CHAPTER: 1
BACKGROUND

1.1 INTRODUCTION

The metal building industry was the first in recognizing the advantage of integrating the design, detailing and the fabrication technology in order to effectively offer an optimally designed metal building system. The movement towards the design/build has been an integral part of the metal building system industry since its inception.

Many outside the industry still consider the concept that the metal building system is selected from a catalog of standard designs and specifications, based on the geometrical parameters of building. In fact, most metal building manufacturer’s custom design a building by order to within 1.6 mm (1/16 inch) in width, length and height direction, based on the geometrical dimensions, loading conditions, material specifications and the building code under consideration.

Metal building companies have licensed Structural Engineers/Chartered Engineers on staff, who are highly experienced and apply good engineering practices to obtain the optimal solution of metal building systems.

Computer analysis and design methods/software’s are used during the design standardization and optimization to meet the standard shop/plant inventory in majority of the cases.
In today’s scenario, where the industry has initiated to offer custom designed metal building systems to suit the particular needs of each client, the term Pre-Engineered Buildings has become somewhat of a misnomer. The industry now prefers to call its product as “METAL BUILDING SYSTEMS”, even though the same is referred to by its still-common and popular name, Pre-Engineered Buildings.

Metal building systems have evolved over the years into an assemblage of various structural members/components that work together as a very efficient system. While there are many variations on them, the basic elements of the metal building system are having primary rigid/main frames with web tapered I-beams and web tapered I-columns, secondary members consists of roof purlins and wall girts, roof cladding and wall cladding, bracing schemes, end wall system. Metal building systems design at first, seems to be trivial, but design experience indicates that the complex interaction of these structural elements into a stable system is a real challenging task.

Metal building manufacturing companies have demonstrated this expertise and are on the leading edge of the systems design. The individual components of a metal building system are usually purchased from one or more vendors and often shipped out as a complete metal building system.

Steel construction is used for the majority of non domestic single storey buildings, ware house buildings and industrial buildings with and without crane systems, buildings with and without mezzanine systems, this is due to the ability to design relatively light,
very large clear spans, durable structures in steel which are easy to erect safely and quickly. The developments in steel cladding profiles and light gauge purlin and girt system in recent years have enabled architects and structural engineers to create economical, attractive designs for a wide range of applications and budgets.

The rate of change of any activity is very rapid as technology develops. Clients expect therefore, their buildings to have the flexibility to changes in layout, in addition to improvement in the life time. A primary requirement is, the flexibility of planning which results in a demand for as few columns as possible, to meet the functional requirements of the building system. The ability to provide the clear spans up to 60 m to 80 m, but more commonly around 30m to 40m using the steel, has proved very popular for commercial, warehouses and industrial buildings. The lightness and the flexibility of this kind of structures reduce the sizes and the costs of the foundations. The relocations of existing buildings is also quite possible with this concept.

The cost of the structural system is divided among the four areas, and they are design and detailing, material, fabrication and erection. The optimum structural system has the lowest material weight consistent with the standardization of components, few number of the components and smallest amount of detailing work and ease in fabrication and erection.
Metal building system is expected to offer an excellent optimum solution, taking into the account of lower costs in all the four areas specified before. Metal building manufacturers have developed the design and fabrication methodologies to optimize the metal frames (primary frames) and provide the material where it is required through the concept of web tapered I-columns and web tapered I-beams using the welded plate elements by means of automatic welding in the shop floor, as opposed to standard hot rolled sections, providing the opportunity for such optimization.

Optimization is achieved by using tapered webs with an increase in depth in the regions of higher bending moments and by varying the thickness of web and the flange sizes as required. The tapered sections are also used with unequal (mono symmetric) flanges to utilize a larger compression flange in an unbraced/unsupported situation or a smaller flange where it might be in tension condition. The metal frame members are designed with bolted end plate connections for the faster assembly in the field.

