ANALYSIS & DESIGN OF PREFABRICATED BUILDING USING JACK BEAM

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Abstract -Structural steel is a common building material used through construction industry. Structural steel is a friendliest environmental material as it is 100% reusable. Structural design has evolved due to necessity caused due to earthquake seismic condition. The prefabricated building is a structure made up of a combination of assembly of standard plates. The member plates used in the structure are decided on the basis of codes & standards. The concept of prefabricated building is a worldwide concept due to its low cost, time & economy. Every client has a special requirement about space management. For achieving this space management, structural consultants have to work out the plan in brief. They are considering jack beam instead of taking columns. The industrial plant has a requirement for truck moment, machinery assembly, material storage, open office space. By considering jack beam this space management can be achieved properly. Jack beam can be designed as a moment connection or shear connection. In this project, we are designing jack beam as a shear connection. This means jack beam can transfer only shear to the respected columns. Simply they are designed as a simply supported beam.

Key Words:Pre-Fabricated Building, Jack Beam, Slender Column, Vertical Drift, Aspect Ratio, Staad-Pro

1.INTRODUCTION

The concept of prefabricated building has come from European countries. The need for portable shelter required with a very less time & with very less budget in past days. Also it can be dismantled & used any other location for shelter or any other purpose. These buildings are easy to erect as it constructs in very less duration of time. Also funds required for prefabricated buildings are very less as compared to conventional steel buildings & RCC buildings. In this project we are studying about the concept of jack beam which is the primary member in the prefabricated building. Jack beams are used in the building when client has a special requirement about space management. Different industries have large machineries equipment, truck moment for loading unloading in work space. In that case columns are obstructing due to its supporting condition. Client wants column less structure due to space required for machineries, office clear space, truck momentum. Jack beams can be used instead of columns. Jack beams can be designed as a special shear frame or moment frame depending on the end condition of of jack beam. In Staad-Pro software, jack beams are designed by realizing the end moment. MZ can be released for both ends of jack beams. Any moment cannot be produced in the jack beam. Only shear produced at jack beam can be transferred to the respected columns. In this chapter we are studying about the wind analysis, seismic analysis, behavior of the moment frame, jack beam design. Proper optimisation of building is only possible when building has get accurate parameters in Staad-Pro software. These parameters shall be defined before the analysis of building. These paramagnets depend upon wall condition of building. While defining the proper parameters to columns & rafters, the optimisation of building is done accurately.

Ulso a special concept of Jack Beam is employed to support another beam or rafter, thus eliminating a column support at that location. Jack beams are commonly used in multi-span buildings where the client may need additional clear space for equipment or for material handling purpose. Jack beams may also be required in sidewalls where an oversized framed opening (i.e. larger than the bay spacing) is required, thus eliminating a sidewall column. Jack beams are designed to support dead plus live loads i.e. gravity loads, and dead plus wind uplift loads in their major axis. When sidewall jack beams are required, they are generally not designedto withstand any lateral or horizontal wind loads in their minor axis. To eliminate this minor axis bending in the jack beam, the intermediate rigid frame rafter resting on the jack beam should always be braced in the roof back to the adjacent main rigid frames. Therefore the horizontal load from the wind transmitted to the rafter is then distributed through the bracing to the adjacent main rigid frames. These adjacent rigid frames should be designed for additional vertical and horizontal loads from the jack beam.

2. LITERATURE REVIEW

2.1 Ms. Aayillia K. Jayasidhan

Observed that the analysis & design of building was done by standard specification to the possible extend. The analysis of structure was done by standard package software Staad Pro V8i, results are cross checked by manually. Standard code referred as Indian code for hot rolled sections, cold form sections & built up sections.

2.2 Yash Patel, Yashveersinh

Observes that steel buildings are made up with orthodox section of steel which are designed & built using conventional approaches. This directs too weighty structure as compared to prefabricated buildings. Tubular sections are the best alternative to conventional steel structures as it will reduces 15% to 25% in total weight.

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Observes that by considering IS code instead of American code, building weight can be increased by 20% to 23%. As deflection limits as per IS standard are different as compared to American code. Also load combination factor for Indian code 7 American code are different. In result heavy tonnage is coming in Indian standard design as compared to American code design. Design is based on IS 800 2007 LSM. Dead load, live load & wind load is considered as per LSM design.

