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# Study and Analysis of Connecting Position on the Vibration Characteristics for Beam

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***Abstract*—** This study proposes an investigation into the effect of stiffeners where local stiffness varies on the vibration characteristics of I beams. The main focus is to finding out the proper perforation for reducing the deflection that is caused by vibration characteristic of the beam. Based on the study, considering a castellated beam with hexagonal opening is taken as an example to locating the stiffeners where the local stiffness is reduced in the beam. The castellated beam with web openings and they gain its advantage due to its increased depth of section by cutting the beam into two pieces and welded it together to make hexagonal web openings. Hence, due to increase in depth of beam, variable load carrying capacity of the beam is getting increased. The increase in depth of castellated beam leads to local residual stresses in web openings and lateral torsional buckling failure when these beams are subjected to loading. There are many modes of failure like shear buckling, flexural failure, and rupture of the welded joint in a web post. In order to avoid all these failures stiffeners were introduced in the hexagonal castellated beam.

***Keywords-*** *Euler-Bernoulli beam, connecting position, local stiffness, stiffeners, vibrational characteristic, castellated beam***.**

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## I. INTRODUCTION

Beams are very generally used structural components and it has been categorized according to their shapes of geometry like uniform and varying cross sections. If generally suggested, the non-uniform beams with different cross sections provide a better distribution of mass and strength than uniform beams and can be used to meet special functional requirements in many fields like construction, manufacturing industries, robotics, and other innovative engineering applications. Design of those structures is important to resist designed applied loads, which are exposed to wind and earthquakes. It requires importance in the basic knowledge of natural frequencies and mode shapes of those structures. Design of such, structures to increase the flexibility and stiffness of the beam.

### *A. Castellated beam*

A castellated beam is a beam style where can I beam is subjected to a longitudinal cut along its web following a specific pattern in order to separate it, and rejoin the beam with a longer web by means of the cutting pattern. However presence of web openings which causes to various local effects likes residual stress and shear. This causes out-of plane deformations and constitutes the first source of torsional stiffness for these cross-section types.

### *B. Fabrication process of castellated beam*

Castellated beams are manufactured by means of separating a rolled shaped steel into two half and welded the two parts to make a preferred openings as shown in fig-1 .After joining the one portion so that the increased points of the beam web pattern come together. Some changes in design parameters make it convenient to increase the depth even more. This is made by attaching additional plates between high points of the welded sections. These added plates are called increment plates.

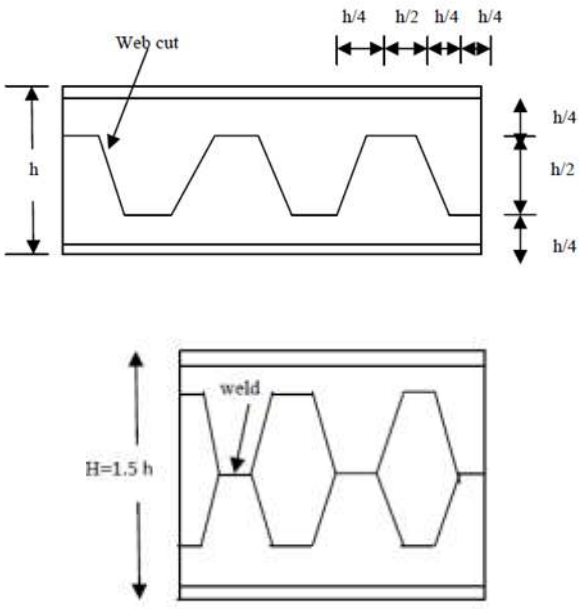



Figure 1. Fabrication of castellated beam with hexagonal openings

### *C. Castellated beam with hexagonal opening*

Castellated beam with hexagonal opening usage become common these days because of its weight to strength ratio. Castellated beams are manufactured by cutting flange of a standard rolled steel I sectioned beam along its longitudinal center and then welding the two halves so that the depth of the

beam gets increased, so it can be more effective to resistance for bending.