Cold formed steel sections namely purlins and girts offers a very high strength to weight ratio. These cold formed sections can be nested to have double sectional properties to resist the higher negative bending moments over the frame rafters and columns. These sections also offer ease of handling and nesting during the transportation/shipping of the materials. Optimized sections can be roll formed by the metal building manufacturers to the desired section depth and thickness in order to carry the specified spans and loads.
1.2 ANATOMY AND CONCEPTION OF THE METAL BUILDING SYSTEM

The skeleton of a typical Metal building system is shown in the figure 1.1. It consists of major elements: roof cladding, wall cladding, secondary steel like purlins and girts to support the roof and wall cladding, framing for doors, windows and the main frame of the structure, end wall columns including all necessary bracing members. In addition, the building requires foundations which have to be designed and built to transmit all the loads to the soil.

Figure 1.1 Structural arrangement of a Metal Building System.
The selection of the best framing scheme is dependent on the interrelationships of numerous considerations and parameters. It may in fact not be possible to give a list of defined rules by which the best scheme can be chosen. Selection of the main framing system including bay sizes and column spacing, primarily depends on owner’s requirements and the functionality of the building. These requirements also influence the relative costs of the secondary members like purlins, girts, beams, and columns.
1.3 PRIMARY FRAMING SYSTEM

Primary framing provides the main support of a metal building system. A mainframe (Rigid frame) and bearing frame (post and beam) are the examples of primary framing.

1.3.1 Main frames

The main frame (rigid frame) is the primary structural member of the metal building system. The main frame consists of columns and rafters as shown in figure 1.2. Columns which are in vertical position to transfer the loads from main roof beams or rafters to the foundations. Rafters are the main beams supporting the roof system. In general, a main frame is structurally stable because of the rigidity of its connections between the columns and the rafters in its own plane. The out of plane stability will be ensured through the purlins, girts and bracing system. The main frame members are connected in such a manner as to make the entire frame act as a single unit.

![Figure 1.2 Roof rafters/column sections](image-url)
The figure 1.3 indicates some of the commonly adopted main frames in the metal building systems. From the profiles of these frames, one can understand that the section depths/member sizes are increased, where it is really required in order to provide a better opportunity for the material optimization.

Figure 1.3 Different types of Rigid/ Main frames.
1.3.2 Load paths of stability bracing

The outside flanges of the main frame columns/rafters are braced by purlins and girts framing directly into the primary members. These secondary members may be simply supported or continuous. Continuous members are attached to the outside flanges of the main frame columns/rafters with varying degrees of moment continuity. Lateral bracing forces induced by the primary frame members due to the connections to the secondary members (purlins and girts), induce axial forces into the secondary members.

1.3.3 Knee/haunch area

Three common types of connections used to connect major parts of a main frame are diagonal, vertical and horizontal as shown in figure 1.4.

The knee/haunch is the area of the metal frame where the frame column connects to the frame rafter and ties these structural members rigidly and offers continuity into a single unit to carry all the loads, vertical and lateral. In general, the area of the knee/haunch of the main frame (rigid frame) is the deepest in section, which makes it the strongest area of the metal frame. This is recommended primarily because of the vertical loads due to dead loads, collateral loads (due to lighting, ducting, false ceiling, sprinkler systems), live loads, snow loads, ponding loads, equipment loads, crane loads and lateral loads due to crane surge forces, wind or seismic loads but at the same time it enables the frames to offer lateral strength. The important aspects of panel shear check need to be verified in this zone. A similar kind of
situation also exists especially when the interior columns are having a fixed connection at the interior column top with the main frame rafter as shown in figure 1.6.

Figure 1.4 Knee types of the main frames a) Diagonal connection b) Vertical connection c) Horizontal connection

Figure 1.5 Rafter Splices with End plates

Figure 1.6 Connection of interior columns to the rafters in multispan mainframes.
Stiffeners are used to counteract the resistant thrust. Stiffeners are usually extended to the outside flanges and also serve to stiffen the entire web. The mainframes (rigid frames) may be considered as arches in their structural action and accordingly they produce a horizontal thrust at their bases, either inward or outward. Main frames (rigid frames) belong to the classification of continuous structures because all the joints are rigid in a structural sense. Because of this behavior, the mainframes are analyzed and designed as a complete system and not as an assembly of individual members.

