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SCHOOL OF CIVIL, ENVIRONMENTAL AND LAND MANAGEMENT ENGINEERING

CIVIL ENGINEERING MASTER THESIS

"PRE-ENGINEERED BUILDINGS : THE FUTURE OF INDIAN INDUSTRIAL INFRASTRUCTURE"

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Academic Year 2020-2021

Acknowledgements

At the end of this thesis work, I would like to thank everyone that has supported and helped me during the course of this thesis as well as throughout my course of study.

I would firstly like to thank my parents for being my support, for providing me with encouragement whenever I needed it and for providing me with the opportunity to study in Politecnico di Milano. I thank them for making me understand what was right and wrong and for helping me understand what my path could be in times of indecisiveness. Their valuable advice has made me what I am today.

I thank my supervisor, Professor Fabrizio Tellarini, for giving me the opportunity to carry out this thesis and for providing me with a good opportunity to grow professionally as well as personally.

I would also like to thank my Internship supervisors, Mr. Rahul Dingane and Mr. Shrikanth Iyer, for helping me out in every step of writing this thesis and for providing me with invaluable suggestions during the entire course of the internship.

Finally, I would like to thank all my friends for supporting me and helping me out in everything throughout my course, in and out of the university. I will always treasure the moments that I spent with you.

Abstract

Giving an overview of pre-engineered building system in India, the PEB industry is still in its infancy but, over the last six years, there has been a phenomenal growth in this sector due to increasing awareness amongst consultants and customers. PEB has started getting its due credit as a favourable alternative construction methodology today.

Pre-Engineered steel construction market has been growing in double figure year-on-year for the last few years. Also it would certainly not be an exaggeration if we say the industry is catching-up very rapidly. Sectors such as automotive, power, logistics, pharma, FMCG, and retail provide huge growth opportunity for PEB in India. There is undoubtedly, a very promising future for this sector in the coming years.

We at Vastustruct, undertake all types of structural designing jobs and related services, exceling in the PEB market. The principal objective is to offer innovative and cost effective solutions to meet the client's specifications. Customer satisfactions comes first at Vastustruct.

Through the duration of these 6 months at Vastustruct, I have gained immense knowledge in not just the steel structure design but also how a business works in India, what factors come into play, licensing and sanctioning of projects along with my overall development and ofcourse, made a lot of good friends and connections along the way.

Contents

List of Figures

1. ABOUT VASTUSTRUCT

Vastustruct is a well-established structural designing firm with the background of reputed works carried out within a short period of time. It is a team of young & highly experienced engineers, structural designers and architects. Experience, which can compete with best of the standards in this profession, is acquired while working on a spectrum of prestigious projects within the state. We undertake all types of structural designing tasks and other related services.

The principal objective is to offer Innovative and Cost Effective Solutions to meet the client's specifications. The firm offers total Engineering Design, including Design Management, Review of Design with Value Engineering, and Continual Technical support at all stages of works.

Vastustruct has been practicing in India, working with big corporate companies like TATA group and others. Experience range of projects include industrial projects for warehouses, factory buildings and industrial plants, hotels, hospitals, commercial complexes, high rise structures, and many others to name a few. We also give consultancy in foundation design for Pre-Engineered Buildings as well as proof consultancy for PEB's with best and efficient design approach.

Vastustruct is an Engineering Consultancy Firm which makes honest efforts to provide its clients a professional service of uniform and high quality. It believes that it is responsible to provide its clients with the most appropriate solution approach to problems encountered in Design and Construction of the project. It is always responsive to the needs of the client without being unresponsive to genuine difficulties of contractors and sub-contractors of our projects. The team endeavors to provide immediate, thoughtful and technically correct response to all problems which may arise during execution of the project.

It are dedicated to the concept of individual liberty inside of the framework of an overall professional ethic. It respects the rights of individuals and believes that individuals working for the company will retain control over their own destiny. It endorses and demands adherence to the higher standards of ethical conduct as promulgated by the professional societies in our field. It is of the firm opinion that Structural Engineers are accountable for the Designs they produce: professionally, technically and morally.

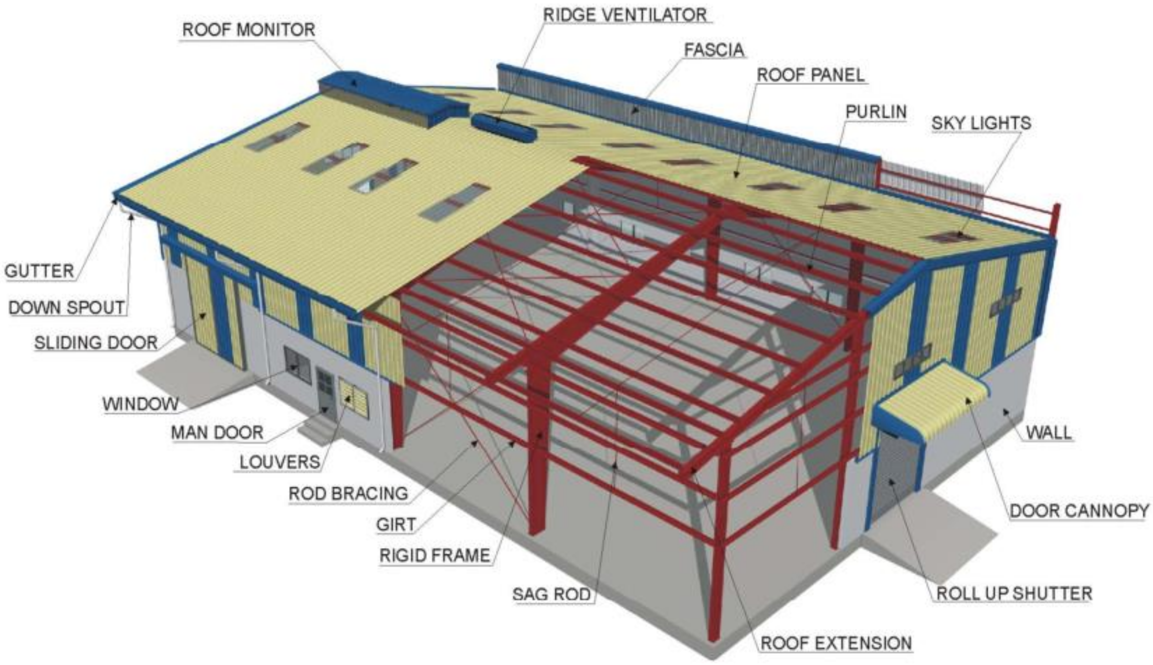
2. INTRODUCTION TO PRE ENGINEERED BUILDINGS

2.1. Why Steel?

Steel is the material of choice for design because it is inherently ductile and flexible. It flexes under extreme loads rather than crushing and crumbling. Structural steel's low cost, strength, durability, design flexibility, adaptability and recyclability continue to make it the material of choice in building construction. Today's structural steel framing is bringing grace, art and function together in almost limitless ways and is offering new solutions and opportunities to create challenging structures, which were once thought impossible. Steel structures have reserve strength. Simple "stick" design in the steel framings allows construction to proceed rapidly from the start of erection.

2.2. What are Pre Engineered Buildings?

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. Historically, the primary framing structure of a pre-engineered building is an assembly of I shaped members, often referred as I beam. In PEB, I section beams used are usually formed by welding together steel plates to form of I section. I section beams are then field-assembled (e.g. bolted connections) to form the entire frame of the pre-engineered building. Cold formed Z and C-shaped members may be used as secondary structural elements to fasten and support the external cladding. Roll-formed profiled steel, wood, tensioned fabric, precast concrete, masonry block, glass curtain wall or other materials may be used for the external cladding of the building.



In order to accurately design a pre-engineered building, engineers consider the clear span between bearing points, bay spacing, roof slope, live loads, dead loads, collateral loads, wind uplift, deflection criteria, internal crane system and maximum practical size and weight of fabricated members. Historically, pre-engineered building manufacturers have developed pre- calculated tables for different structural elements in order to allow designers to select the most efficient I beams size for their projects.

In Pre-Engineered Building concept the complete designing is done at the factory and the building components are brought to the site in CKD (completely knock down condition). These components are then fixed/jointed at the site and raised with the help of cranes. The pre-engineered building calls for very fast construction of buildings and with good aesthetic looks and quality construction. Pre-Engineered Buildings can be used extensively for construction of industrial and residential buildings. The buildings can be multi storied (4-6 floors). These buildings are suitable to various environmental hazards. Pre-engineered buildings can be adapted to suit a wide variety of structural applications; 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.

2.3. Features of PEB's

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 air tight, 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, facias, 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.

The most common and economical type of low rise buildings is a building with ground floor and two intermediate floor plus roof. The roof of low rise buildings may be flat or sloped. Intermediate floors of low rise buildings are made of mezzanine systems. Single storied houses for living take minimum time for construction and can be built in any type of geographical location like extreme cold hilly areas, high rain prone areas, plain land obviously and extreme hot climatic zones as well.

2.4. Advantages of Pre Engineered Buildings

Reduction in Construction Time: Buildings are typically delivered in just a few weeks after approval of drawings. Foundation and anchor bolts are cast parallel with finished, ready for the site bolting. In India the use of PEB will reduce total construction time of the project by at least 50%. This also allows faster occupancy and earlier realization of revenue.

Lower Cost: Due to the systems approach, there is a significant saving in design, manufacturing and on site erection cost. The secondary members and cladding nest together reducing transportation cost.

Flexibility of Expansion: Buildings can be easily expanded in length by adding additional bays. Also expansion in width and height is possible by pre designing for future expansion.

Larger Spans: Buildings can be supplied to around 80M clear spans.

Quality Control: As buildings are manufactured completely in the factory under controlled conditions the quality is assured.

Low Maintenance: Buildings are supplied with high quality paint systems for cladding and steel to suit ambient conditions at the site, which results in long durability and low maintenance costs.

Energy Efficient Roofing and Wall Systems: Buildings can be supplied with polyurethane insulated panels or fiberglass blankets insulation to achieve required “U” values.

Architectural Versatility: Building can be supplied with various types of facias, canopies, and curved eaves and are designed to receive pre cast concrete wall panels, curtain walls, block walls and other wall systems.

Single Source Availability: As the complete building package is supplied by a single vendor, compatibility of all the building components and accessories is assured.

2.5. Applications of PEB’s

Almost every conceivable building use has been achieved with PEB; the most common applications are industrial, institutional and commercial. In India, Pre-engineered building systems find application primarily in the construction of warehouses, & industrial sheds & buildings. The recent focus has also shifted to cover rural as well as urban, individual and mass housing projects, farmhouses, slum re-organization projects and rehabilitation projects, amenity structures like health centers, kiosks, primary schools, panchayat ghars etc. The pharmaceutical industries and exhibition centers, and functional requirements like offices, seminar halls, call centers, supermarkets, showrooms etc. have also attracted PEB. Earthquake-resistant buildings are the recent applications of PEB with wide and immediate acceptance. PEB concept has acted as a catalyst in the infrastructure development of the country. Single storied houses for living take minimum time for construction and can be built in any type of geographic location like extreme cold hilly areas, high rain prone areas, plain land, extreme hot climatic zones etc.

2.6. PEB Profile

All over the world, pre-engineered building system or PEB system is becoming an eminent segment in pre-engineered construction industry. It has become possible because pre-engineered building system encompasses all the characteristics that are compatible to modern demands viz. speed, quality and value for money. Pre-engineered buildings find many pre-engineered construction applications, which could be intrinsic and high-end.

2.7. PEB Prospect in the world

Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the pre-engineered buildings. Though its origin can be traced back to 1960’s its potential has been felt only during the recent years. This was mainly due to the development in technology, which helped in computerizing the design. PEB concept has been very successful and well established in North America, Australia and is presently expanding in U.K and European countries. 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. A recent survey by the Metal Building Associations (MBMA) shows that about 60% of the non-residential low rises building in USA are pre-engineered buildings.

2.8. PEB Prospects in India

Although PEB systems are extensively used in industrial and many other non-residential constructions worldwide, it is relatively a new concept in India. These concepts were introduced to the Indian markets lately in the late 1990's with the opening up of the economy and a number of multi nationals setting up their projects. India has an installed steel capacity of 35 to 40 million tons and apparent steel consumption is around 27 to 30 million tons. The current pre-engineered steel building manufacturing capacity is 0.35 million tons per annum. The industry is growing at the compound rate of 25 to 30 %.

2.9. Future of PEB in India

The steel structures market in India is in excess of 4.5 Mn.MT, growing at a rapid pace of more than 10% p.a. over the past few years. This market has experienced a higher growth compared to both Indian steel industry as well as Indian construction GDP. Overall construction sector accounts for majority (greater than 80%) of the steel structures market (volume terms) in India.

3. TECHNICAL PARAMETERS OF PEB

3.1. Width or span of building

The center to center 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 to 150 meters or above with intermediate columns. Aircraft hangars, manufacturing industries, Stadiums possess major span width. No modifications or extending span be done.

3.2. Length of building

The length of PEB is the total length extending from one front end to the rear end of the building. The length of PEB can be extendable in future.

3.3. Building height

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.

3.4. Roof slope

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 snow fall locations can go up to 1/30 to 1/60. Any practical roof slope is possible as per customer's requirement.

3.5. Design loads

Unless otherwise specified per-engineered buildings are designed for the following minimum loads. The designed loads play a crucial role in case of PEB. The failure of the structures occurs if not properly designed for loads. The determination of the loads acting on a structure is a complex problem. The nature of the loads varies essentially with the architectural design, the materials, and the location of the structure. Loading conditions on the same structure may change from time to time, or may change rapidly with time.

Loads are usually classified into two broad groups as dead loads and live loads. Dead loads (DL) are essentially constant during the life of the structure and normally consist of the weight of the structural elements. On the other hand, live loads (LL) usually vary greatly. The weight of occupants, snow and vehicles, and the forces induced by wind or earthquakes are examples of live loads. The magnitudes of these loads are not known with great accuracy and the design values must depend on the intended use of the structure.

***Dead Load**:* The structure first of all carries the dead load, which includes its own weight, the weight of any permanent non-structural partitions, built-in cupboards, floor surfacing materials and other finishes. It can be worked out precisely from the known weights of the materials and the dimensions on the working drawings.

