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Castellated beam optimization by using Finite Element Analysis: A Review.

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ABSTRACT

The review report presents a procedure & software application to optimize the topology, size and shape of castellated beam using finite element analysis. The Castellated beams are produced by cutting and re-welding of hot rolled sections which are made of regularly spaced opening. So for same weight Castellated beam has more height than regular beam. Load carrying capacity of simply supported Castellated steel beams susceptible to web post bucking is studied. FEA method is used to evaluate the load carrying capacity castellated beam. The parameter studies are also carried out in order to assess the cross section classification to compare the ultimate load behavior. Among the main features of these beams can be pointed to architectural features and height which resulting in greater strength and stiffness of the beams without the added weight of the beams. In this paper, the load carrying capacity of castellated beam is reviewed. The unit member with fillet corner opening has a higher load carrying capacity as compared with those with hexagonal, rectangular openings when they have the same opening height, but lower than that with circular opening.

KEYWORDS *- Optimization, Castellated, FEA, Buckling, Beam.*

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I. INTRODUCTION

Steel structure building are becoming more and more popular due to their various advantages such as the better satisfaction with the flexible architectural, durability, strength to weight ratio, design, low inclusive cost and environmental protect as steel is manufacture to precise and uniform shapes. Since the Second World War many attempts have been made by structural Engineers to obtain new ways to decrease the cost of steel structures. Due to the limitations on maximum allowable deflections, the high strength properties of structural steel cannot always be utilized to best advantage. As a result several new methods have been aimed at increasing the stiffness or load carrying capacity of steel members without any increase in weight of the steel required. Castellated beams with web openings were one of these solutions. Castellated beams are fabricated from wide flange I-beams. The Castellated beams are manufactured by cutting and re-welding of hot rolled sections which are made of regularly spaced opening. A number of common and practical web openings are considered in the present study on castellated beam, such as circular, square, rectangular, hexagonal. As height of castellated beam will get increase it gives high bending and shear strength as section modulus of castellated beam will get increase. As a result load carrying capacity will get increase and such type of beams also allows to structural work.

II. METHODOLOGY.

The web openings are cut on the traditional I beam by flame or Laser cut machine, along the horizontal x-x axis along a “Zigzag” pattern. The two halves are then separated and re-welded together to produce a beam of greater depth with circular opening in the web. The web openings may be of different types such as circular, square, hexagonal, sinusoidal etc. The resulting beam has a larger section modulus and greater bending rigidity than the original traditional section without an increase in weight. However, the presence of the holes in the web will change the structural behavior of the castellated beam from that of original plain webbed beams. Experimental tests on castellated beams have shown that beam slenderness, castellation parameters and the loading type on beam are the main parameters which dictate the strength and modes of failure of these castellated beams.

III. LITERATURE REVIEW.

M.R. Soltani has performed number of tests on steel thin webbed castellated beams with hexagonal and octagonal web openings. He has done the experimental work at McGill University. He used Finite element model for his experiments. The main aim of this experimental analysis was to investigate the web-post buckling. A study has shown that for thin webbed castellated beams with higher height web openings, failure would occur by web-post buckling with limited plastic zones. These local internal forces around the web openings are called as Virendeel mechanism [1].

Ehab Ellobody studied the nonlinear behavior of normal and high strength cellular steel beams. The buckling modes of cellular has been studied and presented in this paper. A finite element method for the analysis of simply supported cellular steel beams has been developed. He used ABAQUS software in the analysis of castellated beam. It is also suggested that the use of high strength steel gives a considerable increase in the failure loads of less slender cellular steel beams [2].

Saeed Gholizadeh, studied load carrying capacity of simply supported castellated steel beams, susceptible to web post buckling. He used FE simulation of web post and the flanges of castellated beam using NASTAN software. He did the parametric study on the load carrying capacity of web posts of the steel castellated beams. For this he created parametric model of castellated beam. For his study he selected properties flanges, web and perforations of the web as a setting parameters. He discussed the accuracy of the nonlinear finite element (FE) method to evaluate the load carrying capacity and failure mode of the beams. The numerical results show that the accuracy of the predicted critical load carrying capacities by neural network models is better than that of the proposed equations and among the BP and ANFIS models. The experiments showed that web buckling depends on restraining effect of beam flanges and lateral torsional bracing of upper flange [3].

