**PRE-ENGINEERED BUILDINGS**

**THE LATEST TREND IN BUILDING CONSTRUCTION**

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## ABSTRACT

*Buildings & houses are one of the oldest construction activities of human beings. The construction technology has advanced since the beginning from primitive construction technology to the present concept of modern house buildings. The present construction methodology for buildings calls for the best aesthetic look, high quality & fast construction, cost effective & innovative touch.*

*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 like pre-engineered steel buildings. India has an installed steel capacity of 35 to 40 million tonnes & apparent steel consumption is around 27 to 30 million tonnes. There is a surplus capacity of flat steel products available in India particularly of hot and cold rolled sheets. These steel components can be utilised in the construction of pre-engineered building components. In pre-engineered building concept the complete designing is done at the factory and the building components are brought to the site in 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.*

*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.*

*The paper drafted covers in detail about the concept of Pre-Engineered Building, its construction system, benefits, applications and pictorial representation of various category of buildings*

**INTRODUCTION**

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.

These Pre-Engineered Steel Buildings can be fitted with different structural accessories including mezzanine floors, canopies, fascias, interior partitions, crane systems etc. The building is made water-tight by use of special mastic beads, filler strips and trims. This is a very versatile building system and can be finished internally to serve any required function and accessorized externally to achieve attractive and distinctive architectural styles. It is most suitable for any low-rise building and offers numerous benefits over conventional buildings.

Pre-engineered buildings are generally low rise buildings, however the maximum eave heights can go upto 25 to 30 metres. Low rise buildings are ideal for offices, houses, showrooms, shop fronts etc. The application of pre-engineered concept to low rise buildings is very economical and speedy. Buildings can be constructed in less than half the normal time especially when complimented with other engineered sub-systems.

The most common and economical type of low-rise building is a building with ground floor and two intermediate floors plus roof. The roof of a low rise building may be flat or sloped. Intermediate floors of low rise buildings are made of mezzanine systems. Single storeyed 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.

**COMPONENTS OF PEB**

The pre-engineered building components headings are almost the same as the conventional structural steel building components. Apart from the state of the art technology used for fabrication of pre-engineered buildings, the other main difference is in the assembling of PEB. The varied components of the PEB are joined to each other based on the nut and bolt methodology as against the welding and riveting methodology used for structural steel buildings.

Metal building technologies permit almost complete freedom to the designer and the architect in incorporating whatever features may be needed in the building-structural, thermal, ventilation or acoustical, to name a few.

Metal roofing and siding profiles can be manufactured to any length – limited only by transportation constraints (usually to 12 metres). Lap joints with 150mm to 200mm overlap virtually eliminate water ingress.

Profiling can be carried out at site itself and, with no limit whatever in lengths that can be rolled. This permits a totally joint-less run of roofing, a major advantage to the designers to create roofing with the minimum pitch. Machines have been developed which permit rolling at the eaves level so that even the task of lifting and shifting the rolled profiles in to position is avoided. Standing seam profiles with a pre-determined height of up-stands can be chosen to accommodate the expected run-off of water without overflow on to the crest of the profile.

Pre-engineering of metal buildings can be optimized to meet specific design criteria. Purpose built buildings such as Hangers for aircraft, Warehouses, Manufacturing and Repair facilities, captive power plants, cold storages, office buildings, hospitals, living shelters etc. need roof-slung facilities and utilities imposing localized loads on to the building structure. In automotive manufacturing plants, high altitude living shelters and cold storages, considerable economies have been registered by such optimized designs.

Installation of this type of roofing & cladding system can provide 30 years or more of trouble-free service in most environments.

There are basically nine major components in a pre-engineered building such as :

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| * Main framing or vertical columns * End wall framing * Purlins, girts and eave struts * Sheeting and insulation or prefab panels * Crane system | * Mezzanine system * Bracing system * Paints and finishes * Miscellaneous services |

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 bolting the splice plates of connecting sections together.

For normal housing the main framing columns are of ISMC category.

