Study of Steel Beam with Web Openings: A Review

Arpit Jaiswal
M. Tech Student
Department of Civil Engineering
G.H.R.C.E, Nagpur

Dr. P.Y. Pawade
Head of the Department
Department of Civil Engineering
G.H.R.C.E, Nagpur

Prof. K. R. Dabhekar
Assistant Professor
Department of Civil Engineering
G.H.R.C.E, Nagpur

Abstract

The basis of this study is the serviceability requirement which arouse long after the structural erection has been completed. Beams with web openings can be competitive in such cases, even though more alternatives to solid web beams such as stub girders, trusses etc. are available and height limitation is common problem faced by designers in multistoried buildings due to economic requirements and aesthetical considerations. Substantial spaces are normally required to enable the passage for large pipes and ducts beneath steel beams which leads to uneconomic floor heights. Though web openings could lead to a significant decrease in beam's load carrying capacity depending on the adopted openings shape, size and location but can also be very helpful and important from the point of economy. So this study is concerned with the influence of the web opening on the strength of compressive elements and web crippling strength of steel sections. And the parametric analysis to be focused on size and location of opening. The paper summarizes the relevant study of provisions as given in the corresponding design standard and software based finite element analysis carried out by different authors and review the problem to arrive at meaningful conclusion for the study. And suggestion regarding the scope of further work.

Keywords: Non-Linear Analysis, Steel Structures, Steel beam with web openings, parametric study, ANSYS, Finite element method

I. INTRODUCTION

Steel beams with web openings when provided in place of structural members can affect the strength and other aspects of design. Openings are frequently provided in the structural members so that building services may be incorporated into structural zones and provide simplified layout and installation. The main initiative for use of such sections is the economy and future service requirements.

Beams with web openings can be competitive in cases where long span applications, where the main consideration in the design is moment carrying capacity of members. This type of construction help in achieving a smaller floor depth with placement of services within the beam depth, at the most appropriate locations. When opening in the web of the beam is introduced, it

Fig. 1: Possible Applications of Such Beams

alters the stress distribution within the member and also influences the collapse behavior. Thus, the efficient design of beams and plate girder sections with web openings has become one of the important considerations in modern structures.

Beams with web openings find its application in wide range of construction, specifically in long span structures as if provided in small span construction the cost of production of such members exceeds the economy of the construction. Service incorporations can be condemned within the openings and efficient construction can be achieved.

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Researchers such as Bower (1968), Lawson (1987), and Darwin (1990) have stated that the presence of web openings may have big drawback on load-carrying capacity of structural

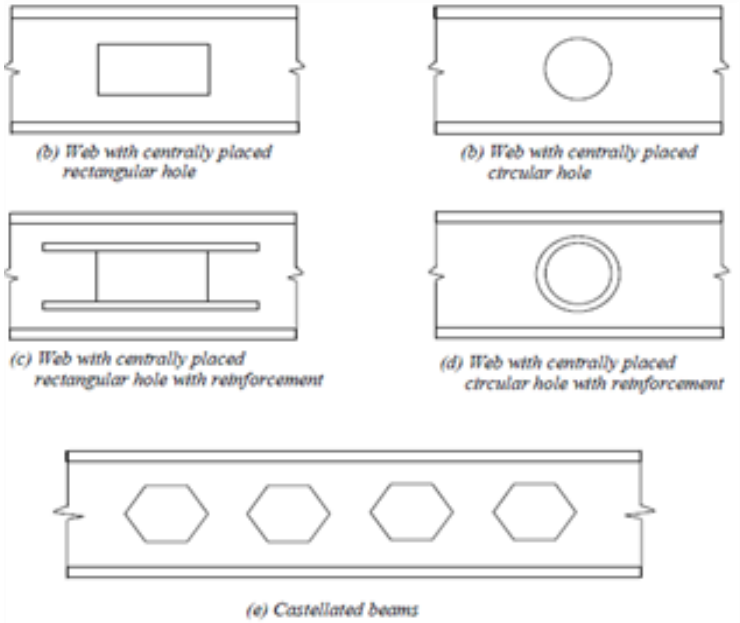

Fig. 2: Common types of Web Opening

members. However, the present design guides and specifications for such beams are either inadequate or difficult to use (SCI P355 2011). This may be due to the fact that the behavior of I-Beams with web openings is complex to understand, analyze and difficult to simplify the design procedures. Therefore, it is imperative that more elaborate investigations are carried out to provide sufficient information to understand the behavior so that a simple design method could be developed.

II. LITERATURE REVIEW

In the later 20th century, studies on different web opening configurations were completed in the US and Canada, including rectangular, circular, square, eccentric concentric, and openings in both non-composite and composite steel beams. In the late 1980s, Darwin and Donahey (1988), Darwin and Lucas (1990) and Darwin (1990) demonstrated that it is possible to produce a unified procedure embodying the different cases that are frequently used in steel building structures. Some national standards, provide simplified rules for opening design in order to avoid weakening of the beam. However, these rules cover a wide range of possibilities, and, therefore, they are very conservative and, in general, restrict the openings to the middle third of the beam depth and to the two central quarters of the beam span. By fixing some parameters, it would be possible to get more flexible and economical results for typical situations in the floors of buildings.