***Live Load**:* All the movable objects in a building such as people, desks, cupboards and filing cabinets produce an imposed load on the structure. This loading may come and go with the result that its intensity will vary considerably. At one moment a room may be empty, yet at another packed with people. Imagine the `extra' live load at a lively party.

***Wind loads**:* Wind has become a very important load in recent years due to the extensive use of lighter materials and more efficient building techniques. A building built with heavy masonry, timber tiled roof may not be affected by the wind load, but on the other hand the structural design of a modern light gauge steel framed building is dominated by the wind load, which will affect its strength, stability and serviceability. The wind acts both on the main structure and on the individual cladding units. The structure has to be braced to resist the horizontal load and anchored to the ground to prevent the whole building from being blown away, if the dead weight of the building is not sufficient to hold it down. The cladding has to be securely fixed to prevent the wind from ripping it away from the structure.

***Roof load**:* Live loads produced by maintenance activities, rain, erection activities, and other movable or moving loads by not including wind, snow, seismic, crane, or dead loads.

Roof snow load: Gravity load induced by the forces of wind blowing from any horizontal direction.

Collateral loads: The weight of any non-moving equipment or material such ceilings, electrical or mechanical equipment, sprinkler system, or plumbing.

Auxiliary loads: Dynamic loads induced by cranes, conveyers, or other material handling systems.

Seismic loads: Horizontal loads acting in any direction structural systems due to action of an earthquake.

Floor Live loads: Loads induced on a floor system by occupants of a building and their furniture, equipment, etc.

3.6. Bay spacing

The distance between the two adjacent frames of a building is called as a Bay spacing. The spacing between two frames is a bay. End Bay length is the distance from outside of the outer flange of end wall columns of center line of the first interior frame columns. Interior bay length is the distance between the center lines of two adjacent interior main frames Columns. The most economical bay spacing is 7.5m to 8.0m. However bay length up to 10m is possible.

3.7. Types of frames

A frame is a combination of Columns and inclined beams (rafters). There are various type of frames.

Clear Span (CS): The span length between two columns without any obstruction. It has split Beams with ridge line at the peak or center of the building. The maximum practical width or span is up to 90 meters, but it can also be extended up to 150 meters in case of Aircraft Hangars.

Arched Clear Span: The column is an RF column while the Rafter is curved. It has no ridge line and peak. The curved roof rafter is used in for aesthetic look. The maximum practical is up to 90 meters, but can be extended to 120 meters.

Multi Span (MS1): The Multi spans (MS1) are those which have more than 1 span. The intermediate column is used for the clear span in which width of each span is called width module.

Arched Multi Span (AMS1): Arched multi span has RF column and a curved Rafter with one intermediate column. It has width module for the entire span. The multispans can be extended up to AMS1, AMS2 and AMS3 etc.

Multi Span 2 (MS2): The Multi Span (MS2) has more than one intermediate span. It has three width modules with one ridge line.

Single Slope: It has two columns with different heights having Roof sloping on both the columns.

***Multi Gable**:* Multi gable has two or more spans where no intermediate columns are used. The columns are added to the extended width and columns are not placed at the ridge lines.

***Roof Systems**:* It has straight columns with Roof having supports are not by TPCA.

***Lean To**:* Lean to slopes is used extremely for an extending to a building on either side with short span. The rafters rest on column designed for lean to on one side and rests on the main column of the building.

***Canopy**:* Canopies are used in case of open ends where there is an easy access. There are columns in straight path having roof extended to a large length.

3.8. Subsystems

Major companies use standard components and designs to manufacture a wide range of structural subsystems according to customers' requirements. These structural subsystems fulfill the requirements of two types viz. Aesthetic and Functional. They produce a large number of structural subsystems according to exact specifications as the strength of the pre-engineered building system depends largely on various incorporated structural subsystems. Subsystems are available for following structures.

End wall Roof Extension: End wall roof extensions consist of end wall panel, Roof panel, Gable trim, soffit panel, and end wall rafter. The end wall is extended to an extent under end wall panel support.

Sidewall Roof Extension: The sidewall roof extension has the same assembly but the soffit panels are above the Roof Extension Rafter.

Centre Curved Fascia: The center curved fascia consist backup panel, soffit panel. It is an assembly of cap flashing, Fascia panel with valley gutter or eave gutter on the rafter with rigid frame support.

Bottom Curved Fascia: The entire assembly of Centre curved fascia contains for the bottom curved fascia a slight change in Connection of wall panel to Frame.

Top and Bottom Curved Fascia: In this the assembly is a combination of Top Curved Fascia which has curvature at top and bottom curved Fascia having bottom Fascia.

Roof Platform: The roof platform has Grating on above and roof panels on the sides.

4. DESIGN OF PEB'S

4.1. Introduction

Pre-engineering of metal buildings can be optimized to meet specific design criteria. Largely Indian and American practice of design is followed by most of the consultants and PEB vendors in India these days. A brief of design codes used in each of these is attached herewith:

The main framing of PEB systems is analyzed by the stiffness matrix method. The design is based on allowable stress design (ASD) as per the American institute of Steel Construction specification or the IS 800. the design program provides an economic and efficient design of the main frames and allows the user to utilize the program in different modes to produce the frame design geometry and loading and the desired load combinations as specified by the building code opted by the user. The program operates through the maximum number of cycles specified to arrive at an acceptable design. The program uses the stiffness matrix method to arrive at an acceptable design. The program uses the stiffness matrix method to arrive at the solution of displacements and forces. The strain energy method is adopted to calculate the fixed end moments, stiffness and carry over factors. Numerical integration is used.

4.2. Design Cycle

The design cycle consists of the following steps:

1. Set up section sizes and brace locations based on the geometry and loading specified for the frame design.

2. Calculate moment, shear, and axial force at each analysis point for each load combination.

3. Compute allowable shear, allowable axial and allowable bending stress in compression and tension at each analysis point.

4. Compute the corresponding stress ratios for shear, axial and bending based on the actual and allowable stresses and calculate the combined stress ratios.

5. Design the optimum splice location and check to see whether the predicted sizes confirm to manufacturing constraints.

6. Using the web optimization mode, arrive at the optimum web depths for the next cycle and update the member data file.

7. At the end of all design cycles, an analysis is run to achieve flange brace optimization.

4.3. Frame Geometry

The program has the capability to handle different types of frame geometry as follows Frames of different types viz. rigid frames, frames with multiple internal columns, single slope frames, lean to frames etc. Frames with varying spans, varying heights and varying slopes etc. Frames with different types of supports viz. pinned supports, fixed supports, sinking supports, supports with some degrees of freedom released. Unsymmetrical frames with off centric, unequal modules, varying slopes etc. User specified purlin and girt spacing and flange brace location.

4.4. Frame Loading

Frame design can handle different types of loadings as described below: All the building dead loads due to sheeting, purlins, etc. and the self-weight of the frame and Imposed live load on the frame with tributary reductions as well. Wind loads input such as basic wind speed or basic wind pressure that will be converted to design wind pressure as per the building code specified by the user and shall be applied to the different members of the building according to the coefficients mentioned in the codes prescribed by the user. The standard building codes like MBMA, UBC, ANSI, IS: 875 parts 3 etc. are used for this purpose. Crane and non-crane loading can be specified by the user and the program has the capability to handle these special loads and combine them with the other loads as required. Seismic loads corresponding to the different zone categories of various international codes can also be defined and combined with other load cases as required. Temperature loads can also be specified in the form of different differential temperature value on centigrade and specifying the appropriate coefficient for the thermal expansion. Load combinations with appropriate load factors can be specified by the user as desired.

5. PRODUCTION

Pre Engineered Steel Buildings are tailor made buildings which are those fully manufactured in the factory after designing. This fabrication is done in a controlled environment with latest technology. The production is done under standard conditions. The Raw material required is imported from major companies like Tata BlueScope to all the companies in India.

Historically, the primary framing structure of a pre-engineered building is an assembly of I shaped members, often referred as I beam. In pre-engineered buildings, I beams used are usually formed by welding web and flange plates together to form I section. 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.

Cold formed Z and C-shaped members may be used as secondary structural elements to fasten and support the external cladding. Roll-formed profiled steel sheet, wood, tensioned fabric, precast concrete, masonry block, glass curtain wall or other materials may be used for the external cladding of the building.

5.1. Manufacturing or processing

Manufacturing is done through the raw material which is imported from steel production companies. The imported steel is in the form of rolled sheets. For the hot rolled and cold formed sheets cutting is done to desired dimensions and welded with submerged arc welding.

The PEB production process primarily consists of FOUR major parallel processing lines, as under:

1. Built-up members for Primary frame

2. Cold forming for Secondary framing

3. Profiling for roof and wall sheeting

4. Accessories & bracings like gutters, down take pipes, ridge vents, skylights, clips etc.

The design and final processing inspection is done for production, ready for shipment in completely knocked Down Condition (CKD) conditions.

1. Plate cutting using Shear/Plasma/Multi-torch through nesting software for optimized use of plate area.

2. H-beam welding on automatic welding machines using SAW or MIG welding process

3. Fabrication for fitments like end plates, stiffeners and connections cleats.

4. Cleaning the surface for painting

5. Slitting HR coils for cold forming operations to make Z and C sections with punching

6. Cutting and threading sag rods and bracing rods

7. Fabrication of Diagonal bracing angles or pipes

8. Profiling the Galvalume/Zincvalume sheets for roofing and wall cladding

9. Manufacturing Gutters, down take pipes in press bend

10. Procuring and assigning required matching fasteners for connections

11. Organizing some bought out accessories

12. Quality control tests & inspection; and matching with project wise Bill of Quantities as given by the engineering department.

13. Dispatching to project sites as per sequence of erection

5.2. Structural framing

All framing members shall be shop fabricated for field bolted assembly. The surfaces of the Bolted connections shall be smooth and free from burrs or distortions. All shop connections shall be in accordance with the manufacturer's standard design practices.

5.2.1. Primary framing

All rigid frames shall be welded built-up "I" sections or hot-rolled sections. The columns and the rafters may be either uniform depth or tapered. Flanges shall be connected to webs by means of a continuous fillet weld on one side. All end wall roof beams and end wall columns are in cold formed "C" sections, mill-rolled sections, or built-up "I" sections depending on design requirements. All base plates, splice and flanges shall be shop fabricated to include bolt connection holes. Webs are shop fabricated to include bracing holes.

5.2.2. Secondary Framing

Purlins and girts shall be cold-formed "Z" sections with stiffened flanges. Flange stiffeners shall be sized to comply with the requirements of the latest edition of AISI. Purlin and girt flanges shall be unequal in width to allow for easier nesting during erection. They shall be pre-punched at the factory to provide for field bolting to the rigid frames. They shall be simple or continuous span as required by design. Connection bolts will install through the webs, not flanges.

5.2.3. Bracing

Diagonal bracing in the roof and sidewalls shall be used to remove longitudinal loads (wind, crane, etc.) from the structure. This bracing will be furnished to length and equipped with bevel washers and nuts at each end. It may consist of rods threaded each end or galvanized cable with suitable threaded end anchors. If load requirements so dictate, bracing may be of structural angle and/or pipe, bolted in place.

5.2.4. Welding

Welding is a fabrication or sculptural process that joins materials, usually metals. In Pre Engineered Steel Buildings the hot rolled steel sections are subjected to Submerged arc welding. Shielding gas is used in order to protect the welding region. Welding is done by passing the steel plates into the welding machine, which welds along the joints. In PEB, the tapered sections are welded, but at some locations manual welding is done. Double side welding is preferred according to Indian Code but Single side Welding is much beneficent because it increases the Quality of steel sections. Single side welding is more economical, all manufactures follow the American code which states Single side welding. Base plates are welded to base of columns for the structural strength. These base plates are provided with bolt holes. Anchor bolt dimensions are taken into account for Base plate preparation.

5.2.5. Anchor Bolts

Anchor bolts are manufactured with circular steel rods having threading portion at the top for bolting and bent up at the bottom for Foundation. These are bent at 90 degrees for embedding into the soil. The dimensions for Anchor bolts are taken from support reactions of the columns.

5.2.6. Surface Preparation

The surface of columns and rafters are prepared in order to protect it from rusting. Abrasive paper is used to scrub the top layers of columns and rafters in order to remove accumulated rust on the top of the sections. This is old method, it is done manually. Advancement technologies avoided manual procedure and brought Sand blasting and short blasting into existence.

Sand blasting: Sand Blasting is a method in which sand is blown with high velocities to the members. This is blown with sand particularly with 2 to 4 mm thick sand and surface is cleared.

Short Blasting: Short blasting is a latest process in which members are sent into the machine and hit with iron balls of 3mm thick under a huge velocity. Periodical removal of rust is done in case of short blasting. Short blasting is observed as more efficient surface cleaning process.

5.2.7. Varnishing or Painting

Normally the primary and secondary steel are coated with one coat (35 microns) of red oxide paint without any special treatment to steel. However, if some special paint has to be applied to steel in order to give better anti-corrosion properties etc. then the steel members have to be shot-blasted and then coated with the special paints.

6. ERECTION

6.1. Introduction

Steel construction is considered as a process that involves many related activities. Pre-engineered buildings (PEB) steel parts are required to be installed in a specific order due to structural safety requirements and to the logical sequence of erection. However, shipping, transportation, unloading and on-site storage does not take into account the erection order of the assembly. As a result, considerable time is consumed locating, sorting, and identifying steel components.

Integrating promising information technologies such as radio frequency identification (RFID), mobile computing devices and wireless technology can be useful in improving the effectiveness and convenience of information flow in construction projects. Pre-engineered buildings require repetitive operations and assembly of many structural elements Pre-engineered buildings (PEB) steel parts are required to be installed in a specific order due to structural safety requirements and to the logical sequence of erection.

6.2. Erection Drawings

Erection drawings provide the field erection crew (raising gang) with the roadmap of how to erect (put together) the steel assemblies after they are delivered to the field. Essentially, they are a set of instructions on how to put the puzzle pieces together. Every assembly shipped to the field is given a shipping piece number to identify it. This number is noted on the drawing and is also stenciled onto the actual assembly of steel. Erection drawings illustrate how the connections will be fabricated in the field.

