100M & 150M Span Single Ridge Steel PEB Warehouse Made of Wide Flange Rolled Sections

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ABSTRACT

Buildings & houses are one of the oldest construction activities of human beings. The construction technology has advanced since the beginning from primitive construction technology to the present concept of modern house buildings. The present construction methodology for buildings calls for the best aesthetic look, high quality & fast construction, cost effective & innovativeness. The manufacturing of structural members is done on customer requirements. Pre-engineered buildings can be adapted to suit a wide variety of structural applications and the greatest economy will be realized when utilizing standard details. An efficiently designed pre-engineered building can be lighter than the conventional steel buildings by up to 30%. Lighter weight equates to less steel and a potential price savings in structural framework. Steel hot rolled sections have been in use in construction since long in India. With advancement of technology to build moment resisting frames to resist frame actions, a review of the existing available sections is required to assess their applicability. PEB construction is 30 to 40% faster than masonry construction. PEB buildings provide good insulation effect and would be highly suitable for a tropical country like India. PEB is ideal for construction in remote & hilly areas as well as for metro cities.
This paper covers in detail about the concept of Pre-Engineered Building, its construction system, benefits, applications and pictorial representation of various categories of buildings with the properties in single span and single ridge sloped PEB frame fabricated with wide flanged roll section with the wind design philosophy and investigates the available sections in light of the different code requirements for desired performance under strong wind conditions.

Key Words: Steel Rolled Sections, Pre-Engineered Buildings, Very Large Spans, Single Slope, Single Ridge.

1. INTRODUCTION

India being a developed country massive warehouse building construction is taking place in various parts of the country. Since 30% of Indian population lives in towns and cities; hence construction is more in the urban places. The requirement of housing is tremendous but there will always be a shortage of house availability as the present masonry construction technology cannot meet the rising demand every year. Hence one has to think for alternative construction system. In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer to be fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. Within some geographic industry sectors these buildings are also called Pre-Engineered Metal Buildings.
Warehouse is defining as a commercial building for goods store. It’s mainly used for manufactures, exports, imports, transport business and customs. This is actually large building in industries at cities, town, and

villages. It's having loading and unloading goods docks from truck, sometimes design for railway, airport or seaports. In our country a warehouse is referred to as a godown. The main function is to display of goods for sale which is used for home trade such as the latest fashion items. Overseas warehouses which are catered for the overseas trade it is becoming the meeting places for overseas wholesale buyers where printed and plain discussed and ordered. Packing warehouses is the purpose of picking, checking, labeling and packing of good for export. Railway warehouses is built close to the major stations in railway hubs and canal warehouses types can trace their origins back to the canal which is used for trans-shipment and storage.

Difference between warehouse and industrial space - It actually offers more than just an area where you can pile boxes one over the other in warehousing parlance that software, machinery and people must all work smoothly and with lesser error than usual. This component is important to attain the accuracy and precision that your warehouse space needs in order to serve your clients. In other hand industrial space covers more than just what warehouse space can offer. Most of the time an industrial space can be used for every integral part of your business operations from assembly fabrication and manufacturing to conducting regular meeting with rest of the team and also take charge every aspect of business operations.

Disadvantages of trussed fabrication - If adequate records of inspection by qualified welding inspectors of roof trusses during their construction or subsequent modification are not available, then section sizes and welds, particularly in closed hollow section tubes, may not be sufficient to meet the required design demands. Closed hollow sections may not have the specified wall thickness. Complete penetration welds in closed hollow sections may not have achieved full penetration and strength. This is particularly likely if backing strips have not been used in preparing the welds in accordance with the welding standard AS/NZS 1554.1. Site welding of trusses, particularly where accessibility is difficult due to height or confined spaces, may not have been completed or achieved the specified quality. Compression splices without full contact on bearing plates or abutting sections may significantly reduce truss capacity.

2. HISTORY OF PEB

It includes evolution history of the industry and overall industrial scenario for PEB market.
Early 1900s concept of metal building originated in USA. Simple industrial structures using truss rafters, straight columns, section roofs and well created. Wedge pins used for connections.
1940s Mass production of Nissan and Quonset Housing and storage modules for US Army during World War II. Metal building system recognized as a favorable method of construction over conventional methods.
Late 1950s and Early 1960s Computerized design allowed building to be tailored to individual customer requirements. Roll forming lines allowed continuous span cold rolled Z-purlins. Color coated panels and factory insulated panel improved architectural appearance. Major increased in design possibilities contributed to the boom in metal building. The term PEB comes into existence.
1990s PEB start dominating the low rise building market. Precision roll forming lines for the cladding and section members introduced. Automatic production lines for steel and cladding introduced. Statistics shows, about 60% of low rise industrial and commercial building in USA use PEB system.