1.3.4 End wall frames

The main frames indicated earlier will support a roof area/wall area of the two half bays on either side. The expandable main frame end wall is designed to support two half bays of roof load/wall load, in order to support an additional half bay in the future. The non expandable frame is designed to support one half bay of roof load/wall load plus the setback loading and is not included to support an additional half bay in the future. This type of non expandable frame is also called “a post and beam frame” or a “bearing frame” as shown in figure 1.8. Main frame end walls do not require any bracing and have clear end wall bays for large framed openings or open wall conditions. To facilitate any openings on the end wall where the end wall is not proposed to have a future expansion, a main frame with half tributary width along with setback portion, can also be designed as a special case.
A bearing frame (Post and beam) is generally made of cee-sections, hot rolled or built up straight members. The end wall columns support the rafter and also serve the purpose for the attachment of the end wall girts and transmit the gable wind loads to the bracing system and finally to the foundation. Bearing frame end walls also requires the bracing in the form of a diaphragm action or in the form of a x-bracing in order to achieve the lateral stability.

Figure 1.7  Rigid Frame’s (Main Frames) Moment resisting ability

Figure 1.8 Post and Beam Frame
1.4 SECONDARY FRAMING MEMBERS

Secondary framing members are those members that join the primary framing members together to form building bays and provide the means of supporting and attaching the wall cladding, roof cladding and framed openings for the roll up doors/sliding doors and windows. Secondary framing members are: Eave struts, purlins, girts and bracing.

1.4.1 Eave strut

The eave strut is a roughly “C”-shaped cold formed member as shown in figure 1.9 or the eave strut can also be a “Z” shaped section. Eave struts will be subjected to bending due to vertical loads from roof, lateral loads from wall and also axial forces to transfer the bracing forces from roof to wall bracing and finally to the foundation. An eave strut provides an attachment and supports to the end of the roof sheets and wall sheets.

![Figure 1.9 Typical Eave strut](image_url)

1.4.2 Purlins

Purlins are secondary members that serve to support roof panels and transfer the roof loads to the rafters. They are generally “Z”-shaped members. Bypass purlins are attached to the outside flange of the rafters to derive efficient behavior. These purlins are lapped at each frame line, to take in to consideration, the advantage
of continuity, as they behave as beams spanning from bay to bay. In addition to serving the important means of providing the framing for the attachment of roof covering, the purlins also play a significant role in the structural stability of the complete building system. Purlins connected at roof bracing nodes act as a struts and help in transferring the bracing forces from the roof to wall bracing system. Also the purlins which are in the line of the end wall columns help transferring part of the gable wind forces to the roof bracing. The purlins are effectively used to offer lateral restraint to the main frame rafters in order to minimize their unbraced length in their out of plane behavior.

1.4.3 Girts

Girts are secondary framing members that run horizontally between the main frame columns and between the end wall columns. Girts are secondary members that serve to support wall panels and transfer the lateral wall loads to the columns. They are generally “Z”-shaped members. Bypass girts are attached to the outside flange of the columns to derive efficient behavior. These girts are lapped at each frame line, to take in to consideration, the advantage of continuity, as they behave as beams spanning from bay to bay. In addition to serving the important means of providing the framing for the attachment of wall covering, the girts also play a significant role in the structural stability of the complete building system. Girts connected at wall bracing nodes act as a struts and help in
transferring the bracing forces from the wall to foundation system. The girts are effectively used to offer lateral restraint to the main frame columns and the end wall columns in order to minimize their unbraced length in their out of plane behavior.

Cold formed “Z”-sections range in depth from 75 mm to 400 mm with different flange width and thicknesses. These purlin/girt sections are formed from steel sheets of high strength material, either by press braking or by roll forming; to obtain the” Z/C “shaped cross sections and the improvised zeta/sigma sections. In order to increase the local buckling strength, the outer edges of the flanges are edge stiffened or lipped as shown in figure 1.10.