*D. Castellated hexagonal beam with stiffeners*

Stiffener are those secondary plates which are used to attached with beams along the longitudinal, transverse and along the edge of opening But if the castellated beams are subjected to uniform loading in such case castellated beam prove to be not suitable. Under this condition castellated beams must be stiffen against the places where these load concentrations occur. For example by inserting plates called as stiffeners, into one or more of the web openings by additional fitting and welding work.

## II. REVIEW FROM PREVIOUS STUDY

In recent times, analysis and design of castellated beam has been carried out by research work, especially with hexagonal openings. There is no universally accepted design method for castellated beam because of complexity in geometry accompanied by complex mode of failure. Some of the commonly occurred failures of castellated beam namely, formation of residual stresses, flexural failure, formation of Vierendeel mechanism in circular castellated beam, rupture of welded joint, shear buckling of web post and compression buckling of web post. Various research studies carried out for analysis and design of castellated beams are presented in the following section.

The load carrying capacity of optimally designed castellated beam with various number of holes and spacing. Finite element analysis of same beams is also carried out under the application of centrally applied point load and failure patterns are studied and verified using ANSYS. Study shows that, even though the members are relatively of shorter spans, lateral supports are governing factor for the analysis of beams due to torsional buckling. It is concluded that, the beam fails in Vierendeel mode when the load is applied above the openings while it fails in web post buckling when load is applied in between space of the openings [1].

Analysis of three models of plate girder without stiffener using software program. And the same model providing with three plates stiffener are evaluated. The post buckling behaviour of shear web panel was explained using model called as shear analogy It was found that the transverse stiffeners are not subjected to compression force. But the strength of the intermediate transverse stiffener is very important parameter as it provides strength to the web of the beam [3].

Studied on the interaction of buckling modes in castellated beam with hexagonal opening analytically as well as experimentally. 62 models of castellated beam were developed with all nonlinear material properties in Finite Element programming software. The parametric study was extended in order to study the effects on the beam when the geometries of the specimen is changed also the length of the beam was considered [4].

## III. DESIGN PARAMETERS FOR CASTELLATED BEAM

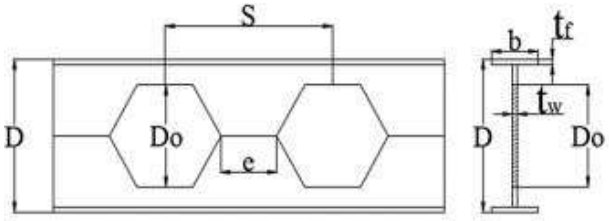



Figure2. Typical cross section of a beam

Where,

| | | |
|---|---|---|
| Do | = | Depth of opening provided. |
| D | = | Overall depth of the opening. |
| S | = | spacing between the two opening |
| e | = | Clear distance between two opening |
| b | = | Width of flange of I beam |
| tf | = | Thickness of flange of I beam |
| tw | = | Thickness of web of I beam |

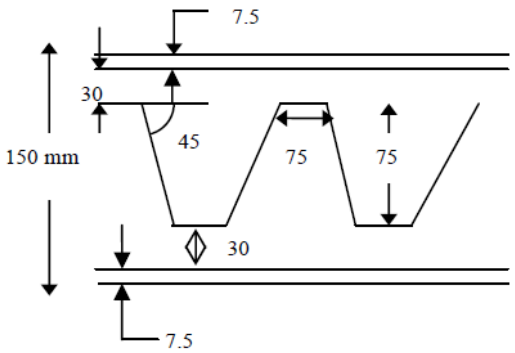
*A. Guidelines for Perforations in Web*

The perforations made in the beam plays a vital role in structural performance of the beam. Therefore, some logical and practical considerations need to be observed while providing perforations in the beam. Following are the general guidelines based on the field or practical considerations.