3. MAINTENANCE

In PEB the maintenance area is the steel roofing & cladding. Steel roofing & side wall cladding requires minimum maintenance. The roof should be inspected immediately after installation to check if cleaning of the roof has been carried out fully. It is very often seen that the drilled out metal and debris are not swept away. These can act as initiators of corrosion and lead to premature failures.
Installed roofing must be inspected at least once a year. Any exposed metal that can rust or has rusted should be painted. Leaves, branches and trash should be removed from gutters, at ridge caps and in corners. Also watch out for discharge from industrial stacks and particulate matter and high sulphur exhaust from space heaters which could get piled up.
Roof top ancillaries and air conditioner supports, drains and housing should be checked. Particular attention should be paid to add-on roof ancillaries that create new roof penetrations. Roof-top air conditioners should

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be installed on curbs designed to avoid ponding water. Condensate from air – conditioning and refrigeration equipment should never be allowed to drain directly on to the roof panels. The drainage contains ions from condenser coils that accelerate corrosion.
In the event of a roof leak, do not indiscriminately plaster the suspected leak area with tar or asphalt or use repair tape. Water can collect under the repair material causing corrosion. Instead, have an experienced roofing foreman locate the leak, identify its cause and properly repair the roof.

4. ADVANTAGES OF PRE-ENGINEERED BUILDINGS

PEB System is zero maintenance & superior in strength than conventional:

- Optimized design of steel reducing weight
- Easy future expansion/modification
- Voluminous space (up to 60M clear spans, 30 M eave heights)
- Weather proof
- No fire hazards
- International Quality Standards
- Seismic & Wind pressure resistant
- Quality design, manufacturing and erection
- Quick delivery and Quick turn-key construction
- Architectural versatility
- Energy efficient roof and wall system using Rockwool & PUF insulation
- Water-tight roofs & wall coverings
- Pre-painted and has low maintenance requirement
- Easy integration of all construction materials
- Erection of the building is fast
- The building can be dismantled and relocated easily.

5. ADVANTAGES OF WIDE FLANGE ROLLED SECTIONS IN PEB

- Very large span portals can be easily made
- No welding or bolting is required as the section is hot rolled
- Wide flange provides more restrained condition against lateral buckling
- Thus permissible stresses are higher with lower the member weight

6. EXAMPLE OF A 100M AND 150M SPAN SINGLE SLOPED AND SINGLE RIDGE PEB

STRUCTURE CONFIGURATION DETAILS FOR 100M SPAN

Selected structure is having the dimensions length 500m, width 100m, eaves height 10m (clear), & roof slope 1:10 with single ridge point. Structure is situated in seismic zone II with basic wind speed 47 m/sec considering the life span of structure as 50 years. Complete structure configuration details can be found in below table:

Location : India	Wind speed : 47 m/sec	Importance factor : 1
Length : 500 m	Wind Class : C	Wind terrain category : 2
Width : 100 m	Life Span : 50 years	Upwind slope : less than 3^0
Eaves height : 10m (clear)	Slope of roof : 1:10	Frame spacing : 6 m

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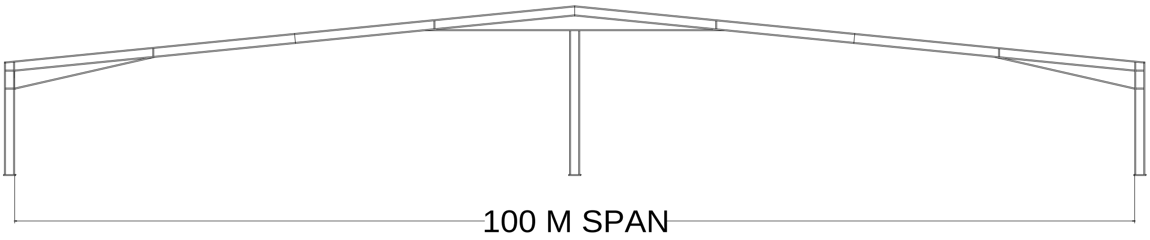

Figure1 100m Span PEB Frame

Load Calculation

Dead Load Calculation

Dead load calculation includes the weight calculation of sheeting, sag angles, purlins and insulation material as follows:

Sheeting unit weight & Purlin wt	20 kg/m^2 = 0.2 kN/m^2
including Insulation material wt	6 kg/m^2
UDL due to Dead load	20 * 6 = 120 kg/m = 1.2 kN/m

Live Load Calculation

Calculation of live loads includes consideration of live loads according to different codes (Indian, American) as follows in calculation of live load as per IS: 875 (part-2) -1987-Table-II (Imposed loads on various types of roofs).

