REVIEW ON COMPARATIVE STUDY OF CASTELLATED BEAM WITH DIFFERENT WEB OPENINGS

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Abstract

Nowadays, Engineers are actively seeking to improve construction materials and properties. In that, the usage of the castellated beam is become very popular due to its advantageous structural applications Castellated beams are those beams which have openings in their web portion. Castellated beams are fabricated by cutting the web of hot rolled steel (HRS) I section into zigzag pattern and thereafter rejoining it over one another. Use of castellated beams is become very popular now a day due to its advantageous structural applications. This is due to increased depth of section without any additional weight, high strength to weight ratio, their lower maintenance and painting cost. The principal advantage of castellated beam is increase in vertical bending stiffness, ease of service provision and attractive appearance. However, one consequence of presence of web opening is the development of various local effects. In this research we have suggest the Indian Standard Code based methodology for designing of castellated beams. So, the first objective of this research is to investigate the performance of castellated beam designed by IS code method against which is designed by British Standard method. The study of performance is based on deflection, load carrying capacity of castellated beam. We compare the castellated beams design by IS Code method with conventional castellated beams design by British Standard based on their load carrying capacities. The opening is generally provided in web hexagonal, rectangular, diamond or square in shape. By studying the different research paper, it found at castellated beams with hexagonal, rectangular or square opening mostly fails due to shear concentration at the corner opening, the second objective of this research is to provide new web opening that is sinusoidal opening to avoid failure of castellated beam due to shear stress concentration at the corner of the opening. The study of this project is based on deflection, load carrying capacity of new sinusoidal opening shape castellated beam compare to castellated beam with hexagonal web opening.

Keywords- Castellated beam, fabricated, Strength

1. INTRODUCTION

Castellation is a process of fabricating a section with improved section properties from virgin rolled section by increasing depth ultimately improving moment of inertia. There by increase in moment of resistance and controlled on deflection. This process increases the depth of the beam by approximately 50%, therefore increasing the strength and stiffness by about 20 to 30% without increasing the weight of the beam. Also, the holes in the web allow ductwork to run through beams instead of 2 underneath ultimately reducing the depth of the floor system.

ANSYS

ANSYS is a finite element analysis (FEA) software package. It uses a preprocessor software engine to create geometry. Then it uses a solution routine to apply loads to the meshed geometry. Finally, it outputs desired results in post- processing. Finite element analysis was first developed by the airplane industry to predict the behavior of metals when formed for wings. Now FEA is used throughout almost all engineering design including mechanical systems and civil engineering structures. ANSYS is used throughout industry in many engineering disciplines. This software package was even used by the engineers that investigated the World Trade Center collapse in 2001.

Advantages

Increase in depth d results increase in moment of inertia, increases moment carrying capacity of Castellated Beam up to 50% of the original capacity.

1. The length of the castellated beam can be extended up to 90 ft.

2. It has a high stiffness-to-weight ratio

3. Installation is fast and easy as the span of the beam is longer.

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4. Same section can be used for longer span after castellation which covers more column free area.

5. Since, webs of beams are perforated AC ducts, plumbing lines, Electric wiring can be easily passed through it which otherwise have hampered the headroom.

6. Improve aesthetic view of the ceiling.

7. Tapered and curved section can be easily fabricated.

8. Optimum use of material there by saving in material.

9. Innovative and ecofriendly structure.

10. Proves economical as castellated section gives 50% more moment of resistance

11. The overall cost of the structure will be reduced as castellated beams are more economical.

12. Castellated beam requires low maintenance

13. Handling of the beam is easy due to the lighter weight

14. Installation is fast and easy as the span of the beam is longer.

15. It minimizes the floor vibration issues

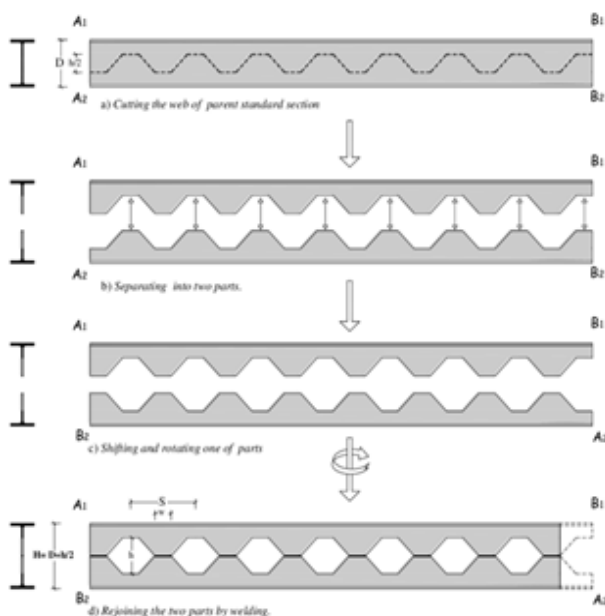16. The beam can be designed asymmetrically in case of increased loads.