6.3. Construction overview

Before the PEB components arrives, the site and foundation should be prepared. This includes leveling the terrain and constructing the foundation.

A. Remove trees, debris, and other items from the building location.

B. Smooth and level the ground where the foundation is to be made.

C. Construct the foundation using the materials recommended as per design parameters.

Transiting on all corners the foundation locations are determined and trenches are made for foundation. In foundation trenches the Anchor bolts are set along with the concrete.

6.4. Anchor Bolt Setting

It is extremely important that anchor bolts be placed accurately in accordance with the anchor bolt setting plan. All anchor bolts should be held in place with a template or similar means, so that they will remain plumb and in the correct location during placing of the concrete. Check the concrete forms and anchor bolt locations prior to the pouring of the concrete. A final check should be made after the completion of the concrete work and prior to the steel erection. This will allow any necessary corrections to be made before the costly erection labor and equipment arrives.

6.5. Unloading and Preparing for assembly

The vehicle transporting your building parts must gain access to the building site from the adjacent highway or road. Such access should be studied and prepared in advance of arrival. When the truck arrives with the building, unload the truck promptly, stack the steel parts evenly on blocks and protect them from the weather. Unloading and placing the steel parts of the building in the most convenient places for assembly will make the process easier and faster. Blocking under the columns and rafters protects the splice plates and the slab from damage during the unloading process. Extra care should always be exercised in the unloading operation to prevent injuries from handling the steel and to prevent damage to materials. If water is allowed to remain for extended periods in bundles of primed parts such as girts, purlins, etc., the pigment will fade and the paint will gradually soften reducing its bond to the steel. Therefore, upon receipt of a job, all bundles of primed parts should be stored at an angle to allow any trapped water to drain away and permit air circulation for drying. Puddles of water should not be allowed to collect and remain on columns or rafters for the same reason.

6.6. Location of Building Parts

All the parts are placed around the foundation so that they will be in the most convenient locations for installation. Bolts and nuts are placed where they will be accessible to the parts. Purlins and girts, depending on the number of bundles, are usually stored near the sidewalls clear of other packages or parts. Sheet packages are usually located along one or both sidewalls off the ground and sloping to one end to encourage drainage in case of rain. Accessories are usually unloaded on a corner of the slab or off the slab near one end of the building to keep them as much out of the way as possible from the active area during steel erection.

6.7. Components erection

The major components comprise of rigid frame, columns and rafter, eave struts, purlins, girts, flange braces, end-wall columns and bracing systems which may be cables, rods angles or portals. All materials for the first bay erection are prepared. The rafter sections required are identified by part number, and then assembled as near as possible to their lifting positions. Then the first four columns are erected at the braced bay, meanwhile the part number, orientation and position over anchor bolts were verified. Next step is to position the crane for lifting the assembled rafter sections.

6.8. Raising Rigid Frames

The intermediate or interior frames nearest the bearing end wall are usually erected first. This bay usually contains the diagonal bracing. The proper completion and plumbing of this first bay is extremely important to the successful completion of the building. Although several methods are used to erect rigid frames, it has been found most satisfactory to erect the columns first, tie them together with the girts and tighten the anchor bolts. On small spans and short eave heights, columns can often be set in place by hand without the use of hoisting equipment. Temporary bracing should always be installed as soon as sections are lifted in place.

6.9. Completing and Plumbing the First Bay

After the first intermediate or interior frames have been set, all purlins, girts, and eave struts be installed in the braced bay and the entire bay plumbed, aligned and braced before proceeding further. If the building is designed without cable bracing, the erector is responsible for providing temporary erection bracing. When this bay is properly and accurately plumbed and braced, the remaining members, to a large degree, will automatically plumb and align when installed. After the columns have been erected, the ground-assembled rafter is hoisted into place and connected to the columns. The size of the rafter that can be safely handled depends on the equipment available and the experience of the erection foreman. Generally as many connections as possible are made on the ground. The flange brace should be bolted to the rafter prior to raising in order to save time. The hoisting equipment should never be released from the rafter until the frame is adequately braced, so it cannot buckle or tip in the longitudinal direction of the building. The same general procedures of erection apply to either clear span or multiple span frames. Two words of caution concerning the erection of rigid frames are in order. The first is that rigid frames, especially free ends or cantilevered sections should never be left "for the day" in an unsupported, unbraced condition. Such practice has resulted in the total loss of considerable amounts of erected steel because of wind. The second word of caution pertains to the additional care required in the erection of multiple span frames compared to clear span frames. Frames with interior columns, because of closer supports, have much lighter sections. They are much more apt to buckle during erection than clear span frames, and consequently require greater care in rigging and handling.

6.10. Erecting column beam end walls

Column and beam end walls of 50 feet or less in span may be raised into position and set on the anchor bolts as a unit. All rafters, column, girts (except outside end wall girts which connect to the sidewall girts), door headers, door jambs, clips, diagonal brace rods, etc. should be assembled on the ground with the bolts left finger tight. A spreader bar should be used to raise the end wall frame. Because of the flexibility of the column and beam frames, care must be taken in locating the points of attachment of the cables, and in raising the frame, to avoid bending about the minor axis. For spans of 60 feet and greater, the columns are usually erected first and then capped with the end wall rafter. Girts, headers, jambs and diagonal brace rods are then added between the end columns. During this erection process, the frame must be properly braced or guyed before the lifting lines are disengaged. Final bolt tightening should be done once the frame is plumb and square.

6.11. Erecting the remaining frames

The remaining frames are erected in like manner, initially with only a few purlins being installed in each bay, as shown below, working from one end of the building to the other. To lend overall rigidity to the structure, install flange braces to the purlins at specified locations. All purlin, girt and eave strut connection bolts are left loose so that the entire skeleton framework can be plumbed without undue difficulty. The remaining purlins can be positioned on the rafter in each bay to facilitate the completion of the roof framing.

6.12. Installation of Bracing

Diagonal bracing in metal buildings is critical. They provide support for wind loads or other longitudinal loads, such as those created by an overhead crane in the completed structure. Many times additional temporary bracing is needed to stabilize the structure during erection. On some smaller buildings, diagonal bracing is not needed for the building design, so the erector must furnish any erection bracing needed. Assemble the next brace cable the same way and connect to the next column to form an “X” with the other cable. To square the building, measure the length of the diagonal cables and tighten or loosen the turnbuckle/eye-bolt until the cable lengths are the same. Brace each sidewall frame the same way so that you have an x-brace on each side. Tighten the column anchor nuts after insuring that the building is square. The diagonal bracing is cable. It should always be installed as shown on the erection drawing and should be tensioned so that the building will not sway or rock when the wind blows. Care should be taken, however, not to over tighten and bend the structural members. The workman should watch the structural members carefully as he tightens the bracing. Occasionally the bracing in the wall of a building cannot be installed in the specified bay because of doors or other complications. Usually these can be moved to other bays without affecting the structural integrity of the building.

6.13. Bolting Procedure in steel structures

This procedure applies to the permanent fixing of steel structures including the erection of steel. Construction drawings shall indicate the grade and diameter of all bolts, nuts and washers required for the construction. Drawings shall indicate whether a “Friction-Type” or “Bearing Type” connection is required. The nominal size of the bolt holes (other than holes in a base plate) shall be 2mm larger than the nominal bolt diameter for a bolt not greater than 24mm in diameter and not more than 3mm larger for bolts of diameter more than 24 mm.

6.14. Alignment and assembly

The parts to be joined shall line up in such a way that a drift of equal diameter to the bolt can pass through the bolt holes. Drifting to align the bolt holes shall be done is such a 3 way as not to bend or damage the parts nor enlarge the holes. Packing shall be provided as required to ensure parts have full contact over the mating surfaces. Prior to inserting the bolts the nut should be run up the threads to ensure there are no thread defects that would impede the tightening process. Bolts shall be inserted through the holes after alignment from such a direction that the nut has easiest access for tightening.

6.15. Bolt Tightening (Snug Tightening)

Bolt Tightening is required for all Bearing-Type Connections and as a pre-requisite to friction type connections. The sequence of tightening the bolts shall proceed from the stiffest part of the connection towards the free edges. High strength bolts that are to be tensioned may be tightened during erection to facilitate assembly but they shall not be finally tensioned until all bolts have been snug tightened in the correct sequence. Bolt tightening is also known as snug-tightening. Bolt or snug tightening is achieved either by subjecting the nut to a few impacts of an impact wrench after standard effort tightening with a podger spanner or by the full effort of a person using a standard podger spanner. The sequence of tightening is to firstly tighten all nuts with a standard effort and then to snug tighten using a full effort or an impact wrench.

6.16. Wall Insulation

Fiberglass blanket insulation is the most common type used, and these instructions pertain to this type only. One side of the blanket insulation should have a vapor barrier that must face the inside of the building regardless of whether the insulation is for heating or cooling. Cut the insulation to length allowing an additional 6" or more to facilitate handling. The wall panel can be used as a guide. The first run of wall insulation should be installed so that its forward edge is just ahead of the leading edge of the wall panel. This keeps the forward edge of the insulation ahead of the wall panel for joining the next blanket.

6.17. Roof Insulation

Precut roof insulation to reach from eave to eave allowing approximately 2 feet of additional length to facilitate handling. Hold insulation at one sidewall and roll out insulation across the purlins, vapor barrier to the inside of the building. Stretch the insulation to provide a tight and smooth inside surface. Double sided tape or contact adhesives can be used to hold insulation in place while the roof sheets are being installed. Trim excess insulation to the edge of the eave trim and cut fiberglass approximately 4 inches from end leaving only facing. Fold facing over end of blanket insulation to seal the end.

6.18. Aligning the Girts

Installation of the building walls is generally done before the roof. Before starting the wall installation, check to be sure that the eave strut and girts are straight and plumb. One method of aligning the girts is to cut temporary wood blocking to the proper length and install between the lines of girts. This blocking can be moved from bay to bay, which will reduce the number of pieces required. Normally, one line of blocking per bay will be sufficient. Banding can also be used to hold the girts straight and plumb.

6.19. Screw alignment

Good alignment of the screws, especially on the wall panels, will give a professional appearance to the wall panel installation. One way this can be accomplished is by pre-drilling holes in the panels at identical locations. Up to 15 panels can be stacked together and drilled using a template panel. 1/8” or 5/32” diameter drill bit is used for panel to structural fasteners and a 1/4” diameter bit for the side lap clearance holes. It is important to clean metal filings off panel surfaces after drilling to avoid rust stains.

6.20. Installation of wall Panels

Adjoining panels are installed with the overlapping rib toward the last erected panel. Position panel to structural making sure that it is kept plumb and install fasteners at lapped rib. Check for proper coverage and correct as necessary. Install remaining fasteners.

6.21. Fastener Installation

Correct fastener installation is one of the most critical steps when installing roof panels. Drive the fastener in until it is tight and the washer is firmly seated. Do not overdrive fasteners: A slight extrusion of neoprene around the washer is a good visual tightness check. Always use the proper tool to install fasteners. A fastener driver (screw gun) with and rpm of 1700-2500 is used for self-drilling screws.

6.22. Preparing the Eave

After installing the first run of insulation, prepare the eave for the first roof panel by applying tape sealant along the eave outside of the insulation and leaving release paper in place. Sealant must be applied in a straight line and without voids. Splice a full closure to the starting closure and apply along the top of the eave sealant. If roof is subject to ice and snow build-up, the splice in the closure strip must be caulked to insure weather tightness.

6.23. Installation of the first roof panel

Once the eave is prepared, the first roof panel may be installed. The roof panel is set in place over the inside closure (after removing the paper from the mastic) ensuring the major ribs of the panel nest properly with the inside closure. Align the center of the major rib of the panel edge with the edge of the endwall roofline. With the panel properly placed, secure the panel to the structure with appropriate fasteners.

6.24. Roof Sheeting Sequence

It is recommended that both sides of the ridge of a building be sheeted simultaneously. This will keep the insulation covered for the maximum amount of time and the panel ribs can be kept in proper alignment for the ridge panel.

6.25. Final Installation

While back lapping the last roof panel (to match panel coverage with the building length) is routinely done, this installation method can compromise the integrity of the roof by trapping moisture between the panels. This moisture could, in time, create an environment conducive to rust and metal failure. Manufacturer recommends field cutting the final panel lengthwise to create the desired panel width necessary to finish off the building. The cut edge of the panel should always be installed on the outside edge, not the lap edge. The “narrow” panel should be handled with care, and foot traffic avoided until the final panel is completely installed.

6.26. Skylight Installation

Skylight panels are installed using the same procedures as a steel panel. Care should be taken when installing fasteners in the skylights to avoid cracking the material. Install roof panels, leaving the light-transmitting panel run open, except for lower light transmitting panel run panel. Install tape sealer to panel side laps and across panel width as normal. Lay light transmitting panel in place overlapping lower metal panel 12”. Apply double run of tape sealer across light transmitting panel width at lower and middle purlins. Tape sealer should align with beginning and ending edge of top flange of purlin.

7. SCOPE FOR FUTURE STUDY

7.1. Tracking growth of PEB

Emerging from their hiding places in concrete columns pre-engineered steel structures (PEBs) are innovative solutions for construction projects across several sectors. As Infrastructure construction across the country is combining speed, economy, safety, strength and aesthetics at awe inspiring levels, steel structures, until now a primary foundation element, have risen as complete solutions in construction projects for various structural requirements. India is growing fast as an economy for pre-engineered buildings (PEBs) as it is witnessing a boom in the infrastructure sector. Structural steel buildings or PEBs are addressing parameters including finishes, environment control and life cycle with a panache derived from product innovation and technology advancement.

Emerging as a strong alternative to conventional concrete construction methods, PEB in India is validated by the 33% market share of PEBs in the construction industry. While this figure is lower than some European countries, it marks India's growing global market share at 9.5 percent -- a step ahead of China's 8.5 percent. "The market demand is pegged at

425,000 TPA with a 15% growth per annum,"(Kirby). "Current market size is around Rs.3,500 Crore and it is expected to grow at 10% to 15% per year,"

7.2. Strength Building

With the country's five year plan catering for infrastructure addition in the form of airports, metros and bridges sector differentiation is expected to separate industrial buildings and building systems. These include Design & Engineering, Manufacture and Construction & Erection. This pattern of restructuring indicates an industry that sees PEBs coming into its own with experiencing exponential growth with diversification into various sectors and segments.

