Experimental Study on Buckling Analysis And Stress Behaviour of Castellated Column

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Abstract- *Castellated column is defined as the column in which increasing width of column without increasing the self-weight of column. Now a day castellated column is a new technique. A castellated column is fabricated from a standard steel I-shape by cutting the web on a half hexagonal line down the center of the column. The two halves are moved across by one spacing and then re-joined by welding. This process increases the width of the column and hence the major axis bending strength and stiffness without adding additional materials. Due to the opening in the web, castellated column is more susceptible to lateral-torsional buckling. The main benefit of using a castellated column is to increase its buckling resistance about the major axis. However, because of the openings in the web, castellated columns have complicated sectional properties, which make it extremely difficult to predict their buckling resistance analytically.*

Keywords- ANSYS, CASTELLATED COLUMN

I. INTRODUCTION

Now a day high-rise buildings of steel structure are of huge attention due to their many advantages, such as, ductility, fast construction etc. Since the construction cost of high-rise building steel structures is generally more than that of a concrete one, decrease of the construction cost of high-rise steel structures is of great importance for designers as well as builders. Many attempts have been made by engineers to decrease the cost of steel in buildings. Sections having webs penetrated by large closely spaced openings over almost the full span are now common.

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Use of steel as structural member in structure is rapidly gaining interest now a days. In steel structures, the concept of pre-engineered building (PEB) is most popular because of ease and simplicity in construction. Such pre-engineer buildings have very large spans but comparatively subjected to less loading. So generally, steel sections are safe in strength requirement, however, sections do not satisfy serviceability requirements. So it becomes essential to use columns with more depths so as to satisfy this requirement. Use of perforated web or open web columns is the best solution in order to overcome this difficulty.

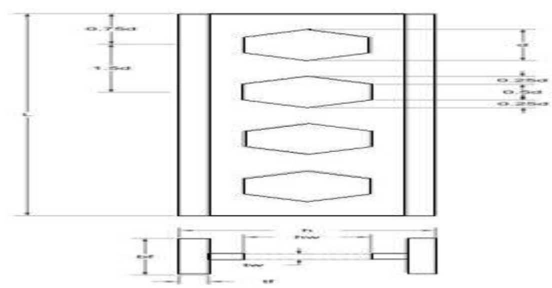

Figure 1 Geometry of a typical castellated column

The behavior of steel moment-resisting frames (MR) is greatly affected by the properties of the column-to-column connections, especially in seismic zones. According to experimental tests, there were 8 possible failure modes in steel columns with web openings (Kerdal and Nethercot, 1984; Mohebkhah, 2004; Zirakian and Showkati, 2006).These failure modes are caused by column geometry, web slenderness, type of loading Under applied load conditions, failure is likely to occur due toone the following modes

1. Formation of a Vierendeel mechanism;
2. Lateral torsional buckling of the entire span;
3. Lateral torsional buckling of the web post;
4. Rupture of the welded joint

Considering the high usage of steel columns with web openings, particularly in high-rise buildings, study of their behavior is essential. Many investigations have been conducted regarding the behavior of these columns.

Using finite element analysis software ANSYS.

When compared with a solid web solution where services are provided beneath column, the use of castellated columns could lead to savings in the cladding costs. Moreover, because of its lightweight the castellated column is more convenient in transportation and installation than the normal I-column. The web openings in the castellated column, however, may reduce the shear resistance of the column.

II. LITRATURE REVIEW

The introduction of Castellation in steel column is important for the advanced design of steel building. In the given literature review contains the buckling analysis of castellated column. Typically web opening that are commonly exposed steel structure include hexagonal, octagonal and cellular perforation. In the current report studied the hexagonal perforation opening.