Figure 1 Beam Sections

Disadvantages

1. As web is perforated and not uniform shear carrying capacity of beam reduces.

2. Shear concentration will be there at re-entering corners in case of rectangular and hexagonal patterns and may be a cause of failure.

3. Loss of web material in case of castellated beam with circular sections.

4. High skilled labor is required.

2. OBJECTIVES

The aim of the present work is to develop new methodology for designing of castellated beam based on IS Code. In the present work we have developed the IS 800-2007 Code based methodology for designing of castellated beam for hexagonal web opening and compared with British standard code BS 449 based methodology. From the observation of past result, it is found that castellated beam with hexagonal web opening fails due to shear stress concentration at the corner of hexagonal web opening. To avoid this concentration of shear stress at the corner of hexagonal web opening we suggest the new web opening pattern Sinusoidal web opening form by filleting the corner of hexagonal web opening in castellated beams.

3. SCOPE OF RESEARCH

The first objective of this research is to investigate the performance of castellated beams designed by IS code method against which is designed by British Standard Method. The study of performance is based on deflection, load carrying capacity of castellated beam compare to parent beam. The second objective of this research is to examine the ultimate flexural strength of different web opening castellated simply supported beams.

4. LITERATURE REVIEW

Prof. U. S. Ansari (2021)

To investigate and evaluate the use of the finite element method for the analysis of castellated beams. The analysis is to be carried on the castellated beams and calculated the stresses values. By knowing stresses values we can calculate the deflection, load carrying capacity of the beam. The following procedure is used to meet this goal

A literature review is conducted to evaluate previous analytical procedures related to castellated beams.

A calibration model using a commercial finite element analysis package (ANSYS) is set up and analysis is done.

Silda Ghazi Doori, Ahmad Reshad Noori (2021)

The aim of this study is to investigate the static behavior of castellated beams with different web openings. A 3D finite element analysis is performed using ABAQUS, to find out which type of beam gives the best performance under the same distributed load and fixed support condition. Different shapes are used for the web openings and compared with the basic shape of the hexagon, taking the same area into consideration for all shapes. In this paper, a new design model is developed using more than one shape in the web opening. Displacement and stress results are carried out and compared for various cases.

A Tjahjono, E J Wijayanti1 (2021)

Castellated beams are commonly used in steel construction. This study will focus on castellated beams with circular-shaped openings, which are known as cellular beams. Cost optimization of cellular beams is needed to maintain cost efficiency. The optimization considers the selection of a root beam, the diameter of holes, and the total number of holes in the beam as the variables. Four metaheuristic algorithms are used to

optimize the design, namely, the particle swarm optimization (PSO), differential evolution (DE), symbiotic organisms search (SOS), and artificial bee colony (ABC). A four-meter span beam with a 50 kN point live load in the middle of the beam and a 5 kN/m uniformly-distributed dead load are taken as the case study. The results indicate that the SOS algorithm yields the best optimization results in terms of the average, consistency, and convergence behavior with a 30 out of 30 success rates.

Ahmed I. Khaleel, Mushriq F. K. AL-Shamaa (2021)

In this study is devoted to investigating the structural behavior of double-channel cast steel beams. In this project, two pieces of a rolled hot steel channel were connected to form a new section used in the testing program. Five beams of different sections were manufactured and tested using the same length and all testing parameters conditions with only a difference in the number of openings and distance (e) between each hole to study the behavior of section to different bearing loads and deformation. Two loading points were placed on a third of the length of the castellated steel beam. This study showed that when the web holes are few, the total bearing strength decreases. As the number of web holes increased to a specific limit, the bearing strength continued to rise, and if openings exceeded a specific limit, the bearing force decreased.