![Z and C Shapes](image)

**Figure1.10 Secondary Member Cross sections (Z Shape and C-Shapes)**

The Z-purlin/girt sections are advantageous in metal building construction because they are light weight sections, nestable and can be lapped with suitable cross section and shape. They can be fabricated, shipped and erected easily.
1.4.4 Purlin bridging

When the live load is acting on a roof, the presence of through fastened roof panels helps to prevent the lateral movement of the purlins, but does not restrict the lateral translation on the entire roof system. This lateral movement and twisting significantly decreases the flexural strength of the roof system. This behavior warrants the need for lateral restraint suitably seen in the form of lateral bracing. Bracing is typically used along each purlin at discrete locations as shown in figure 1.12. This bracing is provided through support (torsional) restraints, third point restraints and midpoint restraints. The restraint elements are generally attached to the purlin at the bottom flange and/or near the top flange. The location of these restraints also depend upon the type of the roof panel types, i.e., standing seam roof or the through fastened roof panels. In the case of the through fastened roof panels, the bridging at the inner flanges may be sufficient as shown in figure 1.13 and in the case of standing seam roof panels, the bridging may also may be required at the outer flanges of the purlins as shown in figure 1.14. However the complete analysis and design should be performed in order to decide the location and the number of rows of the bridging system.
Figure 1.11 Purlin lateral displacements due to lateral buckling
(In the absence of purlin bridging)

As well known, an unbraced compression flange of any single-web flexural member, even of a perfectly symmetrical one loaded through its web, has a tendency to buckle (or warp) laterally under vertical loading. A singly symmetrical (C section) or a point-symmetrical (Z section) cold-formed purlin is even more susceptible to
buckling because it has its shear center in a location quite different from the point of loading application, which is typically the middle of the top flange. Also due to inclination of the web with respect to the principal axes of purlin section, and any downward load produces a lateral component. Because of these factors, the unbraced “C” and “Z” sections tend to twist and become unstable even under gravity loading on a perfectly horizontal roof. In sloped roofs, the purlin web is tilted from the vertical position, a fact that further complicates the problem of twisting. Gravity loading acting on a sloped “C” or “Z” purlins can be resolved into the components parallel and perpendicular to the roof, both of which tend to overturn the purlin, although in different directions if the purlins are properly oriented. The purlin bridging also plays an important role in order to minimize the unsupported length of the purlin/girt flanges. The final restraint forces will be transferred to the main frames at the point of connections of purlins with main frame rafters. This will be achieved either by providing the antiroll clips or by checking the purlin web bending.

Figure 1.13 Purlin Bridging at the inner flange locations of purlins
Figure 1.14 Purlin Bridging at the outer and inner flange locations of purlins

1.4.5 Girt Bridging

A girt is commonly analyzed and designed as a continuous beam for wind loading and as a continuously supported beam for gravity load, which consists of the girt's own weight and that of any supported wall cladding. Sag rods are ultimately supported by the eave girt. The lateral bracing for cold formed girts is very important. With through-fastened metal wall cladding, the girts can usually be considered braced at their exterior flanges. Room finishes such as liner panels or drywall carried on steel studs, can provide bracing for the interior flanges, which otherwise are deemed unbraced. There are two ways to design a girt. The first approach simply assumes that the interior flange of the girt is unsupported from column to column and second approach considers the bridging elements as effective restraints in order to minimize the unsupported length of the girt inner flange. The second approach recognizes a restraining action of
the bridging and the same was illustrated in figure 1.15 and 1.16. The girts are considered laterally supported at each bridging row. The inner flange tries to buckle laterally, the most probable mode of failure it will rotate and move vertically. This movement is prevented both at the outer flange by the wall cladding attached through the fasteners to the girts and at the bridging row locations at the inner flange locations. The inner and the outer flanges are, of course, tied together by the web, which acts as a cantilevered beam in restraining the unbraced flange. It is commonly assumed that the compression flange of a flexural member may be considered braced if the brace can resist about 2% of the compressive force in the flange. The bracing action of the web occurs, therefore, if the web is strong enough to resist this force by lateral bending between the braces. For this model to work, the sag rods must be attached to the foundation or to the eave strut which is provided at the roof line on side walls and the rake line on the gable walls. The outer flanges of the girts may also be considered as fully unsupported where there is no attachment of the cladding to the girts. The situation may arise when there is glass panels on the outer flanges of the girts or some other panels which are not fastened to the outer flanges of the girts. The solution in such circumstances for reducing the unsupported length of the outer flange is to provide the bridging on the outer flange locations of the girts as shown in figure 1.17 and 1.18. The cost of the cladding is estimated as 60 % of the total cost of steel work in such structures. The structural behavior of the purlin –cladding and girt-cladding system
is complicated due to the interaction between the purlin and the cladding, girt and the cladding, the asymmetric nature of the purlin and girt cross section and the presence of the intermediate bridging and lapping.