1. $1.08 < S/Do < 1.5$
2. $1.25 < D/Do < 1.75$
3. $Do \leq 0.8\ D$
4. $e \leq 0.4\ Do$
5. Width of end post $\leq 0.5Do$

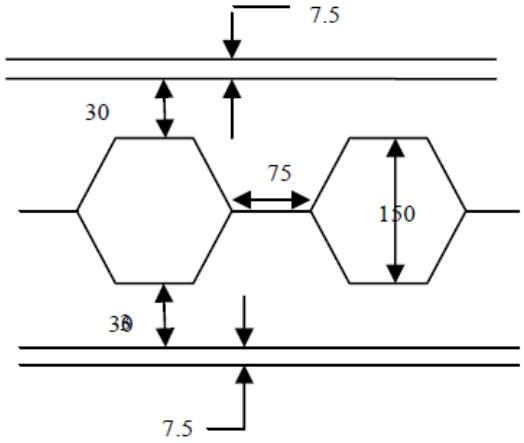
## IV. INVESTIGATION OF CASTELLATED BEAM

Indian Standard Medium Beam (ISMB 150) is selected for analyzing castellated beams. The castellated beams were fabricated such that depth of the beam is 1.5 times the original depth with an angle of cut 45°.




[3]

Figure 3. Design parameters of castellated beam




[3]

Figure 4. Design parameters of castellated beam

Various size and spacing of hexagonal openings were considered on ISMB 150 as shown in table-1. These different openings play a vital role in behaviour of castellated beam under certain loads.

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TABLE1. Parameters considered for hexagonal castellated beam

| Sr. No. | Do (mm) | D (mm) | D/Do | S/Do | S (mm) | e (mm) |
|---|---|---|---|---|---|---|
| 1 | 115 | 150 | 1.30 | 1.4 | 182 | 52 |
| 2 | 105 | 145 | 1.38 | 1.4 | 168 | 48 |
| 3 | 95 | 140 | 1.47 | 1.4 | 154 | 44 |
| 4 | 85 | 135 | 1.58 | 1.4 | 140 | 40 |
| 5 | 75 | 130 | 1.72 | 1.4 | 126 | 36 |
| 6 | 65 | 125 | 1.92 | 1.4 | 112 | 32 |

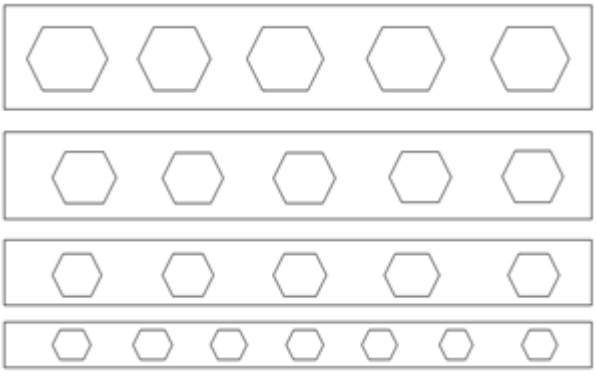

Figure 5. Castellated beam with various perforations

## V. FINITE ELEMENT ANALYSIS OF CASTELLATED BEAM WITH HEXAGONAL OPENINGS

In this paper, a three dimensional (3D) finite element model is developed using Solidworks and analysed using ANYSIS for ISBM 150 beam. 20node Solid 186 element type is selected for various finite element models and it has been analysed by means of both the ends fixed with uniform loads acting on top surface of the castellated beam as shown in fig-5.

Material properties of ISBM 150 beam,

1. Yield strength = 2.5*E8 N/m$^2$
2. Young's modulus = 210*E9 N/m$^2$
3. Poisson's ratio = 0.3
4. Density of Steel = 7830 kg/m$^3$

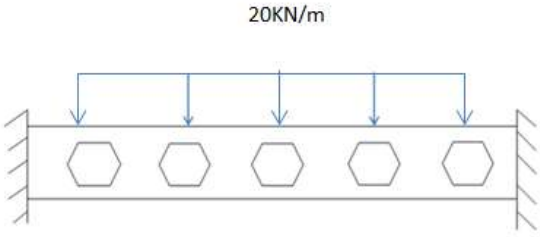


Figure 6. Fixed beam with uniformly distributed load

Modelled castellated beam is imported into Ansys to find out maximum deflection which are caused by applied loads for castellated beam with and without stiffeners. The deformed models are shown in fig- 7 and fig-8.

