Finite Element Analysis of steel beam with web opening of different shapes

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Abstract- In this paper, analytical models for calculating the deflections due to uniformly applied transverse loads have been developed. A steel beam is selected and is analyzed for constant loading and support condition by using ANSYS software and the stress and deflection pattern at the center of beam is studied for different parametric conditions by changing section of beams and by changing the position of openings along the length of the beam. Area of opening is constant. Graphs are plotted for each condition to get comparative results. An investigation of previous literature on steel beams with web openings was conducted for deflections, shear and moment from which data were obtained in order to make comparison between theoretical results and software results.

Keyword- finite element analysis; web openings; directional deformation; von mises stresses.

INTRODUCTION

Steel beams with web openings are combine beauty, versatility, economy in steel design. These are fabricated from standard rolled section and are engineered to save time of construction, enabling saving in steel and reducing building cost. In modern building, openings are frequently required to be provided in structural members so that building services may be incorporated into structural zones for simplified layout and installation.

Moreover, the overall depth of the construction zone may be reduced accordingly, and this is beneficial for multi-storey buildings with large headroom requirement. As reported by Lawson (1987), Darwin (1990), Redwood (1993), K.F. Chung, C.H. Liu and A.C.H. Ko (2003), the presence of large web openings may have a severe penalty on the load carrying capacities of floor beams, depending on the shapes, sizes, and the locations of openings.

The main initiative for producing and use of such sections is to suppress the cost of material by applying more efficient cross sectional shapes made from standard profiles in combination with aesthetic and architectural design considerations. The web openings can also be utilized for cross passing utility systems in building floors. Though, the production cost for short span beams is higher than the material economy. Thus the majority of cases in which such beam types are employed are long span applications, where the main consideration in the design is the moment carrying capacity of the member.

In the present work, finite element models have been developed, and different failure patterns like Vierendeel mechanism, shear failure, Y-directional deformation and Von mises Stress patterns are studied for different parameters. Data were obtained in order to make comparison between theoretical results and software results. Graphs are plotted for each condition to study the structural behaviour.
FINITE ELEMENT ANALYSIS

In this paper, a three dimensional (3D) finite element model is developed to stimulate the behavior of steel beams with web openings having an I-shaped cross section. Various finite element models for determining the Y-directional deformations and von mises stresses of I-beam with various shapes of web openings are developed and useful results have been obtained. More specifically, 4m-span simply supported I-beam models have been analyzed and the corresponding deflections and stresses are obtained for a variety of cross sectional geometries, shapes and size of beams as listed in table 1. where d is depth of web opening, D is depth of beam. Modeling is conducted using the general purpose finite element software package ANSYS. In fig. 1. A representative model case of a steel beam with web openings subjected to uniformly distributed load of 100 kN/m² and typical finite element mesh is shown. All web openings are concentric to the mid height of the sections.

All finite element models are discretized into a refined mesh of elements sufficient to produce accurate results. The model shown in fig. 1 has been discretized into 2266 elements with 4673 nodes, while the same mesh pattern is kept the same to all model cases. In this paper four different opening shapes, five different section sizes for constant area of web openings, constant load and different positions of opening were covered. All parameters are shown in table 1.

Table 1. Parametric characteristics of finite element I-beam models

<table>
<thead>
<tr>
<th>Size of beam</th>
<th>Shapes of openings</th>
<th>Position of openings</th>
<th>d/D ratio</th>
<th>Load</th>
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ANSYS GEOMETRY MODELS

ANSYS models for analysis of ISMB-300 beam, d/D=0.5, at position 0.5m, 1m, 1.5m, 2m, for circular web openings is carried out. Y-directional deformation and von mises stresses are shown. Similarly we have done analysis for ISMB-350, 400, 450, 500 for hexagonal, octagonal and square web openings.

(a) Deflection for position of opening at 0.5m
(b) Deflection for position of opening at 1m
(c) Deflection for position of opening at 1.5m
(d) Deflection for position of opening at 2m

(a) Von mises stress for position of opening at 0.5m
(b) Von mises stress for position of opening at 1m
(c) Von mises stress for position of opening at 1.5m
(d) Von mises stress for position of opening at 2m
### TABLES FOR DEFLECTIONS

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### TABLES FOR STRESSES

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Table 2. Y-directional deformation (mm) and Von mises stresses(kN/m²)
GRAPHS FOR DEFLECTION AND STRESSES

Graphs are plotted for length versus deflection, and length versus stresses, for ISMB-300 as shown below. Similarly we have plotted for all ISMB.

Graph 1. Graphs for deflection (mm) and stresses (kN/m²) for all openings.
CONCLUSIONS

The analysis of steel beams with web openings for deflection and stresses is done by ANSYS software. Area of opening and load are constant and the results are observed from table2 and graph1.

As size of beam is increasing, deflection of beam is decreasing. Deflection for ISMB-300 is more and deflection for ISMB-500 is least. As the web opening move towards the center of beam, deflection goes on reducing. Deflection for circular opening is least as compared to all other openings. Deflection for square opening is more among all the openings considered. Deflection is less in solid web beams as compared to beam with web openings. As web openings move towards the center of beam, stress goes on decreasing. Stress is decreasing as section of beam is increasing. Stress is more for ISMB-300 and least for ISMB-500. Stress is least for circular web opening and more for square web opening.

REFERENCES


