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A Study on Pre Engineered Steel Building Structures

¹J.Jayavelmurugan , ²J.R.Thirumal, ³Padmanabhan haridas

¹Department of Civil Engineering, Bharath University, Selaiyur, Chennai, India

²Department of Civil Engineering, Bharath University, Selaiyur, Chennai, India

³ Department of Civil Engineering, Tata consultancy engineers Chennai, India

Abstract: Buildings & houses are one of the oldest construction activities of human beings. The construction technology has advanced since the beginning from primitive construction technology to the present concept of modern house buildings. The present construction methodology for buildings calls for the best aesthetic look, high quality & fast construction, cost effective & innovative touch. Pre Engineered Steel Buildings are manufactured or Produced in the plant itself. The manufacturing of structural members is done on customer requirements. The detailed structural members are designed for their respective location and are numbered, which cannot be altered; because members are manufactured with respect to design features. These components are made in modular or completely knocked condition for transportation. These materials are transported to the customer site and are erected. 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.

I. INTRODUCTION

India being a developed country massive house building construction is taking place in various parts of the country. Since 30% of Indian population lives in towns and cities; hence construction is more in the urban places. The requirement of housing is tremendous but there will always be a shortage of house availability as the present masonry construction technology cannot meet the rising demand every year. Hence one has to think for alternative construction system for steel or timber buildings, but timber is anyway not suitable to tropical countries like India. 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 sheet, 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

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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 look 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 steel buildings use a combination of built-up sections, hot rolled sections and cold formed elements which provide the basic steel frame work with a choice of single skin sheeting with added insulation or insulated sandwich panels for roofing and wall cladding. The concept is designed to provide a complete building envelope system which is airtight, energy efficient, optimum in weight and cost and, above all, designed to fit user requirement like a well fitted glove. Pre engineered steel buildings can be fitted with different structural accessories including mezzanine floors, canopies, fascias, 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 metres. 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

II. TECHNICAL PARAMETERS OF PEB

Pre Engineered Buildings are custom designed to meet clients requirements. PEBs are defined for definite measurements. The produced members fit to the designed dimensions. Measurements are taken accurately for the requirements. The basic parameters that can define a PEB are

2.1 Width or Span of Building

The centre to centre length from one end wall column to the other end wall column of a frame is considered breadth or span of the building. The width between two columns can be measured as span. The span length for different buildings varies. The design is done on span length given by customer. The basic span length starts from 10 to 150 meters or above with intermediate columns. Aircraft hangars, manufacturing industries, Stadiums possess major span width. No modifications or extending span be done.

2.2 Length of Building

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

2.3 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.

2.4 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 snowfall locations can go up to 1/30 to 1/60. Any practical roof slope is possible as per customers' requirement.

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2.5 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.

2.5.1 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.

2.5.2 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.

2.5.3 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.

2.5.4 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.

2.5.5 Roof Snow Load

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

2.5.6 Auxiliary Loads

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

2.5.7 Seismic Loads

They are the Horizontal loads acting in any direction structural systems due to action of an earthquake.

2.5.8 Floor Live Loads

Loads induced on a floor system by occupants of a building and their furniture, equipment, etc

2.6 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 centre line of the first interior frame columns. Interior bay length is the distance between the centre 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.

2.7 Types of Frame

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

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2.7.1 Clear Span (Cs)

It's the span length between two columns without any obstruction. It has split Beams with ridge line at the peak or centre 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.

2.7.2 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 90meters, but can be extended to 120 meters.

2.7.3 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.

2.7.3.1 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 multi spans can be extended up to AMS1, AMS2 and AMS3 etc.

2.7.3.2 Multi Span 2 (Ms2)

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

2.7.4 Single Slope

It has two columns with different heights having Roof sloping on both the column.

2.7.5 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.

2.7.6 Roof Systems

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

2.7.7 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.

2.7.8 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

III. COMPONENTS OF PEB

A typical assembly of a simple metal building system is shown below to illustrate the Synergy between the various building components as described below:

Primary components

Secondary components

Sheeting (or) cladding

Accessories

3.2 Primary Components

3.2.1 Main framing

Main framing basically includes the rigid steel frames of the building. The PEB rigid frame comprises of tapered columns and tapered rafters (the fabricated tapered sections are referred to as built-up members). The tapered sections are fabricated using the state of art technology wherein the flanges are welded to the web. Splice plates are welded to the ends of the tapered sections. The frame is erected by

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bolting the splice plates of connecting sections together. 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 shall be cold-formed "C" sections, mill-rolled sections, or built-up "I" sections depending on design requirements. Plates, Stiffeners, etc. All base plates splice plates, cap plates, and stiffeners shall be factory welded into place on the structural member's .Built- up I section to build primary structural framing members (Columns and Rafters)

3.2.2 Columns

The main purpose of the columns is to transfer the vertical loads to the foundations. However apart of the horizontal actions (wind action) is also transferred through the columns. Basically in pre-engineered buildings columns are made up of I sections which are most economical than others. The width and breadth will go on increasing from bottom to top of the column. I section consists of flanges and web which are made from plates by welding.

