OPTIMAL DESIGN OF INDUSTRIAL BUILDING

Mr. Deepak Dnyandev Nalawade

M.Tech Student, Department of Civil Engineering, G. H. Raisoni College of Engg. &Management,Wagholi, Pune,

G.V.Joshi

Professor, Department of Civil Engineering, G. H. Raisoni College of Engg. &Management, Wagholi, Pune.

Abstract- The realistic parameter and deflection behaviors of industrial steel portal frame building are understand only if the effect of rigidity of gable end frame and profiled steel cladding are included. The conventional design ignore these effects and very much based on idealized 2D frame behavior. Traditional analysis and design practice do not consider 3D structural behavior of industrial building. In the present study, the 2D analysis and design on industrial building as a truss as well as gable portal frame is carried out according to industrial requirement. The typical details of industrial building are, plan area 6 * 24.2 m and height is 13m. Various loads taken into account are DL, LL, WL and gantry load. Compound fink type roof truss having span 12.1m is to be designed for various load combination. A 200KN capacity gantry is designed according to industrial requirements. Gable rafter, gable column, gable wind girder and bracing are designed for critical load cases Single bay and single storey industrial frames are statically indeterminate and should be analyzed by well Known method of structural analysis. The design of the structural members is carried out by using allowable stress method as per the provision of IS codes of practice for the maximum force/ moment for the various load combinations. Alternatively structural arrangement as 2D gable portal frame will be analyzed and design with plastic theory. Behavior of truss column structure and gable portal frame will be compared.

Keywords- Gable rafter, gable column, 2D gable portal frame.

1. INTRODUCTION

Design is not just a computational analysis, creativity should also be included. Art is skill acquired as the result of knowledge and practice. Design of structures as thought courses tends to consist of guessing the size of members required in a given structure and analyzing them in order to check the resulting stresses and deflection against limits set out in codes of practice.

1.1 General

The term industrial building has come to mean any building structure used by industry where at least a part of the enclosed area is of one-story height. Included are buildings for steel mills, structural shops, train sheds, automotive assembly plants, and air- craft factories. These diverse structures all have the common requirement of large open floor areas frequently requiring roof trusses that provide adequate headroom for the use of an overhead travelling crane.

1.2 Classification of Industrial Building

Regarding the details of loading conditions and method of calculations the cycle as mentioned here in under for classifying an industrial building, reference shall made to IS: 8640-1977

1. Group A: Cover the industrial buildings where certain members may experience 500000 to 2000000 repetitions of loading condition 3 or 2 million and above repetition of loading condition in the estimated life span of building of 50 years. After considering the service, determination of loading conditions shall be decided. The main industries that will fall under this category will be batch annealing building, billet yard, continuous casting building, foundries, mixer building, and mould conditioning building. Scraping yards, steel making building and other building based on predicted operational requirements.
2. Group B: Cover the industrial buildings where certain members may experience a repetition of 100000 to 600000 cycle of specified loading condition in the estimated life span of about 50 year. The industries consider under this group are: Metal industries for manufacturing equipment like heavy machinery, boiler, ships, locomotives, aircrafts and other building based on predicted operational requirement.
3. Group C: Cover the industrial buildings where certain members may experience repetition of 20000 to 100000 cycle of specified loading condition in the estimated life span of about 50 years. The industries consider under this group are: Industries for manufacturing cars, scooters, inch moving equipment, machine shops and other building based on predicted operational requirements.
4. Group D: Cover the industrial buildings where certain members may experience below 20000 repetition of specified loading condition in one estimated life span of about 50 years. The industries consider under this group are: Generally all the light, utility and process industries.

5. Group E: Cover industrial structure that requires special consideration based on the process or utility and which may not be provided with cranes or if provided with cranes, they may be used only for maintenance. In such cases in addition to the dead loads, wind/seismic forces, live loads/superimposed loads as required for each individual situation shall be considered. In addition, stresses due to temperature caused by the process, airborne vibration, special needs of height, etc. may have to be considered. Typical structures under this group are: Thermal power stations, fertilizer units, petrochemical units, transformer test stations. Compressor house, textile mills, paper mills, etc.
6. Group F: Structure which are not provided with cranes and that which do not come under group E. These structures generally are of simplest type involving live, dead and wind/seismic load. Typical structures under this group are: Storage building garages, repairs shop without cranes, consumer goods manufacturing units, small scale industries where use of crane is not required

1.3 Objective

1. In a developing country like India the capital outlay under each Five Year Plan towards setting up of industries and consequently construction of industrial building is very high.
2. In addition the quantity of steel produced in the country is not sufficient to meet the requirement of the industries.
3. It is therefore necessary that the parameters of the industrial building have to be optimizing by considering economy, stress and safety.
4. To Check The Economy Of Industrial Building By Plastic Design
5. To Check The Utilization Of Material Strength By Conventional Elastic Design
6. To Check The Defection Of Industrial Building By Plastic And Elastic Design

1.4 Structural Steel for Industrial Building

Compared to other materials, particularly reinforced or prestressed concrete, steel has major advantages. Its high strength-to-weight ratio and its high tensile and compressive strength enable steel buildings to be of relatively light construction. Steel is therefore the most suitable material for long-span roofs, where self-weight is of prime importance. Steel buildings can also be modified by connecting steel sections to existing work.

