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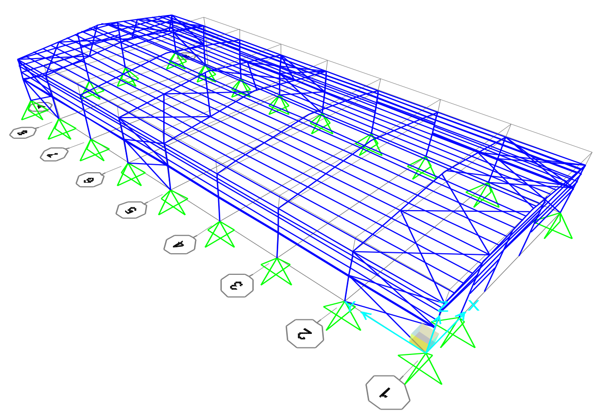
The Analysis and Design of the Steel Warehouse



By:

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- Abstract

Structural design is aimed to design a structure that fulfills its intended purpose during its intended life span and be adequately safe in terms of strength, stability, and structural integrity, serviceability in terms of stiffness, durability, etc., and be economically viable, aesthetically pleasing, and environment friendly. This paper presents the studies on the analysis and design of the steel warehouse structure. The optimum design of the structure is carried out using finite element software STAAD PRO. The analysis of the structure is carried out for suitable steel sections with different load carrying capacity. The steel quantity required for the structure is calculated. Finally along with material optimization, technoeconomical design to achieve the reliable performance of the warehouse structure is carried out. Abstract Keywords: Warehouse, STAAD Pro, Finite element method.

- Descripsion

Steel warehouse is a kind of building structure used for storing items, goods or equipments, adopting steel as the main structural material. It has the following features and advantages:
High Strength and Stability: Steel has high strength and stability and is capable of withstanding large loads and forces. Steel structure warehouse can provide strong support to ensure the structural stability of the warehouse and can withstand the weight of heavy goods or equipment.
Large Spans and Heights: Steel warehouses typically have large spans and heights, providing a wide range of storage space. The high strength and rigidity of steel allows warehouses to be cantilevered without columns or with fewer columns, resulting in more interior space and improved storage efficiency.
Rapid construction and demountability: Steel can be prefabricated in the factory and then quickly erected and assembled on site. This allows steel warehouses to be built faster, saving time and labor costs. In addition, steel structures are demountable, allowing for easy disassembly and relocation.
Weathering and Corrosion Resistance: Steel has good weathering and corrosion resistance, which allows it to withstand the effects of weather and environmental conditions on the building. This is especially important for warehouses, which are exposed to a variety of climatic conditions over time, such as high and low temperatures, humidity and chemicals.
Flexibility and customizability: steel warehouses can be flexibly designed and customized according to different needs. The size, layout and supporting facilities of the warehouse can be determined according to the size, quantity and special requirements of the items to be stored to meet the specific needs of the users.
Environmental sustainability: Steel is a recyclable and reusable material, and the use of steel structure warehouse can reduce the consumption of natural resources. In addition, steel structures can be designed with energy-saving features, such as optimized insulation and ventilation systems, to reduce energy consumption.

1-Introduction

A Steel warehouse is a structural building, which is used by industries to store raw materials and the produced ready goods. Steel warehouse is also called as the industrial building. There are two types of industrial buildings such as normal type of industrial building and special type of industrial building. Normal type of warehouses are the simple roofed structures on the open frames. Special type of industrial warehouses are such as cold storage buildings, etc. In the steel buildings such as the warehouses, the beams and columns are of steel sections of different sectional dimensions. The steel framed structure could be erected for the several bays adjoining each other based on the requirements. The horizontal and vertical bracings are provided appropriately to the structure to resist lateral load properly. These bracings minimize the deflection in beams or any other structural elements due to moving loads in the large industries. Sheeting, supporting trusses and purlins are supported on the columns provided on the structural roofing system.

- Steel frame structure and its various parts

Steel frame structure and its various parts Steel frame is a building technique with a frame of vertical steel columns and horizontal I-beams constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. The frame needs to be Protected from fire because steel softens at high temperature. Steel structure warehouse is generally done with a series of steel structure, including steel columns, steel beams, purlin and so on. These main components constitute the load-bearing structure of the warehouse. Due to light weight and easy construction, there is a great demand for the structural steel warehouse

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- Various parts in steel framed structure –

• PURLINS

Purlin is a horizontal beam or bar used for structural support in structures, most often below the roof. Purlins are supported either by the building's rafters or its walls. These are most commonly used in steel frames. Purlins carry the roof deck or sheathing loads and are supported by large rafters and/or building walls, steel beams, etc. In comparison to closely spaced rafters, the use of purlins is common in Pre engineered buildings.

