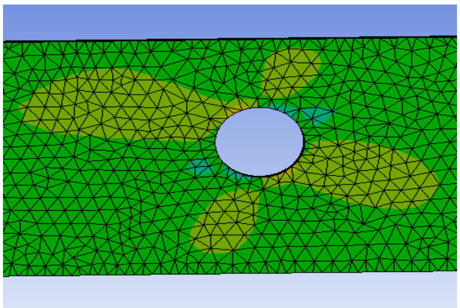

Figure 6. Shear stress around circular opening

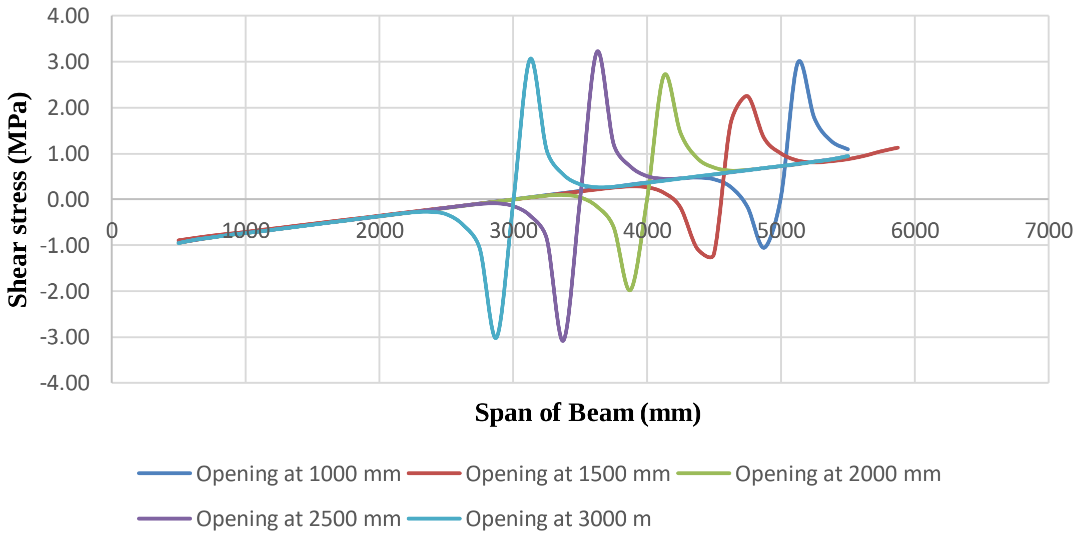

Figure 7. Shear stress for square opening at top level of opening

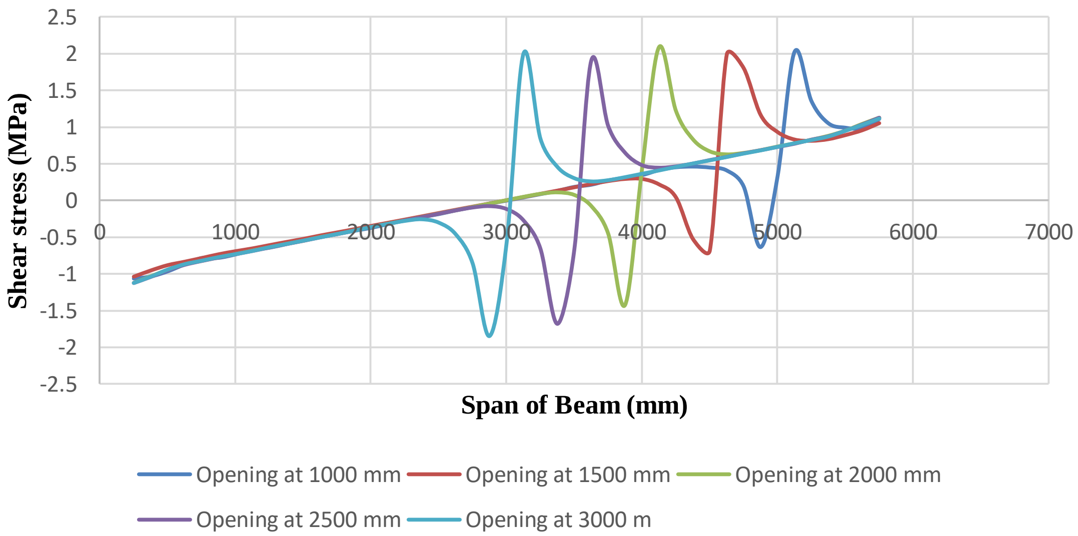

Figure 8. Shear stress for circular opening at top level of opening

iii) **Normal stress**

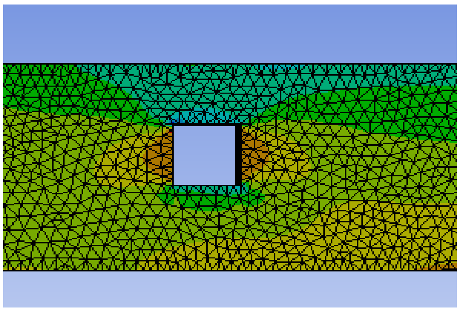

Figure 9. Normal stress around square opening

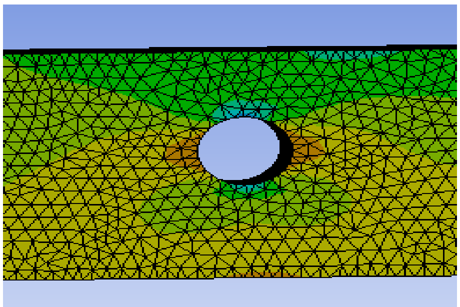

Figure 10. Normal stress around circular opening

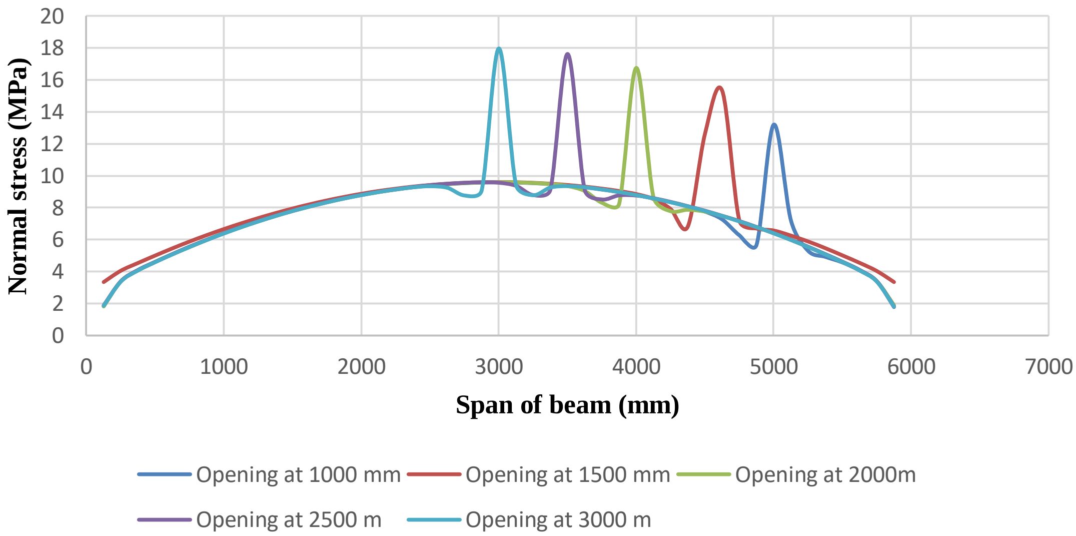

Figure 11. Normal stress for square opening at top level of opening

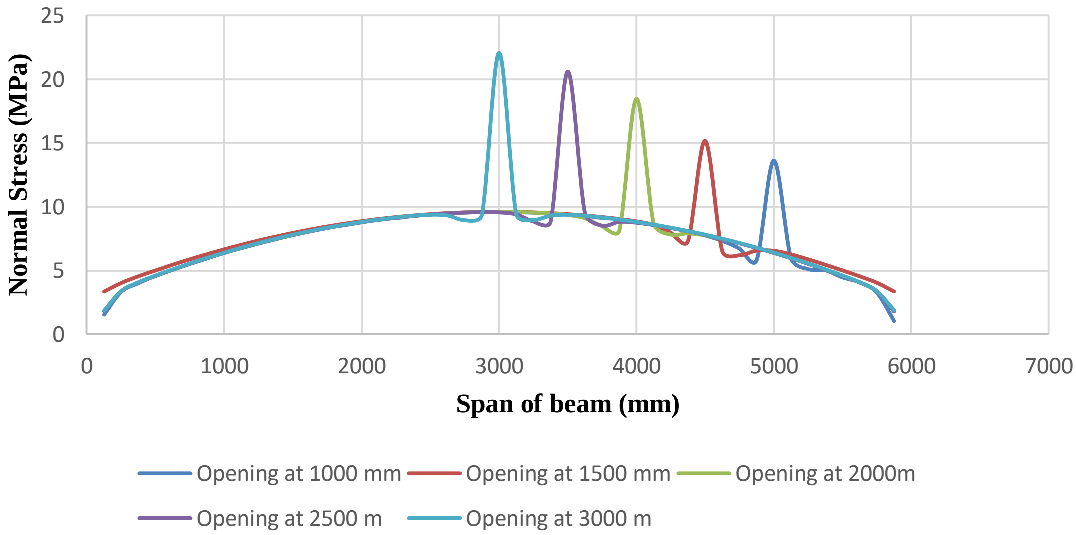

Figure 12. Normal stress for circular opening at top level of opening

4. DISCUSSION

1. Table 3. Shows the results of deflection of beam for different shape configurations and location of opening. It is observed that, due to the opening in beam the maximum deflection of beam increases. As opening location changes it will not show much significant change in the deflection but as we move opening towards the support the deflection is goes on reducing. Also it is observed that the circular opening shows the less deflection as compared with the square opening.
2. It is observed that the maximum shear stress occur at the opening corners with the different signs. Applying the vertical load causes vertical tensile stress which causes stress concentration at the upper left and the lower right corners of the opening. Due to this the shear carried by the concrete elements at these two corners decrease. As a result the other two corners which are subjects to vertical compressive stresses will carry more shear stresses. Figure 2. And figure 3. Shows the effect of opening around the square and circular opening respectively. From figure 3. And figure 4. it is observed that the value of shear stress is less at the location 1.5 m from the support in case of both circular and square opening. It is also observed that the shear stress around the opening are less in circular opening as compared with the square opening.
3. As due to the opening the moment of inertia of section is reduced at that location therefore the increase in the normal stresses is observed at the vicinity of the opening. Figure.9 and figure.10 shows the normal stress distribution around the square and circular opening respectively. From figure 11. And figure 12 it is observed that as we move opening near the center span of the beam the normal stress around the corners are increases.

5. CONCLUSION

Analysis was carried out to determine the static load response of prestressed beams with square and circular opening. Based on the results and above discusssions the following conclusions can be made.

1. It has observed that the presence of opening does not have a significant influence on the maximum midspan deflection of the beam.
2. The circular opening has the better performance under the influence of the loads as compared with the square opening.
3. The prestressed concrete beam with opening may crack in different patterns a) Cracking at the upper left and lower right corners of the opening. b) flexural cracking at the corners of the opening due to secondary moments. c) Cracking at opening at opening corners due to shear.

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