1.5 Choice of Industrial Building

Initial options in respect of preferred location, site acquisition and environmental needs must first be decided. Then main dimensions, process operation, plant layout. Foundation needs, handling systems, day lighting, environmental control, service routes, staffing level and access all require definition. The location of internal columns and the internal headroom are always important, and considerations of these requirements alone may determine the choice. The advantage of freedom to plan the building to suit requirements closely and allow for future development is very valuable.

1.6 Shapes of Industrial Buildings

Because of its economy, the most widely used building shape is the pin-based single or multi-bay pitched roof portal frame (shown in fig. 1&2). Hot-rolled, welded or cold-formed sections are usually used for the members. During recent years an increasing use of welded sections has occurred. This increase is the result of progress achieved in making welding automatic and the ability to adapt the cross-section to the internal forces. Lattice girders (shown in fig 3) are lighter than portal frame rafters for wider spans, but the additional workmanship increases fabrication costs. Based on structural requirements alone, lattice systems are likely to be cost-effective for spans above 20m. Roof trusses may also be used for structures, which support heavy crane as (shone in fig 4).

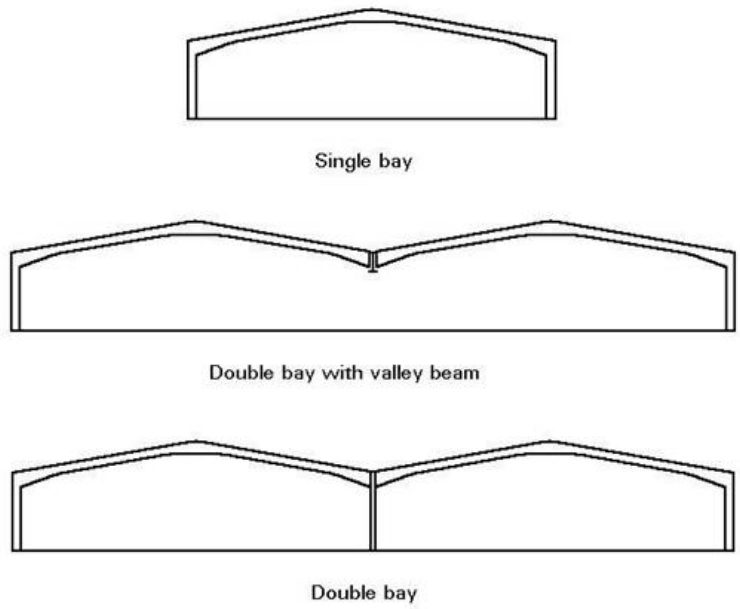


FIG 1, 2, 3: Typical portal frames

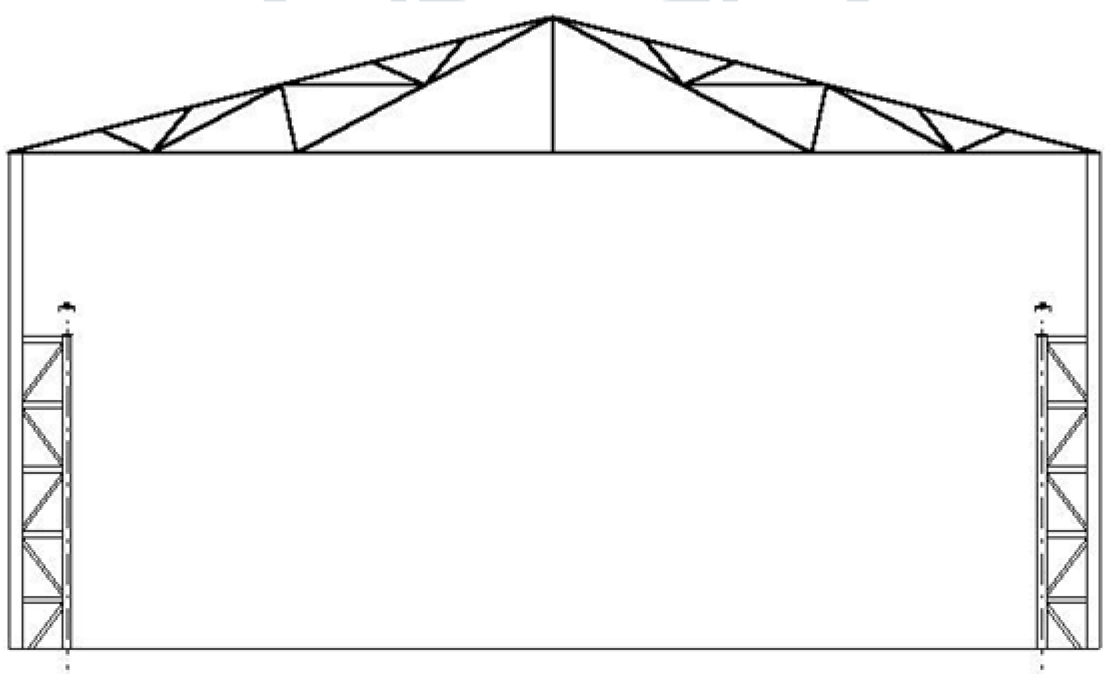


Fig.5 Lattice Columns and Roof Truss

2. LITERATURE REVIEW

Swapnil D. Bokade et al. Various types of industrial building. From the design it is clear that using angle section for Truss and channel section for purlins, Steel Truss Building using pipe section and PEB is found to be economical compared to Steel Truss Building using angle section. By using proper selection of material the Industrial Steel truss Building is economical compared to PEB. In the future, Design of Industrial Building and PEB for multistoried can be studied. Design of Industrial Building and PEB considering crane load can be studied. This methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. The concept includes the technique of providing the best possible section according to the optimum requirement. This concept has many advantages over the Conventional Steel Building (CSB) concept of buildings with roof truss.