Tianhua Zhou[etal] (2017) In this paper studiedusual design practice for distortional buckling considers a lower bound solution as the actual buckling load. Inreality, this practice is inconsistent with actual case since the obtained buckling load is a constant value nomatter how long the column is and whatever the end condition is. According to available literature, the research dealt with such a problem is found quite rare. In this scenario, this paper presents an analytical approach to establish a new distortional buckling formula, which takes both the effects of column length and end conditioninto consideration. The formula was derived based on an edge stiffened plate model. The model was assumed to be pin-ended and fix-ended so as to investigate their effects. The Galerkin method was employed to derive the distortional buckling formula. Further, simplifications to the rigorous formula were made to allow them to be easily used by the engineers. Subsequently, in order to verify the accuracy of the derived formula, the results obtained from the derived formula were compared with the numerical results obtained from the computer software GBTUL. In addition, the performance of the derived formula was further verified by comparing the corresponding ultimate strength based on Shafer's DSM expressions with numerical result from the literature. The comparison and validation result shows that the derived formula (i) can be used successfully in estimating the distortional buckling load for both pin-ended and fix-ended columns with practical length and (ii) can general more rational buckling strength estimation due to the consideration of column length and end condition effect.

Radek Pichal[etal] (2017) This paper studied prestressed stayed compression members are frequently required as very slender load-bearing structural components by bothinvestors and architects. Behavior of these members depends on their geometrical and material properties, prestressing and boundary conditions. In the paper are discussed respective critical buckling loads and post-buckling paths with regards to 2D and 3D GMNIA (geometrically and materially nonlinear analysis with imperfections) using ANSYS software. Former tests and recent detailed analyses of other authors are commented with respect to the 3D analysis, level of imperfections, boundary conditions at central crossarm (fixed or sliding stays) and nonlinear stainless steel material.

Delphine Sonck[et al] (2016) In this paper theCellular and castellated members are usually produced by performing cutting and rewelding operations on a hot rolled I-section member. As illustrated in previous work, these operations will influence the residual stresses present in the members in a manner which is detrimental for the flexural buckling resistance. Up to now, this has not been considered in the limited amount of literature concerning the flexural buckling resistance of these members. In this paper, the weak-axis flexural buckling resistance is examined, taking into account the influence of the modified residual stress pattern and the modified geometry of cellular and castellated members. Therefore, the critical buckling load and the buckling resistance of simply supported cellular and castellated members were investigated numerically. In the numerical model, a modified residual stress pattern was introduced, based on earlier measurements. As the amount of measurements was relatively limited, the results of these simulations should be considered as preliminary results, in attendance of a confirmation of the utilized residual stress pattern. The results of the simulations illustrate the detrimental influence of the expected residual stress pattern modification on the buckling resistance. By comparing the results with the European buckling curves, preliminary best fit curves could be selected. This comparison was executed with a 2T approach, in which all cross-sectional properties are calculated for the 2T section at the center of the opening.

Jian-zu Gu[etal] (2016) This paper presents an analytical solution for calculating the critical buckling load of simply supported cellular columns when they buckle about the major axis. The solution takes in to account the influence of web shear deformation on the buckling of cellular columns and is derived using the stationary principle of potential energy. The formula derived for calculating the critical buckling load is validated using finite element analysis results. It is shown from the present analytical solution that the web shear deformation can significantly reduce the buckling resistance of cellular columns. The influence of the shear deformation on the critical buckling load increases with the cross-section area of the tee section and the radius of circular holes but decreases with the length and the web thickness of the cellular column.

Yu-Chen Song [et al] (2016) This paper presents a theoretical study on both local and post-local buckling behavior of partially encased composite (PEC) columns, made with thin-walled, welded H-shapes and concrete encasement between flanges; transverse links are welded between flange tips to reinforce the section. Nonlinear finite element analysis (FEA) was conducted to predict buckling behaviors and strengths of steel shapes. Finite element models were verified through a comparison of FEA results with experimental results. A parametric study was then performed using validated FEA models to investigate the effect of several parameters on the buckling behaviour of PEC columns. The residual stress of steel shapes, which is introduced through welding process, was discussed in detail.