Angle of roof truss (α)	$\tan^{-1}(1/10)$: 5.71^0
Live Load	0.75 kN/m^2
Spacing of Frames	6 m
UDL due to LL	6*0.75 = 4.5 kN/m

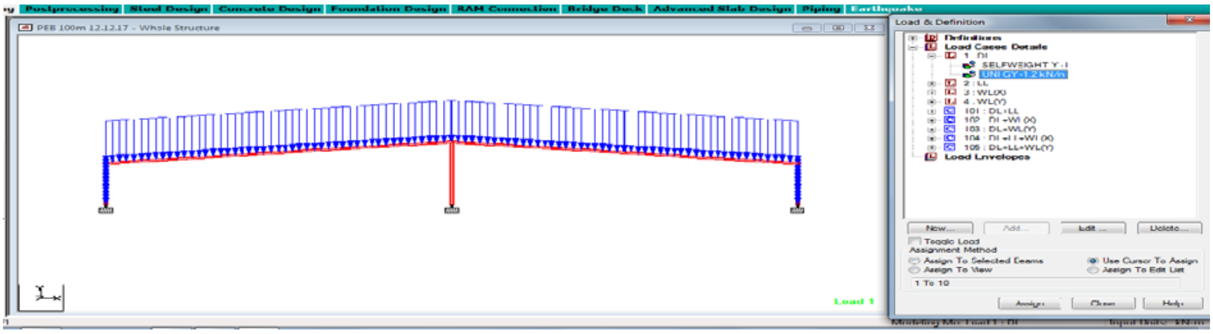

Figure 2 Dead Load

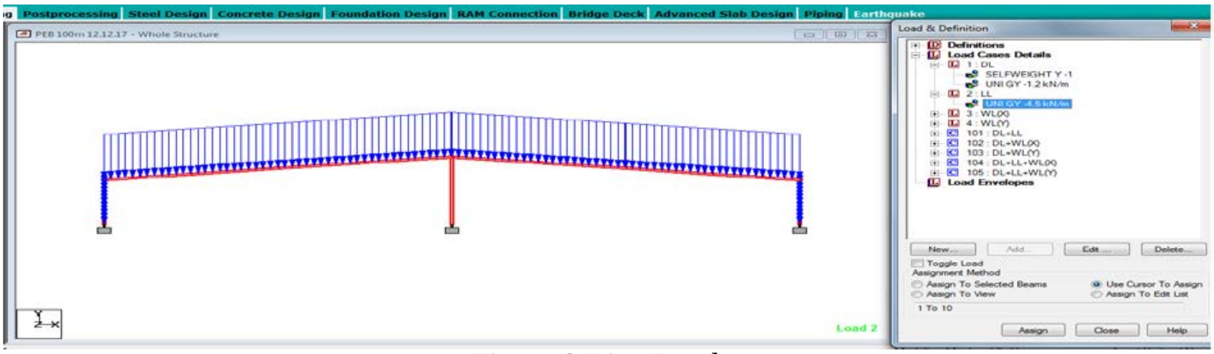

Figure 3 Live Load

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Wind Load Calculation

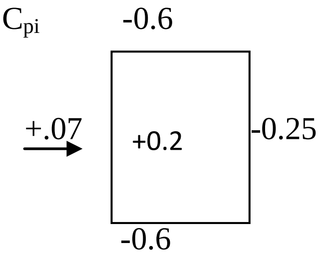
Wind load calculation is done according to Indian code IS: 875 (part-3)-1987-Cl.5.3, as follows:

Wind speed (Vb)	47 m/sec
Risk coefficient (K1)	1
Probability factor (K2)	0.95
Topography factor (K3)	1.0
Design wind speed (Vz)=K1*K2*K3*Vb	1*0.95*1*47 = 44.65 m/sec
Design wind pressure (Pz) : 0.6*(Vz)^2	0.6*(44.65)^2 = 1196.17 N/m^2 = 1.196 kN/m^2