K.PRABIN KUMAR et al. Various loads acting onto the structure was done using Indian code provisions. Then, load combinations were developed and the foundation design was done based on the loads acting the base of the structure. The design of the hanger was done and analysis of the structure was carried out using both manually and STAAD.PRO software. Its primary purpose is to form a skeleton for the structure, essentially the part of the structure that holds everything up and together. Steel is one of the friendliest environmental materials which are 100% recyclable. Structural design has evolved, mostly due to the necessity caused by earthquakes. By using the available ISMB steel sections the desired design requirements cannot be met, especially for the highly loaded structures, as the moment of inertia and cross sectional play major role.

N I Marchuk et al. The application of the design algorithm, we can solve similar problems for determining the rational design of structures, obtained through a developed series of industrial building and structures, and reduce the cost for design options. The resulting designs of load-bearing constructions have maximum hardness with a minimum amount of material that determines the cross-sections of the elements with a load bearing capacity in accordance with the requirement of design standards. The objective was to test the algorithm for the rational design of structures for typical construction objects using the case of a problem of optimization of load bearing structures for an industrial building.

Shivani Meher et al. Proposed warehouse design was decided and proper architectural plan was prepared according to the requirements. The forces acting on the adjacent members when one of the members is under loading and calculating the excess stresses and ratios induced in these connected members and also, the moments and forces produced are obtained and mentioned. Then different members of warehouse for e.g. Truss members, columns and connections, etc. were designed and final result are obtained. Finally the conclusion is made that warehouse can be designed easily adopting simple design procedure and IS specifications. Based on which different members like truss members, columns, purlins, etc. were selected and designed. The entire process was completed as per the standards laid down by Indian Standard. The paper effectively conveys that the industrial warehouse can be easily designed by simple design procedure in accordance with the country standards.

ErsilioTushaj et al. The process of sizing can be continuous or discrete. In a continuous sizing optimization any positive value can be assigned to the cross sectional areas of the elements. In practical cases the structural members should be adopted from a set of available sections, so the design problem turns into a discrete sizing optimization. The structural optimization algorithms were divided in two maxi-groups: the deterministic and non-deterministic methods. The two bigger goals are: efficiency in the number of iterations and robustness in finding the optimal solution. The deterministic methods have the advantage of requiring less iteration to the optimal design; but have the disadvantage of managing only problems with less than 100 variables. Instead the non-deterministic methods generate candidate designs using a fitness equation that is not influenced by the values of the candidate optimal design, so may handle bigger size problems, and guarantee a greater effectiveness. As disadvantage they need more iteration.

Subodh.S.Patil et al. In the present work, Pre Engineered Buildings (PEB) and Conventional steel frames structure is designed for wind forces. Involves the comparative study and design of Pre Engineered Buildings (PEB) and Conventional steel frames. Design of the structure is being done in Stead Pro software and the same is then compared with conventional type, in terms of weight which in turn reduces the cost. Three examples have been taken for the study. Comparison of Pre Engineered Buildings (PEB) and Conventional steel frames is done in two examples and in the third example, Pre Engineered Building structure with increased bay space is taken for the study.

Yash Patel et al. The structural members having larger span length can be designed with tubular sections which will be benefitted in overall economy. For smaller span lengths one would have to design roof truss with minimum sections for both conventional steel sections and tubular steel sections which would affect overall economy due to larger initial cost. Even if cost for tubular sections is more compared to conventional sections, but because of comparatively less dead weight it has proved more economical for the industrial roof truss as well as for other steel structures. This research's objective was to estimate the economic importance of the Hollow Sections in contrast with conventional sections. This paper was carried out to find out the percentage economy accomplished using Hollow Sections so as to understand the importance of cost efficiency. The technique used in order to reach the objective involves the comparison of various profiles for different combinations of height and material cross -section for given span and loading conditions.

Aayillia. K. Jayasidhan et al. The industrial training, taken through a period of one month allowed having ample exposure to various field practices in the analysis and design of multi storied buildings and also in various construction techniques used in the industry. The analysis was done using the software package STAAD Pro V8i, which proved to be premium software of great potential in analysis and design sections of construction industry. All the structural components were designed manually and detailed using AutoCAD 2013. The analysis and design was done according to standard specifications to the possible extend. The analysis and designing was done according to the standard specification to the possible extend. The analysis of structure was done using the software package STAAD PRO.V8i. All the structural components were designed manually. The detailing of reinforcement was done in AutoCAD 2013. The use of the software offers saving in time. It takes value on safer side than manual work.