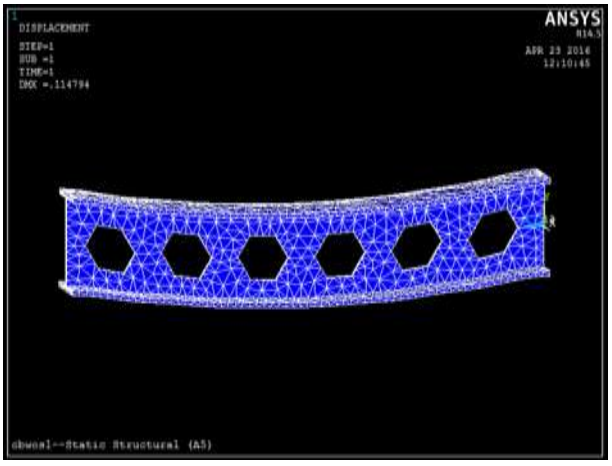


Figure 7. Ansys analyzed model without stiffeners

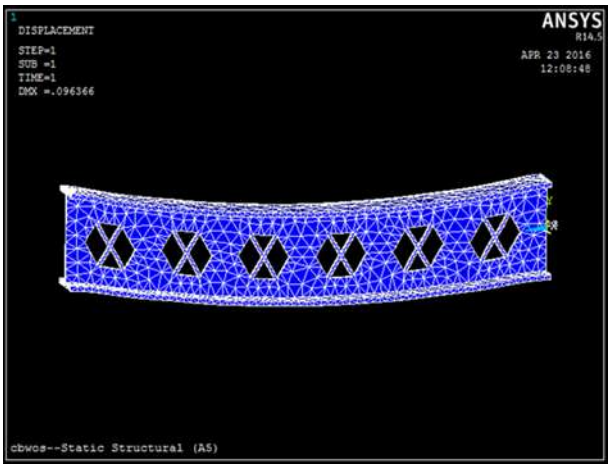


Figure 8. Ansys analyzed model with diagonal stiffeners

## VI. RESULTS AND DISCUSSIONS

TABLE 2.Results obtained from Ansys for castellated beam without stiffeners (wos) and with diagonal stiffeners (wds)

| Sr. No. | Do (mm) | D (mm) | Max Deflection (mm) | | Max stress ($N/mm^2$) | |
|---|---|---|---|---|---|---|
| | | | wos | wds | wos | wds |
| 1 | 115 | 150 | 0.174 | 0.091 | 186.55 | 132.06 |
| 2 | 105 | 145 | 0.183 | 0.099 | 187.83 | 133.52 |
| 3 | 95 | 140 | 0.191 | 0.113 | 189.02 | 135.10 |
| 4 | 85 | 135 | 0.198 | 0.147 | 191.43 | 137.45 |
| 5 | 75 | 130 | 0.211 | 0.172 | 192.98 | 139.37 |
| 6 | 65 | 125 | 0.229 | 0.197 | 194.73 | 142.64 |

From the results obtained from ANSYS, it was observed that maximum deflection and maximum stress between two cases of beam which are analyzed without stiffeners (wos) and with diagonal stiffeners (wds) shows variation in values with same uniformly distributed load 20kN/m. Hence after introducing diagonal stiffeners it is observed that the beam with diagonal stiffeners along hexagonal openings gives effective reduction in deflection than the castellated beam without stiffeners.

## VII. CONCLUSION

Study and optimization of the castellated beam is done by many researchers. From the research gap it have been concluded that study of the behaviour of the castellated beam with stiffeners varies for different perforations and various designed loads. But on the other hand the day by day use of the castellated beam is increasing widely and demand of good performance of the beam under uniform loading is increasing. This will also give a rise to a new area of optimizing the design of stiffener. Analysis and design of castellated beam with hexagonal openings carried out by using stiffeners along the openings of the beam in order to minimize the deflection. Optimization of castellated beams with stiffeners by varying the parameters namely, size and positions in web portion is obtained. Hence diagonal stiffeners provided on the opening of the web is effective than the beams without stiffeners.

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