CYCLIC RESPONSE OF PERFORATED BEAM IN STEEL BEAM COLUMN JOINTS - STATE OF ART

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Abstract - *The steel frame joints should be made with adequate strength and considerable stiffness to resist the external force like earthquake and wind loadings and internal forces by the framing members. It is essential for the connection to be sufficiently strong enough and robust, mobilizing the stresses to a desired location along the length of the beam away from the connection assembly, creating the "weak beam-strong column" mechanism with the formation of plastic hinges. Providing a perforation near to the end of beam is suggested as a potential method to improve seismic behavior of these structures. According to the studies, great damages are mainly due to the cracking of the weld between the beam flange and the column face. Many factors are believed to contribute to the occurrence of brittle fracture; they are excessive beam strength, weld defects and notch effects, fracture toughness of deposited weld metal, low temperature, high stress triaxiality due to severe structural restraint conditions residual stresses, geometry of access holes and stress distribution on the flange of beam. A useful approach to reduce the stress concentration at the panel zone is the use of reduced web section (RWS) which ensures the formation of plastic hinge under loading, which will occur at the beam and not at the column.*

***Key Words*: Reduced web beam section, Cyclic loading, Energy dissipation, Nonlinear analysis, Moment resisting frame.**

1. INTRODUCTION

Design connections play an important role in multi-story buildings with structural steel frames. In these buildings unexpected damage occurs generally at the panel zone which causes brittle failure in the structures. Steel frames which are subjected to external loading experiences the largest stress and strain demands in their most vulnerable locations i.e. at the beam-column joints where the connection welds and heat-affected zones are located.

It was observed that in many earthquakes, the major drawback in steel framed structures is the presence of crack in the panel zone followed by a brittle type of failure. After initiation of cracks it propagates from the weld into other parts of the joint, depending on loading and connection behavior. In some cases, it was found that the crack moves through entire weld and in other cases, the propagation will be through the flanges of column and in the worst case, extends to the web of column and travels across the panel zone which results in total fracture across the column section itself. Once the beam column connection subject to fracture, it will undergo large reduction in strength and rigidity to resist the external force to open up the cracks. Presence of these cracks will leads to a large reduction in strength and stiffness of beam-column connection and will tend to decrease the amount of dissipated energy within a loading cycle.

2. LITERATURE REVIEW

Numerous studies had been carried out based on empirical and software analysis regarding cyclic loading and its impact on beam column joint. Among the wide spectrum of researchers a brief review of some of the relevant research work has been provided.

D.T.Pachoumis et al (2010) analyzed the cyclic performance of steel moment-resisting connections with RBS, using European profiles. The results obtained from the experimental study are compared with those of finite element analysis and found to exhibit excellent performance as plastic hinges are formed at the RBS area. In this research paper it was found that during loading the RBS can be viewed as a ductile fuses that forces yielding to occur within the reduced section of the beam rather than near the face of the column. Based on the results obtained they concluded the need to readjust in the geometrical characteristics of RBSs in to be safely applied to European profiles. [1]

K.D. Tsavdaridis and T. Papadopoulos (2016) focused in the study of interaction of beam column joint connections and the mobilisation of stresses from panel zone to perforated beam. The parameters introduced were the location of first opening and intermediate web opening spacing. It was observed that RWS connections with circular openings provide better performance in terms of the distribution of stresses along the length of beam without affecting the beam column connection when undergoes cyclic loading. They suggested that a wide range of section properties of web opening shapes as well as the connected members should be studied in the future to be able to non-dimensionalize the results and reveal the influence of all geometric parameters onto the performance of RWS connections with cellular beams. [2]

L.Budhi et al (2017) In this research paper an optimization study of castellated steel beams using finite element method was conducted and the result is verified by implementing laboratory test. The parameters introduced were the opening angle and opening distance of hexagonal holes. The results points out that the distance of each hole has an influence with the location of maximum stress concentration. For wider hole distance the stress concentration was at corner area of hole and for shorter hole distance stress concentration moves to weld joint area of web post. The optimum model of beam obtained was that having holes with 60° angle size and hole distance between 0.186 h0 to 0.266 h0. [3]

K.D. Tsavdaridis et al (2014) studied fully fixed (welded) perforated beam column connections that can be used as strengthening techniques under seismic loading. The parametric study reveals that all the geometric parameters affect the behavior of connection in different ways and was concluded that large isolated perforations improves the behavior of beam column joint by improving their rotational capacity, ductility, and energy dissipation capacity. It is found that an effective distance from the column's face can be suggested dependent on the geometry of the opening. When compared to other conventional methods, the novel shaped web opening (combination of hexagon and circle) performs better. [4]