Duoc T. Phan et al. A real-coded genetic algorithm (RC-GA) is therefore applied to optimize the design of cold-formed steel portal frame with a mixture of design variables, in which building topology is processed as the continuous variables and section sizes as the discrete variables. It is worth noting here that the binary-coded GA encounters a limit in achieving the required accuracy with continuous variables. The frame obtained from the proposed algorithm can be considered as the most economical design in each case, since the critical design constraint in all examples becomes active. The reliability and robustness of the algorithm has been demonstrated. In addition, the high consistency of the optimum results was achieved through a number of trials for minimizing the objective function. However, the time for solving the optimization problem is still large. the position of the purlins and side rails and their cost will be considered, taking into account buckling of the column and rafter members between points of lateral restraint. Technique to enhance real-coded GA to reduce the computing time will also be considered.

Valentinas Jankovski et al. Mathematical model created for solving the problem of minimal volume design steel frame structures at shakedown. The shakedown and stability (for a part of the truss) constraints-conditions as well as the structure's stiffness requirements (i.e. the restriction of displacements and deflections) are evaluated. Extreme energy principles of the deformable body mechanics, as well as shakedown and mathematical programming theories of elastic-plastic structures are used in the work for creating the structure's volume optimization problem. Discretization is based on equilibrium finite elements with interpolation functions of internal forces. The elements are designed using HI, IPE, RHS steel profile assortments and considering dispersion of geometrical characteristics of profile assortment sets. Optimal design of steel structures is realized by using the tool system JWM SAOSYS Toolbox v0.47 created by the authors in MATLAB environment. A new analysis module EPS Optima-SD is also discussed. The possibilities of the system SAOSYS are demonstrated by a numerical example of industrial building frame design with standard strength, stability and stiffness constraints. The assumption of small displacements is adopted in optimization of nonlinear problems.

3. BRACED INDUSTRIAL BUILDING

The industrial buildings are planned on basis of operation to be performed during the manufacturing processes. Industrial building may be classified into two categories:

1. Normal or simple industrial building
2. Sophisticated industrial building.

Normal industrial building consists of single storey industrial shed, with or without gantry girder, to house workshop, warehouses or factories, and do not contain Internal columns Sophisticated industrial buildings, usually called steel mill buildings, are used to house big industries in which some manufacturing processes, need spaces with specific and controlled environmental condition

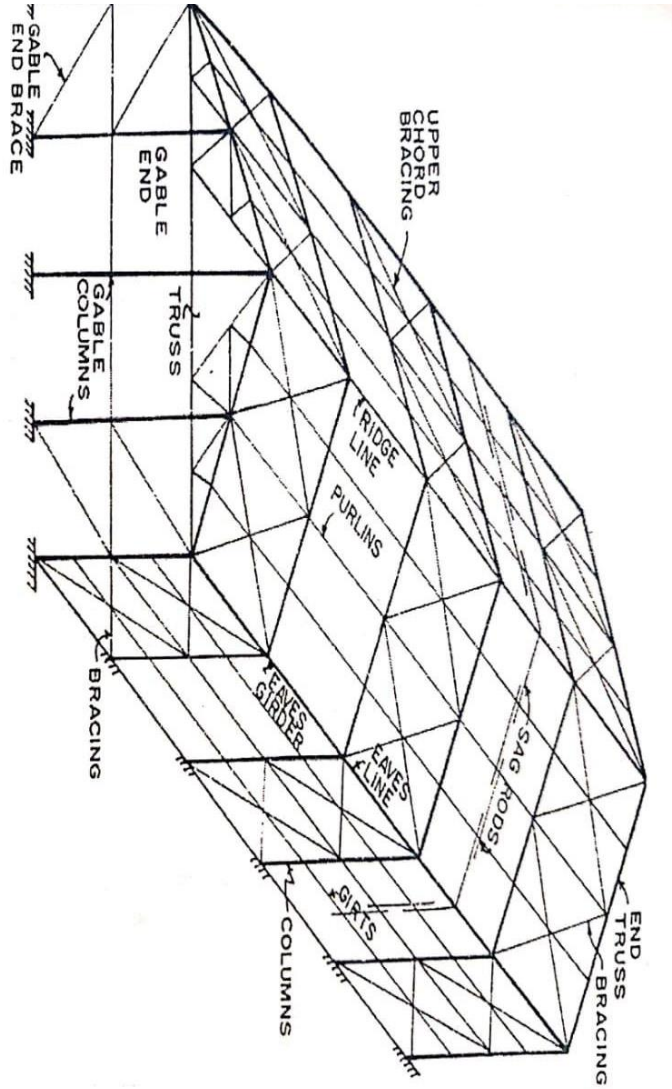


Fig 5. Structural Framing for Industrial Building

3.1 Major Component of Industrial Building

The major component of industrial building in general as shown consist of following

a. Roof Truss
b. Gantry girder
c. Side rails (or girt) with Claddings
d. Gable rafter
e. Gable column
f. Rafter bracing
g. Vertical bracing in longitudinal side
h. Gable wind girder at eaves level
i. Eaves girder
j. Main column
k. Column brackets