7.3. Preferred Alternative

While the application of PEBs has a wide potential, the concept is recognized and preferred in the industrial construction segment. Add to that the reduced time to completion with the benefit of quality, and there is recipe for success.

"PEB is getting its due credit as a favorable alternative construction methodology in India today. More sectors are realizing the benefits of metal over brick and mortar. The scope of metal/steel buildings is very vast for the Indian market. PEB proves to be relevant and beneficial to several construction verticals including warehousing, infrastructure, oil & gas refineries as well as group housing,"(Kirby). "The advantages of having a steel structure or building over traditional concrete are far too many. 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".

8. JOURNEY FROM A PAPER TO REALITY

8.1. Acquiring the Project

A tender of the project with primary details such as land area, proposed plan, height of structure and any other specific requirements with a brief presentation of it, is floated among a few contractors by the client.

Once the tender reaches the contractor network, the contractors then forward it to their specific architect, for a rough plan of how the structure might look aesthetically taking into consideration all the by-laws and guidelines to be respected with respect to the total built up area, safety grades, working conditions, hygiene maintenance and other immediate thumb rules to be satisfied. This plan is again sent to the client through the contractor, who then decides which options he/she likes the best. A total of 4-5 options get through this preliminary screening, though a small fee needs to be paid for the service all the architects have provided, irrespective of the outcome of the decision.

These 4-5 options that have been selected are then sent to the respective Structural Designers/Consultants for the estimated weight and cost break-up of the structure (excluding the aesthetical or landscaping requirements of the client). The structural consultants strictly work on the built up structure and nothing more. Taking into consideration all the primary details of the structure a tentative weight break up is prepared. A cost estimate is then given based on the calculated total weight of steel and concrete (steel in our case) depending on the market costs on that particular day. The market is not very volatile and does not see huge drops or rises in the prices but just to be on the safe side the date, and the prices on that day are clearly mentioned in the cost break up document. A particular deadline has been assigned to all the consultants to submit these details to the client to avoid any kind of delays in the project and to ensure the smooth running of the same. The deadline are expected to be met, although delay of a couple of days is accepted.

Once the total weight and cost summaries are presented to the client by the representing designer from each firm, the client understand the approach each of them have taken and goes with the best suitable one which does not necessarily mean the lowest cost estimate. So the designers are expected to have a detailed understanding of the client's needs and the project right from the primary phase. Smaller consultancies have a comparatively tough time as they not only have to compete with skilled designers, but they also have to compete with the brand value that these big consultancies carry with them and the psychological effects they have on the client. No client wants to take a risk by choosing a design by a smaller and less popular consultancy that actually could cost him/her less money. It's a very common phenomena among consumers. Branded products which come comparatively expensive but guaranteed quality are preferred as opposed to second/third tier brands which are less expensive but where quality is not guaranteed because they have not flourished yet, so not many people know them.

This is a brief way in which a designing firm acquires the project. The Indian market is highly competitive as the entrepreneurial culture has begun to flourish vastly in all parts of India, especially the first and second tier cities. So along with technical competency, one also needs excellent people skills in order to make a mark in this ever increasing industrial sector.

8.2. Designing and Detailing

Once the project is confirmed as a job for the consultancy, there is a particular path that needs to be followed through the organizational structure before the conclusion of the project. Now that the primary design and the tentative weight and cost break up is ready, it goes to the refining stage where each and every detail is discussed in with the client and the exact need is understood. Various options are suggested to the client which fit in the given weight analysis and it is up to the client to choose one out of the lot. Once the design option is selected it goes through rigorous optimization rounds right from the junior designers to the senior most designers so as to ensure the most optimized structure right down to the most insignificant detail. This design is then sent to the client for an approval.

As the approval is received, we start with the Anchor Bolt plan and the RCC Footing design and drawings. The soil report and all other geographical parameters are taken into consideration during this step. After multiple checks of the design, the CAD files are forwarded to the client for confirmation of the exact column to column and other necessary dimensions of the structure. Revisions and changes are expected at this stage of the project. In order to do justice to the revisions, enough flexibility and time boundaries are ensured.

This final design is then sent to the draftsmen for what is called the "General Arrangement" or the GA drawings which consists of the detailed framing, plan views, elevation views and the roof and wall sheeting drawings which consist the sections used for the columns, rafters and other structural components. By the time a project has come in its GA phase all the brain stuff is already taken care of. Its just a matter of time before the details in the designer's brain are produced on a sheet. These drawings too, follow a certain protocol of going through checks from the roots to the tips of it. Once finalized, these set of drawings are sent to the client for an approval again. Changes aren't expected at this stage of the project, as it has entered its conclusion unless and otherwise required for a major change. The GA drawings are the ones that are used by the site engineers during the erection of the structure, hence they are expected to be as close to perfect as possible.

These GA drawings then travel to the Detailing Department where our team of highly skilled detailers work on the 3D renders and precise connection details that makes the fabricator's life easy who has to make the section up to a detail of every millimeter with bolting holes in the exact locations, etc. You can consider this to be one of the most important task in the journey of the project and requires in depth knowledge, not only of the software but also the Indian Standards/American Standards which specify particular guidelines for connections. Detailing is the last step that the consultancy has to take care of. All the drawings then go to the clients, contractors, fabricators, site engineers, and other authorities that it may concern to.

Once the drawings are released it needs on an average 8 weeks for the structure to come to reality. There can be connection or erection problems that may arise which need the designers attention at all times. Periodical inspections are a part of the quote provided to the client by the consultancy. This is the time when the designer should be well equipped to take spontaneous decisions under time and performance pressure. That is what differentiates a good designer from just another designer.

To be honest, it is a very different feeling knowing that the structure that is now standing in front of you was once a piece of paper lying on your desk. Due to the joint efforts of a lot of different teams, this dream turns into a reality.

9. ME AS AN INTERN

These 6 months have been nothing less than a rollercoaster ride, except, there were just ups, no downs at all and I am deeply grateful to Mr. Rahul Dingane for considering me capable of taking on this challenging task. Though I was an Intern on paper, my job was that of a Structural Designer. I was surrounded by an amazingly talented team who always encouraged me at all checkpoints, and made me feel just at home. The kind of knowledge I received from all of them is unmatched for and it is safe to say that I have thoroughly enjoyed this journey so far and hope I get to embark upon it as an employee soon.

November 2nd, 2020 was officially my first day at work. Not for one second did I feel like an outsider and I was an integral part of the team in no time. Work was delegated, introductions were made, food was shared, laughs were cracked, meetings were held, my first day saw it all. I had never imagined, I would be so excited to go for a 9am-5pm job ever in my life. I have always been business minded and working for someone else has never been an option in my head and it still is not. But initially I was mentally shut to the fact that a job could be fun too, a corporate life could be something exciting too. These 6 months have entirely changed my outlook on that and I give al the credit to how Vastustruct was managed and I will shed some light on it later.

As previously mentioned, the forte of Vastustruct has been Pre Engineered Buildings, so Steel is to Vastustruct what Oxygen is to us humans. I consider myself lucky to have been well acquainted with STAAD Pro well before I had Vastustruct in my vision. So the "Training Period" did not last for more than 10 days. I was shown around how things work and I was ready to go head on.

Around that time, we were given a huge project for designing steel mezzanine structures for stacking and moving goods for the e-commerce giant, Amazon. The 2 locations for these projects were Delhi and Mumbai which would take about a month of designing before it saw its completion. Mr. Rahul Dingane is of the strong belief that "You cannot learn how to swim unless you are thrown in the water and you have no other option but to move your hands and legs so frantically that you are bound to float", and that's exactly what happened with me. I was given the responsibility of this humongous project all by myself. Shubham, my colleague and a very good friend now, was told to mentor me incase doubts did arise, which was bound to happen. I have immense respect for Shubham, for the way he treated me in those 2-3 weeks. Any obstacle I hit, he was always there to solve it and he is so technically gifted, that I never felt the need to go to Mr. Rahul for my doubts. No wonder we have become the best of friends in these 6 months.

Mr. Rahul Dingane was quite impressed with the progress he was seeing in me as the days passed. He always says that Civil Engineering is a field where you can get acquainted to about 20% of it by sitting at the desk, keeping your collars white, but for the rest 80% you have no option but to sweat it out on site and get your hands dirty. What he meant was, until we see what is happening with our own eyes, what goes on, on the site, we will always be oblivious to the reality not really knowing the depths of the subject. As the Amazon project reached its conclusion, I was told to go inspect the projects I was working on for at least 2 days a week and I can vouch for it that this has given me more that what my 6 years of education did. Inspection ranged from RCC slabs, beams, columns, overhead tanks, conventional steel sheds, PEB structures, racking systems, foundations, and much more. At first I had accompanied Mr. Rahul at one of the site inspections and was keen to take on the responsibility. To my surprise, I was sent alone thereafter. Mr. Rahul has his own way of showing that he believes in me and I did not let him down.

Two months passed by in the blink of an eye and these 2 months had taught me how design of structures as a profession is, what inspection of sites really means, how quotations are filled, how handling of clients is as crucial as a safe design, and how a structural designer must respect his profession and not bend down to client demands so easily. I felt like I had seen it all but I was wrong. There was a lot more in the bag for me.

The next couple of months, were spent on AutoCAD, getting familiar with GA drawings, proposal drawings, Anchor Bolt plans, RCC footing drawings, etc. This really tests your basic knowledge about the structure. The drafting team was of great help when it came to solving doubts at any stage of the project. The list of projects that I worked on will be highlighted later on in this report. These 2 months passed in a breeze. They say when you are doing something you thoroughly enjoy, time passes by even before you know. That is exactly what was happening here. I think it is safe to say that I have achieved reasonable mastery over AutoCAD in the period of 2 months.

March and April were tough. COVID had arrived again and we were forced to work from home. This meant that no more site inspections, no more physical client meetings, no more office timings, etc. At first it was a bit tough. As I was still in the learning phase, a lot of doubts used to arise but getting them solved over a phone call seemed tough. But we started having video conferences twice a day and that had pretty much solved most of my issues. We were all getting used to this virtual world, having client meetings online, presenting project quotes online, the business took a hit but it was fun nevertheless.

Today as I look back over these 6 months, there is no downside that I see. I am very happy that I decided to do this internship back in India, around people I know, in conditions that I will be tested against in the coming future, people that I will be negotiating with, government departments that I will be in contact with. All these factors were considered while choosing an internship in India and I can gladly say that it has paid off. There is still a very long way to go before I step into this entrepreneurial world myself, but a lot has been learnt in this short but compact period of 6 months. I am sincerely indebted to Vastustruct for this.

10. VASTUSTRUCT CULTURE

What I liked the most about Vastustruct was the environment I was working in. I had heard a lot about MNC's and how you become a slave to your boss in there and I was not a very big fan of it, obviously. So I was a little skeptical about working at Vastustruct at first because of this image that had been created in my head.

To my surprise, Vastustruct was nothing like it, but exactly the opposite. Here, everyone had flexibility over their work hours, freedom over the attire to be worn, holidays were not an issue as long as deadlines were met, exchange of ideas, not only work related but in general about life as well. I never felt that I was working for someone here. This was the major reason why I was enjoying working here. Next to no stress, everyone took their own responsibilities seriously resulting in minimal confusion during projects and the most important thing was that everyone was accountable enough to not be begging to them for the completion of their part.

I still wonder what ensures so much peace in here that other companies often complain about. The key was how the interviews were actually carried out and how employees were selected. I remember Rahul sir asking me very few technical questions during my interview. The session was all about knowing each other, knowing my passions, where I see myself in the next 5 years, all of this being very transparent. We spent a great deal of time talking about my life in Italy and to be honest, Mr. Rahul was quite fascinated with all that I had to share about Polimi and Italy.

Open-minded, caring, considerate, extremely humble, technically superior, experienced and focused on what he really wants from life were some of the many qualities that makes Mr. Rahul an exceptional leader. He is a friend to us, not someone who we work for. He knows more about me than most of my friends do, to be honest. His willingness to give to the people around him was more than visible during the first wave of the pandemic. He has helped our employees not only financially but emotionally as well.

Talking about the management, here are some aspects of Vastustruct that make it ever so efficient:

1. **Flexible Work Hours**

Flexible work hours lets employees work when they're the most productive and efficient, whether that's late at night or early in the day. Giving employees the ability to choose their hours will also make them happier and more likely to stick to work-related tasks when they're on the job.

2. **Updated Technology:**

More than often, the efficiency of employees is primarily related to the systems they use, the software they work on, which become obsolete in a few years. It is necessary to keep up with the advancements in technology, so that you are not left behind. This comes with a price attached to it but the ROI surely makes up for it.

3. Mapping of Processes:

Sometimes everything seems to be working fine from the outside but still the goals do not meet their given deadlines. In this case, mapping of all the processes for a particular project bring a great deal of clarity to the inside picture. You revise problem statements for that day and tackle problems one at a time by this mapping technique and get to the roots of why a particular job is taking time at a particular department.

4. Encourage Team Building:

They say "the more the merrier" which is debatable for some activities but it definitely works in our favor here. Any particular job is always assigned 2 designers. A junior and a senior designer. There is a lot of learning involved for the junior designer and its always better to brush up details, for the senior engineer. One might argue that this may take more time than necessary, but the amount of knowledge gained, different possibilities discussed, different point of views considered, is a great deal than just time.

5. Happy Work Environment:

Employees who are happy at work are more efficient with their time, do their jobs better and are more productive overall. They also tend to focus on the task at hand instead of getting distracted by non-work tasks, like checking personal social media accounts. Factors that contribute to this environment could be something as basic as the amount of sunlight coming in, activities that take your mind off work, handling failure to meet deadlines in the correct manner, etc.