Figure 1.15 Details of End wall girt bracing at inner flanges of girts.

Figure 1.16 Details of side wall girt bracing at inner flanges of girts
Figure 1.17 Details of end wall girt bracing at outer and inner flanges of girts.

Figure 1.18 Details of side wall girt bracing at outer and inner flanges of girts.
1.5 BRACING SYSTEMS

In addition to main frames, end wall frames, eave struts, girts and purlins, the building system must have adequate bracing to make the system stable in both the longitudinal direction and span direction where end walls are not having rigid/main frame. Bracing system transfers wind loads/earthquake loads/stability forces from end walls to roof plane and roof plane to side walls and finally to the foundation. In case of frames supporting cranes, longitudinal and surge forces from cranes are also transferred by these bracings to the column bases. Bracing systems of this type also serve a secondary purpose of resisting the transverse sway of the building.

The following are the methods available for providing bracing to resist wind/earthquake/crane longitudinal (braking) forces on the building. In addition to the standard method of considering diaphragm action, alternatives include x-bracing (cable/rods/pipes/tubes), fixed base columns, portal frames attached to the column or with independent base plates. When bracing must occur in bays where doors or other accessories are required, fixed based columns or portal frames should be used.

1.5.1 Diaphragm action (Stressed skin Design)

Diaphragm action utilizes the diaphragm resistance of the roof panels/wall panels to transmit lateral wind or seismic forces to the foundation. The most economical roof/wall bracing is achieved by the use of a roof/wall diaphragm. When the metal deck is provided as the roofing and the wall element, effective diaphragm action is inherent.
Diaphragm action may be used in conjunction with a roof/wall cross bracing. Sometimes diaphragm action alone is effective enough as bracing system. A light gauge steel diaphragm is analogous to the web of a deep plate girder. The main function is to resist the shear distortion. The members at the perimeter of the diaphragm thus serve as the flanges of the plate girder. Design of the diaphragm is essentially to realize that for the web of a deep beam shear deformations are usually more significant due to the principle stresses in the chord elements. In fact the interaction of the structural frame work and cladding significantly affects the behavior of the complete building system. Consequently frame moments and deflections calculated on the basis of the bare frame, are quite fictitious and are usually quite different from the real values. By taking the roof and wall cladding interaction in to account, the behavior of the building can be predicted more accurately, leading to better optimization of the total building system.

**Benefits of diaphragm action based design**

- Frame stresses and deflections are usually smaller compared to bare frame analysis.
- Bracing in the plane of the roof /wall may be eliminated.
- Frame details are standardized by omission of bracing and lead to saving in engineering time, simplifying fabrication and improving ease of erection.
- The method is particularly effective where lateral loads act only on one or two frames.
• The actual forces on the cladding and fasteners are derived and help checking inadvertent overstressing of these components.

**Conditions of diaphragm action based design**

• End walls must be braced or sheeted.

• Edge members must be connected to panels and these members and their connections must be designed to carry the flange forces.

• Sheeting must be fastened to members with proper connections and seams between sheets must be fastened with proper connections.

• Suitable structural connections must be provided to transmit diaphragm action forces into the main framework.

• The average shear stress in the sheets should be less than 25% of the maximum bending stress in the sheets.

• Complete analysis of diaphragms should be made in case where there are openings in roof and wall claddings.

• The design documents and drawings should clearly draw attention to the fact that diaphragm action is used.

