

# A Review - Optimization of Castellated Beam with Stiffener

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**Abstract** - Optimization of stiffener for the castellated beam element is principal issue of the future demand of construction industry to tackle many structural failure problems in castellated beam. The make use of castellated beam construction is rising fast as it offers well-organized and inexpensive structure with more strength in addition to reduced steel quantity of steel. Also, there is decrease in overall accumulation of the frame which helps in satisfying the performance of the structure. The design procedures suggested by various codes are given in accordance with some empirical formulae. The study of the complex behaviour of the castellated beam with stiffener is not yet completely revealed. Consequently current study defines the behaviour of the castellated beam with stiffeners and further extends to optimization of stiffeners considering location size and its thickness.

**Key Words:** Castellated beam, codes, stiffener, behaviour, optimization, performance.

## 1. INTRODUCTION

Castellated beam have had infrequent practice inside this state for many years, throughout which time they were shaped by uncomplicated hand procedures. Even if these manufacture methods were not favourable to wide growth, castellated beams have long been documented as helpful structural members. The pattern of holes in the web presents an attractive demonstration for beams uncovered to view. The web holes are unappealing still extra purposeful with the increase of piping, conduits and ductwork in present building. The majority benefit, however, is the economy effect by the increased load carrying capacity and stiffness. In developing this structural member, this Mississippi valley structural steel. Carried on top of a wide-ranging program of intend examination, manufacture studies in addition to economic comparisons. European production methods and product applications were reviewed, because resting on that continent castellated beams have been used extensively for much natural life. This development took place in Europe because of the limited numeral of sections available from European mills and because of the high ratio of material price to labour cost. Study and appraisal of this process led to the conclusion that it is particularly adaptable to large volume production and automatic methods; therefore the tackle and the constitutional rights for its use be acquired. The development of well-organized production has opened a broad new field of economical applications of castellated beams. In the last few years such members have been used as various types of structural elements in many different kinds of buildings.

## 2. LITERATURE SURVEY

**S. Durif and A. Bouchair (2016)**, Experimental and numerical investigations have been conducted on cellular beams with sinusoidal openings. They showed specific failure modes, in comparison with common opening shapes, mainly the local buckling of the panels around the opening. Detailed analysis of the stress distribution around the openings allowed understanding the behaviour of those beams at ultimate limit state with the aim to develop a specific analytical model. The direct application of existing analytical approaches to beams with sinusoidal openings showed that the predictions need to be improved. Indeed, in order to obtain an accurate prediction of the buckling strength of the web sinusoidal parts, the analytical model is modified. In this paper, an analytical approach is proposed, based on the existing methods for multiple openings and on the plate buckling theory. A formula for the calculation of the critical stress coefficient is proposed and a simple method is described to take into account the additional strength. This approach considers simple equivalent rectangular plates. The analytical model is validated against finite element results regarding the values of critical stress coefficient obtained through an Eulerian calculation. Then, the ultimate strengths of cellular beams with sinusoidal openings are evaluated through a comparative study with FEM for different parent beam profiles and opening shapes.

**Amin Mohebkah, Mojtaba G. Azandariani (2015)**, Lateral-torsional buckling (LTB) resistance of an I-beam depends on the minor axis moment of inertia of its compression flange and torsional rigidity of the section. A practical solution to increase lateral buckling of I-beams is to add two Delta stiffeners between the compression flange and web plates to form a hollow compression flange. Although these beams known as Delta hollow flange beams (DHFBS) have been introduced about half a century ago for bridge construction, however, their LTB behavior has not been investigated, yet. This paper develops a three dimensional finite-element model using ABAQUS for the inelastic nonlinear flexural-torsional analysis of DHFBs and uses it to investigate the effects of unbraced length and central off-shear center loading (located at center, top flange and bottom flange) on their moment gradient factor in different behavioural zones. It was found that the  $C_b$  factor and moment resistance curve given by AISC-LRFD in Specification for structural steel buildings are not accurate for intermediate (inelastic) and short plastic DHFBs leading to an unconservative design. Therefore, a modified moment resistance equation is proposed to be used instead of the

code equation in inelastic zone for the investigated load cases in this paper.

**Delphine Sonck and Jan Belis (2015)**, The evenly spaced circular web openings in I-section cellular beams have an advantageous effect on the material use if these beams are loaded in strong-axis bending. However, not all aspects of the behavior of such beams have been studied adequately, such as the lateral-torsional buckling failure. For the latter failure mode, the existing design approaches conflict. Furthermore, the detrimental effect of the modification of the residual stresses by the production process, as recently demonstrated by the authors in previous work, was never taken into account. In this paper, the lateral-torsional buckling behavior of cellular beams is investigated using a numerical model that was validated based on experimental results. In this model, the effect of the modified residual stress pattern was aptly taken into account. Using the results of the parametric study, a preliminary design approach was proposed. This approach is based on the currently existing European guidelines for the calculation of the lateral-torsional buckling resistance of I-section beams, but with a modified calculation of the cross-sectional properties and a modified buckling curve selection.