**End wall framing**

The end wall frame of a pre-engineered building may be designed as a main rigid frame (i.e. similar to the interior frame) or as a post and beam frame. The decision depends on the customer’s requirement (mainly as to whether he wants to go in for future expansion or not)and / or building’s requirements (is the end wall open for access).

The post and beam end wall system of framing consists of columns (posts) with pinned ends, supporting horizontal beams known as end wall rafters. Girts are flush framed between posts to provide lateral stability and a neat appearance. Post and beam end walls are assumed to be laterally stiff due to the diaphragm effect of the wall sheeting. The diaphragm action is proven to be sufficient enough to resist the transverse wind force acting on the small tributary area of the end wall.

For single storied normal houses end wall framing is same as main framing.

###### **Purlins, girts and eave struts**

Purlins, girts and eave struts are also known as secondary cold-formed members. There is no welding involved in their preparation. They are prepared by just bending the steel coil giving it the desired shape (Z-shape for purlins and girts, and C-shape for eave struts).

**Purlins:** Purlins are secondary members supporting the roof panels. Z-shaped purlins are adopted for pre-engineered buildings that provide a great advantage of being lapped at support points and nested together to increase the stiffness. This capability provides additional strength and reduces deflection. On the other hand C-shaped purlins lack this capability and thus are not used as purlins or girts.

The purlins are subjected to the following loads :-

Gravity loads (dead + live)

Wind uplift (suction) load

Axial force due to longitudinal wind loads (especially for the strut purlins)

**Girts**: Girts are used to provide framework for wall cladding for sidewalls and endwalls. Generally, for sidewalls by-framed (by-pass) construction is employed for taking advantage of lapped girts and flush construction is employed for end wall girts in order to use diaphragm action effectively. All flush end wall girts are simply supported members attached to the end wall column web.

The girts are subjected to the following loads :-

Gravity load (dead)

Wind pressure and suction.

**Eave Struts**: All eave struts are cold formed C sections. These are simply supported members (180mm in depth and 2.0mm or 2.5mm in thickness). Eave struts are well suited at the corners to support sheeting’s.

The eave struts are subjected to the following loads:-

Gravity loads (dead + live)

Wind uplift (suction) load

Axial loads accumulated through bracings

**Panels and insulation**

Single skin profile steel sheets are used as roof and wall sheeting, roof and wall liners, partition and soffit sheeting. The steel sheets are generally made from steel coils and aluminium coils. Minimum thickness of steel coils used is 0.5mm high tensile steel. The profiles depends upon the stiffness required, the governing loads (dead/live/wind) etc. The strength of the sheets depends on its profile, and the depth and number of ribs

The steel sheets are normally zincalume or galvanized profiled sheets permanently colour coated either plain or the sheets can be coated with special paints like PVF2, if required, for better anti-corrosion properties.

These buildings can be properly insulated by providing fibrous insulation slabs / rolls of non- combustible Rockwool, Aluminium foil laminated, placed over a metal mesh bed created between the purlins, and then the roofing steel sheet fixed over it. The siding walls can also be insulated by providing a double skin profile steel sheet wall cladding having Rockwool Insulation slab sandwiched in between and held in position with the help of ‘Z’ spacers in between the two profile steel sheets. In similar pattern a double skin insulated roofing system can also be erected.

Liner panels are used to conceal the roof purlins, wall girts and the Rockwool insulation on the inside of the building when neat finished appearance is required. If the temperature inside the building has to be controlled, insulation of different thickness can be provided below the panels. Another alternative is to provide pre-fabricated insulated panels, which comprises of two single skin panels (plain steel sheets zincalume colour coated) with polyurethane foam insulation in between. These panels are intended for use as thermally efficient roof and wall claddings for buildings e.g. in high altitude areas and cold storages.

For normal housing the wall panels comprises of outside profiled steel sheet fixed on to the columns and purlins. Rockwool insulation placed between the purlins and then the inner sheet of a particle / rigid board type again fixed on to the columns and purlins thereby totally concealing the steel structure. The roof is of profile steel sheet with insulation fixed underneath. False Ceiling of particle / rigid board is fixed to a steel frame work hung from the trusses. Insulation can also placed over the false ceiling packed in polythene. Here a 2 ft. high brick wall is required to be given on the outside for protection.

