Use of Castellated Beam as A PEB Component

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ABSTRACT

Use of castellated beams is become very popular now days due to its advantageous structural applications. Castellated beams are those beams which has openings in its web portion. The openings made in the webs are of generally hexagonal, circular, diamond or square in shape. There is lot of study has been done in optimizing sizes of castellated beams with various openings, and hence there is need to optimize the beams with other shaped openings. As we are using ISMB 150 for the making the tapered beam it is easy to manufacture and designs the web opening section with varying the depth. It is also observed that, castellated beams are mostly tending to fail in their local modes of failure.

A pre-engineered building (PEB) is a metal building that consist of light gauge metal standing seam roof panels on steel purlins spanning between rigid frames with light gauge metal wall cladding. It has a much greater vertical and horizontal deflection .Primarily speed and quality of construction are the top two benefits. Steel buildings are fire, quake and cyclone resistant – hence from a safety and longevity perspective, these buildings are timeless Pre-engineered buildings are nothing but steel buildings in which excess steel is avoided by tapering the sections as per the bending moment's requirement. It consist of a complete steel framed building system, with components pre designed to fit together in a vast variety of combinations to meet the unique requirements of specific end uses. If we go for regular steel structures, time frame will be more, and also cost will be more, and both together i.e. time and cost, makes it uneconomical. Thus in pre-engineered buildings, the total design is done in the factory, and as per the design, members are pre-fabricated and then transported to the site where they are erected in a time less than 6 to 8 weeks.

KEYWORDS: Pre-engineered building, castellated beam

INTRODUCTION

Historically, the primary framing structure of a pre-engineered building is an assembly of I-shaped members, often referred as I-beams. In pre-engineered buildings, the I-beams used are usually formed by welding together steel plates to form the I section. The I-beams are then field-assembled (e.g. bolted connections) to form the entire frame of the pre-engineered building. Some manufacturers taper the framing members (varying in web depth) according to the local loading effects. Larger plate dimensions are used in areas of higher load effects. Other forms of primary framing can include trusses, mill sections rather than three-plate welded, castellated beams, etc. The choice of economic form can vary depending on factors such as local capabilities (e.g. manufacturing, transportation, construction) and variations in material vs. labour costs. Typically, primary frames are 2D type frames (i.e. may be analyzed using two -dimensional techniques). Advances in computer-aided design technology, materials and manufacturing capabilities have assisted a growth in alternate forms of pre-engineered building such as the tension fabric building and more sophisticated analysis (e.g. three-dimensional) as is required by some building codes.

NECESSITY

Pre-engineered steel buildings use a combination of built-up sections, hot rolled sections and cold formed elements which provide the basic steel frame work with a choice of single skin sheeting with added insulation or insulated sandwich panels for roofing and wall cladding. The concept is designed to provide a complete building envelope system which is airtight, energy efficient, optimum in weight and cost and, above all, designed to fit user requirement like a well fitted glove. Pre-engineered steel buildings can be fitted with different structural accessories including mezzanine floors, canopies, fascia's, interior partitions etc. and the building is made water proof by use of special mastic beads, filler strips and trims. This is very versatile buildings systems and can be finished internally to serve any functions and accessorized externally to achieve attractive and unique designing styles. It is very advantageous over the conventional buildings and is really helpful in the low rise building design. Pre-engineered buildings are generally low rise buildings however the maximum eave height can go up to 25 to 30 meters. Low rise buildings are ideal for offices, houses, showrooms, shop fronts etc. The application of pre-engineered buildings concept to low raise buildings is very economical and speedy. Buildings can be constructed in less than half the normal time especially when complemented with the other engineered sub systems

OBJECTIVE

The basic aim of this work is, by using IS code we can develop new methodology for designing of castellated beam. By using IS 800-2007 Code based methodology we can develop the procedure of designing of castellated beam for hexagonal web opening in this present work. It is found that from the observation of past result castellated beam fails due to shear stress concentration at the corner of hexagonal web opening. So just to avoid this Vierendeel failure i.e. concentration of shear stress at the corner of hexagonal web opening we suggest the new web opening pattern which is form by filleting the corner of hexagonal web opening that is Sinusoidal web opening in castellated beams.

METHODOLOGY

Structural Specifications

The centre to centre length from one end wall column to the other end wall column of a frame is considered breadth or span of the building. The width between two columns can be measured as span. The span length for different buildings varies. The design is done on span length given by customer. The basic span length starts from 10 to150 meters or above with intermediate columns. Aircraft hangars, manufacturing industries, Stadiums possess major span width. No modifications or extending span be done. The length of PEB is the total length extending from one frontend to the rear end of the building. The length of PEB can be extendable in future. Building height is the eave height which usually is the distance from the bottom of the main frame column base plate to the top outer point of the eave strut. When columns are recessed or elevated from finished floor, eave height is the distance from finished floor level to top of eave strut. This is the angle of the roof with respect to the horizontal. The most common roof slopes are 1/10 and 1/20 for tropical countries like India. The roof slope in snowfall locations can go up to 1/30 to 1/60. Any practical roof slope is possible as per customer's requirement.

There are many structures using steel as there constructional element. In order to decrease the cost of steel structures and increasing the stiffness of steel members, castellated beams have been developed. These beams and columns steel structures may replace the steel elements used in PEB frames. The Castellated beams are beams with holes in its web portion. Such beams are fabricated by cutting a zigzag pattern in its web portion and then welding together the two halves in such a way that the holes are formed in the web portion. Due to its availability and cheap labour cost, castellated beams were used in early 1950s in Europe. By splitting and then expanding the steel section modulus is increased.