**Konstantinos Daniel Tsavdaridis James J. Kingman, Vassili V. Toropov (2015)**, This paper focuses on the application of structural topology optimization technique to design steel perforated I-sections as a first attempt to replace the traditional cellular beams and better understand the mechanisms involved when subjected to bending and shear actions. An optimum web opening configuration is suggested based on the results of parametric studies. A FE analysis is further employed to determine the performance of the optimized beam in comparison to the conventional widely used cellular type beam. It is found that the optimized beam over performs in terms of load carrying capacities, deformations, and stress intensities. Barriers to the implementation of the topology optimization technique to the routine design of beam web are highlighted

**Khaled M. El-Sawy, Amr M.I. Sweedan, Mohammad Iqbal Martini (2014)**, The flexural capacity of cellular steel beams is influenced by both local and global instabilities. In the current paper, the finite element method is employed to investigate the inelastic behavior of cellular steel beams under combined buckling modes. A three-dimensional non-linear finite element model, that takes into consideration possible interaction between lateral torsional/distortional buckling modes and localized deformations of the cross section is developed and validated against available results in the literature. The study considers simply supported beams subjected to three different load configurations; mid-span load, uniformly distributed load and end moments. An extensive parametric analysis is conducted to assess the impact of various geometrical parameters on the inelastic stability of cellular steel beams. These parameters include the dimensions of the beam cross-section; flange width and thickness, web height and thickness, and hole size and

spacing. The moment gradient factors that correspond to various buckling modes experienced by the wide range of dimensions considered in the simulation study are reported. The outcomes of this study are expected to provide more insight into the behavior of cellular steel beams and enable accurate prediction of the moment gradient factor and consequently the flexural capacity of this special type of steel beams.

**Peijun Wang, Xudong Wang, Ning Ma (2014)**, The shear buckling behavior of the web-post in a castellated steel beam with fillet corner hexagonal web openings is studied using the finite element method. The buckling modes and buckling capacity of the web-post in the castellated beam with fillet corner hexagonal web openings are compared with those having circular and elongated circular openings. The web-post in a castellated steel beam with the proposed opening shape can achieve as good structural performance as that with circular openings. The effects of the opening distance, the opening height, and the web thickness on the buckling behavior of the web-post are investigated. The Strut Model is modified for predicating the shear buckling capacity of the web-post in the castellated steel beam with fillet corner openings. The equivalent rectangular opening is also modified to calculate the Vierendeel failure capacity of the castellated steel beam with the fillet corner hexagonal openings at the perforated sections. The load bearing capacity of the castellated steel beam with the proposed opening shape is the minimum value among the web-post buckling capacity, the Vierendeel failure capacity at the perforated section, and the shear rupture capacity of the horizontal weld.

**Ferhat Erdal and Mehmet Polat Saka (2013)**, The objective of the current research is to present ultimate load carrying capacities and finite element analysis of optimally designed steel cellular beams under loading conditions. The tests have been carried out on twelve full-scale non-composite cellular beams. There are three different types of NPI\_CB\_240, NPI\_CB\_260 and NPI\_CB\_280 I-section beams, and four tests have been conducted for each specimen. These optimally designed beams which have beginning span lengths of 3000 mm are subjected to point load acting in the middle of upper flange. The design method for the beams is the harmony search method and the design constraints are implemented from BS 5950 provisions. The last part of the study focuses on performing a numerical study on steel cellular beams by utilizing finite element analysis. The finite element method has been used to simulate the experimental work by using finite element modeling to verify the test results and to investigate the nonlinear behaviour of failure modes such as web-post buckling and Vierendeel bending of steel cellular beams.

**Ehab Ellobody (2012)**, This paper discusses the nonlinear analysis of normal and high strength cellular steel beams under combined buckling modes. A nonlinear 3-D finite element model has been developed, which accounted for the initial geometric imperfection, residual stresses and material

nonlinearities of flange and web portions of cellular steel beams. The nonlinear finite element model was verified against tests on cellular steel beams having different lengths, different cross-sections, different loading conditions and different failure modes. Failure loads, load–mid-span deflection relationships and failure modes of cellular steel beams were predicted from the finite element analysis. An extensive parametric study involving one hundred and twenty cellular steel beams was performed using the verified finite element model to study the effects of the change in cross-section geometries, beam length and steel strength on the strength and buckling behaviour of cellular steel beams. The results of the parametric study has shown that cellular steel beams failing due to combined web distortional and web-post buckling modes exhibited a considerable decrease in the failure loads. It is also shown that the use of high strength steel offers a considerable increase in the failure loads of less slender cellular steel beams. The failure loads predicted from the finite element model were compared with that predicted from Australian Standards for steel beams under lateral torsional buckling. It is shown that the Specification predictions are generally conservative for normal strength cellular steel beams failing by lateral torsional buckling, unconservative for cellular steel beams failing by combined web distortional and web-post buckling and quite conservative for high strength cellular steel beams failing by lateral torsional buckling.