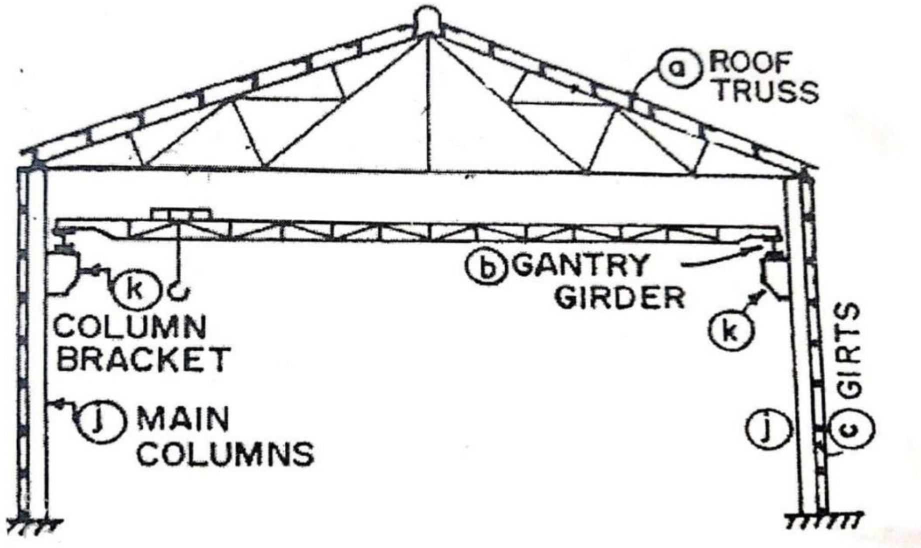
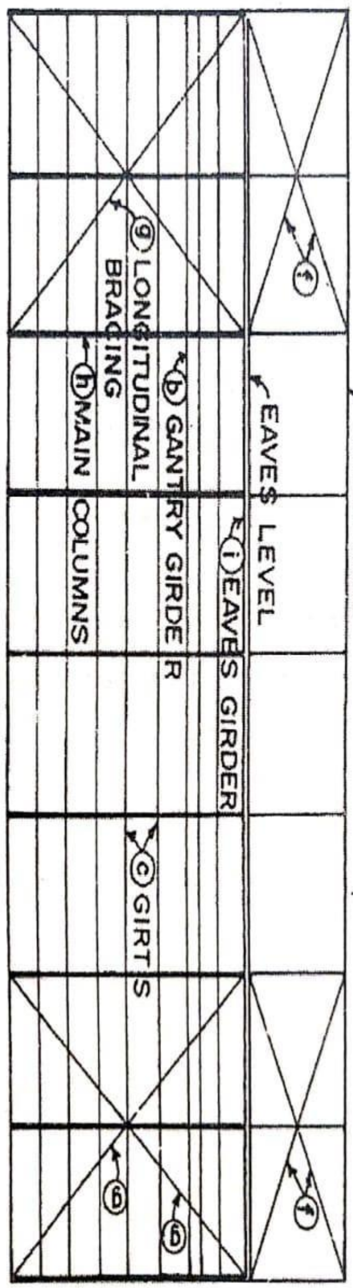
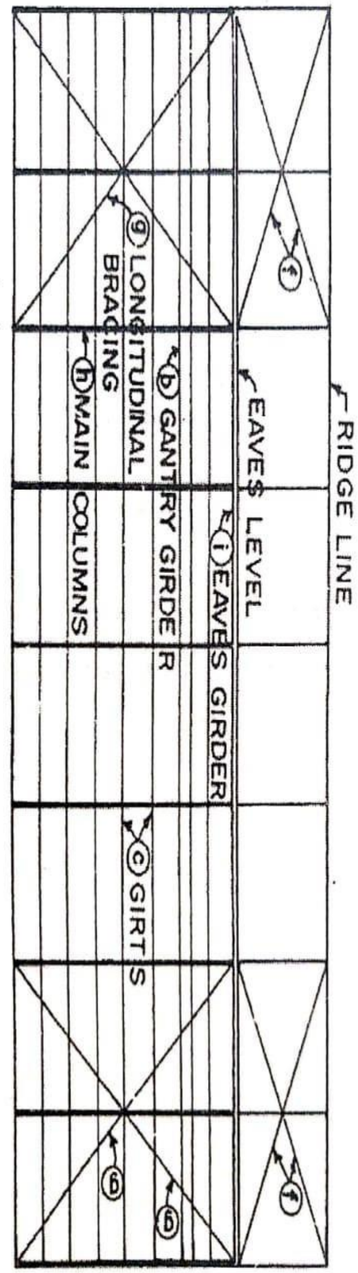