Munjal Kumar H. Upadhyay, Vishal B. Patel (2021)

The objective of the castellated beam is to improve load-carrying capacity without increasing its weight to full fill loading criteria and serviceability criteria. Therefore, in this research work, nonlinear numerical modelling analysis is carried out to observe the behavior of castellated beams having a newly proposed irregular shape of the opening. Curve-in-curve (Arch) type of opening shape is prepared from the parent ISMB 250 section. The finite element model was prepared using ABAQUS/CAE 6.11 version. The average load carrying capacity of a curve-in the curve type of opening increases by 27% and 15% for circular and hexagonal shaped castellated beams respectively.

Awadhut Chandrakant Dhage. Prof. K. B. Pimpale. (2021)

Castellated beam is used as operational affiliates in multistory buildings, commercial, industrial and additionally in portal frames. The castellation procedure rises the overall depth of the parent section, this rise contributes effectually in adapting the strength of castellated beams in contrast with the asset of parental section. Castellated beams are steel beams with web beginnings and they enhancement its advantage due to its improved depth of section lacking any extra weight. However, one significance is the presence of web opening. The presence of the web openings influences the member's failure behaviour around the openings, new local failure modes come into presence, such as the buckling of the web post between the openings, or yielding around the openings. Castellated beams with octagonal introductions frequently fail due to mesh post buckling because of the enlarged depth. The current study is attentive on enlightening the performance of the castellated beam with octagonal openings using steel Ring stiffener and Slanting stiffeners. In this work, the modelling and analysis of the beam is done by using ANSYS software. Here two dissimilar models of castellated beam one with Diagonal stiffener and other with Ring stiffener were analysed. Both the beams were subjected to identical point load acting at the centre of the beam. The stress distribution and the deflections of the beams were moderately studied.

Kumar Agurubaran 2021

It aims to analyse the effect of web openings if it is strengthened or not by the intervention of the stiffeners on the beam, which is used to enhance the resistance of the web opening. This paper investigates the measurement of multiple solutions applying the shear and bend loading in a vertical direction on the beam with different numbers of stiffeners placement. At last castellated beam and deflection effects with increased depth of web, openings are analysed with the aid of Finite Element Analysis software ANSYS 16.0. The experimental findings and observations demonstrate the efficacy and the limits of the various studies of stiffening solutions.

Hayder A. Hashim 2021

This research is carried out to study the effect of the external post-tensioning technique on the flexural capacity of simply supported composite castellated beam experimentally. In this research, seven composite castellated beams having the same dimensions and material properties were cast and tested up to failure by applied two concentrated loads at 700 mm from each end. Two external strands of 12.7 mm diameter were fixed at each side of the web of strengthening beams and located at depth 180 mm from top fiber of the section (dps) at each end of the beam. The strands have been tensioned by using a hydraulic jack with a constant stress of 100 MPa.

Munjal Kumar H. Upadhyay 2021

The average load carrying capacity of a curve-in the curve type of opening increases by 27% and 15% for circular and hexagonal shaped castellated beams respectively. Two different parameters considered for analysis of curve-in the curve type of opening castellated beam in this paper is (1) the length of its first opening provided from the end support condition of the beam and (2) load-displacement variation of a curve-in the curve type castellated beam prepared from parent ISHB 450 sections for its varying web thickness. An increment in load-carrying capacity is also measured for both the models having reinforcement around the web opening.

Awadhut Chandrakant Dhage 2021

The castellation procedure rises the overall depth of the parent section, this rise contributes effectually in adapting the strength of castellated beams in contrast with the asset of parental section. Castellated beams are steel beams with web beginnings and they enhancement its advantage due to its improved depth of section lacking any extra weight. However, one significance is the presence of web opening. The presence of the web openings influences the member's failure behaviour around the openings, new local failure modes come into presence, such as the buckling of the web post between the openings, or

yielding around the openings. Castellated beams with octagonal introductions frequently fail due to mesh postbuckling because of the enlarged depth. The current study is attentive on enlightening the performance of the castellated beam with octagonal openings using steel Ring stiffener and Slanting stiffeners. In this work, the modelling and analysis of the beam is done by using ANSYS software.