Jeppe Jonsson[et al] (2016) This paper represent the information about Eurocode allows for finite element modelling of plated steel structures; however the information in the code on howto perform the analysis or what assumptions to make is quite sparse. The present paper investigates the deterministic modelling of flexural column buckling using plane shell elements in advanced non-linear finite element analysis (GMNIA) with the goal of being able to reestablish the European buckling curves. A short comprehensive historical review is given on the development of the European buckling curves and the related assumptions made with respect to deterministic modelling of column buckling. The European buckling curves allowing deterministic analytical engineering analysis ofmembers are based on large experimental and parametric measurement programs as well as analytical, numerical and probabilistic investigations. It is of enormous practical value that modern numerical deterministic analysis can be performed based on given magnitudes of characteristic yield stress, material stress–strain relationship, and given characteristic values for imperfections and residual stresses. The magnitude of imperfections and residual stresses are discussed as well as how the use of equivalent imperfections may be very conservative if considered by finite element analysis as described in the current Eurocode code. A suggestion is given for a slightly modified imperfection formula within the Ayrton-Perry formulation leading to adequate inclusion of modern high grade steels within the original four bucking curves.

G. Panduranga[etal] (2015) In this paper the buckling analysis of 4140 alloy steel with different cross sections like I-section, C-section and T-section is done in fixed free conditions. Columns are the basic parts of a many engineering structures, they may be aero structures or civil structure or any other mechanical load carrying structures. The columns majorly take the axial loads and try to resist the bending caused due to the applied axial loads. It is to show that the actual application of the axial loading governs the buckling behavior of the column. The critical buckling load is calculated for the three columns with different cross sections according to theoretical formulation. From the critical buckling load calculations, it is observed that the critical buckling load values are different for different cross sections. Conservatively it is taken the minimum load value to do the safe analysis. In this paper the maximum deflections and maximum stresses are compared with the three columns with different channel sections made of same material subjected to same load. The solid models are designed in CATIA V5 tool and the buckling analysis is carried out in ANSYS software.

Laura Kinget (2015) In this master's dissertation the inuence of the presence of openings in the web of castellated and cellular columns is investigated. First, the geometry of those members is further studied, as well as the limitations of fabrication. An overview of the buckling behaviour of columns in general is given, whereby attention is paid to the adapted residual stress pattern proposed by Sonck (2014) for castellated and cellular members. The determination of the critical buckling load for battened compression members is also looked into, as it is expected that the buckling behaviour of castellated and cellular columns will be comparable to that of battened compression Members. Additionally, approximate formulas are studied that predict the additional deflection of cellular or castellated columns due to the presence of the openings in the web. In essence, these formulas propose an equivalent bending stiffness, in which the inuence of the openings is incorporated, so that this might be used to determine the critical buckling load of castellated and cellular members. Eventually, the buckling behaviour of said columns obtained in the finite element program Abaqus is studied, and compared to analytical expressions to determine thecritical buckling load as well as compared to the buckling curves found in Eurocode 3 (CEN,2005) to determine the buckling resistance.

Philippe Le Grognec[etal] (2015) Sandwich structures are widely used in many industrial applications thanks to their interesting compromise between light weight and high mechanical properties. This compromise is realized thanks to the presence of different parts in the composite material, namely the skins which are particularly thin and stiff relative to the homogeneous core material and possibly core reinforcements. Owing to these geometric and material features, sandwich structures are subject to global but also local buckling phenomena which are mainly responsible for their collapse. The buckling analysis of sandwich materials is there for an important issue for the mechanical design. In this respect, this paper is devoted to the theoretical study of the local/global buckling and post-buckling behavior of sandwich columns under axial compression. Only symmetric and which materials are considered with homogeneous and isotropic core/skin layers. First, the buckling problem is analytically addressed, by solving the so-called bifurcation equation in a

3D framework. The bifurcation analysis is performed using an hybrid model (the two faces are represented by Euler–Bernoulli columns, where as the core material is considered as a 2D continuous solid), considering both an elastic and elastoplastic core material.