Fig 6. Sections X2-X2


RIDGE LINE
EAVES LEVEL
(i) EAVES GIRDER
(b) GANTRY GIRDER
(g) LONGITUDINAL BRACING
(h) MAIN COLUMNS
(c) GIRTS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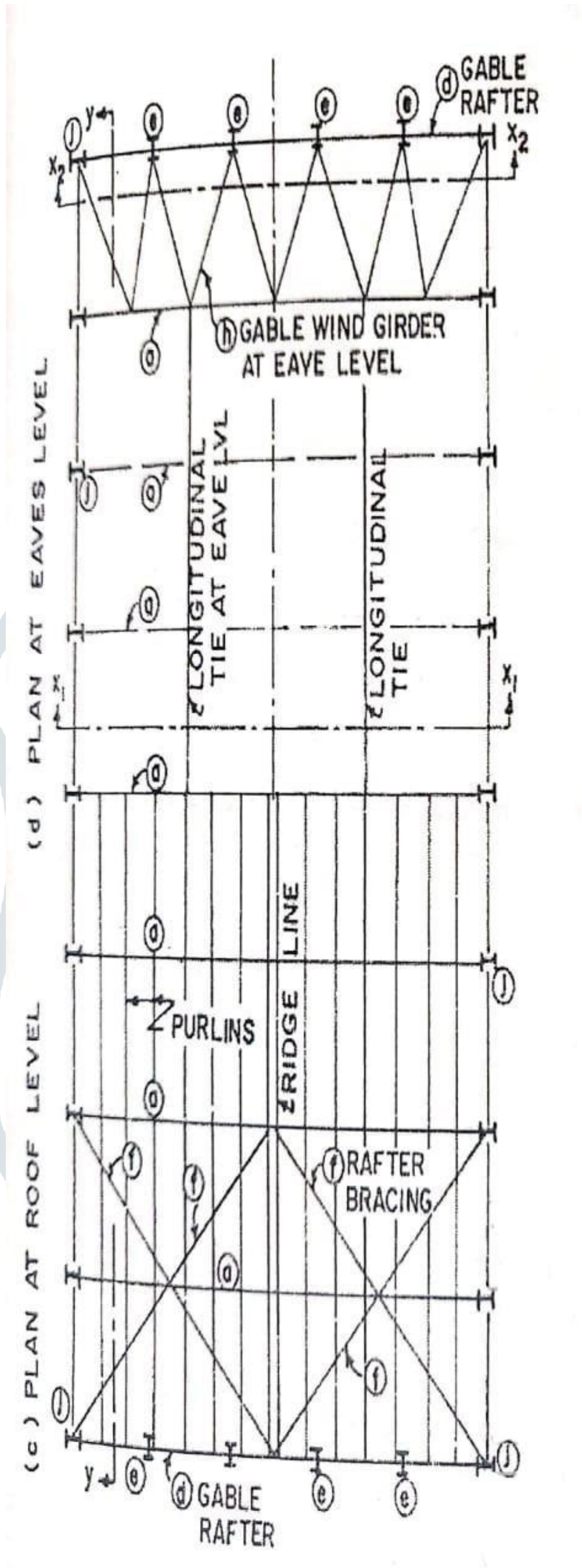

FIG 7 General Major Component Of Industrial Building

3.1.1 Roof trusses

A roof truss is a framework, which supports the roofing and ceiling material, and is supported at the either end on either wall or line of column. When a roof truss is attached to and rate on steel column at the end, it gives rise to a bent. The complete design of roof truss consist of the design of following components:

1. Principal rafter or lop chord
2. Bottom chord or main tie
3. Ties
4. Struts

5. Sag ties
6. Purlins
7. Connection to columns

3.1.2 Gantry Girders and Column Bracket

3.1.2.1 Gantry girder

Gantry girder or crane girder carry hand operated or electric overhead Cranes in in industrial buildings, to lift heavy materials, equipment etc. and to carry them from one location to the other within the building. The essential components of crane system are as shown below

