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Web Openings in Steel Beam Structures

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Abstract— ***In modern buildings, the openings are provided in beam flanges for ventilation ducts, electrical wirings etc. which may reduce the strength of beams. The objective of current research is to evaluate the strength of I shaped beam with and without web opening using Finite Element Method. The CAD modelling and structural analysis of beam is conducted in ANSYS simulation package. The use of computer simulation package can enable to evaluate the effect of web openings on beams. From the FEA analysis, the critical regions of high stresses and deformation are identified. The incorporation of rectangular web opening in beams caused reduction in strength of beam significantly.***

Index Terms— ***Web Openings, FEA, Beams***

I. INTRODUCTION

In various cases, the building structures are required to have openings to facilitate ducting, tubes, pipes, electric cables. The incorporation of web openings may affect the serviceability and strength of beams which significantly reduces the load carrying capacity of beams [1,2].

Figure 1: Web openings in beams [12]

With the reduction in moment of inertia of beams, the deflection in beams is reduced. The interaction of shear and moment causes plastic deformation in beams with web openings. The moment capacity of beam with web openings also reduces as its resistance is by beam flange. Nevertheless, the reduction in shear resistance at a section within the openings is substantial [3]. The loss of strength can be compensated with the reinforcement of openings and not placing the openings in close proximity.

II. LITERATURE REVIEW

Chen et al. [4] have conducted analysis on beams encompassing web openings. The analysis type conducted is of numerical nonlinear type. From the research the effect of plate moment-shear ration, opening size is evaluated to determine the mechanical behaviour of beams. The research findings have shown that by applying stiffeners, the mechanical behaviour of beams with openings can be improved.

Li et al. [5] have conducted numerical investigation on continuous steel-concrete composite beams encompassing web openings. The analysis is conducted with nonlinear techniques in ANSYS software. The effect of reinforcement rate and slab thickness is investigated and the effect of geometric imperfections is evaluated.

Gizejowski and Khalil et. al. [6] have conducted research on cellular composite beams which is subjected to negative moment. The research findings have shown that due to web distortion the compression is observed at the bottom surface of the flange.

Redwood and Wong et. al. [7] have conducted experimental investigation on composite beams with web openings to determine the different failure modes. The testing is conducted for low moment-shear ratio and for high moment shear ratio. The research findings have shown that failure modes of beams are governed by vierendeel mechanism in concrete beams.

Chung and Lawson et. al. [8] have conducted research on developing methodologies in developing design procedure for composite beams. The procedure is based on opening dimensions in beams. The opening dimensions are based on bending strength and shear strength.

In Lawson et al. [9] have conducted research on vierendeel mechanism in composite beams. The composite beams encompassed rectangular web openings. The effect of longitudinal stiffeners in local bending of beams is evaluated along with shear transfer. The "tests presented ductile behaviour, without the occurrence of cracking and crushing of the concrete, and web buckling. The formation of the Vierendeel mechanism governed the resistant capacity of the experimental tests. The results were compared with Lawson's publication. The method was based on the previous experimental tests" [10,11].

III. OBJECTIVE

The objective of current research is to evaluate the strength of I shaped beam with and without web opening using Finite Element Method. The CAD modelling and structural analysis of beam is conducted in ANSYS simulation package.

IV. MET HODOLOGY

The methodology proce ss involves modeling of I shape beam. The beam dime nsions are taken as sh own in figure 2. The beam cross section is extruded and meshed as shown in figure 3.

