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COMPARATIVE STUDY OF DIFFERENT WEB OPENINGS IN CASTELLATED BEAM

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ABSTRACT

A castellated beam is a beam which has perforations or openings in its web portion. Generally, steel structures satisfy strength requirements, but the difficulty is that the section has to satisfy the serviceability requirements, i.e., the deflection criteria in safety check. For this it is necessary to use beams with greater depth. Using castellated beam is the best way to overcome this difficulties. With the improvements in materials and techniques of construction, castellated beams have be pushed to span much greater lengths. The castellated beam find use in many varieties of structures, in garages, parking lots, steel frames, industrial buildings. In this project the effect of different web openings in castellated beam is investigated.

INTRODUCTION

This project work is mainly focused on comparative study of different web openings in castellated beams. The main aim of work is to optimize the sizes of openings provided in the beam. In this chapter some introductory information about castellated beams are summarized. 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.These beams are classified based on the shape of the holes provided in the web section. Hexagonal, circular (also known as cellular opening), octagonal, diamond, etc., are the most common shapes of openings. Castellated beams have 1.5 times more depth than the parent section, while their weight is almost the same.

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

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

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

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

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

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

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

7. Improve aesthetic view of the ceiling.

8. Tapered and curved section can be easily fabricated.

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

10. Innovative and eco-friendly structure.

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

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

13. Castellated beam requires low maintenance

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

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

16. It minimizes the floor vibration issues

DISADVANTAGES

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

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

d)High skilled labour is required.

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

Types of castellated beam

Depending upon opening there are different types of castellated beams. Following are the different types of castellated beams. Circular opening, Sinusoidal opening, diamond opening.

LIMITATIONS

There are a number of possible failure modes for castellated beams, which are as follows

•Vierendeel Mechanism:

Vierendeel bending is caused by the need to transfer the shear force across the opening to be consistent with the rate of change of bending moment, in the absence of local or overall instability, hexagonal castellated beams have two basic modes of plastic collapse, depending on the opening geometry. The failure is dependent on the presence ofa shear force of high magnitude in the holes through span

•Lateral Torsional Buckling of the web:

Non-compsosite castellated beams are more susceptible to lateral-torsional buckling than composite beams due to lack of lateral support to the compression flange. The lateral torsional buckling behaviour of castellated beams is similar to that of plain webbed beams. The holes had a significant influence on lateral torsional buckling behavior.

•Rupture of welded joints in the web:

Rupture of a welded joint in a web-post can result when the width of the web-post or length of welded joint is small. This mode of failure is caused by the action of the horizontal shearing force in the web-post, which is needed to balance the shear forces applied at the points of contra flexure at the ends of the upper I section.

History of perforated web beam

Castellated name come from the Latin word whose meaning is to structurally fortify. Before castellated beams, I-beams were used in construction because they are strong and solid way of supporting houses and other industrial structures. Castellated beams were developed as structural channels to increase the beam's depth of parent I-beam and strength without adding additional material causing no change in weight. Since the 1950, because of shortage of steel and increase in cost of steel, castellated beams get started to be used in the construction. Castellated beams were advanced in Europe to overcome the steel shortages and high cost of steel. Castellated beams are the beams having different geometrical shape perforations in the web of beam. The different shapes such as hexagonal, circular, rectangular, diamond, sinusoidal etc. are used in castellated beams. These shapes are constructed with the help of computer controlled cutting torch to cut the section according to given geometry.

In the 1990s, cellular beams were invented. They eventually replaced many uses for castellated beams, though they are still used for over a fifth of the long-span construction projects in the UK and beyond!

CASTELLATED VS. CELLULAR BEAMS

While there are many design similarities, there are also some striking differences between castellated and cellular beams. And each kind of beam provides its own unique sets of advantages dependent on your

particular construction needs. The castellated beams are filled with pseudo-hexagonal holes while the cellular beams focus on circular holes. For castellated beams, the holes have size limitations, which means beams may require modification to accommodate larger services. The different hole sizes and fabrication process for cellular beams provide some advantages over the earlier processes.

Cellular beams allow you to change spacing for each beam, allowing you to reduce both the overall number of holes and the amount of infilling you must do. They are also flexible enough to allow various diameters of cell without raising your prices or even changing up your fabrication process.

Cellular beams also allow you to create a range of depths and customize each beam however you see fit, making them ideal for custom projects and unconventional designs.

However, castellated beams still have their own advantages that make many architects and engineers prefer them. For instance, even after all these years, castellated beams offer a desirable weight to strength ratio at a very affordable cost. They have also been the standard for so long that they are easy for any installers and electricians to work with.