Wei-bin Yuan [et al] (2014) This paper shows the majority of the existing literature on castellated members is focused on columns. Very little work has been done on the stability of castellated columns although they have been increasingly used in buildings in recent years. This paper presents a new analytical solution for calculating the critical buckling load of simply supported castellated columns when they buckle about the major axis. This analytical solution takes into account the influence of web shear deformations on the buckling of castellated columns and is derived using the stationary principle of potential energy. The formula derived for calculating the critical buckling load is demonstrated for a wide range of section dimensions using the data obtained from finite element analyses published by others. It was found that the influence of web shear deformations on the critical buckling loads of castellated columns increased with the cross-sectional area of a tee section and the depth of web opening, but decreased with the length and the web thickness of the column. It is shown that the inclusion of web shear deformations significantly reduces the buckling resistance of castellated columns. Neglecting the web shear deformations could overestimate the critical buckling load by up to 25%, even if a reduced second moment of area is used.

Mara Junus[etal] (2014) The purpose of this study is to determine the behavior of column-column sub-assemblages castellated due to cyclic loading. Knowing these behaviors can if be analyzed the effectiveness of the concrete filler to reduce the damage and improve capacity of column castellated. Test column consists of column castellated fabricated from normal column [NB], castellated columns with concrete filler between the flange [CCB] and normal column [NB] as a comparison. Results showed castellated column [CB] has the advantage to increase the flexural capacity and energy absorption respectively 100.5% and 74.3%. Besides advantages, castellated column has the disadvantage that lowering partial ductility and full ductility respectively 12.6 % and 18.1%, decrease resistance ratio 29.5 % and accelerate the degradation rate of stiffness ratio 31.4%. By the concrete filler between the column flange to improve the ability of castellated column, then the column castellated have the ability to increase the flexural capacity of 184.78 %, 217.1% increase energy absorption, increase ductility partial and full ductility respectively 27.9 % and 26 %, increases resistance ratio 52.5 % and slow the rate of degradation of the stiffness ratio 55.1 %.

Wei-bin Yuan[etal] (2014) In this paper the majority of the existing literature on castellated members is focused on columns. Very little work has been done on the stability of castellated columns although they have been increasingly used in buildings in recent years. This paper presents a new analytical solution for calculating the critical buckling load of simply supported castellated columns when they buckle about the major axis. This analytical solution takes into account the influence of web shear deformations on the buckling of castellated columns and is derived using the stationary principle of potential energy. The formula derived for calculating the critical buckling load is demonstrated for a wide range of section dimensions using the data obtained from finite element analyses published by others. It was found that the influence of web shear deformations on the critical buckling loads of castellated columns increased with the cross-sectional area of a tee section and the depth of web opening, but decreased with the length and the web thickness of the column. It is shown that the inclusion of web shear deformations significantly reduce the buckling resistance of castellated columns. Neglecting the web shear deformations could overestimate the critical buckling load by up to 25%, even if a reduced second moment of area is used.

Delphine Sonck[etal] (2014) The global buckling resistance of hot-rolled steel I-section members is adversely influenced by the presence of residual stresses. It is expected that thermal effects during the production of cellular and castellated members will influence the already present stresses in the hot-rolled parent sections, but it is yet unknown to what extent. In this paper, the experimental investigation of the residual stresses in these members is described, and it is shown that the production process increases the already present compressive flange stresses, which will be detrimental for their buckling resistance. This effect will be even more pronounced for deviating production procedures.

III. CONCLUSION

From literature survey it is observed that Stresses developed in castellated column are more as compared to regular column. Studying all the end condition it is clear that the both end fixed condition is more suitable for the column.

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