**Hossein Showkati, Tohid Ghanbari Ghazijahani, et al. (2012)** Castellated beams are widely used as flexural members in steel construction. The economical and structural advantages of these elements have prompted many researchers to investigate the failure behavior of such structures. Despite numerous reported researches on the buckling stability of castellated beams, no experimental study is found on lateral–torsional buckling of these elements with elastic bracing. In this paper, the experimental study of nine full-scale castellated beams is reported with the aim of investigation of the performance as well as effect of elastic bracing on the buckling stability of these structural elements. In addition to the presentation of the experimental observations and findings, the current test results are compared with the results of other reported experimental, analytical and numerical studies. Ultimately, the experimental findings and results are evaluated by considering the AISC 360–05 code requirements and predictions.

**M.R. Soltani, A. Bouchair, M. Mimoune (2012),** A numerical model is developed to predict the behaviour of castellated beams with hexagonal and octagonal openings up to failure. The numerical model takes into account both material and geometric nonlinearities. To initiate buckling, an initial small out-of-plane geometric imperfection, obtained from an eigen values buckling analysis, was imposed to the model. Results of experimental data obtained from previous works have shown that the model is able to predict, with good accuracy, the ultimate load and to some extent the mode of failure. A parametric study is then

realized to assess the cross-section classification to compare between the ultimate load behavior of castellated beams with hexagonal and octagonal openings when subjected to flexure and shear force.

**Tadeh Zirakian, Hossein Showkati (2006),** In previous studies of the structural behaviour of castellated steel beams, different possible failure modes of these extensively used structural members have been identified and investigated. On the other hand, during the past 25 years or so, a proliferation of research work has been undertaken on the distortional buckling of steel members. Nonetheless, no studies are found in the literature on the distortional buckling of castellated beams. Accordingly, tests of six full-scale castellated beams are described, in which the experimental investigation of distortional buckling was the focus of interest. In addition to the test strengths, the accurate critical loads of the beams have been obtained using some extrapolation techniques, and ultimately a comparison has been made between the obtained test loads and some theoretical predictions.

**Amin Mohebkhaha and Hossein Showkatib (2005),** Lateral–torsional buckling can be avoided by properly spaced and designed lateral bracing. Bracings are usually assumed to be elastic, and so may be characterized by their elastic stiffness's. It is well known that an elastic lateral brace restricts partially the lateral buckling of slender beams and increases the elastic buckling moment. However, a full study of the effect of lateral braces on inelastic buckling has not been made especially for castellated beams, and it is not known whether the limiting stiffness for elastic buckling can be applied to castellated beams that buckle in elastically. This paper develops a three dimensional (3-D) finite-element model using a finite-element program and uses it to investigate the effect of elastic lateral bracing stiffness on the inelastic flexural–torsional buckling of simply supported castellated beams with an elastic lateral restraint under pure bending. It was found that for inelastic castellated beams, the effect of bracing initially is increased to some extent as the lateral unbraced length increases and then decreased until the beam behaves as an elastic beam. In other words, the effect of bracing depends not only on the stiffness of the restraint but also on the modified slenderness of the beam. Also, the results show that winter's simplified method to determine full brace requirements cannot be applied to inelastic castellated beams. Therefore, a general equation is proposed to determine the value of optimum stiffness ( $k_{opt}$ ) in terms of the beam's slenderness, applicable to all castellated beams under pure bending.

**Richard Redwood and Sevak Demirdjian (1998),** Tests of four castellated beams are described, in which the buckling of the web-post between openings was the focus of interest. Evidence of web-post buckling was observed in all test beams, although one also underwent lateral displacements. Elastic finite-element analysis was used to predict the buckling loads. The test results showed that the buckling loads were not sensitive to moment-to-shear ratio, and the

maximum test loads exceeded the finite-element predictions by margins varying between 4 and 14%. A finite-element parameter study was conducted, and general results that can be used for a range of whole geometries are presented.

### 3. CONCLUSION

Use of Perforated beams in steel constructions are rapidly increasing due to its very advantageous properties like light in weight, ease in construction, advanced load deflection characteristics, more strength and stiffness and also due to aesthetic view offered by perforated beam. Usually pre-engineered buildings are safe as far as strength parameters are considered. But, these sections does not satisfies the serviceability requirement i.e. check for deflection. The beam have more depth can be satisfying these requirements. Hence, instead of choosing the section of more depth the beam can be fabricated in such a method that the depth of the beam increases. This can reduce the cost as the depth required is obtained in same material.

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