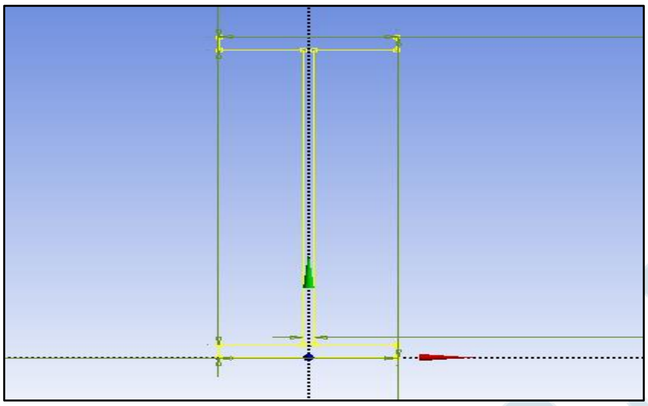

Figure 2: Dimensions of I beam

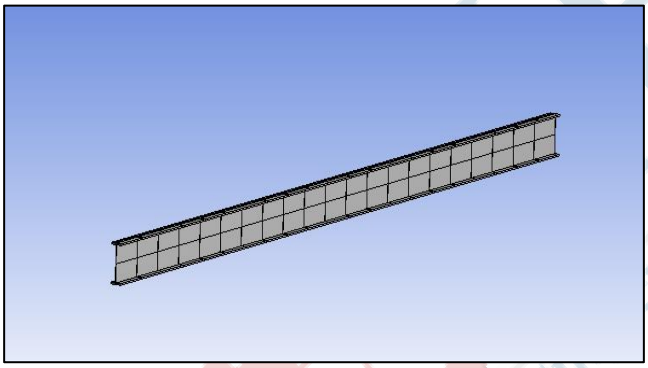

Figure 3: Meshed model of I beam

The beam model is meshed with hexahedral/brick elements. The element sizing is set to fine and 1.2 growth rate with adaptive shape function.

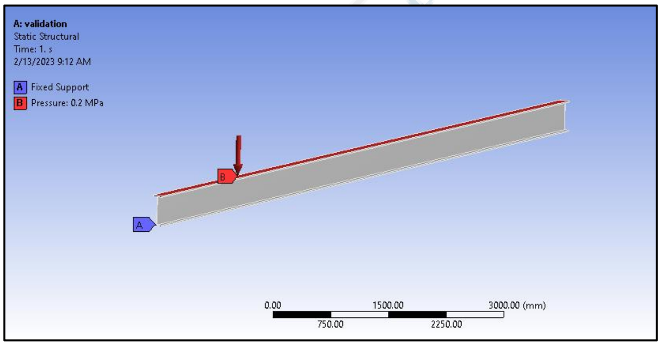

Figure 4: Loads and boundary condition on I beam

The structural loads and boundary conditions are applied on I shaped beam. The structural boundary conditions include fixed support at the side surfaces and pressure of 0.2MPa at the top surface of the beam as shown in figure 4 above.

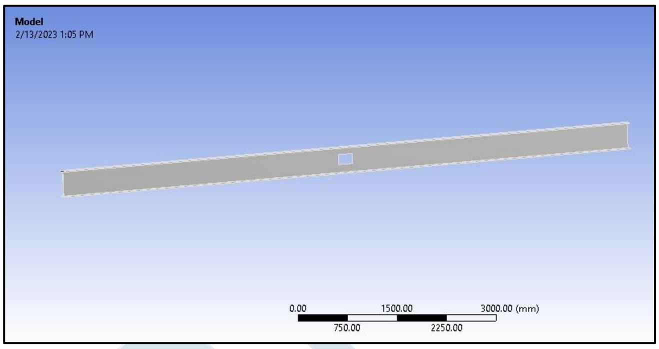

Figure 5: CAD model of beam with opening

The subsequent analysis is conducted on beam with web opening. The web opening is provided at the center of the beam which is of rectangular shape. The FEA analysis is then run to determine deformation, stresses.

V. RESULTS AND DISCUSSION

From the FEA simulation, the equivalent stress plot is obtained for the beam with I section. The equivalent stress distribution plot shows high magnitude of stress at the corner ends wherein the magnitude is more than 198MPa and is lower at the mid-section of the beam.