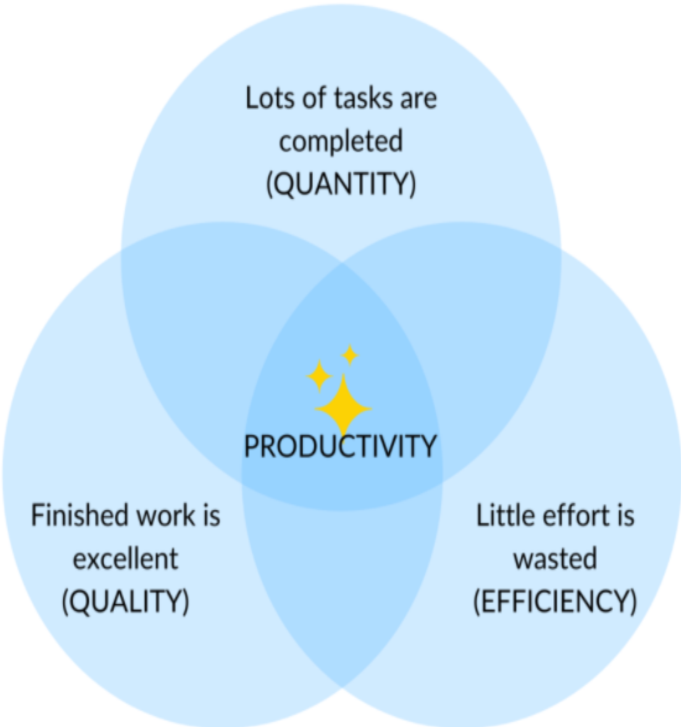
6. No Meeting Madness:

A survey conducted in USA shows that companies spend around 35 billion dollars on meetings every year and employees spend about 37% of their work hours in meetings according to the Entrepreneur. Having the right project management tools will help eliminate the need for many meetings. Of course there will always be a need for face-to-face meetings, but maybe not so many of them.

According to a CareerBuilder survey, about 75 % of employers say that more than two hours of efficient work are lost every day. But it is not always obvious what exactly kills your team productivity.

10.1. What is Team Productivity?

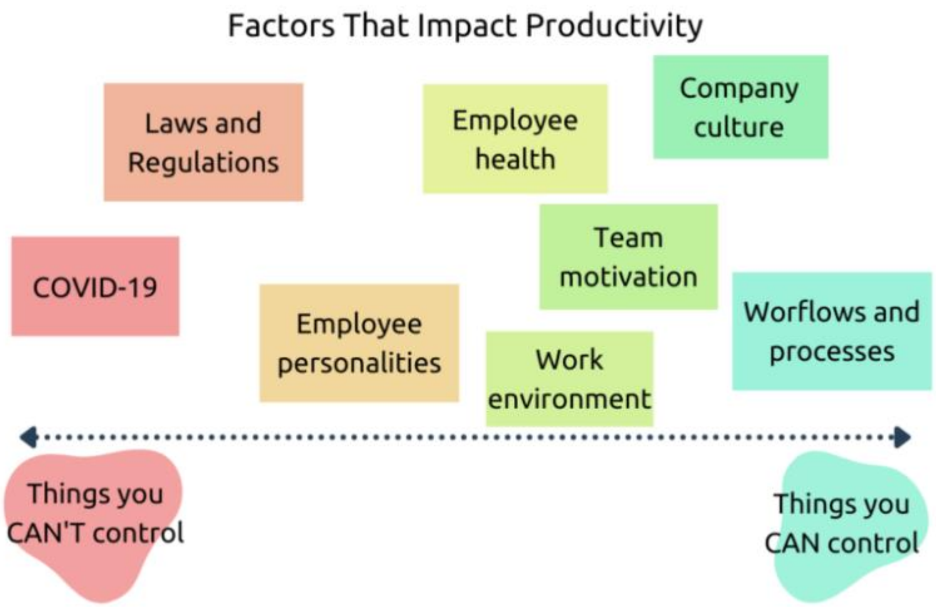
It is more than just getting stuff done. It means that your team is effective and efficient at the same time. If they are using work hours wisely to produce more and better results in less time, they are being productive.



A person is productive if he/she focusses on the right things at the right time. "Work smarter, not harder" has been overused but what exactly is smart work? Are you spending more time on an activity that is nor urgent neither important? If the answer is yes, things need to be reconsidered. One can breeze through hundreds of tasks everyday, but it is of no use if they are the wrong set of tasks.

10.2. Which factors are affecting your team's productivity?

To deal with productivity issues can be a complicated task at hand. It more than often has multiple sources, some which are out of your control, one being a Global Pandemic for example. Although, a plenty of things can be done in order to help your employees to be more productive. Focus more on the things in your control and worry less about things you cannot fix.



1. Physical and Mental Health:

Before the pandemic, 61% of employees reported that they feel burnt out at their job. 31% feel high levels of stress too. We come across so many companies that offer wellness programs. Studies show that these wellness programs can improve productivity by 11%.

- Encourage a 10 minute break for free your legs or some stretching exercises.
- Encourage a healthy work life balance by setting clear communication rules.

- Grant permissions to take holidays when they are feeling mentally and emotionally low.
- Make sure you participate.

2. **Skills and Knowledge:**

An employee with great organizational skills and a strong sense of responsibility is more likely to be efficient. One should give a thought to the way knowledge is shared at your company.

- How easy is it to find data about procedures and processes?
- Is historical data accessible to take calculated decisions?
- Are all decisions going through you? Can that be automated?

3. **Workflows and Processes:**

A survey showed that 39% of employees feel that the data management systems are broken, or they cannot locate important pieces of information as and when they need it. 55% of newly hired employees demand access to the files but do not get it. Roles should be well defined. Processes should be written down. Documents should be accessible.

4. **Ergonomics:**

It is more than a buzz word. A good chair helps prevent injury and reduce pain so your team can focus on doing productive work.

5. **Company Goals:**

A team will have nothing to focus on, if the company goals are not made clear. Just finishing daily tasks and checking off things from the list cannot help you move towards the bigger picture. There must be some cohesion among the employees.

Goals set should be SMART.

S – Specific

M – Measurable

A – Achievable

R – Relevant

T – Time bound

Improving Employee Productivity

1. **Set Clear Expectations:**

    - Being clear about what is important to you and what is not plays a major role. It is not as obvious as you think it is.
    - When performance expectations are set, be sure that it is something that is in the control of your employee or something that he/she can directly influence.
    - Due dates will keep your team working together and help you manage your priorities.

2. **Micromanaging:**

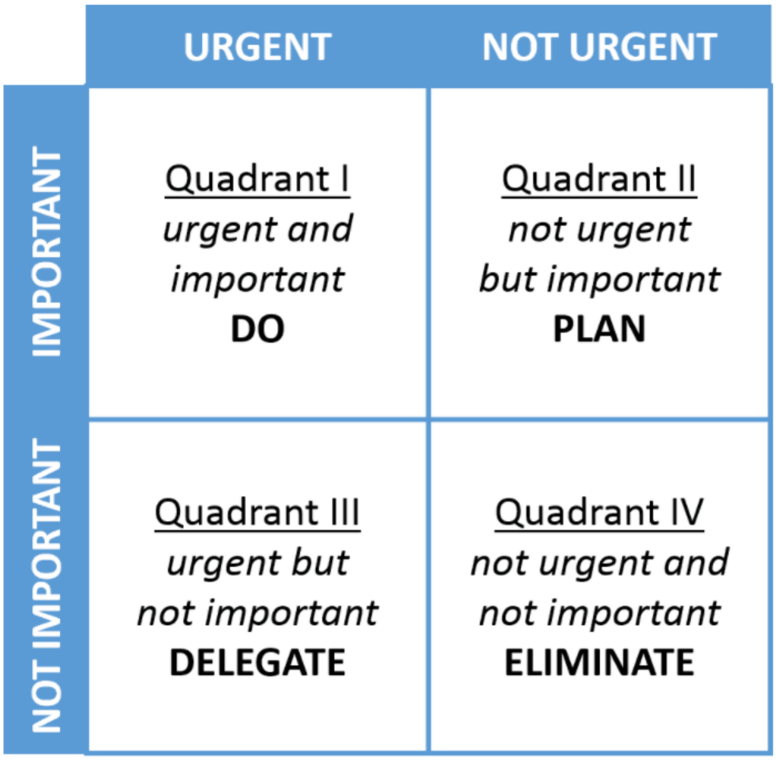
    - The urge to be on top of everything that goes on in your company is quite natural. But cut your employees some slack. Nobody likes being told every detail of their job. Its not just you who want the goals of the company met, the employees are working towards the same goal.

- Concentration from your tasks at hand reduces when you try to manage something that is not really your work to do. This leads to major bottlenecks.

What exactly is Micromanagement?

- You shy away from delegating work because you think you can do a better job than your employee? That's micromanagement.
- You feel the need to proofread and approve everything? That's micromanagement.
- Have suggestions on every tiny details that comes to your desk for approval? That's micromanagement.
- Do you end up making all the decisions and solving all the problems? That's micromanagement.

Eisenhower Matrix is something that is quite impressive and has been widely used by management executives to ensure right delegation of work.



3. **Hire a Culturally Fit Candidate:**

   - The team can be full of diversity but still have a unified culture. Building of culture around important ethics and goals should be a top priority.

   - Welcome different perspectives and backgrounds for a stronger and diverse team.

4. **Recognize the achievements of your team:**

   - 40% of employees think they would put in more effort into their work if the effort was acknowledged more often.

   - Lack of recognition can lead to dissatisfied and disengaged employees.

5. **Provide Feedback:**

   - According to a McKinsey study, 82% of employees agree that they would actually like some sort of a feedback for their work.

   - Focus on performance and behavior.

- Criticize in private, praise in public.
- Be prompt with feedbacks.

11. DESIGN OF AN AIRCRAFT HANGAR

The majority of Hangar buildings are made out of steel for obvious reasons of high strength/weight ratio. A study, on the Efficient Design of Large span hangars/structures, is presented.

Structure with Span larger than 40 m can be regarded as long span structures and need to be carefully designed keeping a balance of all the aspects like its weight, deflections (sway) and foundation forces. There are many combinations of designing large spans, like conventional truss & RCC column combination, truss & steel columns, Pre-engineered building (PEB) etc.

These days with the concept of PEB, the major advantage we get is the use of high strength steel plates (usually Fe 350), lighter but high strength cold form purlins, and 550 MPa Galvalume profiled sheets. The use of PEB not only reduces the weight of the structure because high tensile steel grades are used but also ensures quality control of the structure. In the following study, we have designed a hangar using this modern concept of PEB.

11.1. STAAD Pro V8i

STAAD pro features state of the art user interface, visualization tools, powerful analysis and design engines with advanced finite element (FEM) and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification STAAD pro is the professional first choice. STAAD pro was developed by practicing engineers around the globe. It has evolved over 20 years and meets the requirements of ISO 9001 certification.

11.2. Design process and principles

11.2.1. Loads on Structure

The determination of the loads acting on a structure is a complex problem. The nature of the loads varies essentially with the architectural design, the materials, and the location of the structure. Loading conditions on the same structure may change from time to time, or may change rapidly with time.

11.2.2. Dead load

Dead loads shall cover unit weight/mass of materials, and parts or components in a building that apply to the determination of the dead loads in the design of buildings and shall be considered as per IS: 875 (Part 1) - 1987 according to the densities of the possible components. This includes main frames, purlins, girt, cladding, bracing and connections etc.

11.2.3. Live Load

Imposed loads shall be considered as per IS: 875 (Part 2) – 1987. Live load shall be considered as 0.75 KN/sum for the analysis and design.

11.2.4. Wind Load

The basic wind speed and design velocity which shall be modified shall be taken As per IS: 875 (Part 3) – 1987. The basic wind speed at Hyderabad shall be considered as 44m/sec as per IS: 875 (Part III). This shall be considered for calculating the wind loads. Analysis shall be carried out by considering future expansions if any which has been indicated in the building descriptions and critical forces shall be taken for design.

11.2.5. Seismic Load

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 (Part 1). For analysis and design, Zone II shall be considered as Mysore region falls under this zone as per IS: 1893-2002 (Part 1). Earthquake analysis shall be carried out using STAAD PRO 2007 as per the provisions of IS: 1893-2002 (Part 1) & IS: 1893-2005 (part 4).

The analysis parameters shall be taken as per the following.

The seismic load is considered for Hyderabad location which falls under Zone II.

- Zone Factor: 0.16
- Importance Factor: 1.00
- Response Reduction Factor: 5

11.3. Design codes

Following are the main design codes generally used:

AISC: American institute of steel construction manual

AISI: American iron and steel institute specifications

MBMA: Metal building manufacturer's code

ANSI: American national standards institute specifications

ASCE: American society of civil engineers

UBC: Uniform building code

IS: Indian standards (IS1893-2002 PART 1 FOR EQ) and (IS 875 PARTIII FOR WIND)

11.4. Design philosophy

The design under discussion is a 42 meter clear span hangar for aircrafts maintenance. We have designed this Hangar in 3D on STAAD software, for proper simulation of the load distribution uniformly in three co-ordinates system i.e. X, Y and Z. Dead, Live, Wind, Temperature, seismic etc. have been taken into consideration for designing of the frames. The structure has been designed under enclosed as well as open condition for application of wind loads, because of the opening & closing of the large sized Hangar Door. The Load calculations are done as in the case of a regular frame. Normally, the critical case governing the designs would be (DL+WL) or (DL+LL) conditions as the PEB slopes are minor (like 1 in 10).

The support conditions are normally hinged, but it is sometimes beneficial, on a selective basis to use a fixed condition giving a gusseted base plate and Anchor bolt combination. In Hinged base condition, the section is normally tapered down and provided with a Bolted connection to the base. All the other Joints would be normally designed as rigid joints and steel connections are moment connections, transferring the axial, moment and shear values between the sections connected. In the Wind load calculations, the design wind pressures should be arrived at after a careful analysis and combinations of internal and external pressure coefficients or force coefficients, referring to IS-875 pt.3 latest version. Proper load combinations with Wind, earthquake and crane loads should be investigated.