• The diaphragm strength also depends upon the connection made either in valley or crest portion of the roof/wall cladding. Detailed analysis must be made before applying the diaphragm action.
Figure 1.19 Stressed skin action (Diaphragm action) [106]

Principle of diaphragm action illustrated in figure 1.19, shows how horizontal forces, acting on a metal building, are carried by the roof cladding action to the more rigid end frames, which are stiffened in their own planes by bracing or claddings acting as shear diaphragms. The cladding transfers part of the spread or sway forces from the internal frames to the end frames. Based on the sway and spread, flexibility of metal frames and the direction of the forces, the steel cladding panels, together with the supporting purlins or girts, tend to resist any in-plane displacement, behaving like web of a deep plate girder spanning between end frames.

Edge members (purlins) act as flanges, taking the axial tension or compression forces, and cladding acts as a web, carrying the shear forces while the end frames take the reactions. This means that the relative horizontal displacement between the frames is dependent on
the cladding panel. In general, the end frames are more rigid than internal frames, and thus their deflections are relatively small compared with those of the internal frames. This causes the panels between the end frames and the first internal frame to be more critical from both the strength and deflection points of view. Further, because of this combined action, the deflections of internal frames and thus of bending moments are greatly affected by both the frame’s sway/spread, flexibility and the cladding’s shear flexibility. Therefore, in a computer analysis attempting to model the true strength and deflection behavior of the entire building, the cladding has to be modeled just like the metal frames, purlins and girt. However, it is rather difficult to model cladding using finite element analysis programs. The modeling of the cladding is be done generally by using the equivalent truss theory.

Through wall and roof diaphragm behavior, the wall and roof panels are generally assumed to resist any axial bracing forces in girts or purlins that are not near X-brace lines. If the X-brace lines are assumed to be fixed against a lateral motion, then the diaphragm can provide relative bracing points to the intermediate girts and purlins.

1.5.2 X-Bracing

When diaphragm action of the panels is inadequate or not allowed, the first alternative is to provide cable or rod bracing between the main frame columns/ frame rafters for transferring the forces from end wall to roof plane and further to wall plane. Finally, the x-
bracing transfers the forces to the foundation. Typical X-bracing locations and its end connectivity's are shown in figure 1.20 to 1.22.

Figure 1.20 Typical bracing Locations

Figure 1.21 Typical end wall bracing locations.
Tension only x-bracing is generally provided in the plane of wall and roof bays near the building end walls. It is sized to resist the longitudinal wind forces/seismic /any other forces. These braced bays will join the frame at the eave and at every end wall column location along the roof, providing the eave strut and purlins near the x-brace attachment points with a means of resisting the axial bracing forces in addition to their main function of resisting the bending action.

1.5.3 **Fixed base columns**

If the openings in the wall are such that they do not allow for the use of x- bracing, then fixed base columns may be used. A fixed base column is a column with a special base plate condition, which allows the wind load/seismic load/any other lateral loads to be transferred to the foundation through induced moments and horizontal forces as shown in figure1.23.
1.5.4 Portal Frame

If neither x-bracing nor fixed base columns are acceptable, a portal frame (wind bent) can be used. A portal frame as shown in figure 1.24 is fabricated with I-shaped prismatic/web tapered I-sections of rolled or built up material consisting of two columns and a rafter, running parallel to the side wall, and attached to the web of the side wall columns or supported on separate base plates which are connected to foundation.
1.5.5 Brace to interior main frame

A method of bracing used for an open bearing frame end wall is to provide bracing in the roof of the end bay as shown in figure 1.25. In this case the lateral forces on the end wall are transferred to the first interior main frame. The main frame is designed to resist this additional lateral force also. This bracing can also be used as a general roof bracing in resisting the longitudinal wind loads/seismic loads/other loads.

![Diagram of Brace to interior main frame](image)

Figure 1.25 Brace to interior main frame

1.5.6 Flange braces

Flange braces as shown in figure 1.26 to 1.28 are structural members that attach purlins/girt to main frame rafters and columns. Flange braces are used to prevent the main frame columns and the rafters from twisting and/or lateral buckling under the application of the loading. The flange braces are the important structural
components and should be installed correctly all the defined locations with proper connectivity's. Flange braces are also effective in aligning the purlins and the eave struts for ease in roof installation. Flange braces are the diagonal members bracing the bottom flange of rafters/columns by attachment with purlins/girts to stabilize the inside flange when the same is in compression.