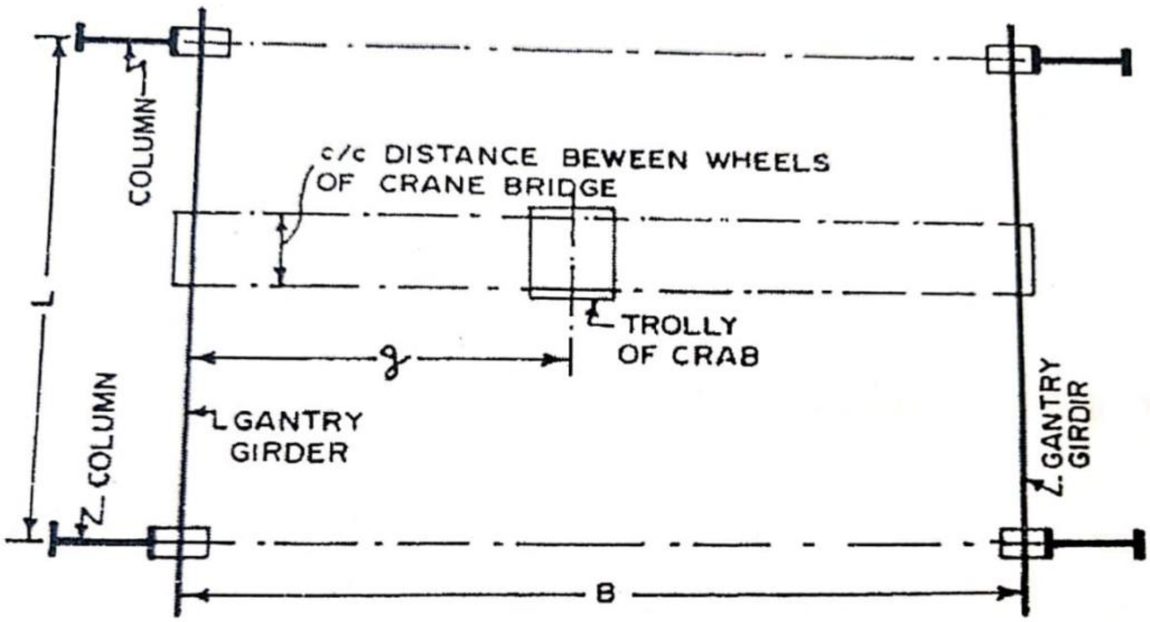

Fig 8. Plan of Crane System

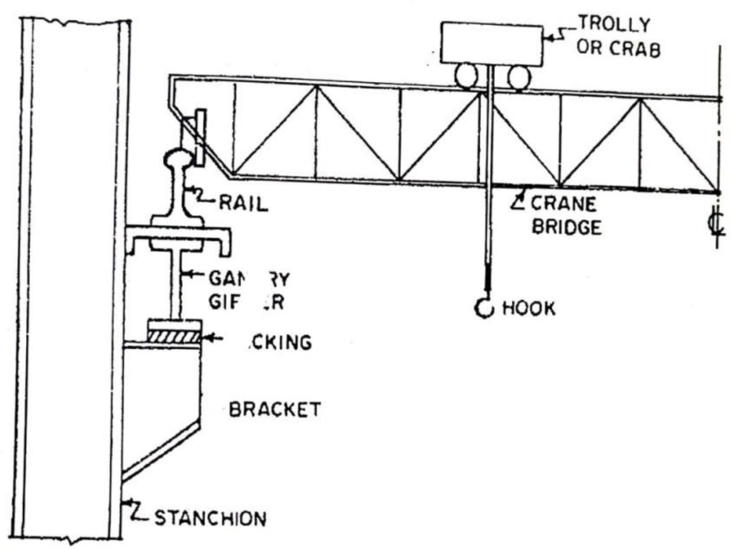

Fig 9 Component of Crane System

1. Crane bridge or cross girder
2. Trolley or crab mounted on Crane Bridge
3. Gantry girder for crane girder
4. Crane runway (rail)
5. Column brackets

The crane bridge spans the bay of the shop. The trolley or crab mounted on crane bridge, can travel transversely along the bridge. The bridge has wheels at the ends, and capable of moving longitudinally on rails. The rails are mounted on gantry girders. The gantry girders span between brackets attached to columns, which may either, be of steel of RCC. Thus the span of the gantry girder is equal to center-to-center spacing of columns.

3.1.2.2 Column bracket

The gantry girder spans between the brackets attached to columns. The position of wheel for maximum reaction at the bracket can easily found. The bracket along with its connections to the column may be designed for shear force and additional shear due to torsion. Care be taken for impact load which is transfer from gantry girder.

3.1.3 Gable Rafter, Gable Wind Girder and Gable Column

3.1.3.1 Gable rafters:

The gable end no is profit, but At the gable end no truss is evided it be safer provided, as shown in Fig. 7, These gable s ierbetdongble walls of openings are required) or supported . The able cm when provided, permit wider openings at the gable end, and the same time support the dead Load and wind load acting on the gable end cladding. For span of truss up to 10 mon c h o columns, but for larger spans, intermediate columns feeble columns) can be provided w spacing of 4 to 6 m. The configuration so provided is known able frame. The configuration of gable frame should be chosen so that it can resist the Wind load acting on the gable face in addition to the DL+ LL coming from the roof sheeting. Thus, the members of the gable (ie. gable rafters) are subjected to both bending as well as axial forces, in contrast to the rafters of the truss, which are subjected to only axial forces if the purlins are provided at nodal points. The depth of the members is so chosen that flexural deflection be within limits.

3.1.3.2 Gable wind girders:

Gable wind girder is provided at the eaves level, at the end panel of the building, to resist the wind loads on the gable end. It is thus a horizontal girder formed by bracing together the lower node points of the end truss and the gable columns.

3.1.4 Eaves Girder

Eave is the edge of a leaking roof. Eaves girder is a girder or stiffener beam taken round the building, at the eaves level, to serve several functions:

1. It acts as stiff binder beam
2. Side cladding may be hung from the caves girder, in some cases
3. The wind bracing along with the caves girder acts as a truss in plain view, in which eaves girder is a compression chord
4. It supports drain gutters and other secondary members. Two channels face to face (or I-beams) are used as eaves girders, as shown in Fig 10

3.1.5 Side Rails (Or Girts)

The height of Industrial buildings may range from 6 m to 12 m. It is not advisable to build the side walls of such height, since these will bend as cantilever. Such walls will be very thick and will require heavier foundations. Alternatively, one may construct the side walls up to 3 to 4 m height, and then provide sheet cladding. These side sheets are supported on side rails. These side rails are spaced 1 to 1.5 m apart. These rails are, in turn, supported directly (shown in fig. 10) or indirectly on columns. The side rails are subjected to vertical bending due to dead loads and horizontal bending due to wind loads. If the spacing of the columns is more (say greater than 6 m), the size of rails becomes uneconomical. In that case, grid framing, consisting of horizontal beams and vertical runners are to be provided.