C-beams have also become a major part of the architectural aesthetic in America and throughout the world. Using them in construction virtually guarantees that your final building will look classy and elegant to everyone who sees it!

Properties of Castellated Beams

The properties of castellated beams are:

1. Highly Efficient Steel

The principal property of a castellated beam is that we can increase the depth of the beam without increasing its weight. As a result, castellated beams are highly efficient when it comes to enhancing the load-bearing capacity. They have 40% more moment-carrying capacity with no added steel.

2. Beam Length

The length of the beam can be increased up to 28 m which makes the castellated beam optimal for wide-span and wide-open bay designs.

3. Asymmetric Design

Unique split fabrication of beam gives the ability to lower the weight of the top half of the beam, thus increasing the load-carrying capacity while minimizing the weight of the beam.

4. Other Properties

The design and erection of the castellated beam are elegantly simple.

The physical characteristics of the castellated beam can be changed to achieve several goals. This beam can be customized from section to section; thus, the castellated beam is extremely versatile.

The weight of the beam can be lowered up to 40% when compared to the wide flange steel beam

OBJECTIVES

The following are the main objectives of this project

1. To analyse castellated beam with different web openings by using finite element software and experimentally.

2. To validate result obtained using finite element software with experimental results.

3. To optimize castellated beam with different openings for various parameters by using finite element software.

4. To suggest suitable guidelines for optimized opening shape.

LITERATURE REVIEW

The study on castellated beam based on various size and shape of opening, varying Centre to Centre distance between two openings was studied in Various literatures in addition to that the behavior of castellated beam for flexural was also studied. But the very little study on effect of lateral torsion on castellated beam.

Sahar Elaiwi, Boksun Kim, Long yuan Li (2017), "Bending Analysis of continuous castellated beams". In this paper author find out the effect of web opening on transverse deflection. Author used both analytical and numerical method. Analysis has been done by using ANSYS software, validation was done with analytical method. The analysis of beam with hexagonal opening with continuous supports and uniformly distributed load has been done. Analysis was based upon total potential energy method, the effect of web shear deformation also considered. The results obtained from analytical method were in

excellent agreement with those predicted from finite element software. Shear effect is very important for short and medium span beam with narrow section. If we ignore the effect of shear we could under estimate the deflection. Effect of web shear on deflection gets reduced for increased length of castellated beams. Comparative study shown that analytical calculation and numerical calculation does not exceed (1.13%-31.94%).

S. Durif, A.Bouchair (2016), "Analytical model to predict the resistance of cellular beams with sinusoidal openings" In this paper experimental study has been done on beams with sinusoidal opening. According to author existing methods for predictions has to improved hence modification has been done for accurate prediction of buckling strength. An analytical approach has presented by studying the existing method for multiple opening and on plate buckling theory. Formula has derived for calculation of critical stress coefficient. Easy method is suggested to considerer additional strength provided by the intermediate web-post to the adjacent web panel. Analytical model has validated with finite element results.

S. Durif et al (2014), "Experimental and numerical investigation on web-post specimen from cellular beams with sinusoidal openings" In this research experimental and numerical exploration has been done for isolated web spaced specimen. Models were tested with symmetric loading and lateral supports are also provided to avoid lateral buckling. Experimental results shown that failure modes two quadrants of opening are similar to those observed in whole beam. Two failure modes were observed one of them is yielding of section at linear part of opening and other one is local buckling of web post in sinusoidal opening. Experimental and numerical exploration has been done for three different geometrical configurations. Analytical approach derived in this paper shown results in good agreement in comparison with numerical model results.

Delphin sonck, janbelis(2014),"Lateral– torsional buckling resistance of cellular beams." In this research, the authors studied lateral torsional buckling behaviour of cellular beams with the help of numerical model. The results were validated using experimental results. The equally spaced circular openings in web have more benefit on material use, when beams are loaded on strong axis. Study was limited to the lateral torsional buckling failure. Preliminary design approach was proposed from the parametric study. This new preliminary approach is based on the currently existing European guidelines with only moderation in calculation of cross-sectional properties and modified buckling curve selection.

Prof. R. R. Jichkaret al (2014), "Analysis of Steel Beam with Web Openings Subjected to Buckling Load." In this paper author uses steel beam having section ISMB 300 with span of 5- meter length with circular, hexagonal and square shape web openings. Author also changed the support conditions and analysed all the openings mentioned above. Firstly, the beam with no web opening was analysed with ANSYS software. Then for next beams number of openings was gradually increased from two to six. Comparison of all

Jamadar A.M., Kumbhar P.D. (2015), "Parametric study of castellated beam with circular and diamond shaped openings." In this paper researcher has done analysis of two types of perforated beams namely circular and diamond shaped. The analysis was done using Abaqus software. Results of hexagonal shape opening in steel I beam were taken from previous papers. Comparison of hexagonal, diamond, circular shape opening has been done. Analysis results shown that diamond shaped opening take more load than other two shapes of opening. Reason behind diamond shape opening carrying maximum load is because of it has more shear transfer area. beams were finally done for deflection and buckling load.