Experimental study was conducted on steel beam with and without web openings. Deflection is determined after loading and the better one was selected having maximum load carrying capacity and lesser deflection value.

Guidelines for Perforations in Web

The perforations made in the web are greatly affecting the 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 which are given by Euro code and some of them are based on the field or practical considerations. These standards in web perforations can be changed or modified without affecting the structural performance of the beam.

These guidelines are as follows;

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

Design of Castellated Beam

1. The angle of cut is selected to be300, 45° and 60o. For a good design the depth of stem of the I-section at the minimum beam cross-section should not be less than by 4 of the original beam section.

2. The load over the section from the roof are a curtained and the maximum bending moments are computed.

3. The cross sectional area of the I-section at the open throat is calculated. Neutral axis of the section is determined and moment of inertia about the neutral axis is calculated.

4. The moment of resistance of the castellated beam which is the product of the resultant tensile or compressive force and the distance between the centroid of I-section is calculated.
M.R.= A×σat ×d
Where A = area of the I section at open throat D = distance between the centroid of I section
The moment of resistance of the castellated beam should be more the maximum moment.

5. The spacing of castellated beam should not exceed the spacing determined by following equation
S = P/ W× l
Where S= c/c distance between the castellated beam in meter, P = net load carrying capacity in N, W = design load in N / m2 l = span of the beam in meter

6. The beam is checked in shear. The average shear at ends is calculated from following equation τva = R/d'× t < 0.4 fy Where R = end reaction in N, d' = depth of the stem of I section

7. The maximum combined local bending stress and direct stress in I Segments is also workout and should be less than the permissible bending stress.

8. The maximum deflection of I Segment is calculated. This occurs at the mid span is due to the net load carrying capacity load capacity. Let, δ1 = deflection due to net load carrying capacity δ 2 = deflection due to local effects I = average moment of inertia of the section P = number of perforation panels in half spanδ1 = 5 WL^3 /384 EI ,
δ2= VavgP(m+n)/324EI, δ= δ1 +δ2 < L/360

Fabrication of Castellated Beam

According to IS 800 steel section having size ISMB 150 is selected for the fabrication of solid as well as castellated beam. Markings for which cutting should be done was made and then gas cutting machine is used to cut the specimen along its markings. After cutting, the two pieces were welded together oppositely to form a tapered castellated beam.

Experimental Work and Test

Rectangular hot rolled section is selected as the parent section for fabricating castellated beam. The castellated beams are fabricated such that the depth of the beam at one face is 1.5 times the original depth while other face is 1.33 times of original depth. Thickness of flange is 5 mm, thickness of web is 10 mm, depth of opening is 150 mm, and length of the beam is 2000 mm. Universal testing machine (UTM) is used for testing the castellated beam. Below figures shows the schematic diagram of parent section, castellated steel beam with hexagonal and circular opening used for the analysis.

Load Vs. Deflection for

Sinusoidal Section IS1

SR. NO.	LOAD	DEFLECTION
1	30	0.5
2	40	0.9
3	50	1.3
4	60	1.7
5	70	2.3
6	80	2.6
7	90	3
8	100	3.6
9	110	4.4
10	120	5.8
11	126.46	8.2

Load Vs. Deflection for

Hexagonal Section I_{H1}

SR. NO.	LOAD	DEFLECTION
1	30	0.2
2	40	1.2
3	50	1.7
4	60	2.1
5	70	2.6
6	80	3
7	90	3.7
8	100	4.7
9	110	6.3
10	115	8.7

Load Vs. Deflection for

Sinusoidal Section I_{S2}

SR. NO.	LOAD	DEFLECTION
1	30	0.5
2	40	0.8
3	50	1.2
4	60	1.6
5	70	1.8
6	80	2.2
7	90	2.8
8	100	3.4
9	110	4.6
10	120	6.3
11	123.6	8

Load Vs. Deflection for

Hexagonal Section I_{H2}

SR. NO.	LOAD	DEFLECTION
1	30	0.4
2	40	0.8
3	50	1.5
4	60	1.9
5	70	2.3
6	80	2.6
7	90	3
8	100	3.4
9	110	4.1
10	119	5.3

Load Vs. Deflection for

Sinusoidal Section IS3

SR. NO.	LOAD	DEFLECTION
1	30	0.47
2	40	0.62
3	50	0.98
4	60	1.37
5	70	1.86
6	80	2.4
7	90	2.95
8	100	3.47
9	110	4.98
10	120	6.87
11	125.3	7.42

Load Vs. Deflection for

Hexagonal Section I_{H3}

SR. NO.	LOAD	DEFLECTION
1	30	0.2
2	40	0.5
3	50	0.9
4	60	1.4
5	70	2
6	80	2.7
7	90	3.5
8	100	4.3
9	110	5.4
10	114.8	5.8

CONCLUSION

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

2. The Castellated beam with sinusoidal web opening has as good structural performances as that with hexagonal openings in forms of the stresses distribution, the shear capacity and failure mode, etc.

3. Also the Castellated beam with Sinusoidal web opening has a higher shear capacity than that with hexagonal web opening.

4. Sinusoidal web opening castellated beam has less deflection as compare hexagonal web opening castellated beam.

5. Experimental analysis shows that shear stress get easily redistributed at the fillet corner of Sinusoidal Web Opening Castellated Beams.

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