3. STRUCTURAL CONFIGURATIONS

3.1 Building Parameters

Table1-Parameters

Location	Pune, Maharashtra
Length	45.0m C/C
Width	22.27m C/C
Height	10.5m (clear)
Seismic zone	III

Wind speed	39 m/sec
Wind terrain category	2
Soil type	Medium
Importance factor	5
Bay spacing	7.5 m C/C

3.2 Codes Standards & References

Table2-codes

MBMA 2010	Metal Building manufactures association
IS 875-Part 1987	Code of practise for design loads
IS 1893-part I 2002	Earthquake design
AISC	American Institute of Steel Construction
AISI	American Iron of Steel Institute

4. STRUCTURAL LOADS

4.1 Seismic load calculation

Earthquake loads affect the design of structures in areas of great seismic activity. The proposed structures in this project shall be analyzed for seismic forces. The seismic zone shall be considered as per IS: 1893-2002 (Part1). For analysis and design, Zone III shall be considered as Pune region falls under this zone as per IS: 1893- 2002 (Part 1).

4.2 Dead load calculation

Dead load calculation includes Purlins, sheeting, sag rod and insulation material. The total load transferring from these components is 0.10 KN/m². Total Dead load = 0.1*7.5(Bay Spacing) = -0.75 KN/m

4.3 Live load calculation

Live Load is considered as 0.57 KN/m² according to American code of practice for roof where access is not provided except for maintenance and for a roof where slope is greater than 10 degree then there is reduction of 0.02 KN/m² for every degree in increase above 10 degree. Total Live load = 0.57*7.5(Bay Spacing) = -4.275 KN/m

4.4 Wind Load calculation

Basic wind speed = 39 m/sec

Risk coefficient (K1) = 1

Terrain height & size factor = 0.98, Topography factor = 1

Design wind speed (Vz) = Vb x K1 x K2 x K3

= 39x1x0.98x1 = 38.22 m/s

Design wind pressure (Pz) = 0.6x (Vz)2

(Pz) = 0.876 KN/m²

Design Wind Pressure (Pz) = 0.876 kn/m2

Wind load is calculated as per IS873 (PartII). The wind load over the roof can be provided as uniformly distributed load acting outward over the roof and which is calculated as per table 16 given in IS-875 part III . For side walls, the wind load is applied as uniformly distributed load acting inward or outward to the walls according to the wind cases. The Staad-Pro used in structural analysis and design structure. The procedure for design of structure is modelling the structure, specs to structure, support, loading and load combination, of analysing and design of the structure. In Staad-Pro utilization ratio indicates the suitability of the member as per codes. Normally a value higher than 1 indicates the given member is no suitable for a given loading & load combination, and

valuebelow 1.0 indicates the reserve capacity available. The critical conditions used as criteria to determine Pass/Fail status are Slenderness limits, axial compression and bending, axial tension and bending, Maximum w/t ratios and Shear. Rigid steel frames of the building are mainly considered as the Main Frames of PEB. PEB rigid frame comprises of tapered columns and tapered rafters (the fabricated tapered sections are referred to as built-up members). The tapered sections are fabricated using the state of art technology wherein the flanges are welded to the web. Splice plates are welded to the ends of the tapered sections. The frame is erected by bolting the splice plates of connecting sections together.

5. STAAD-PRO RESULT

While optimizing the above building using jack beam, building can be checked for horizontal & vertical deflection. As per (AISC) American Institute of Steel Construction, different criterion for deflection has been given as follows. Below is deflection criterion as per Staad-Pro Results & manual results. PEB rigid frame comprises of tapered columns and tapered rafters (the fabricated tapered sections are referred to as built-up members).

5.1 Jack Beam Design

In the above building jack beam is designed as a simply supported beam. It does not transfer any moment to the respected columns. Only it transfers shear to the supporting column. Below are the shear force & bending moment generated at the jack beam as follows:

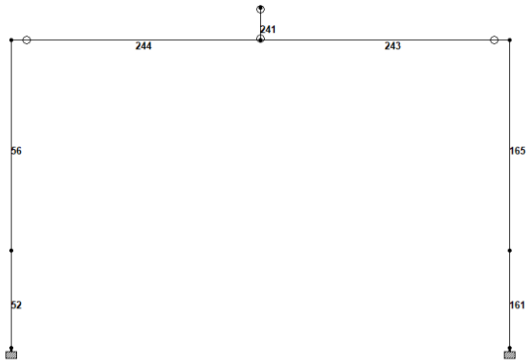

fig.1. Jack beam member number

Beam no 243 & 244 is a jack beam part of building. As it does not transfer any moment to respected columns numbers 52, 56, 161, 165. Jack beam can transfer only shear to the respected columns. At supporting column location moment at end is zero due to MZ realese condition assigned to jack beam. Moment at intermediate location is 92 kN-m which is high due to supporting frame. In the below graph Bending & shear for jack beam as per Staad-Pro is as follows:

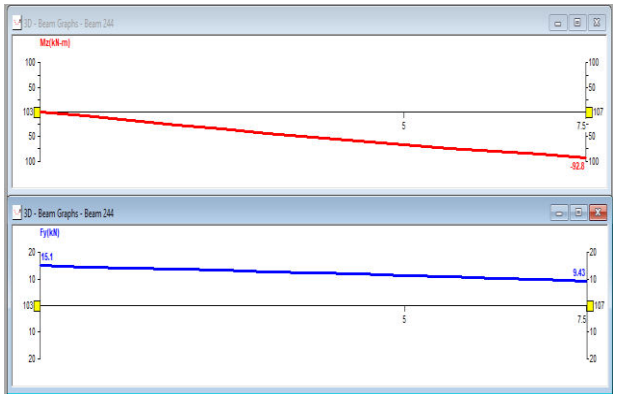

fig.2. Bending & Shear for Jack beam

5.2 Jack Beam Drift summery (Vertical)

As the optimization of jack beam is the main issue as it is very critical in vertical drift. In this building jack beam can be designed for 15m span center to center. In Staad-pro software, jack beam is designed as a simply supported beam with a point load of corresponding rafter. As per AISC code, jack beam is checked for vertical deflection of span/240.
Allowable deflection = 15000 / 240 = 62.5 mm

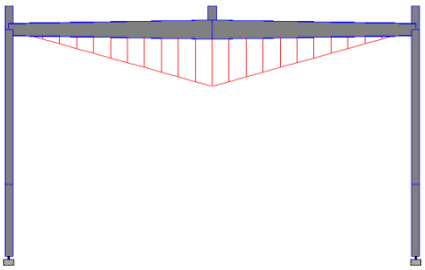

fig.3. Bending for Jack beam

The vertical drift can also be controlled by the end condition of Jack bean. As the beam can be designed for deflection as a shear connection & moment connection. We have considered shear connection as Jack beam will not transfer any moment to the corresponding column. Moment can be released at start & end of the Jack beam.

Table3- Jack Beam Vertical Drift

Node No	Actual deflection (mm)	Allowable Deflection (mm)	Governing Case
104	17.166	62.5	Live load

5.4 Aspect Ratio

The main concept of optimization is to reduce the tonnage of building. As in market so many completion is there for won the project. Bidding is the only process, as who has the minimum tonnage, that client won the project. This is the main funda of optimization of building. In Staad- Pro utilization ratio indicates the suitability of the member as per codes. Normally a value higher than one indicates the given member is no

suitable for a given loading & load combination, and value below 1.0 indicates the reserve capacity available. The critical conditions used as criteria to determine Pass/Fail status are Slenderness limits, axial compression and bending, axial tension and bending, Maximum w/t ratios and Shear. Density of building is the ration of total tonnage of building to the area of respected building, mezzanine area, canopy area. It is measured in kg/m2. Total tonnage of building is obtained from Staad-Pro software.

6 SUMMARIES

In the above study paper, building can be designed as per American code, pressure calculation is done as per Indian Standard. If client has a special requirement about space in the structure, structural engineer has to correspond this requirement. For achieving their requirement, he has to design jack beams in the structure. Jack beam is designed as a shear connection beam in actual case. Both end connection for jack beam is pinned shear connection. It did not transfer any moment to corresponding column. Only shear produced due to supporting frame is transferred to side wall columns. Single point load of frame weight is considered for jack beam design. Jack beam is also designed for horizontal forces from wind in longitudinal direction.

7 CONCLUSIONS

The main concept of space management can be achieved by considering jack beam instead of columns. Also The weight of building is reduced drastically due to jack beam instead of columns. The density of building is reduces by considering jack beam.

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