3.3.2 Rafter

A rafter is one of a series of sloped structural members (beams) that extend from the ridge or hip to the wall-plate, down slope perimeter or eave, and that are designed to support the roof deck and its associated loads.

3.3 Secondary Components

Purlins, Girts and Eave struts are secondary structural members used as support to walls and roof panels. Purloins are used on the roof; Girts are used on the walls and Eave struts are used at the intersection of the sidewall and the roof. They are supplied with minimum yield strength of 34.5KN/m. Secondary members act as struts that help in resisting part of the longitudinal loads that are applied on the building such as wind and earthquake loads and provide lateral bracing to the compression flanges of the main frame members for increasing frame capacity. Purloins, Girts and Eave struts are available in high grade steel conforming to ASTM 607 Grade 50 or equivalent, available in 1.5 mm, 1.75 mm, 2.0 mm, 2.25 mm, 2.5 mm and 3.0 mm thickness. They come with a pre-galvanized finish, or factory painted with a minimum of 35 microns (DFT) of corrosion protection primer. 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.

3.3.1 Purlins and Girts

Purlins and girts shall be roll formed Z sections, 200 mm deep with 64 mm flanges shall have a 16 mm stiffening lip formed at 45 to the flange. 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 AISC .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.

3.3.2 Eave Struts

Eave Struts shall be unequal flange cold-formed "C" sections. Eave struts are 200 mm deep with a 104 mm wide top flange, a 118 mm wide bottom flange, both are formed parallel to the roof slope. Each flange has a 24 mm stiffener lip.

3.3.3 Bracings

The Cable bracing is a primary member that ensures the stability of the building against forces in the longitudinal direction such as wind, cranes, and earthquakes. 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.

3.4 Sheeting or Cladding

The sheets used in the construction of pre- engineered buildings are composed of the following: Base metal of either Galvalume coated steel conforming to ASTM A 792 M grade 345B or aluminium conforming to ASTM B 209M . Galvalume coating is 55% Aluminium and about 45% Zinc by weight. An exterior surface coating on painted sheets of 25 microns of epoxy primer with a highly durable

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polyester finish. An interior surface coating on painted sheets of 12 microns of epoxy primer and modified polyester or foam. The sheeting material is cold-rolled steel, high tensile 550 MPA yield stress, with hot dip metallic coating of Galvalume sheet.

3.5 Accessories

3.5.1 Anchor bolts

Bolts used to anchor the structural members to the concrete floor, foundation or other support. This usually refers to the bolts at the bottom of all columns. Anchor bolts are manufactured with circular steel rods having threading portion at the top for bolting and bent up at the bottom for Foundation.

3.5.2 Turbo ventilators

A Turbo Ventilator is a free spinning roof ventilator that works on free wind energy. When there is a difference in thermal or wind pressure between the inside and outside of the building, the air is forced to move through the opening of the Turbo Ventilator in order to maintain an equilibrium condition. The benefits of using turbo ventilators are that it improves air circulation and cuts off the suffocation. Eco friendly turbo ventilator involves no operating cost, are free from maintenance and are has trouble free operations.

3.5.3 Sky lights (or) wall lights

Sky lights may consists of poly carbonate sheets which is translucent sheet that allows maximum light and minimum heat. High strength translucent panels are glass fiber reinforced polyester, high strength and may be either and it provides with an estimated light transmitting capacity of 60%. High strength translucent panels match standard panel profiles, are 1/16 thick, weigh 8 ounces per square foot, and are white with a granitized top surface. Insulated translucent panels are available in type 1, "R" panel and standing seam profiles only. Damper, Standard size is 3000 mm long with a throat opening of 300 mm.