The basic philosophy of rigid frame design is by adopting ‘Fixed’ or ‘Pinned’ column base conditions. A fixed column base is always a sturdy frame and helps in controlling allowable deflection (side sway) in the frames. Steel designers always prefer fixed base to pinned base frames. On the contrary, for foundation designers the design of foundations becomes a nightmare particularly in large span buildings. In fixed base design, the frame is rigid, but transfers heavy moments to the foundations. On weak soil, designing foundations becomes tedious task. Likewise for pinned support, the frame does not transfer any moment to the foundation and only vertical & horizontal reactions affect the design of foundation. It looks simple but in case of large spans, controlling deflections of frame in pinned base condition is a challenging task.

Usually, checking the Combination Stresses and comparing with the limiting values (in LSD or WSD) is done using interactive software, which calculates the Exploitation efficiency of the section, i.e., if the Actual Stress/permitted stress is 0.95, it means that the section is exploited for 95% of its strength. For this, the total weight of the frame is calculated. A number of trails are done such that sections are designed with Variables like Flange thickness, Web thickness, Flange Width, Web Depth, so that the Entire frame becomes theoretically safe, and is of minimum wt! Checking for deflections is the next step. Many times sections need to be revised to hold the theoretical maximum deflections within the permissible ones.

To control this deflection, the simplest way is to increase the Geometrical properties/sectional sizes of frame, but it is not advisable as it adds to the tonnage of the whole building, adding not only to the seismic forces but also adding to the cost subsequently. We need a solution wherein the sway of the frame can be controlled and the section sizes are also not increased.

The best way we could find is to 'Brace' the frame to control the excess deflection. In the present case we have provided bracing at eave level (braced eave) on both sides of the structure along the length for this purpose. Span of this Eave bracing is taken approximately L / 10 of each side. We can observe in the following example that eave bracing is of a great help in controlling Horizontal deflections and leading to lighter foundation design. Some Vendors exploit 90% of the section, leaving 10% for probable lapses in manufacturing, transporting, assembling & erection. But the competition has made (forced) people believe that there are no lapses anywhere! The Next important step is to design the welds between the flanges and Webs. Here too, Efficiency of the weld plays an important part. Hence, PEB manufacturer will avoid any weld at the site, because a 4.5 mm weld at the shop may be better than 6 or 8 mm weld at the site.

Next step is to design the Field joints (Where the parts are assembled at the site). The resultant forces are known at the joints; bolted connection, preferably perpendicular to the plane of frame, to exploit tensile capacity of bolts for BMs rather than the shear capacities. Hence, Number of bolts required for the connection will reduce. These joints are also placed at Optimum locations. That is the advantage of pre engineering. The secondary members like Purlins and Girts are designed as per codes for thin Cold Formed Sections, with or without lip. One can use many span reducing and Lateral supporting techniques like sag rods and knee bracings, tie rods to optimize the sections.

11.5. STAAD Editor

The input given to the STAAD is read from the STAAD Editor. The input for the execution of the design is as

STAAD PLANE

START JOB INFORMATION

END JOB INFORMATION

* BUILDING INPUT DATA

* WIDTH= 60 METERS

* LENGTH= 120 METERS

* EAVE HEIGHT= 24 METERS

* BAY SPACING= 7.5 METERS

* BRICK WORK= 3 METERS

* SLOPE = 5.71 DEGREES

INPUT WIDTH 79

UNIT METER KN

JOINT COORDINATES

1 0 0 0; 2 0 23.5 0; 3 30 26.5 0; 4 60 23.5 0; 5 60 0 0; 6 3.13397 23.8134 0;

7 6.11908 24.1119 0; 8 9.1042 24.4104 0; 9 12.0893 24.7089 0;

10 15.0744 25.0074 0; 11 18.0595 25.306 0; 12 21.0447 25.6045 0;

13 24.0298 25.903 0; 14 27.0149 26.2015 0; 15 56.866 23.8134 0;

16 53.8809 24.1119 0; 17 50.8958 24.4104 0; 18 47.9107 24.7089 0;

19 44.9256 25.0074 0; 20 41.9405 25.306 0; 21 38.9553 25.6045 0;

22 35.9702 25.903 0; 23 32.9851 26.2015 0;

********************** NODE X Y Z ******************

MEMBER INCIDENCES

1 1 2; 2 2 6; 3 6 7; 4 7 8; 5 8 9; 6 9 10; 7 10 11; 8 11 12; 9 12 13; 10 13 14;

11 14 3; 12 23 3; 13 22 23; 14 21 22; 15 20 21; 16 19 20; 17 18 19; 18 17 18;

19 16 17; 20 15 16; 21 4 15; 22 5 4;

****

DEFINE MATERIAL START

ISOTROPIC STEEL

E 2.05e+008

POISSON 0.3

DENSITY 76.8195

ALPHA 1.2e-005

DAMP 0.03

END DEFINE MATERIAL

****

UNIT MMS KN

CONSTANTS

MATERIAL STEEL ALL

MEMBER PROPERTY INDIAN

****

********** COLUMN**********************

1 22 TAPERED 1332 10 1332 350 16

*********** RAFTER************

2 21 TAPERED 1524 12 1224 325 12

3 20 TAPERED 1224 10 1224 325 12

**SPLICE

4 19 TAPERED 1220 10 1120 250 10

5 18 TAPERED 1120 10 1120 250 10

6 17 TAPERED 1120 10 1220 250 10

7 16 TAPERED 1220 10 1220 250 10

**SPLICE

8 15 TAPERED 1228 12 1528 350 14

9 14 TAPERED 1528 12 1628 350 14

10 13 TAPERED 1628 12 1628 350 14

11 12 TAPERED 1628 12 1628 350 14

****

SUPPORTS

1 5 FIXED

********** SEISMIC FORCE*****************

********** IS 1893 PART 1 2002 ZONE II*******

UNIT METER KN

DEFINE 1893 LOAD

ZONE 0.16 RF 5 I 1 SS 1 DM 3

****

SELFWEIGHT 1

MEMBER WEIGHT

******** 0.1* 7.5 = 0.75 KN/M***************

2 TO 21 UNI 0.75

****

LOAD 1 EQ +X DIR

1893 LOAD X 1

****

LOAD 2 EQ -X DIR

1893 LOAD X -1

****

LOAD 3 DEAD LOAD

MEMBER LOAD

2 TO 21 UNI GY -0.75

****

LOAD 4 LIVE LOAD

MEMBER LOAD

2 TO 21 UNI GY -4.275

****

*NO COLLATERAL LOAD

LOAD 5 WL 0+ IN

****

MEMBER LOAD

1 UNI GX 11.04

22 UNI GX -2.3

2 TO 11 UNI Y 4.051

12 TO 21 UNI Y -0.92

****

LOAD 6 WL 0- IN

MEMBER LOAD

1 UNI GX 1.84

22 UNI GX 6.9

2 TO 11 UNI Y 13.25

12 TO 21 UNI Y 8.28

****

LOAD 7 WL 180+ IN

****

MEMBER LOAD

1 UNI GX 2.3

22 UNI GX -11.04

2 TO 11 UNI Y -0.92

12 TO 21 UNI Y 4.051

****

LOAD 8 WL 180 - IN

****

MEMBER LOAD

1 UNI GX -6.9

22 UNI GX -1.84

2 TO 11 UNI Y 8.28

12 TO 21 UNI Y 13.25

****

LOAD 9 WL 90+ IN

****

MEMBER LOAD

1 UNI GX 0

22 UNI GX 0

2 TO 11 UNI Y 2.76

12 TO 21 UNI Y 2.76

****

LOAD 10 LOADTYPE None TITLE WL 90- IN

****

MEMBER LOAD

1 UNI GX -9.2

22 UNI GX 9.2

2 TO 11 UNI Y 11.9

12 TO 21 UNI Y 11.9

************* LOAD COMBINATIONS **********

************* MEMBER DESIGNS *************

LOAD COMB 11 1.0DL + 1.0LL

3 1.0 4 1.0

****

LOAD COMB 12 0.75DL + 0.75WL1

3 0.75 5 0.75

LOAD COMB 13 0.75DL + 0.75WL2

3 0.75 6 0.75

LOAD COMB 14 0.75DL + 0.75WL3

3 0.75 7 0.75

LOAD COMB 15 0.75DL + 0.75WL4

3 0.75 8 0.75

LOAD COMB 16 0.75DL + 0.75WL5

3 0.75 9 0.75

LOAD COMB 17 0.75DL + 0.75WL6

3 0.75 10 0.75

************* EQ COMBINATIONS*************

LOAD COMB 18 0.75DL + 0.75EQ +X

3 0.75 1 0.75

LOAD COMB 19 0.75DL + 0.75EQ -X

3 0.75 2 0.75

** COMBINATIONS FOR SERVICEABILITY CRITERIA **

****

LOAD COMB 20 1.0DL + 1.0WL1

3 1.0 5 1.0

LOAD COMB 21 1.0DL + 1.0WL2

3 1.0 6 1.0

LOAD COMB 22 1.0DL + 1.0WL3

3 1.0 7 1.0

LOAD COMB 23 1.0DL + 1.0WL4

3 1.0 8 1.0

LOAD COMB 24 1.0DL + 1.0WL5

3 1.0 9 1.0

LOAD COMB 25 1.0DL + 1.0WL6

3 1.0 10 1.0

****

LOAD COMB 26 1.0DL + 1.0EQ +X

3 1.0 1 1.0

LOAD COMB 27 1.0DL + 1.0EQ -X

3 1.0 2 1.0

PERFORM ANALYSIS

PRINT ANALYSIS RESULTS

****

LOAD LIST 11 20 TO 27

PRINT SUPPORT REACTION

PRINT JOINT DISPLACEMENTS LIST 2 3 5

LOAD LIST 11 TO 19

PARAMETER 1

CODE AISC

FYLD 345000 ALL

BEAM 1 ALL

CB 0 ALL

*************** DESIGN PARAMETERS**************

*************** COLUMN************************

LY 3 MEMB 1 22

UNL 3 MEMB 1 22

LZ 24 MEMB 1 22

KZ 1.5 MEMB 1 22

* *************RAFTER ************************

LY 1.5 MEMB 2 TO 21

UNL 1.5 MEMB 2 TO 21

LZ 30 MEMB 2 TO 21

****

CHECK CODE ALL

UNIT METER KG

STEEL TAKE OFF ALL

FINISH

11.6. STAAD Output

```
1. STAAD PLANE

INPUT FILE: ac hangar.STD

2. ************************

3. START JOB INFORMATION

4. ***************************

5. ENGINEER DATE 09-APR-12
```

6. *********

7. END JOB INFORMATION

8. *******************

9. **********************

10. * BUILDING INPUT DATA

11. * WIDTH= 60 METERS

12. * LENGTH= 120 METERS

13. * EAVE HEIGHT= 24 METERS

14. * BAY SPACING= 7.5 METERS

15. * BRICK WORK= 3 METERS

16. * SLOPE = 5.71 DEGREES

17. **********************************

18. INPUT WIDTH 79

19. *********************88888

20. UNIT METER KN

21. JOINT COORDINATES

22. 1 0 0 0; 2 0 23.5 0; 3 30 26.5 0; 4 60 23.5 0; 5 60 0 0;

6 3.13397 23.8134 0

23. 7 6.11908 24.1119 0; 8 9.1042 24.4104 0; 9 12.0893

24.7089 0

24. 10 15.0744 25.0074 0; 11 18.0595 25.306 0; 12 21.0447

25.6045 0

25. 13 24.0298 25.903 0; 14 27.0149 26.2015 0; 15 56.866

23.8134 0

26. 16 53.8809 24.1119 0; 17 50.8958 24.4104 0; 18 47.9107 24.7089 0

27. 19 44.9256 25.0074 0; 20 41.9405 25.306 0; 21 38.9553 25.6045 0

28. 22 35.9702 25.903 0; 23 32.9851 26.2015 0

29. ******** NODE X Y Z

30. *****************************

31. MEMBER INCIDENCES

32. 1 1 2; 2 2 6; 3 6 7; 4 7 8; 5 8 9; 6 9 10; 7 10 11; 8 11 12; 9 12 13; 10 13 14

33. 11 14 3; 12 23 3; 13 22 23; 14 21 22; 15 20 21; 16 19 20; 17 18 19; 18 17 18

34. 19 16 17; 20 15 16; 21 4 15; 22 5 4

35. ***************************88888888888888

36. *****************************

37. DEFINE MATERIAL START

38. ISOTROPIC STEEL

39. E 2.05E+008

40. POISSON 0.3

****

STAAD PLANE PAGE NO.2

****

41. DENSITY 76.8195

42. ALPHA 1.2E-005

```
DAMP 0.03
END DEFINE MATERIAL
***************************
**********************88888888
UNIT MMS KN
CONSTANTS
MATERIAL STEEL ALL
*************************
MEMBER PROPERTY INDIAN
***********************************8
********** COLUMN********
1 22 TAPERED 1332 10 1332 350 16
********************
*********** RAFTER************
2 21 TAPERED 1524 12 1224 325 12
3 20 TAPERED 1224 10 1224 325 12
**SPLICE
4 19 TAPERED 1220 10 1120 250 10
5 18 TAPERED 1120 10 1120 250 10
6 17 TAPERED 1120 10 1220 250 10
7 16 TAPERED 1220 10 1220 250 10
**SPLICE
8 15 TAPERED 1228 12 1528 350 14
9 14 TAPERED 1528 12 1628 350 14
```

67. 10 13 TAPERED 1628 12 1628 350 14

68. 11 12 TAPERED 1628 12 1628 350 14

69. ***************

70. SUPPORTS

71. 1 5 FIXED

72. ****************

73. ********************** SEISMIC FORCE***********

74. ********** IS 1893 PART 1 2002 ZONE II

75. UNIT METER KN

76. DEFINE 1893 LOAD

77. ZONE 0.16 RF 5 I 1 SS 1 DM 3

78. ******************

79. SELFWEIGHT 1

80. MEMBER WEIGHT

81. ******** 0.1* 7.5 = 0.75 KN/M

82. 2 TO 21 UNI 0.75

83. **************

84. LOAD 1 EQ +X DIR

NOTE: FOR SOFT STORY CHECKING WRITE "CHECK SOFT STORY" AT THE END OF LOADING UNDER DEFINE 1893 LOAD DEFINITION.