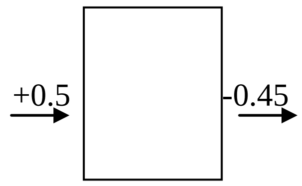
Case 1: L/w = 5 ; h/w = 0.1

Wall Load

C_{pe}, C_{pi}

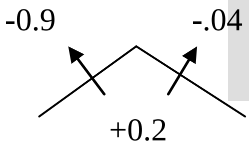


C_{pe} - C_{pi}

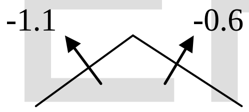


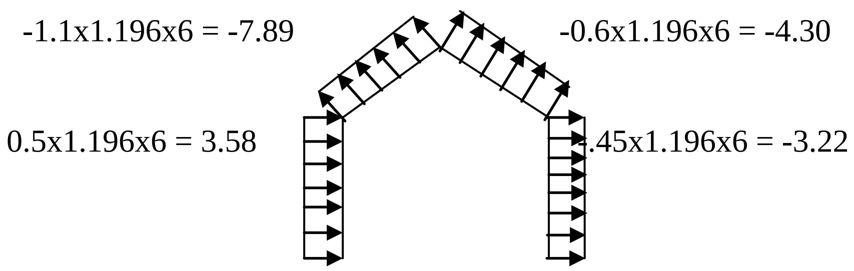
Roof Load:

C_{pe}, C_{pi}



C_{pe} - C_{pi}

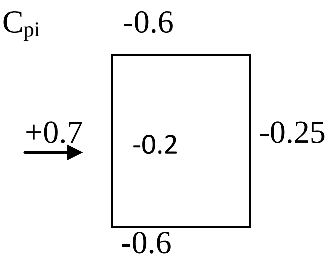




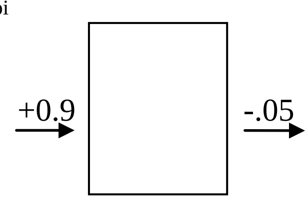
Case:2

Wall Load

C_{pe}, C_{pi}



C_{pe} - C_{pi}

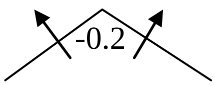


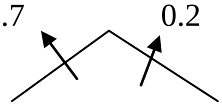
Roof Load:

C_{pe}, C_{pi} C_{pe} - C_{pi}

-0.9 -0.4 -0.7 0.2

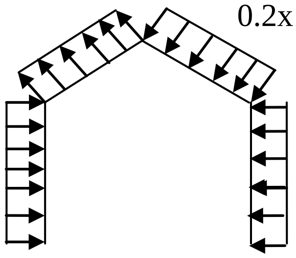
-0.2





-0.7x1.196x6 = -5.02 0.2x1.196x6 = 1.435

0.9x1.196x6 = 6.45 0.05x1.196x6 = 0.358



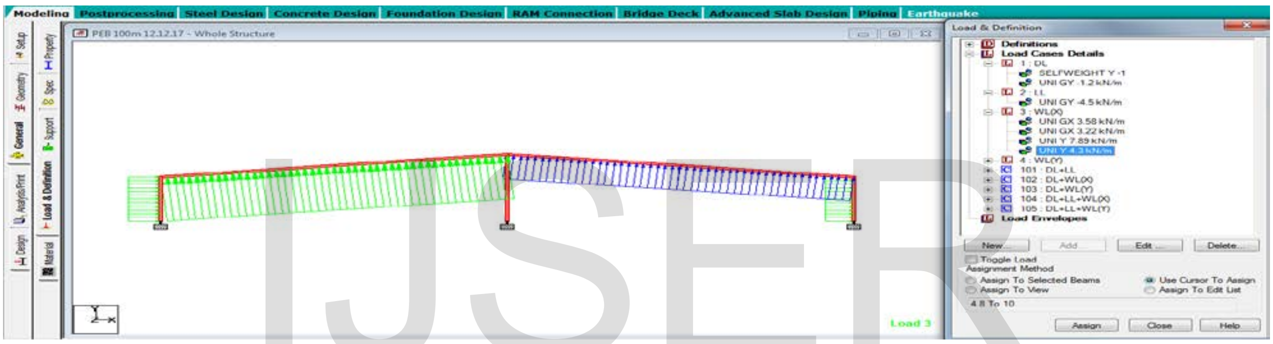
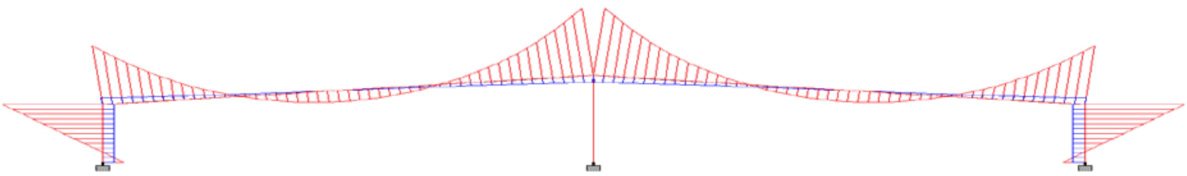