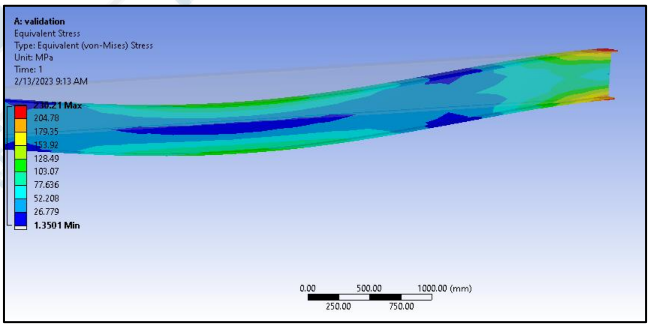

Figure 6: Equivalent stress distribution of beam

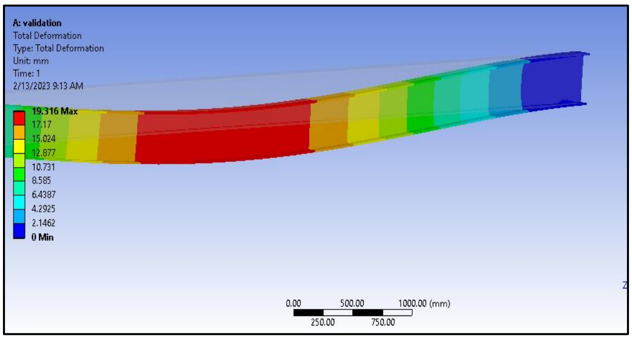

Figure 7: Deformation plot of beam

The total deformation distribution plot is obtained for the I shaped beam as shown in figure 7 above. The deformation is obtained at the center of the beam with magnitude of more than 17mm. The deformation is lower at the corner end of the beam.

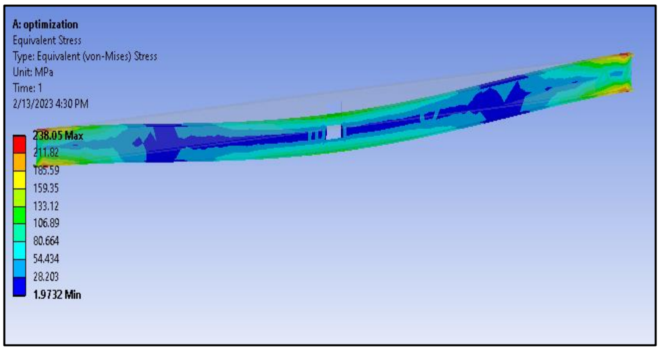

Figure 8: Equivalent stress plot of beam with opening

The equivalent stress distribution plot is generated for beam with rectangular opening as shown in figure 8 above. The equivalent stress is higher at the corner of the beams with magnitude of more than 211MPa and is lower at the center of the beam with magnitude lesser than 55MPa.

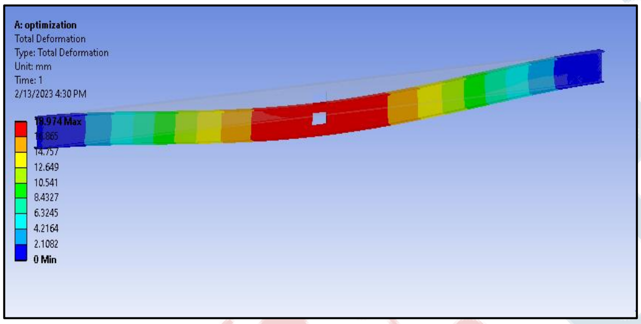

Figure 9: Total deformation plot of beam with opening

The total deformation distribution plot is obtained for the I shaped beam with rectangular web opening as shown in figure 9 above. The deformation is obtained at the center of the beam with magnitude of more than 16.86mm. The deformation is lower at the corner end of the beam.

VI. CONCLUSION

The use of computer simulation package can enable to evaluate the effect of web openings on beams. From the FEA analysis, the critical regions of high stresses and deformation are identified. The incorporation of rectangular web opening in beams caused reduction in strength of beam significantly.

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