For walls a second alternative can be by way of welding metal mesh on to the columns and purlins on both sides with insulation sandwiched in between and spraying 50mm thick cement plaster on to the mesh with spray gun.

**Crane system**

Crane in industrial buildings are used to improve material handling productivity and to allow more efficient utilization of space by reducing or eliminating traffic due to forklifts etc. The crane runway beams are simply supported built-up sections with cap channels. Also, since it’s a built-up member, it can be tapered – saving the beam costs for large spans.

**Mezzanine system**

Generally, the mezzanine framing is connected to the main rigid frame columns for lateral, stability. Mezzanine beams and joists are analyzed and designed as simple span members. Standard mezzanine structure consists of built-up beams (that may be tapered for large spans or heavy loads) that support built-up, hot-rolled or cold-formed mezzanine joists which in-turn support a metal deck. A reinforced concrete slab is cast on the metal deck as a finished surface. The metal deck is not designed to carry the floor live loads, it is intended only to carry the reinforced concrete slab during pouring. The reinforced concrete slab must be designed to carry the floor loads. Interior mezzanine stub columns are hot rolled tube sections or built-up sections.

Sometimes, in place of concrete flooring, chequered plates or grating may be used. Sometimes, a structural framing system is mounted on top of the roof and is designed to support heavy roof accessories, such as HVAC units, water tanks and other miscellaneous roof equipment. These we call as roof platforms. Also, a narrow walkway, used primarily for maintenance crews to provide access to mechanical equipment supported on roof platforms, called as catwalk is provided at times. Catwalk are usually mounted alongside crane beams, suspended under rigid frame rafters or elevated above the top of the building roof.

###### **Bracing system**

Longitudinal cross bracing, used to provide lateral stability to the structure against wind, seismic or other forces, comprises of 7-strand twisted galvanized cables with an eye bolt and an adjusting nut at both ends, located near the outer flange of columns or rafters and attached at the web of the rigid frame. In buildings supporting cranes, crane longitudinal loads will be transferred to the foundation using smooth round bars or hot rolled angles in lieu of cables. Also, when the sidewall has to be open for access etc., portal bracing is provided. For narrow width buildings with low eave heights, the fixed base column can be designed in the minor axis direction to resist the lateral forces applied along the length of the building, thus saving the additional bracings. Bracings are usually provided in large roof area industrial sheds. This is not required for houses.

###### **Paints and finishes**

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. Also, the other option is for going in for galvanized secondary steel and hot-dip galvanize the primary steel for better steel properties. For houses inside painting on walls & ceiling is to be provided.

###### **Doors and windows**

Steel or aluminium framed doors and windows are fixed to the purlins either by welding or bolted to the flanges already fixed to the purlins. Proper flashings are applied wherever necessary.

###### **False ceiling**

This is usually required for residential building or offices. A metal frame work is hung from the ceiling and false ceiling of rigid boards are either bolted or placed over the frame work.

###### **Partition walls**

This is usually required for residential building or offices. Partition wall comprises of two rigid boards having insulation sandwiched in between and fixed to the steel columns and purlins. Alternatively prefab sandwich panels can also be fixed to the columns and purlins.

**Flooring**

Flooring is usually of conventional nature consisting of cement concrete.

###### **Design Codes**

Design codes that govern the design procedures and calculations are as follows :-

* Frame members (hot rolled or built-up) are in accordance with AISC (American Institute of Steel Construction) Specifications for the design, fabrication and erection of structural steel.
* Light gauge cold-formed members are designed in accordance with AISI (American Iron and Steel Institute) Specification for the design of light gauge cold formed steel structural members.

IS: 8750 - 1987 : Code of practice for design loads of buildings & structures.

IS: 800 -1984 : Code of practice for general construction in steel.