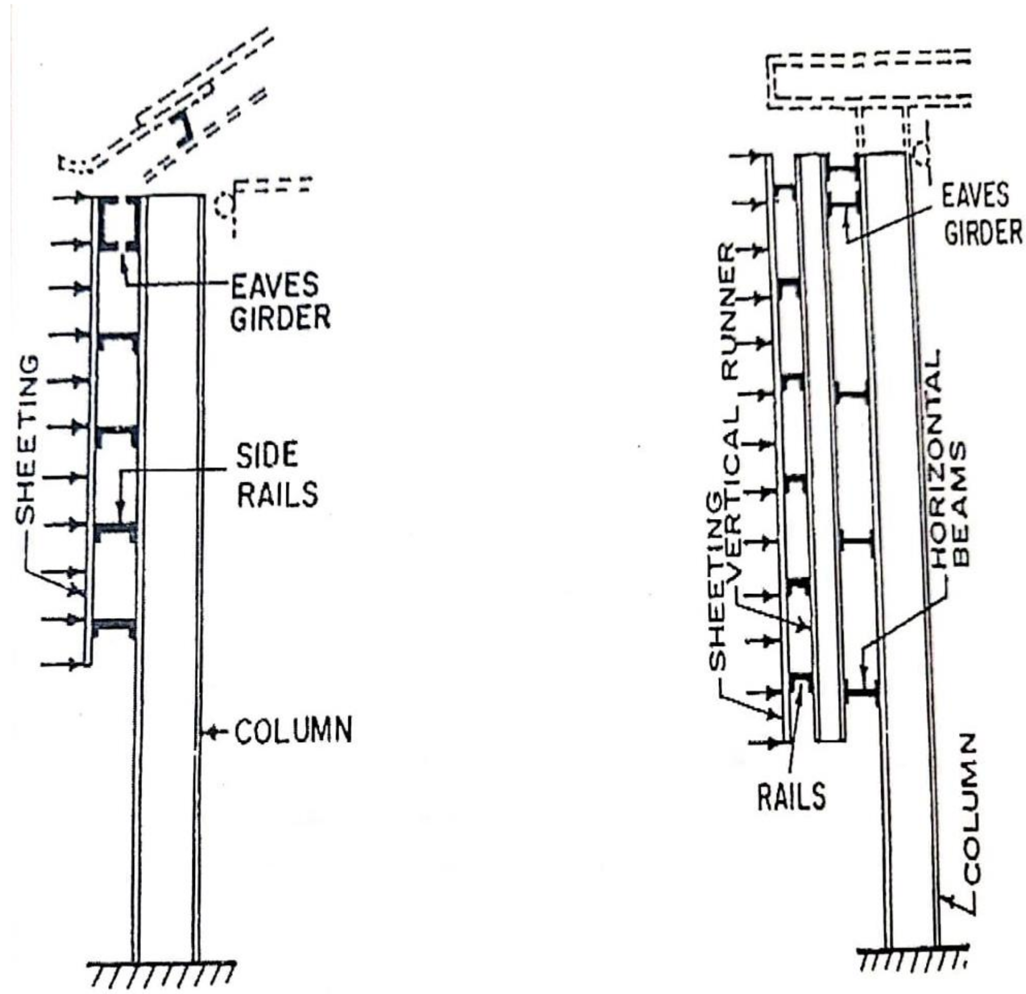

Fig 10 Side Rail Arrangement

3.2 Bracing of Industrial Building

The bents, consisting of truss and columns can resist vertical loads and all horizontal loads acting in their own planes. However, they offer very little resistance to horizontal loads acting normal to their planes. The trusses and columns of an industrial building must be thoroughly braced to preclude collapse of structure due to wind or earthquake or the effects of moving loads such as cranes. The function of bracing is to transfer horizontal forces from the frames to the foundations of the building. Bracing are provided in the following three planes:

1. Inclined plane of the upper chords of truss
2. Horizontal plane of the lower chords of the truss (tie bracing) and
3. Vertical planes of the columns

Braces are provided in the form of X, K or knee bracing. Out of these, X-bracing is quite common. In a long building, every fourth or fifth bay should be braced. Even in shorter building, a minimum of two bays should be braced. Fig. 7 Shows the upper chord bracing. lower chord bracing and vertical plane bracing of columns. When wind blows in the longitudinal direction (i.e. normal to the plane of trusses) a horizontal truss will be required to transmit the wind load on the gable end to the column, and a cross frame (or cross bracing) in the longitudinal vertical planes of the columns will be required to transmit the loads to the foundations.

3.3 Bracing of Industrial Bents in Transverse Direction

An industrial bent, consisting of two end columns and trusses top is braced against transverse forces independent of others. Due to this, each industrial bent remains stable transversely, immediately after construction. When the column load is heavy (due to large span of the truss) and consequently the size of footing is large, the bent can be braced by fixing, the base and providing mechanical hinges! at the top. The method is suitable when height of building is small so that overturning moment is also small. When the span of the truss is small, bent can be braced by providing knee braces. The column base may be resulting in zero B.M. on the foundation, and consequent reduction in the cost of foundation. The reduced moment is transferred to the column at the junction of knee-brace with the column. In the case of a bent with knee-braces and fixed coves the moments are further reduced, through the foundation becomes costlier because these are to resist B.M. Though the knee braces resist the overturning moment caused by lateral loads, they produce additional stresses in the whole of the truss. Knee braces also reduce the headroom. Where they headroom requirements are severe, knee braces are avoided and the bent is braced by fixing the columns at their base, and providing rigid connections between the columns and the truss

CONCLUSIONS

The industrial training, taken through a period of one month allowed to have ample exposure to various field practices in the analysis and design of multi storied buildings and also in various construction techniques used in the industry. The analysis was done using the software package STAAD Pro V8i, which proved to be premium software of great potential in analysis and design sections of construction industry. All the structural components were designed manually and detailed using AutoCAD 2013. The analysis and design was done according to standard specifications to the possible extend.

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