Manoj K. Phatangare, Prof.Amol J.Mehetre (2018)

The shear carrying capacity can be increased by stiffening the web at point concentrated load and reactions. Hence to increase the shear strength of the castellated beam with stiffener and also to reduce the deflection, diagonal and vertical stiffener are introduced along the web opening and also on the solid portion of the beam along the shear zone. Steel I section of ISMB 150 is selected and castellated beam with stiffener are fabricated, such that depth of castellated beam with stiffener is 1.5 times more than the original depth. Experiments are carried out by applying two-point loads and deflection of a beam is studied and different failure mode are analysed.

Dighe Komal Govindrao, Prof. V. R. Rathi (2017)

In this form of construction maintains a smaller construction depth with placement of services within the girder depth, at the most appropriate locations. The introduction of an opening in the web of the beam alters the stress distribution within the member and also influences its collapse behavior. Generally, the castellated beams are with hexagonal or square or circular shaped openings. As a modification, in castellated beam with hexagonal opening, the corners of opening are made round so as to offer smooth stress transfer area to avoid stress concentration. The beams with such curved shaped openings are known as castellated beam with sinusoidal openings. In case of transverse stiffener, each stiffener acts as a single short column and hence integrates the load carrying capacity. It also helps in compensating faults of welded joints. The volume consumed by transverse stiffener is less than the stiffener along the edge of opening.

M. Najafi, Y.C. Wang (2017)

The shear resistance of the perforated section is obtained by calculating a critical shear stress in the T-section. This critical shear stress -direct stress interaction is according to the von Mises equation, but the square power in the von Mises equation is replaced by a function that reflects the influence of T section buckling. A comparison between the numerical simulation results and the analytical results using the proposed method indicates very good agreement, with the inaccuracy mainly attributed to inaccurate calculation of the bending – shear interaction of the existing methods which do not consider the effects of additional compression and T-section buckling.

Riyas, Dr. G. Arunkumar (2017)

The cold formed steel structural members are made through cold forming a thin plate which is normally from 1.2 mm to 3 mm and has a section shape with the right purpose. One of the advantages of cold formed steels is that the strength to weight ratio is much higher than that of common hot rolled shapes, thus it can reduce the total weight of structures Investigation of cold formed I section castellated beam with cellular openings is carried out by varying the size of openings and the spacing between openings. The performance is analyzed using ABAQUS 6.13 by keeping the depth and width of the section's constant. Theoretical investigation is carried out by using North American specification for the design for cold formed steel AISI S-700:2007, Australian/New Zealand design code for cold formed steel AS/NZS 4600:2005. The results predicted using numerical analysis and theoretical analysis are compared and presented. Results showed that, the beam gives better strength results for cellular shaped opening with opening size of 0.4 times the overall depth of the beam. It is also observed that, castellated beams are mostly tends to fail in their local modes of failure.

Sahar Elaiwi, Boksun Kim and Long-yuan Li (2017)

This paper investigates the effect of web openings on the transverse deflection of castellated beams by using both analytical and numerical methods. The purpose of developing analytical solutions, which adopted the classical principle of minimum potential energy is for the design and practical use; while the numerical solutions obtained using ANSYS software are for the validation of the analytical solutions. A comparison of the maximum deflections between analytical solutions using different shear rigidity factors including one with zero shear factor and FEA numerical solution for four castellated beams of different flange widths.

Siddheshwari A. Patil, Popat D Kumbhar (2016)

In this paper the analysis of the castellated beam has been studied using the stiffeners. Two different types of stiffeners that is stiffeners placed along the transverse direction (transverse stiffeners) and stiffeners placed along the edge of openings are used for the analysis. These two types of stiffeners are chosen in order to increase the strength and to decrease the stress concentration near the web openings. The comparative study of these stiffeners is done by using ABAQUS software. It is observed that the percentage steel used for the transverse stiffeners is very less compared to the stiffeners place along the edge of opening. But in spite of increase in steel percentage for the stiffeners along edge of opening, results are not satisfactory in respect of load carrying capacity. Therefore, it is better to provide the transverse stiffener rather than the stiffeners along the edge of opening.

Ajim S. Shaikh1, Prof. Pankaj B. Autade (2016)

The majority of existing literature on castellated beam is focused on Simply supported analysis, but this paper provides new analytical solution for calculation critical buckling load by the cantilever action. By experimentally it was observed that the value of web shear deformation on the critical buckling load of castellated beam increase with the increase in cross sectional area of the tee section and depth of web opening, but decrease with the length and web thickness. Castellated beam are such structural members which are made by flame cutting a rolled beam along its center line and then rejoin the two halves by welding so that the overall depth is enhanced by 50% to increase structural performance against bending.