85. 1893 LOAD X 1

86. ***********

87. LOAD 2 EQ -X DIR

88. 1893 LOAD X -1.

```
**************************************************************
**
STAAD PLANE PAGE NO.3
************************
89. **********************
90. LOAD 3 DEAD LOAD
91. MEMBER LOAD
92. 2 TO 21 UNI GY -0.75
93. **********************8
94. LOAD 4 LIVE LOAD
95. MEMBER LOAD
96. 2 TO 21 UNI GY -4.275
97. *****************************
98. *NO COLLATERAL LOAD
99. ********************************************************
100. ************** WIND PRESSURE CALCULATIONS
*****************
101. * WIND SPEED = 44 M/SEC
102. * RISK COEFFICIENT, K1 = 1
103. * TERRAIN, HT & SIZE FACTOR, K2 = 1.028
104. * TOPOGRAPHY FACTOR, K3 = 1
105. * DESIGN WIND SPEED, VZ = VB * K1 * K2 * K3 = 44 * 1 *
1.028 * 1 = 45.232 M/S
106. * DESIGN WIND PRESSURE, PZ = 0.6 * VZ^2 = 0.6 * 45.232^2
= 1227.560 N/M2 = 1.22
```

```
107. * INTERNAL PRESSURE COEFFICIENT = +/- 0.5

108. * EXTERNAL PRESSURE COEFF'S FROM IS875-III TABLES

109. **************************************

110. * WIND ANGLE 0 DEGREES *

111. **************************************

112. * WALL COEFF (0.7 -0.25 ) *

113. * ROOF COEFF (-0.94 -0.4) *

114. **************************************

115. * WIND ANGLE 90 DEGREES *

116. **************************************

117. * WALL COEFF (-0.5 -0.5) *

118. * ROOF COEFF (-0.8 -0.8) *

119. ********************************************************

120. LOAD 5 WL 0+ IN

121. *****************************

122. ***************BAY SPACING =7.5, PRESSURE=1.227

123. ***************

124. * WINDWARD

LEEWARD

125. * NET WALL COEFFICIENT(CP=CPE+CPI): 0.7+0.5=1.2 -

0.25+0.5=0.25

126. * FORCE ON COLUMNS (F): 11.04 KN

2.3KN

127. * NET ROOF COFFICIENT (CP=CPE+CPI): -0.94+0.5=-0.44 -
```

0.4+0.5=+0.1

128. * FORCE ON RAFTERS (F): -4.051 KN

0.920 KN

129. **

130. MEMBER LOAD

131. 1 UNI GX 11.04

132. 22 UNI GX -2.3

133. 2 TO 11 UNI Y 4.051

134. 12 TO 21 UNI Y -0.92

135. **********************

136. LOAD 6 WL 0- IN

137. ******************

138. ******************************

139. * WINDWARD

LEEWARD

140. * NET WALL COFFICIENT(CP=CPE-CPI): 0.7-0.5=0.2 -

0.25-0.5=-0.75

141. * FORCE ON COLUMNS (F): 1.84 KN -

6.90 KN

****

**

STAAD PLANE PAGE NO. 4

****

142. * NET ROOF COFFICIENT(CP=CPE-CPI): -0.94-0.5=-1.44 -

0.4-0.5=-0.9

143. * FORCE ON RAFTERS (F): -13.25 KN -

8.28 KN

144. *******************

145. MEMBER LOAD

146. 1 UNI GX 1.84

147. 22 UNI GX 6.9

148. 2 TO 11 UNI Y 13.25

149. 12 TO 21 UNI Y 8.28

150. *************************

151. LOAD 7 LOADTYPE NONE TITLE WL 180+ IN

152. *************************

153. ************************

154. * WINDWARD

LEEWARD

155. * NET WALL COFFICIENT (CP=CPE+CPI): -0.25+0.5=0.25

0.7+0.5=1.2

156. * FORCE ON COLUMNS (F): 2.30KN

11.04KN

157. * NET ROOF COFFICIENT (CP=CPE+CPI): -0.4+0.5=0.1 -

0.94+0.5=-0.44

158. * FORCE ON RAFTERS (F): 0.920 KN -

6.809 KN

159. ****************************

160. MEMBER LOAD

161. 1 UNI GX 2.3

162. 22 UNI GX -11.04

163. 2 TO 11 UNI Y -0.92

164. 12 TO 21 UNI Y 4.051

165. ********************************

166. LOAD 8 LOADTYPE NONE TITLE WL 180 - IN

167. *********************

168. ***************************

169. * WINDWARD

LEEWARD

170. * NET WALL COFFICIENT(CP=CPE-CPI): -0.25-0.5=-0.75

0.7-0.5= 0.2

171. * FORCE ON COLUMNS (F): -6.90 KN

1.84KN

172. * NET ROOF COFFICIENT(CP=CPE-CPI): -0.4-0.5=-0.9 -

0.94-0.5=-1.44

173. * FORCE ON RAFTERS (F): -8.28 KN -

13.25 KN

174. **********************

175. MEMBER LOAD

176. 1 UNI GX -6.9

177. 22 UNI GX -1.84

178. 2 TO 11 UNI Y 8.28

179. 12 TO 21 UNI Y 13.25

```
180. *************************
181. LOAD 9 LOADTYPE NONE TITLE WL 90+ IN
182. *****************************
183. ***********************
184. * WINDWARD
LEEWARD
185. * NET WALL COFFICIENT(CP=CPE+CPI): -0.5+0.5=0 -
0.5+0.5=0
186. * FORCE ON COLUMNS (F): 0 KN 0
KN
187. * NET ROOF COFFICIENT(CP=CPE+CPI): -0.8+0.5=-0.3
-0.8+0.5=-0.3
188. * FORCE ON RAFTERS (F): -2.76 KN -
2.76 KN
189. ****************************
190. MEMBER LOAD
191. 1 UNI GX 0
192. 22 UNI GX 0
193. 2 TO 11 UNI Y 2.76
194. 12 TO 21 UNI Y 2.76
195. ******************************
196. LOAD 10 LOADTYPE NONE TITLE WL 90- IN
197. ******************************
*************************************************************
```

```
STAAD PLANE --PAGE NO.5

************************

198. ********************************

199. * WINDWARD

LEEWARD

200. * NET WALL COFFICIENT(CP=CPE-CPI): -0.5-0.5=-1.0 -0.5-

0.5=-1.0

201. * FORCE ON COLUMNS (F): -9.20 KN -

9.20 KN

202. * NET ROOF COFFICIENT(CP=CPE-CPI): -0.8-0.5=-1.3 -

0.8-0.5=-1.3

203. * FORCE ON RAFTERS (F): -11.9 KN -

11.9 KN

204. *********

205. MEMBER LOAD

206. 1 UNI GX -9.2

207. 22 UNI GX 9.2

208. 2 TO 11 UNI Y 11.9

209. 12 TO 21 UNI Y 11.9

210. **************************************

211. *************************************

212. ************* LOAD COMBINATIONS ************

213. ************** MEMBER DESIGNS *****************

214. *****************************************
```

```
215. LOAD COMB 11 1.0DL + 1.0LL
216. 3 1.0 4 1.0
217. *******
218. LOAD COMB 12 0.75DL + 0.75WL1
219. 3 0.75 5 0.75
220. LOAD COMB 13 0.75DL + 0.75WL2
221. 3 0.75 6 0.75
222. LOAD COMB 14 0.75DL + 0.75WL3
223. 3 0.75 7 0.75
224. LOAD COMB 15 0.75DL + 0.75WL4
225. 3 0.75 8 0.75
226. LOAD COMB 16 0.75DL + 0.75WL5
227. 3 0.75 9 0.75
228. LOAD COMB 17 0.75DL + 0.75WL6
229. 3 0.75 10 0.75
230. ***** CONSIDERING EQ COMBINATIONS********
231. LOAD COMB 18 0.75DL + 0.75EQ +X
232. 3 0.75 1 0.75
233. LOAD COMB 19 0.75DL + 0.75EQ -X
234. 3 0.75 2 0.75
235. ***************************************Y
236. **************************
237. ** FOR SERVICEABILITY CHECK **
238. **************************
```

239. LOAD COMB 20 1.0DL + 1.0WL1

240. 3 1.0 5 1.0

241. LOAD COMB 21 1.0DL + 1.0WL2

242. 3 1.0 6 1.0

243. LOAD COMB 22 1.0DL + 1.0WL3

244. 3 1.0 7 1.0

245. LOAD COMB 23 1.0DL + 1.0WL4

246. 3 1.0 8 1.0

247. LOAD COMB 24 1.0DL + 1.0WL5

248. 3 1.0 9 1.0

249. LOAD COMB 25 1.0DL + 1.0WL6

250. 3 1.0 10 1.0

251. *****************

252. **********************

253. LOAD COMB 26 1.0DL + 1.0EQ +X

STAAD PLANE -- PAGE NO. 6

****

254. 3 1.0 1 1.0

255. LOAD COMB 27 1.0DL + 1.0EQ -X

256. 3 1.0 2 1.0

257. PERFORM ANALYSIS

****

**

P R O B L E M S T A T I S T I C S

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 23/ 22/

2

SOLVER USED IS THE OUT-OF-CORE BASIC SOLVER

ORIGINAL/FINAL BAND-WIDTH= 20/ 1/ 6 DOF

TOTAL PRIMARY LOAD CASES = 10, TOTAL DEGREES OF FREEDOM =

63

SIZE OF STIFFNESS MATRIX = 1 DOUBLE KILO-WORDS

REQRD/AVAIL. DISK SPACE = 12.1/ 67490.3 MB

**WARNING: IF THIS UBC/IBC ANALYSIS HAS TENSION/COMPRESSION

OR REPEAT LOAD OR RE-ANALYSIS OR SELECT OPTIMIZE, THEN EACH

UBC/IBC CASE SHOULD BE FOLLOWED BY PERFORM ANALYSIS & CHANGE.

****

* *

* TIME PERIOD FOR X 1893 LOADING = 0.84969 SEC *

* SA/G PER 1893= 0.588, LOAD FACTOR= 1.000 *

* FACTOR V PER 1893= 0.0094 X 235.57 *

* *

****

****

* *

* TIME PERIOD FOR X 1893 LOADING = 0.84969 SEC *

* SA/G PER 1893= 0.588, LOAD FACTOR=-1.000 *

* FACTOR V PER 1893= 0.0094 X 235.57 *

* *

```
*********************************************************
258. *
259. LOAD LIST 11 20 TO 27
260. PRINT SUPPORT REACTION
SUPPORT REACTION
STAAD PLANE -- PAGE No.7
************************
SUPPORT REACTIONS -UNIT KN METE STRUCTURE TYPE = PLANE
JOINT LOAD FORCE-X FORCE-Y FORCE-Z MOM-X MOM-Y
MOM Z
1 11 78.67 151.50 0.00 0.00 0.00
-687.22
20 -208.48 -71.66 0.00 0.00 0.00
1322.85
21 -212.28 -347.64 0.00 0.00 0.00
1887.20
22 -18.00 22.95 0.00 0.00 0.00
-116.25
23 -21.80 -253.04 0.00 0.00 0.00
448.00
24 -31.07 -60.19 0.00 0.00 0.00
271.12
25 -33.94 -334.39 0.00 0.00 0.00
827.36
```

```
26 10.63 22.32 0.00 0.00 0.00

-83.88

27 12.85 22.91 0.00 0.00 0.00

-121.26

5 11 -78.67 151.50 0.00 0.00 0.00

687.22

20 18.00 22.95 0.00 0.00 0.00

116.25

21 21.80 -253.04 0.00 0.00 0.00

-448.00

22 208.48 -71.66 0.00 0.00 0.00

-1322.85

23 212.28 -347.64 0.00 0.00 0.00

-1887.20

24 31.07 -60.19 0.00 0.00 0.00

-271.12

25 33.94 -334.39 0.00 0.00 0.00

-827.36

26 -12.85 22.91 0.00 0.00 0.00

121.26

27 -10.63 22.32 0.00 0.00 0.00

83.88

************** END OF LATEST ANALYSIS RESULT **************

261. PRINT JOINT DISPLACEMENTS LIST 2 3 5
```

JOINT DISPLACE LIST 2

STAAD PLANE -- PAGE NO. 8

****

JOINT DISPLACEMENT (CM RADIANS) STRUCTURE TYPE = PLANE

JOINT LOAD X-TRANS Y-TRANS Z-TRANS X-ROTAN Y-ROTAN

Z-ROTAN

2 11 -1.6065 -0.0718 0.0000 0.0000 0.0000

-0.0041

20 4.1650 0.0339 0.0000 0.0000 0.0000

0.0019

21 6.6578 0.1647 0.0000 0.0000 0.0000

0.0075

22 -3.0735 -0.0109 0.0000 0.0000 0.0000

0.0020

23 -0.5822 0.1199 0.0000 0.0000 0.0000

0.0076

24 0.6290 0.0285 0.0000 0.0000 0.0000

0.0016

25 3.1023 0.1584 0.0000 0.0000 0.0000

0.0072

26 -0.0355 -0.0106 0.0000 0.0000 0.0000

-0.0007

27 -0.4440 -0.0109 0.0000 0.0000 0.0000

-0.0005

3 11 0.0000 -16.7463 0.0000 0.0000 0.0000

0.0000

20 3.6195 5.1882 0.0000 0.0000 0.0000

-0.0011

21 3.6204 31.9770 0.0000 0.0000 0.0000

-0.0011

22 -3.6195 5.1882 0.0000 0.0000 0.0000

0.0011

23 -3.6203 31.9770 0.0000 0.0000 0.0000

0.0011

24 0.0000 6.5863 0.0000 0.0000 0.0000

0.0000

25 0.0000 33.1792 0.0000 0.0000 0.0000

0.0000

26 0.2046 -2.4994 0.0000 0.0000 0.0000

0.0000

27 -0.2046 -2.4994 0.0000 0.0000 0.0000

0.0000

5 11 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

20 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

21 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

22 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

23 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

24 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

25 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

26 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

27 0.0000 0.0000 0.0000 0.0000 0.0000

0.0000

************** END OF LATEST ANALYSIS RESULT **************

262. LOAD LIST 11 TO 19

263. PARAMETER 1

264. CODE AISC

265. FYLD 345000 ALL

266. BEAM 1 ALL

267. CB 0 ALL

268. ****************************

269. *************** DESIGN PARAMETERS**************

270. *************** COLUMN**********

271. LY 3 MEMB 1 22

```
272. UNL 3 MEMB 1 22

273. LZ 24 MEMB 1 22

274. KZ 1.5 MEMB 1 22

STAAD PLANE -- PAGE NO.9

************************

275. ************************************

276. ***************************

277. * *******************RAFTER ****************

278. LY 1.5 MEMB 2 TO 21

279. UNL 1.5 MEMB 2 TO 21

280. LZ 30 MEMB 2 TO 21

281. ***

282. CHECK CODE ALL

STEEL DESIGN

*********** END OF THE STAAD.Pro RUN ***********
```