IS: 801- 1975: Code of practice for use of Cold formed light gauge Steel Structural Members in general building Construction

**METAL ROOFING & WALL CLADDING SYSTEM DESIGN CONSIDERATIONS**

At the initial project planning stage, roof slope is a key consideration for architects incorporating roof systems into their designs. Slopes as shallow as 1:50 are possible ensuring sufficient drainage of water and good long term performance of roof panels. Roof design will dictate the minimum slope for weather tightness. The standing seam roof, for example, can be used at the minimum slope 1:50 (one degree). Its weather tight seams are interlocked together, and raised above the roof’s drainage plane.

Screw down roofs are installed at slopes of 1:20 and steeper to account for panels being overlapped at sides and ends, and attached with exposed fasteners.

Minimum Recommended Roof Slope: ½ inch in 12 inches.

Atmospheric and climate conditions are key elements to consider. Corrosive microenvironments from local industrial operations can exist that influence the performance of steel roofing. Likewise, marine exposure can be severe, making the location of the steel roof with respect to the shoreline an important consideration. Special coatings on steel sheets are available (zincalume, SMP, XRW, PVF2) for corrosive environments.

The base steel is either galvanized having a zinc coating varying from a minimum Mass of 120 gsm./m2 to a maximum of 275 gsm./m2 (total of both sides) or a base steel coating of zinc – aluminium (zinc 45%, aluminium 55%) of total Mass of 150 gsm./m2 (total of both sides) are available with permanent colour coating. The colour coating is also available in various options in polyester paint coating like regular modified polyester, silicon modified polyester and super polyester coatings. Special organic coatings like PVF2 (Poly Vinyl Fluoride) are also made available. These various colour coatings on the base steel with galvanized or zinc aluminium coating provides suitable resistance for various kinds of environment hazards.

Steel roofs can be successfully used in area subjected to extreme weather conditions (for example, high winds, heavy rains and snow falls). Manufacturers should be consulted about special designs and installation details required for such locations. Good quality corrosion-resistant fasteners (galvanized, SS) should be used on steel roofs. Long life compatible flashings and gutters are also recommended. Roof top equipment, such as air conditioners and exhaust fans, should be mounted on roof curbs suitably detailed and installed.

It is important in the planning stage to have options for maximum design flexibility. As an idea alternative to non-metallic systems, steel roofings can be used for both structural and architectural roofs since profiles and panels come either unpainted or pre-painted with attractive colours and finishes.

###### **TYPES OF ROOFING & WALL CLADDING SYSTEM**

These profile steel sheets are usually categorized into two types depending upon the type of fixing arrangement followed. These two types are known as through fastenedand second one is standing seam. In through fastened roofing or side cladding system, the steel profile panels are fixed to the structural members by self drilling fasteners either manually or mechanically by a gun. In this system, the steel sheets are perforated and punctured. These perforated buildings are under stress due to thermal effects and may cause corrosion if proper grade washer and sealants are not used. The second system – Standing Seam roofing or cladding differs from through fastened seam, here the steel sheets are not punctured. A special kind of holding clip made out of galvanized steel is fixed to the underline steel structure and the profile steel sheets are pressed over the clips and get locked. The steel profile sheets are held together and secured to the clips by a mechanical seam. These clips permit the steel sheets to move or float over the structure to bear thermal expansion and contraction brought on by the seasonal changes. Since the steel sheets are not punctured hence there is no chance of any corrosion taking place. With the availability of modern roll forming technology, the profiling machine can be installed at the site and long length profile sheets can be manufactured at site (greater than 12 metre). This makes very quick installation.

The Standing Seam roof design can be used for near flat sloping roof buildings (as low as 10). For such roofs, bare profile steel sheets (un-quoted) can be used for economic reasons as the roof slope is virtually not visible from outside. In Standing Seam roofing, there is only one jointing between the steel sheets that is the longitudinal joint, whereas in case of through fastened system, there is also an overlap horizontally. Usually the longitudinal overlap is of one profile (the profile of one sheet exactly rests over the profile of the over sheet) and the horizontal overlapping is minimum 150mm. The fasteners are fixed on the crests for roofing and on the valley for side cladding. The fasteners usually are galvanized and sometimes SS.