Flavio Rodrigues, Pedro C. G. da S. Vellasco, Luciano R. O. de Lima, Sebastião A. L. de Andrade in the paper "Finite Element Modelling of Steel Beams with Web Openings", presented the web opening FE simulations are calibrated against numerical and test results. The results accuracy enabled a comprehensive parametric analysis of beams with web openings to be made focused on the profile size, web opening location, among others. The obtained results showed the need of using welded longitudinal stiffeners in order to increase the beams ultimate load carrying capacity. The present investigation confirmed that their adoption can double or even triple the ultimate load of beams with rectangular and square opening heights equal to three quarters of the beams height i.e. 0.75 H, respectively.

Gustavo De Souza Veríssimo and Ricardo Hallal Fakury in "Design Aids for Unreinforced Web Openings in Steel and Composite Beams with W-Shapes" presented the results of computational simulations in non-composite and composite steel beams with web openings, based on a unified procedure developed by Darwin (1990), and it is limited to W-shape sections. They provide design aids that allow the identification of the beam region where unreinforced openings with specific characteristics do not reduce the member capacity. And they are compatible with the LRFD Specification for Structural Steel Buildings (AISC, 1999-a) were obtained from computational analyses based on Darwin (1990) to facilitate the design of web openings in steel and composite beams with W-shapes. The set of design aids allow to identify the "neutral zone", a region in the beam web in which openings with some particular characteristics do not reduce the beam strength. This leads to more economical web penetrations.

K. S. Sivakumaran in their paper "Some studies on cold-formed steel sections with web openings" dealt with the influence of a web opening on the (a) strength of compressive elements and (b) web crippling strength of cold-formed steel sections and has been examined through experimental research on C-shaped lipped channel section. The study concluded with some intense results, viz the effective design width equation as given in the Canadian design code [5] may overestimate the strength, the web opening

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reduces the strength and the influence should be considered in the design and the shape of an opening does not appear to be a governing parameter.

Konstantinos-Daniel Tsavdaridis, Cedric D'Mello in "Vierendeel Bending Study of Perforated Steel Beams with Various Novel Web Opening Shapes, through Non-linear Finite Element Analyses" presented a comprehensive FE investigation on perforated beams with circular and novel non-standard web opening shapes was carried out which shows how the Vierendeel mechanism is affected not only by the size, but also by the shape of the web openings. These investigation on novel elliptical web openings presents some positive results and update the current knowledge. Based on the FE model, improvements to the assessment of load carrying capacities of steel beams with large web openings have been obtained by careful observation of plastic hinge formation at both the LMS and the HMS of the perforated sections. The outcome of this research can be effectively applied in various engineering fields, enhancing the structural behaviour of perforated structural forms, without adding stiffeners or taking other strengthening precautions, and prevent local instability due to high stress concentration at specific locations in the vicinity of the web openings, by better understanding of the failure mechanisms.

Prof. R. R. Jichkar, Prof. N. S. Arukia, Prof. P. D. Pachpor in "Analysis of Steel Beam with Web Openings Subjected To Buckling Load" performed buckling load analysis and deflection calculation of different section of beams with different support condition and different loadings with circular, square and hexagonal web openings is done. As the result they found when the section of beam increases, the buckling load will also be increased and it goes on a decrease as the web openings are provided in the section, as number of web opening in the beam increases the buckling load goes on decreasing but deflection of beam will also increase. Cellular beam subjected to mid span concentrated load provide higher moment carrying capacity than those supporting uniformly distributed load.

III. NEED OF STUDY

The use of steel beams with large openings is a practical solution when it is required to pass service ducts and other elements through the structural zone of the beams. However, the presence of large openings in web raises additional considerations. And the studies in the past does not contribute to any Indian standard codes which lacks the guidance for structural designers and engineers to emerge such type of construction. Design guidance was given by SCI publication in design of steel and composite beams with web openings.

IV. CONCLUSION

Following conclusions can be derived from the studies from various studies;

- Different types of openings can affect the beam in different way, so the shape also to be taken under consideration. Web openings affects load carrying capacity badly in structural members.
- Present codes and design specification are difficult to use or lacks details. Which make it difficult to use in practical.
- I-beams with openings shows more complex behaviour than other steel objects which makes it more difficult to understand and use.
- Different research and studies used simplistic approaches lead to different methods and amendments in design guide such as
- Method developed at SCI in 1990 was also incorporated in an amendment in Euro code 3 for beams with web opening.
- Many Authors done experiments and finite element studies on cellular beams and other steel beams with openings for different parameters.

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