Figure 1.26 Details of single sided flange brace

Figure 1.27 Details of double sided flange brace
Figure 1.28 Details of flange braces connected to inside flanges of rafters/columns.

Steel angles are generally used for flange braces. Their cross section varies from manufacturer to manufacturer. Connection to the primary and secondary members is usually accomplished with a single bolt at each end. The lateral bracing forces from the inside flanges are transferred to the girts and purlins, by flange braces and they are resolved into axial and transverse forces. The flange braces typically consist of a truss element that framed into the node at the junction of web and the inner flanges of the columns/rafter and the purlins/girts. When only flange braces are used on one side, the flange braces need to be checked for compression, alternatively when the flange braces are used on both sides of the main frames column and rafters, it can be used as a tension brace only and considering only one angle is effective in resisting the tension. Instances do occur, where a standard flange brace may not work and requires a very special treatment.
1.6 CLADDING SYSTEM

1.6.1 Roof Cladding

A typical metal roof system consists of corrugated roof panels attached to cold formed purlins ("C" or "Z" sections). The roof panels are usually fastened in one of the two ways. In through fastened system the panels are attached directly to the outer flange of purlins using self drilling screws and fasteners typically spaced at every corrugation along each purlin line as shown in figure 1.29. The other is a standing seam system in which one roof panel is overlapped on another with vertical clips. The standing seam roof panels may not offer the diaphragm action.

Figure 1.29 Details of metal roof panels (Through fastened type)
1.6.2 Wall Cladding

A typical metal wall system consists of corrugated wall panels attached to cold formed girts (“C” or “Z” sections). The wall panels are usually fastened directly to the girts flanges using self drilling screws and fasteners typically spaced at every corrugation along each girt line.
1.7 FRAMED OPENINGS

Figure 1.30 Framed opening structural details

The framed openings (as shown in figure 1.30) in a metal building system may be provided to support or to create an opening for the rollup doors, sliding doors, and personal doors or due to permanent access from one area to other area of the building.

The Jambs (the vertical structural members of the framed opening) are considered to be effectively restrained at outer flanges due to the presence of the metal cladding and the outer and inner flanges of the jambs are also considered to be restrained due to the girts framing into the jambs, refer the detail-“DD” of figure 1.30. The header (horizontal structural members) of the framed opening are effectively considered as restrained at the outer flanges due to the metal wall cladding, refer section-‘AA’ of figure 1.30. Sometimes the inner flanges of the headers are also considered to be restrained when the bridging is provided. Because of the presence of the framed openings, the girt system needs to verified for the discontinuity behavior of the continuous spans.
1.8 CRANE BEAMS

For the steel beams supporting the crane systems with small or moderate lifting capacity, the lateral torsional buckling is a very important factor controlling the design of crane runway beams. If the space is not available to connect the lateral braces to the secondary beams, the usual practice is to consider the full length of the crane runway beam as laterally unsupported. The kickers (knee braces) are used to transfer the crane longitudinal forces (braking forces) and these kickers can also be used to improve the member capacity of the crane beam by effectively considering as rigid lateral restraints to the runway beams as shown in figure 1.31. The buckling strength of the crane runway beams is increased due to the kickers dividing the crane runway beam into three segments. The two segments near the supports are very small and will be subjected to lesser bending moments and the middle segment which is longer compared to two end segments and is subjected to higher bending moments due to the simply supported condition of the crane runway beams.

![Figure 1.31 Crane – Tie plate and kicker details](image-url)
When the crane runway beam is subjected to wheel loads the middle segment tends to buckle first and the two end segments will provide restraints to the middle segment due to the provision of kickers. When this philosophy is used in design practice, necessary care must be exercised to design these kickers for the additional restraint forces in addition to the crane braking forces. All the forces transferred from the kickers to the main frames which need to be evaluated adequately.
1.9 MEZZANINE FLOOR

In a building which is having the mezzanine floors, the top flange of the secondary beams (joists) of the mezzanine floor are effectively considered as restrained due to the fasteners connectivity between the metal deck panel and the joists top flange.

Figure 1.32 Details illustrating the deck panel and its connectivity’s

Figure 1.33 Mezzanine joist and deck details.