Steel roof buildings applicable to both residential and non residential buildings are lighter in weight, easier to install, highly resistant to environmental damage due to wind age, rain, snow, marine atmosphere and free of frequent maintenance and repairs. The life is also quite substantial. However, residential roofing requires a more aesthetic pleasing appearance. Various types of roofing and side cladding design is possible in a combination of various colours by steel sheets. The steel sheets can be rounded or crimp curved for providing typical shape and finish to the building. Because of the light weight of the steel sheet, the steel structure underneath can be possible with a lower weight. Taking advantage of this proper insulation system can be fixed below the roofing sheets and the siding walls. The underneath steel structure can be used for placing fibrous insulation material like resin bonded rock wool laminated suitably and held in position with the help of a metallic mesh or a rigid packing. This insulation layer underneath caters to thermal insulation as well as sound barrier from outside. Such insulation reduces the noise level from outside and keeps out heat during summer and cold during winter.

###### **SANDWICH PANELS**

In addition to the above single sheet profiles, sandwich panels also find extensive use in residential as well as non-residential buildings. In sandwich panels two profile steel sheets having insulation in between are used. The insulation can be a fibrous rockwool or a rigid material like polyurethane foam. These sandwich panels can be factory made and sent to the site as a single piece material or fabricated at site. These panels are light weight, rigid and results in very fast erection. The panels provide sufficient insulation and noise reduction properties.

Nowadays large cold storage units (Potato, Onion, vegetables, processed foods etc.) are also made with this pre-engineered building technique. For this application ‘Sandwich Panels’ featuring a core of high efficiency insulation like Polyurethane is used. The inner and outer surface of the panel elements are made up of hot dipped galvanized or zincalume coated pre-painted steel sheets. The steel sheet has light cutting grooves in order to give extra strength as well as to enhance the appearance of the cladding.

Many industrial enclosures call for acoustical barrier - value to be possessed by the building cladding and roofing. In addition, internal absorption may be called for to reduce internally built up noise. It is easy to feature these attributes while featuring metal building concepts by installation of high density Rockwool Slabs insulation underneath the cladding / roofing sheet or sandwiched between two steel profiled sheets.

###### **ERECTION**

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. 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.

**MAINTENANCE**

In PEB the maintenance area is the steel roofing & cladding.

Steel roofing & side wall cladding requires minimum maintenance. The roof should be inspected immediately after installation to check if cleaning of the roof has been carried out fully. It is very often seen that the drilled out metal and debris are not swept away. These can act as initiators of corrosion and lead to premature failures.

Installed roofing must be inspected atleast 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 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.

### BENEFITS

* Optimised design of steel reducing weight
* Easy future expansion/modification
* Voluminous space (up to 60M clear spans, 30 M eave heights)
* Weather proof.
* No fire hazards
* International Quality Standards
* Seismic & Wind pressure resistant.
* Quality design, manufacturing and erection
* Quick delivery and Quick turn-key construction.
* Architectural versatality
* Energy efficient roof and wall system using Rockwool & PUF insulation.
* Water-tight roofs & wall coverings
* Pre-painted and has low maintenance requirement.
* Easy integration of all construction materials
* Erection of the building is fast.
* The building can be dismantled and relocated easily.
* Future extensions can be easily accommodated without much hassle.

**APPLICATIONS:**

Applications of pre-engineered steel buildings include (but are not limited to) the following:

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| * Houses & Living Shelters * Factories * Warehouses * Sport Halls * Aircraft Hangers * Supermarkets * Workshops * Distribution Centres * Commercial Showrooms * Restaurants | * Office Buildings * Labor Camps * Petrol Pumps/Service Buildings * Schools * Community Centres * Railway Stations * Equipment housing/shelters * Telecommunication shelters * “Almost” any low-rise building |

###### **CONCLUSION**

Steel is a preferred material for construction, due to its various advantages like quality, aesthetics, economy and environmental conditions. This concept can have lot of scope in India, which can actually fill up the critical shortage of housing, educational and health care institutions, airports, railway stations, industrial buildings & cold storages etc. 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