Figure 4 Wind Load

PRE-ENGINEERED BUILDINGS ANALYSIS AND DESIGN BY STAAD.PRO

The power tool for computerized structural engineering STAAD Pro is the most popular structural engineering software product for 2D, 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. The software is fully compatible with all Windows operating systems. In STAAD Pro utilization ratio is the critical value that indicates the suitability of the member as per codes. Normally, a value higher than 1.0 indicates the extent to which the member is over-stressed and a value below 1.0 tells us the reserve capacity available. 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. For static or dynamic analysis of Pre-engineered building, STAAD Pro has been the choice of design professionals around the world for their specific analysis needs.

BM AND SF DIAGRAM OBTAINED FROM STAAD ANALYSIS



5 Typical BMD and SFD

SECTION SIZE DISCUSSION

WPB 900x300x251.6 kg/m wide flange rolled section is used as the basic member. At the regions where bending moment and shear forces are larger, section size is varyingly increased up to 2.5m in depth with flange width 300mm, flange thickness 45mm and web thickness 20mm. From the above figures it is clearly observed that the distance for knee is approximately 12.50 m. One internal column is given that is also made by WPB 900x300x251.6 kg/m. As our basic member is rolled section huge amount of welding or bolting connection is avoided resulting hazard free faster construction technology. This is the most advanced way to construct PEBs. Splices shall be provided at suitable locations (nearly 1/4th of 50m distance).

STRUCTURE CONFIGURATION DETAILS FOR 150M SPAN

Selected structure is having the dimensions length of 750m, width 150m, eaves height 10m (clear), & roof slope 1:15 with single ridge point. Structure is situated in seismic zone II with wind speed 47 m/sec considering the life span of structure as 50 years. Complete structure configuration details can be found in below table:

Location : India	Wind speed : 47 m/sec	Importance factor : 1
Length : 750 m	Wind Class : C	Wind terrain category : 2
Width : 150 m	Life Span : 50 years	Upwind slope : less than 3^{0}
Eaves height : 10m (clear)	Slope of roof : 1:15	Frame spacing : 6 m

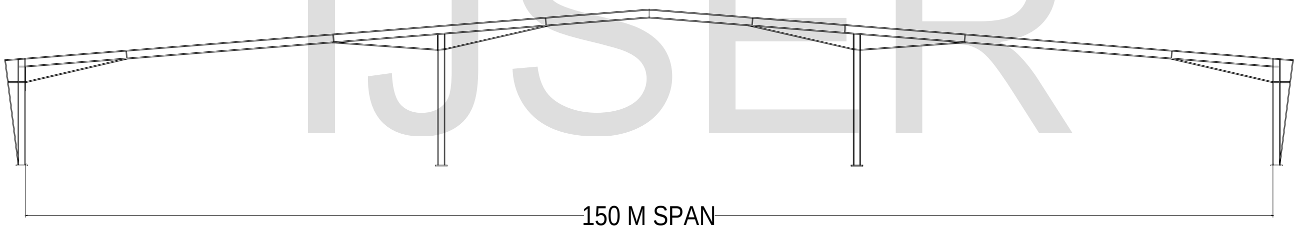


Figure 6 150m Span PEB Frame

Load calculation

Similar to the 100 m span, applied on 150m span PEB Frame.