11.7. Reference images for Aircraft Hangar design

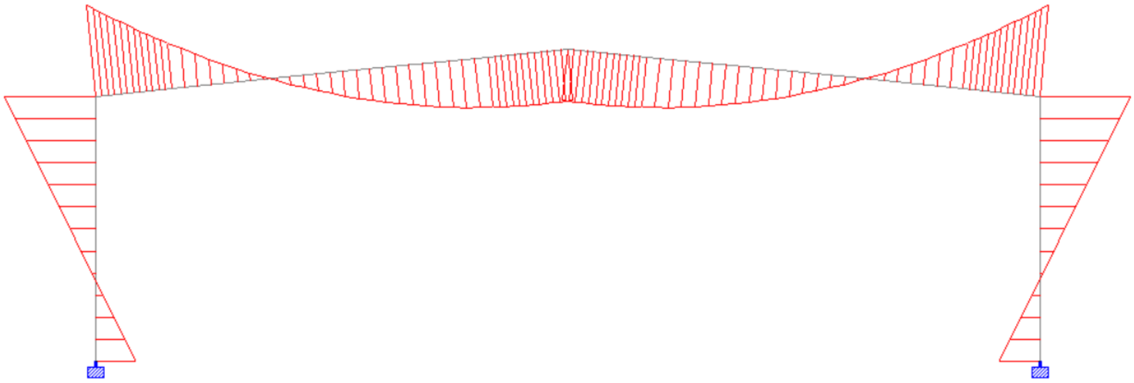


Figure 1 Moment in Z direction on 2D frame

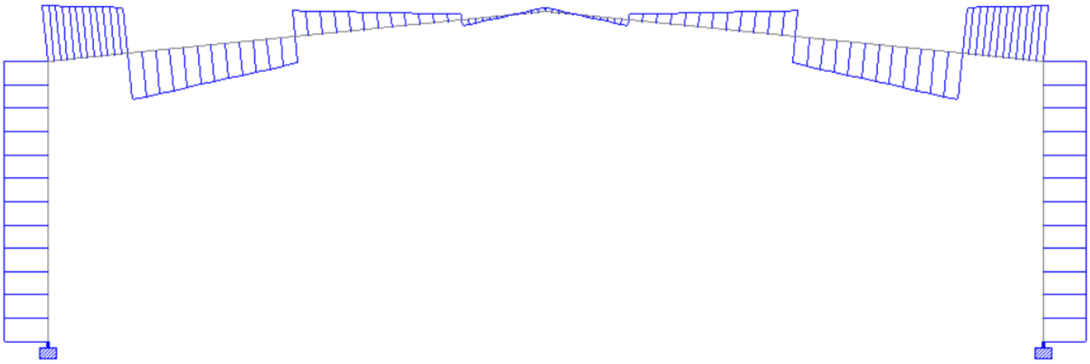


Figure 2 Shear in Y direction on 2D frame

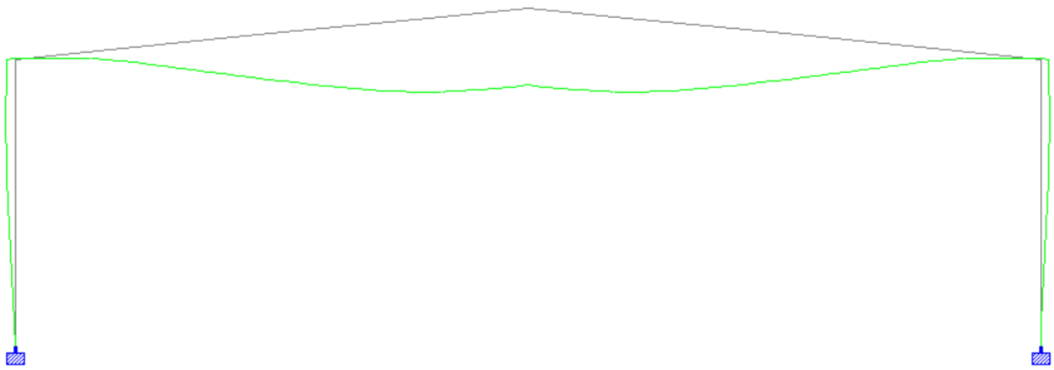


Figure 3 Frame deflection pattern under primary loading

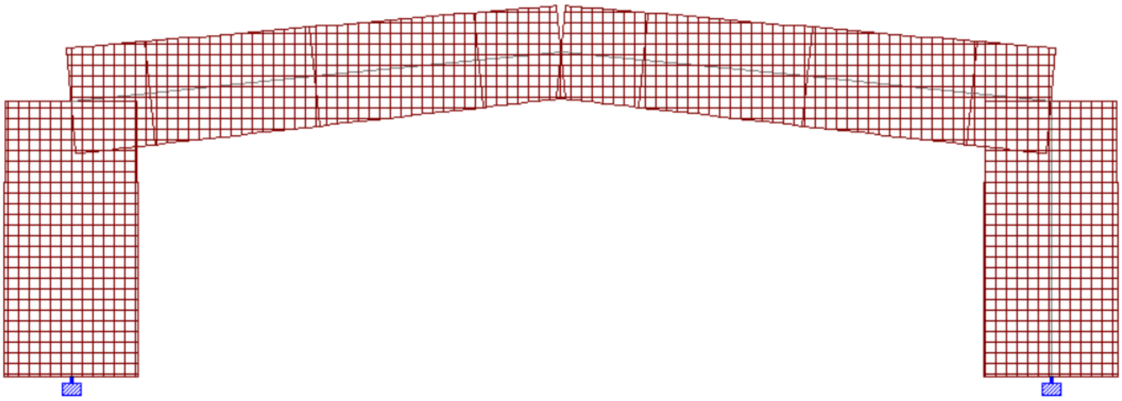


Figure 4 Axial force in local X axis on 2D frame

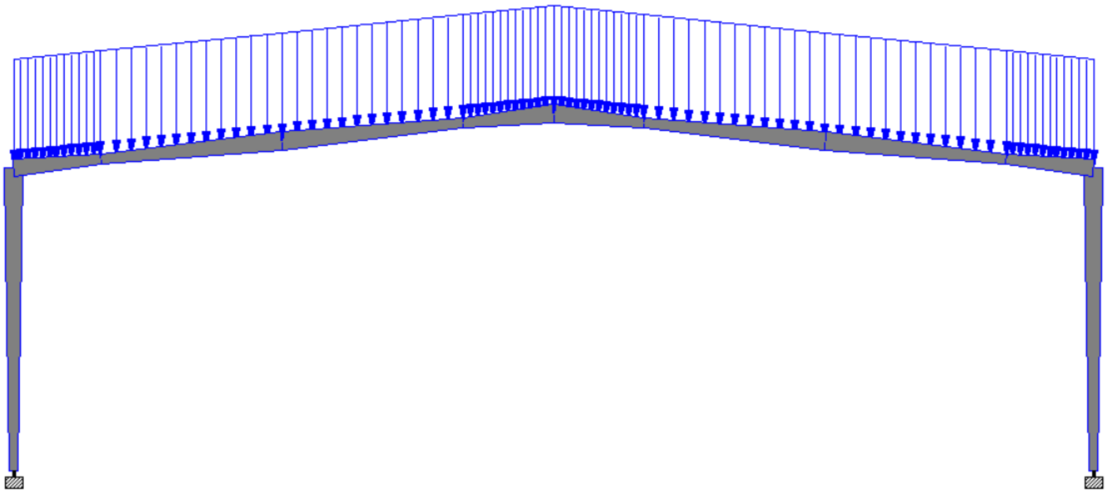


Figure 5 Dead Load acting on 2D frame

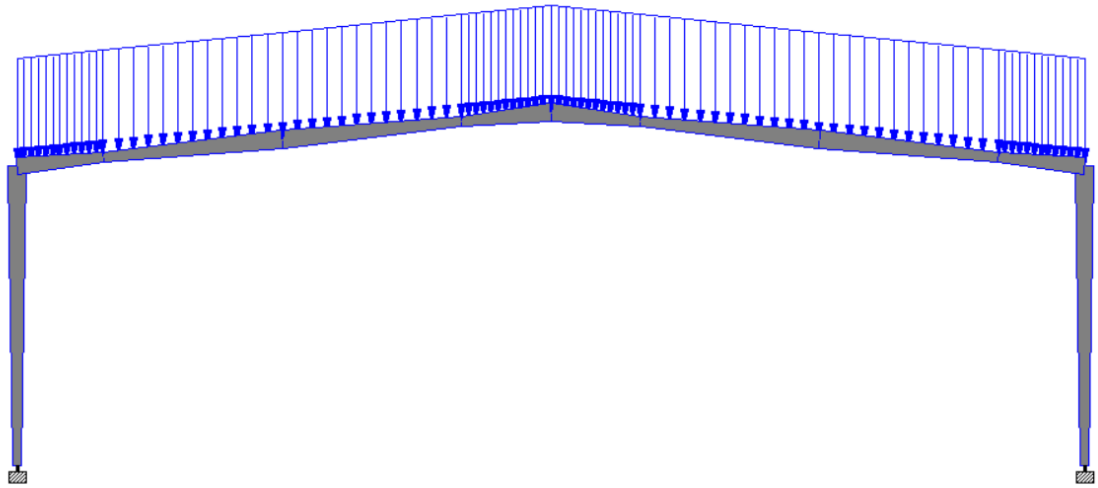


Figure 6 Collateral Load acting on 2D frame

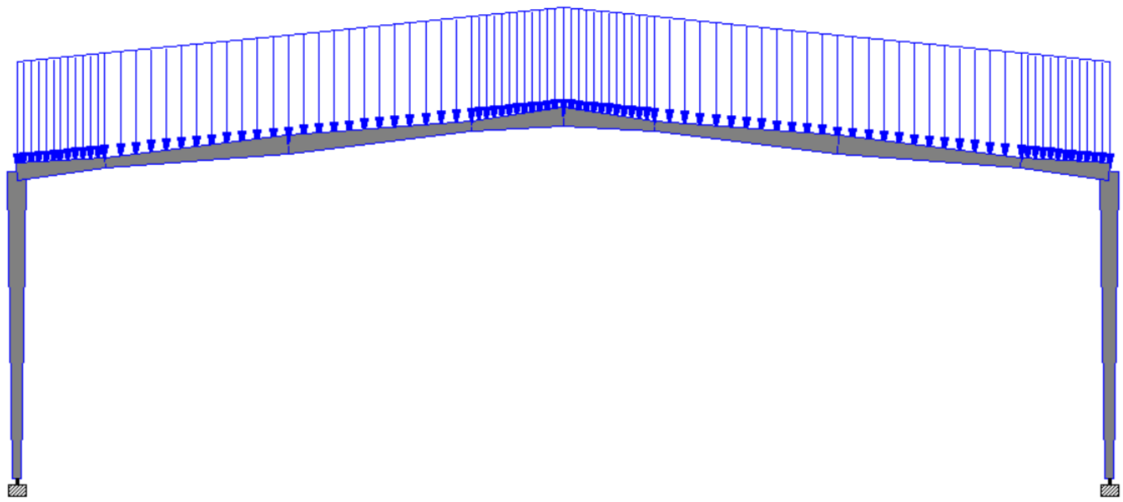


Figure 7 Live Load acting on 2D frame

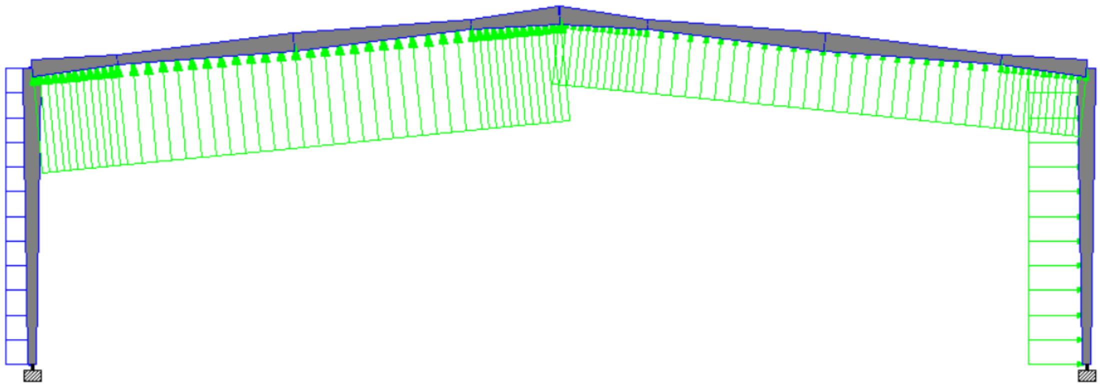


Figure 8 Wind Loads acting on 2D frame

12. CONCLUSION

Steel is such a versatile material that every object we see in our daily life has used steel directly or indirectly. There is no viable substitute to steel in construction activities. Steel remains and will continue to remain logical and wide choice for construction purpose, environmentally also, as much of the steel used is recycled.

Steel building offers more design and architectural flexibility for unique or conventional styling. Its strength and large clear spans mean the design is not constrained by the need for intermediate support walls. As your requirements changes over the years, you can reuse, relocate, & modify the structure.

Pre-engineered Metal building concept forms an unique position in the construction industry in view of their being ideally suited to the needs of modern Engineering Industry. It would be the only solution for large industrial enclosures having thermal and acoustical features. The major advantage of metal building is the high speed of design and construction for buildings of various categories.

13. REFERENCES

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