Samadhan G. Morkhade1, Laxmikant M. Gupta (2015)

The use of steel beams with web openings (SBWOs) for structures such as industrial buildings and high-rise buildings has turned out to be extensive in recent times. There are numerous motives for which openings are kept. In this respect, an experimental investigation was planned and conducted on seven models of SBWOs. The initiative was to identify the maximum load behaviour, and deflection of steel beams with openings in the web. The performance of such beams has been considered only for vertical loads. Hot rolled steel beams of ISMB 100 with openings in the web were tested to failure. The beams were simply supported at the ends and subjected to a concentrated load applied at the mid-span. The openings considered in the experimental study are circular and rectangular only. All the beams were analysed by the finite element method by using general finite element analysis software ANSYS and the results were compared with those obtained experimentally. The test results found to be very useful for optimization of spacing-to- diameter ratio and aspect ratio of openings. The finite element results for deformation and ultimate strength shows good agreement with the corresponding values observed in the experiments. At last, a parametric study was carried out using finite element method to examine that which type of openings gives best performance during loading.

Jamadar A. M., Kumbhar P. D. (2015)

In this paper, parametric study of castellatedbeams with circular (cellular beam) and diamond shaped openings has been carried out to optimize its size by considering ratio of overall depth castellated beam to the depth of opening provided (D/Do) and the ratio of spacing of opening to the depth of opening (S/Do). The finite element analysis (FEA) of the beam using Abaqus/CAE 6.13 software and following the provisions of Eurocode 3 has been carried out for different sizes of openings. Von-misses failure criteria is used to finding out failure load on the beam and the results obtained for optimized beam is validated by experimentation. Results showed that, the beam gives better strength results for diamond shaped opening with opening size of 0.67 times overall depth of the beam. It is also observed that, castellated beams are mostly tend to fail in their local modes of failure. As in case of diamond shaped openings more shear transfer area is available so there are minimum effects of local failure. Therefore, castellated beam with diamond shaped openings proves to be better than the other shaped openings in respect of taking.

Shwetha Saju, Manju George (2015)

Compressive and tensile forces act across the web-post on opposite diagonals. Failure occurs when a local web buckle form adjacent to the web opening as shown by the shaded areas in Figure. The compressive stress acting on the strut is calculated using the force in the upper tee-section or half the applied vertical shear force for a symmetrically placed opening. The effective width of the web-post resisting compression is taken as the half the total width of the web-post.

B. Anupriya, Dr. K. Jagadeesan (2014)

This paper investigates the effect of introducing stiffeners along the shear zone where stress concentration is more so

that deflection is minimized and shear failure is controlled. The study is carried out using Finite Element Analysis (ANSYS 14). From the results obtained from ANSYS 14, it was observed that stresses are distributed across the web opening along the shear zone and shear failure is more near the holes than in the solid web of the castellated beam. From the research work, Shear strength of the castellated beam can be improved by providing diagonal stiffeners on the web opening along the shear zone.

5. CONCLUSIONS

1. The load carrying capacity of castellated beam designed by British Standard and IS Code method is nearly same.

2. Load carrying capacity of castellated beam with sinusoidal web opening is more as compare to castellated beam with hexagonal web opening.

3. Due to presence of the web holes, the failure mechanism of the castellated beams is different from those of the solid webs.

4. The castellated beam with sinusoidal web opening gives better structural performances compare to castellated beam with hexagonal web opening in the form of stresses distribution, shear capacity, and failure mode.

5. Also, from experimental it is concluded that comparing the results of all Sinusoidal Web Opening Castellated Beams it is found that a castellated beam with Sinusoidal Web Opening with m distance is 25mm shows better performance compare to other castellated beams with sinusoidal web opening with m distance 50mm, 75mm, 100 mm opening in both load carrying and deflection as well as BM point of view.

6. Experimental analysis shows that stress get easily redistributed at the fillet corner of Sinusoidal web opening of castellated beam.

7. It is observed from both experimental and software analysis of castellated beams Sinusoidal web opening castellated beams shows compare to hexagonal web opening of castellated beam.

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