3.5.4 Louvers

Standard Louvers shall have a 26 gauge galvanized steel frame, painted, with 26 gauge blades. Heavy Duty Louver frames shall be 18 gauge galvanized steel frame, painted, with 20 gauge blades. Both Standard and Heavy Duty louvers shall be self-framing and self flashing. They shall be equipped with adjustable or fixed blades as specified. Nominal sizes shall be 2'-0" x 20" x 2'-0", 3'-0" x 3'-0" 4'-0" x 3'-0", and 3'-0" x 4'-0.

3.5.5 Fasteners

Standard fasteners shall be self drilling screws with metal and neoprene washers. All screws shall have hex heads and are zinc plated.

3.6 Gantry Girder

In mills and heavy industrial buildings such as factories and workshops, gantry girders supported by columns and carrying cranes are used to handle and transport heavy goods, equipment, etc. there are several types of canes; Overhead travelling, under-slung, jib, gantry, and monorail are among the most common. A building may have one or several of these, either singly or in combinations. Hand operated overhead cranes have lifting capacities of up to 50 KN and electrically operated overhead cranes, called EOT cranes, can have capacities in the range of 10-3000 KN. The overhead travelling crane runway system consists of the following:

1. The crane, comprising the crane girder(crane frame), crab or trolley, hoist, power transmitting devices, and a cab which houses the control and operator
2. The crane rails and their attachments
3. The gantry girder
4. The gantry girder supporting columns or brackets
5. The crane stops

IV. ERECTION AND MAINTENANCE

Steel framing members are delivered at site in pre-cut sizes, which eliminates cutting and welding at site. Being lighter in weight, the small members can be very easily assembled, bolted and raised with the help of cranes.

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This system allows very fast construction and reduces wastage and labour requirement. These buildings can then be provided with roof decking and wall cladding with metal profile sheets and proper insulation. The framing are so designed that electrical and plumbing services are part of it and can be very easily concealed.

For the latest developed technology on pre-fabricated residential house construction without steel columns & purlins, the construction method begins with grouting of 'C' channels to the floor on the periphery of the building. Thereafter placing 1.2mm GI profiled sheets (of high depth crest) over the 'C' channel and fixed with screws. Fixing of high density Rockwool or Polyurethane Foam or Expanded Polystyrene with adhesive on the crests on both sides. Then providing and fixing 8mm cement particle boards on inner side and 10mm cement particle boards on outer side of the profiled GI sheet, with screws, followed by fixing of a 'C' channel on top of the GI profiled sheet. Then trusses are placed over the top 'C' channel and purlins fixed to it at 1500mm distance. Colour coated profile steel sheets are fixed to the purlins. GI 'T' frame work making a grid of 600 x 600mm hung from the trusses with GI rods for false ceiling frame work and 6-8mm E boards are placed over it. Floors are constructed of cement concrete at a raised level for special requirements tiles can be fixed as the final finish. For kitchen and toilets, the floor and walls up to 2-3 feet is constructed or in tradition houses or normal cement finish or with tiles.

For fixing of electrical accessories, grills, shelves and other miscellaneous services wooden supports are pre-fixed to the GI profiled sheet ceiling fan support is taken from the trusses. Doors & windows frames are made of steel and fixed to the profiled GI sheet with proper flashings. Rain guard covers over windows made of steel are fixed to the profiled GI sheet of walls. The gaps between the cement particle boards are filled with putty and finally painting is done on both sides of the walls

In Pre-engineered Pre-fabricated steel houses the maintenance area is the roofing & cladding. Steel roofing & side wall cladding requires minimum maintenance. The roof should be inspected immediately after installation to check if cleaning of the roof has been carried out fully. It is very often seen that the drilled out metal and debris are not swept away. These can act as initiators of corrosion and lead to premature failures. In case of cement particle board walls painting required every 3-4 years.

Installed roofing must be inspected at least once a year. Any exposed metal that can rust or has rusted should be painted. Leaves, branches, and trash should be removed from gutters, at ridge caps and in corners. Also watch out for discharge from industrial stacks, and particulate matter and high sulphur exhaust from space heaters which could get piled up.

Roof top ancillaries and air conditioner supports, drains and housing should be checked. Particular attention should be paid to add-on roof ancillaries that create new roof penetrations. Roof-top air conditioners should be installed on curbs designed to avoid ponding of water. Condensate from air – conditioning and refrigeration equipment should never be allowed to drain directly on to the roof panels. The drainage contains ions from condenser coils that accelerate corrosion.

In the event of a roof leak, do not indiscriminately plaster the suspected leak area with tar or asphalt or use repair tape. Water can collect under the repair material causing corrosion. Instead, have an experienced roofing foreman locate the leak, identify its cause and properly repair the roof.

V. 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,

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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.

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