W.Yuan et al (2014) have undertaken finite element analysis to determine critical buckling load of simply supported castellated column subjected to axial compression. 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 tee section and the depth of web opening, but decreased with the length and thickness of web of column. This paper presents a new analytical solution for calculating the critical buckling load for simply supported castellated columns. The main benefit of castellated column is to increase the buckling resistance about the major axis. However, because of the openings in the web, castellated columns have complicated sectional properties, analytically it extremely difficult to predict their buckling resistance. While comparing the solid web column and the castellated column it was found that castellated column has weak web shear stiffness and thus the shear deformations are more pronounced when the column has a flexural buckling, which reduce the buckling capacity of the columns. [5]

Jamadar A. M et al (2015) In this research paper the flexural behavior of castellated beam with circular and diamond shaped openings was conducted. The finite element analysis (FEA) of the beam was carried out using Abaqus/CAE 6.13 software. The castellated beam with diamond shaped opening with opening size of 0.67 times the overall depth proves to be better than the other shaped openings. In diamond shaped openings the available area will be more for shear transfer so there is minimum effect of local failure within the section also it is revealed that, diamond shaped opening with opening depth ratio of 1.5 and opening location ratio of 1.4 gives more satisfying strength results than the other shapes and sizes. [6]

Nimmi K. P et al (2016) The aim was to study optimum shape and size, stiffness and load carrying capacity of cellular beams under applied load. The parametric study of cellular beam shows that the deflection decreases with increase of spacing ratio and opening ratio and increases with increase of aspect ratio of steel beams with circular openings. It was also found that value of deflection is minimum for circular web opening of same section of beam compared to other shapes of cut. It is observed that when compared to other shape of opening, cellular beam has more load carrying capacity and stiffness. [7]

Bhosale G.A et al (2017) conducted a finite element analysis of castellated beam by using Abaqus software to study the flexural behaviour for different shapes of opening & to optimize the shape of opening. The parametric study of castellated beams with different shapes include circular, square and hexagon shaped openings. Simply supported beam with two concentrated loads at 1/3rddistance from either ends of the span of the beam was considered. The result obtained from analysis shows that castellated beam with hexagon shape opening is best suitable than the conventional I beam as the deflection is found to be less with comparatively large load carrying capacity. The result obtained from finite element method was verified by implementing laboratory test. [8]

M.R.Wakchaure et al (2012) analyzed the behavior of castellated beams; modeling was conducted using finite element software ANSYS14. From the results obtained they concluded that, the castellated beam behaves satisfactorily up to a web opening depth of 0.6h and proved to perform excellent in moderately loaded longer spans where the design is largely controlled by deflection parameter. From this analysis, it was observed that as the depth of opening increases, stress concentrations increases at the corners of openings and at the point of load application therefore they suggest to provide plate below point load, etc. so that the serviceability performance of castellated beams can be improved in practice. [9]

S Erfani et al (2011) conducted a finite element analysis of building frames under nonlinear static pushover, to obtain efficient location for openings along the beam length and the effects of beams with web openings on local and global behavior of frames. Based on the results they concluded that, provision of web openings at two ends of a beam is an efficient method to prevent inelastic flexural deformations which is developing in beam column joint. Also it is found that the presence of web openings at beam elements has reduced effect on global stiffness and strength of structure. Web openings act as a fuse element which prevents beam-column connection from excessive forces and stresses in structures. [10]

Anbuchezian .A et al. (2013) compared cold-formed plain angle beams and cold-formed lipped angle beams under cyclic loading and found that hysteresis behavior of cold-formed steel angle beams depends on the shape and symmetric of cross section of beam. The deformation ductility factor was found to be more for the plain beams than in lipped beams which indicates that, in cold-formed steel elements seismic forces more effectively. Provision of lips in cold formed angle beams increases moment carrying capacity but reduces the ductility factor. [11]

R. Rahnavard et al. (2013) In this study, several moment connections with different shape in reducing beam flange have been modeled and compared during the cyclic loading. The result obtained showed that using different holes, reduced beam section become more ductile and will tend to dissipate more energy. Due to using reduced beam section, panel zone participation in rotation is only about 2-3% of the total rotation; thus, it is concluded that rotational behavior is completely independent of panel zone participation. All the models are considered as fully restrained connection as the values of KL/EI are greater than 20. [12]

3. CONCLUSIONS

Following points can be summarized from the literature survey:-

- The web openings contributed to the inelastic energy dissipation of the connection by sustaining inelastic rotation.
- For each opening height there is a unique opening length associated with the maximum dissipated energy.
- The introduction of stiffeners improves the energy dissipation capacity than beams without stiffeners.
- Various depth of openings and shapes produce different Web Opening Areas (WOA), the magnitude of which determines the performance of beam.

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