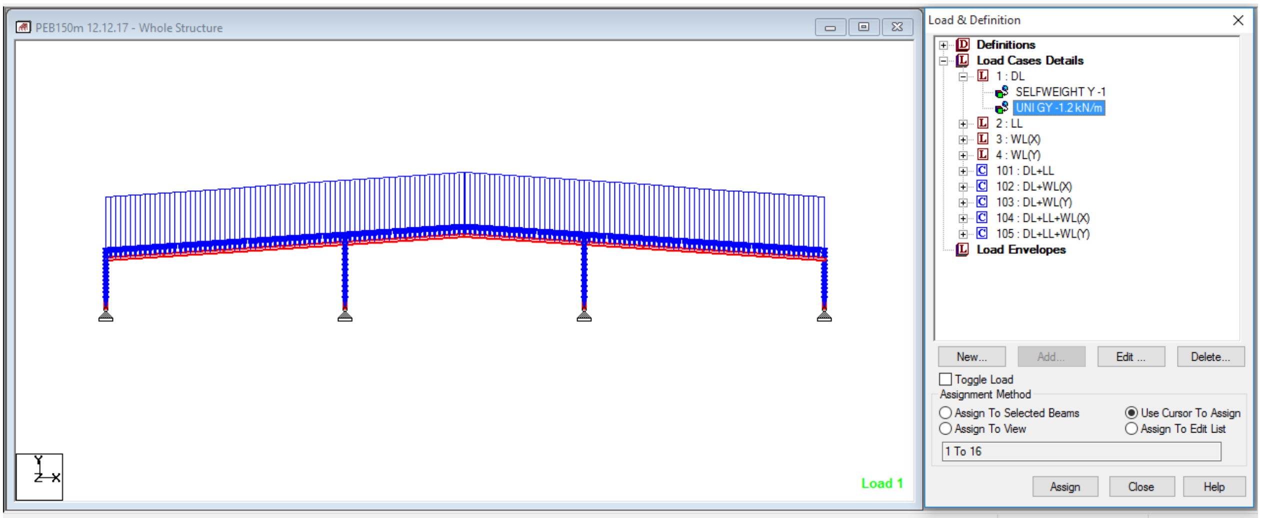


Figure 7 Dead Load

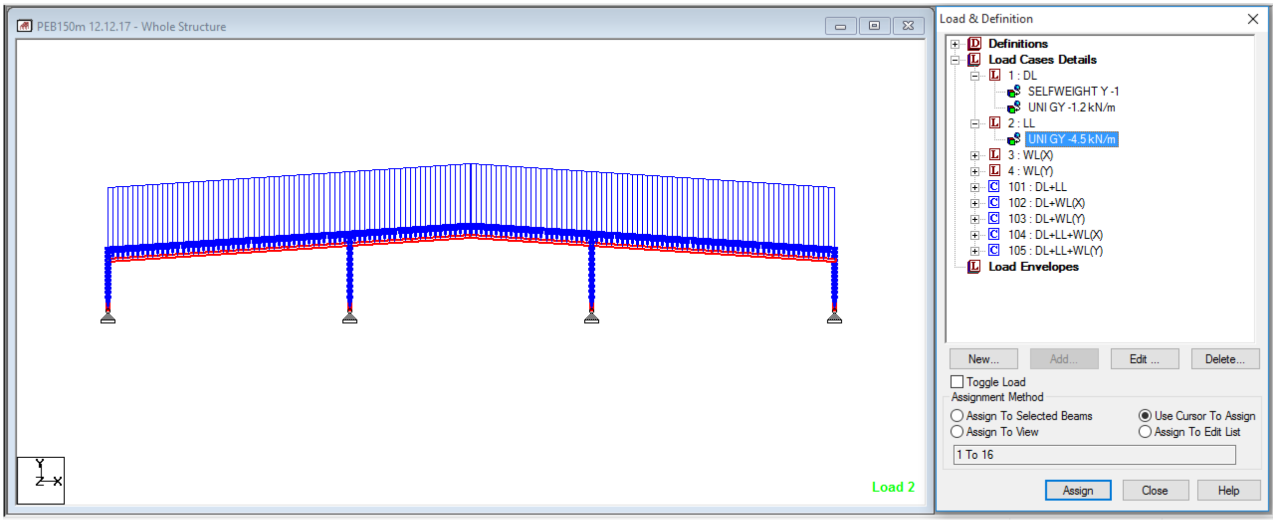


Figure 8 Live Load

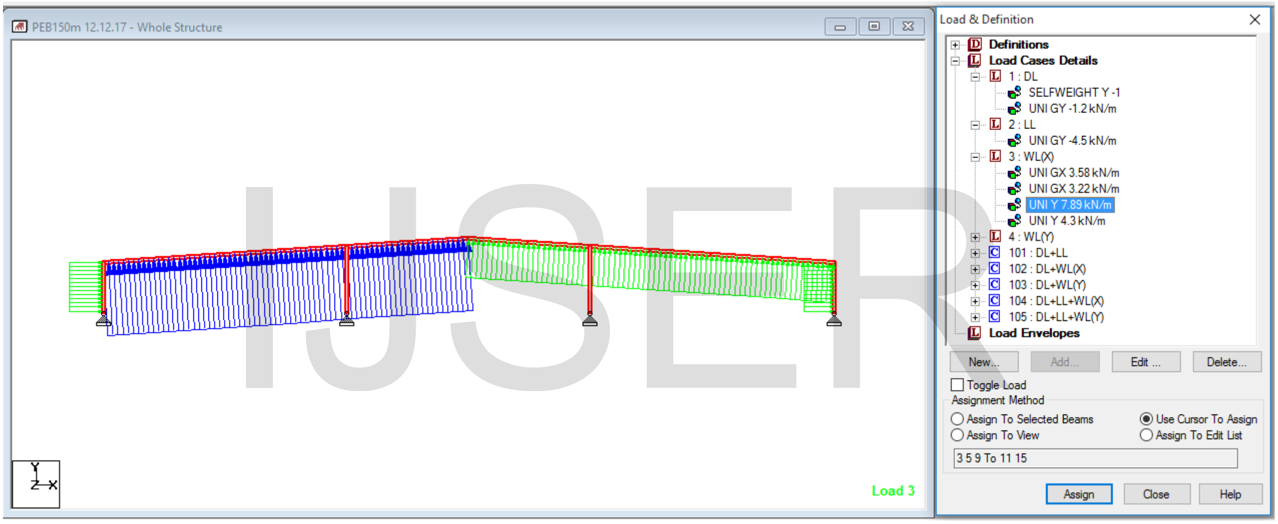


Figure 9 Wind Load

SECTION SIZE DISCUSSION

WPB 900x300x251.6 kg/m wide flange rolled section is used as the basic member. At the regions where bending moment and shear forces are larger, section size is varyingly increased up to 2.5m in depth with flange width 300mm, flange thickness 45mm and web thickness 16mm. From the above figures it is clearly observed that the distance for knee is approximately 12.50 m. Two internal columns are given those are also made by WPB 900x300x251.6 kg/m. As our basic member is rolled section huge amount of welding or bolting connection is avoided resulting hazard free faster construction technology. This is the most advanced way to construct PEBs. Splices shall be provided at suitable locations (nearly 1/4th of 50m distance).

BM AND SF DIAGRAM OBTAINED FROM STAAD ANALYSIS

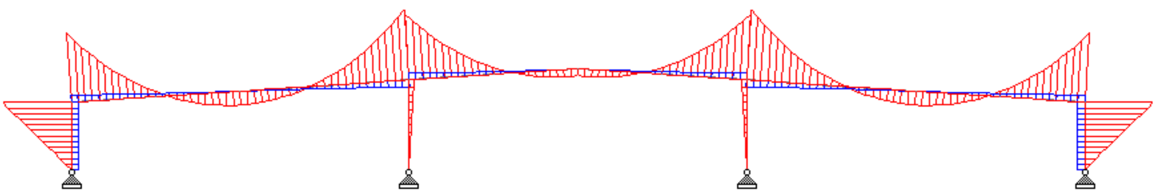


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Figure 10 Typical BMD and SFD

7. CONCLUSIONS

1. The comparative study on Conventional and Pre-engineering Portal leads to the conclusion that PEB proves to be relevant and beneficial for warehouses equipped with cranes and the advantage of having a PEB portal over a traditional steel portal are far too many.
2. Apart from the main parameters like structural load, steel quantity, Concrete Quantity and Cost, Speed and quality of construction are also the benefits. Hence from a longevity perspective these buildings are timeless.
3. Hence PEB should not be looked upon as a sub entity of construction but as a sector with distinct identity of its own.
4. Moreover, for very large span single sloped, single ridge point PEB frames are free from damages due to rain water accumulation. In these types of PEBs, the basic member is considered as wide flange rolled sections that leads to hazard free faster construction technique avoiding huge amount of welding and bolting.

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