S. Durif, performed experimental tests on cellular beams with sinusoidal shape of openings. The experiments show a specific behavior of castellated beam in comparison with the standard circular openings of castellated beam. The tests were realized on three castellated beams representing various dimensions of the openings. The focus was to observe the failure modes of these castellated beams and to obtain the optimum load carrying capacity of castellated beam. The good correlation between the experimental and the numerical results validated the model as predicting tool. Therefore, this numerical is used to closely study the stress effect around the opening of beams. It confirmed that for a high opening size a0/ Htot=0.78 it can be observed a total yielding of the four opening corners [4].

Peijun Wang investigated Vierendeel failure of castellated steel beams with fillet corner web openings by using the Finite Element Method. Virendeel failure is due to the internal forces around the web openings. When force is applied on the castellated beam it gets transmitted through the web posts, which cause the induction in stresses in the local area. This induced stresses are the main cause of the castellated beam failure. Numerical results indicate that castellated beams with the proposed fillet corner web openings have the higher load bearing capacity than those with traditional rectangular or hexagonal openings if they have the same opening height. The fillet radius can promote the stress redistributions around the web openings, which can increase the load carrying capacity of the web-perforated members. According to Wang, the fillet radius which equals to a quarter of the opening web height is the best option for the proposed fillet corner web opening shape [5].

Delphin Snock, studied the effect of residual stresses in steel castellated beam. The presence of web openings will affect the failure behaviour of castellated beam. New localised failure modes can arise around the web opening. The change in geometry and the influence of production processes gives residual stresses. The residual stresses in the castellated beam plays important role while determining the buckling resistance. Delhin expects that castellated beam members manufactured according to the standard procedure will minimize the residual stresses which in turn give the higher load carrying capacity [6].

B.Anupriya and Dr.K.Jagadeesan investigated the behavior of shear strength of castellated beam with and without stiffeners. Castellated beams are steel beams with web openings and these castellated beams have higher load carrying capacity as they gain its advantage due to its increased depth of section. As there is more section modulus, the load carrying capacity will also get increase. Also it is achieved without any additional weight. They carried out experiments and obtained results from ANSYS 14, it was found that stresses are distributed across the web opening along the shear zone. Also shear failure is more near the holes than in the solid web of the castellated beam [7].

T.C.H. Liu and K.F. Chung, done a comprehensive finite element investigations on steel beams with different web openings having various shapes and sizes. All the castellated steel beams with large web openings of various shapes behave similarly on the application of external load. The plastic hinges are formed at both ends of openings at failure. The critical opening length is the most important parameter in the failure of castellated beam. The critical opening length controls the magnitude of local virendeel moments acting on the castellated beam. The transfer of vertical shear forces across the web openings can cause the local bending moments is called as virendeel effect which leads to failure of beam called as virendeel failure. The finite element module is used to examine the effect of fillet corner web openings dimensions on load carrying capacity of castellated beam. [8].

Konstantinos Daniel Tsavdaridis presented an experimental and analytical study on the behaviour of perforated steel castellated beams with closely spaced web openings. The aim of this study the effect of various sizes and shapes of web openings on the load carrying capacity of Castellated beam. The experimental work is compared with Finite element analysis. Seven specimens including two typical cellular beams and five perforated beams with novel web opening shapes were tested to investigate the failure mode and load carrying capacity of the web-post between two adjacent web openings. It was observed that when relatively wide web opening spacing is considered, the maximum shear stresses move from the mid-height of the web-post towards the centroid of the axial forces, closer to the flanges [9].

Ehab Ellobody, investigated the behaviour of normal and high strength castellated steel beams under both lateral torsional and distortional buckling modes. An efficient nonlinear 3D finite element model has been developed for the analysis of the castellated beams. He used ABAQUS software for his experimental analysis. The initial geometric imperfection and material nonlinearities were minutely considered in the analysis of castellated beam. The parametric study of castellated beam has shown that the presence of web distortional buckling causes a considerable decrease in the failure load of slender castellated steel beams [10].

IV. CONCLUSION:-

The unit member with fillet corner opening has a higher load carrying capacity compared with those with hexagonal, rectangular openings when they have the same opening height, but lower than that with circular opening. The high strength steel castellated beam gives considerable increase in failure load. For fillet corner web opening, the fillet radius quarter to web opening is best option. The critical opening length is the main parameter in the failure of castellated beam .When web openings are placed widely from each other, the maximum shear stresses moves from mid height of beam towards the flanges of beam. Material properties of flanges, web post sizes and the web openings are the critical setting parameters for the optimization of castellated beam.

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