M.R.Wakchaure, A.V.Sagade (2012), "Finite Element Analysis of Castellated Steel Beam." In this castellated I beam was selected to analyse. The beam was loaded with two-point load and is simply supported. ISMB150 was selected for fabrication of castellated beam. Author also gave some guidelines for construction of model for castellated beam. Some of the guidelines were eccentricity of opening should be avoided, corners of rectangle should be rounded, etc. the analysis was done by ANSYS software. Deflection is calculated at midpoint of beam. Beams with increase in depth were compared for serviceability criteria. As per author serviceability criteria can be improved by taking corrective measures. Finite element analysis properly shown different failure mode of all beams. As depth of opening increases stress concentration increases at hole.

S. Durif, A.Bouchair (2012), "Behaviour of cellular beams with sinusoidal openings" In this paper, experimental work has been done on full scale model of cellular beams with sinusoidal openings. Two failure modes were observed by formation of four plastic hinges at the opening corner. For understanding actual resistance of sinusoidal openings, isolated part around the opening has been chosen. Experiments have been performed on different quarter of sinusoidal opening to observe the failure mode.

SCOPE OF PROJECT

While designing a power plant structure or multi storied building, the traditional structure steel framing consists of beam and girder with solid web. This hinder provision of pipeline and air conditioning duct. Electrical wiring required for satisfactory functioning for which structure put up. The re-routing structure and additional cost required is unnecessary

One of the greatest advantages of castellated beams are their integration possibilities Castellated beams let facility owners run their utilities directly through web openings. This design opportunity saves several inches of height per floor Beam opening scan also be used as installation conduits for sprinkler piping. HVAC piping, and other utility systems

The future of architectural design relies on this type of structural integration. The use of castellated beams in office buildings may create new solutions for tenants and managers alike Meanwhile, the integration installation capabilities created by castellated beams is creating new opportunities for office building designers.

The installation of conduits within beam depth is advantageous across other building designs, too. Medical buildings, for example, include a variety of data lines and gas lines. Typical construction often requires these lines to be installed, or even relocated, once the project is complete. Castellated steel beams eliminate this need. creating environments conducive to full service integration.

Castellated beams are quickly becoming industry standard options for long lasting ,cost- efficient designs. If you haven't yet, consider their inclusion in your projects.

PROBLEM STATEMENT

Due to limitation on minimum allowable deflection, the high strength properties steel cannot always be utilized to best advantages. As result several new method aimed at increases in weight of steel required, Castellated beam is one of the best solution. While designing a power plant structure or multi storied building, the traditional structure steel framing consists of beam and girder with solid web. This hinder provision of pipeline and air conditioning duct. Electrical wiring required for satisfactory functioning for which structure put up. The re-routing structure and additional cost required is unnecessary.

RESEARCH METHODOLOGY

Following methodology is adopted for dissertation work:

1. Collection and study of literature related to castellated beam with different shape opening.

2. Analysis of castellated beam with finite element software and experimentally.

3. Validation of finite element analysis results with experimentation.

4. Optimization of castellated beam with different openings for various parameters. 5. Suggest the guidelines for optimization of different shapes.

6. Submission of dissertation report

The experimental investigation in this research involves fabrication of castellated beams. To fabricate the castellated beam section ISMB 150 are selected. the beam is cut along its web in a definite pattern and then rejoined together to get an increased depth (50%) of castellated beam with different opening (hexagonal, sinusoidal and diagonal rectangular opening) indicates the Increased depth of Castellated beam. The theoretical design to made as per the Indian code 800-2007 To check the shear strength of different openings. The beam is loaded till its failure and shear strength to study. The beam is tested for 225mm depth for different web openings, hence Single beam will be casted for each type of section. Therefore totally three numbers of beams will be fabricated. The beams will be undergone two point loading until its failure. Analysis will be made with IS code method and ANSYS software. Stress distribution and failure modes for three different web openings will be

studied. Finally, experimental results will be compared with the parent section

EXPECTED OUTCOME:

Our aim is to study flexural behavior of castellated beam for different shape of opening and optimize the shape of opening by using ANASYS software, so that for shape of opening the load carrying capacity is more and the deflection is less.

The expected outcome of this project is to introduce the new shape i.e. the rectangular diagonal shape which can give the better properties than previous shapes.

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