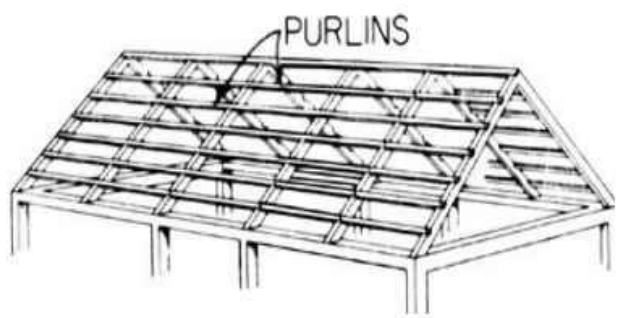

Figure 1. 3 Steel purlin in roof truss

• RAFTERS

Rafter is a structural component that is used as part of a roof construction. Typically, it runs from the ridge of the roof. Rafters are generally laid in series, side by side, Providing a base to support roof coverings. Rafters are typically made of steel and can be concealed within the roof structure. Rafters can be used as a key component of various types of roof design. The rafters sit on a wall plate which is an efficient means of spreading the load exerted by the roof structure down through the walls without creating pressure points where each rafter meets the wall and columns of steel framed structure.

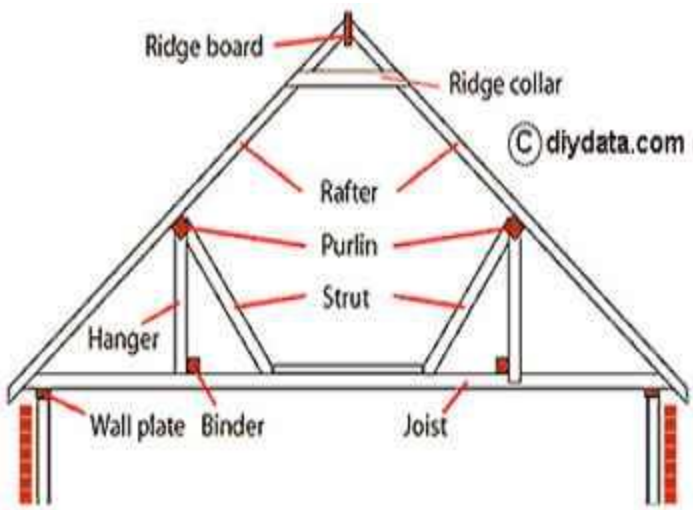

Figure 1. 4 Steel rafter in roof truss

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• JOIST

Joist, ceiling or floor support in building construction. Joists may be of timber, steel, or reinforced concrete are laid in a parallel series across or abutting girders, to which they are attached, usually by metal supports called joist hangers, or anchors. The ends of the joists are grooved or notched so that they are flush with the weight-bearing elements to Provide a smooth horizontal. Before the floor is laid above or the ceiling laths hung below the principal joists, additional strength may be given in the form of

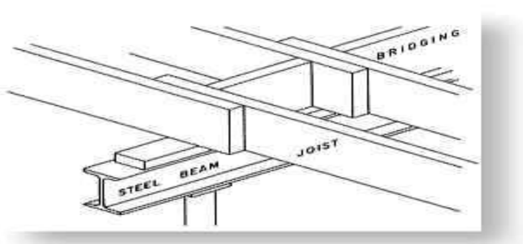


Figure 1. 5 Joist in roof truss

• GIRDER

Steel girders are a type of steel beams. Girders are collector beams; they are the main horizontal supports of a structure which support the smaller beams. So “all girders are beams but all beams are not girders”. Steel girders and beams differ from each other in various aspects like large beams are known as girders. If a large beam horizontally supports a structure then it is a steel girder. Beams are usually smaller in size compared to girders. They are responsible for the support function of any structure. Girders carry dynamic loads and rolling loads. This is typical of steel girders. Due to its high load bearing capability steel girders are widely used in the construction industry. Girders have an I-shaped cross section or they can be box-shaped or Z-shaped. The main 6 function of a steel girder is to transfer the load to the columns on which it rests. A steel beam transfers load to the steel girder.

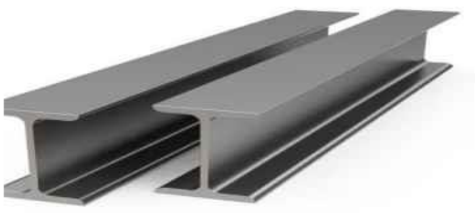
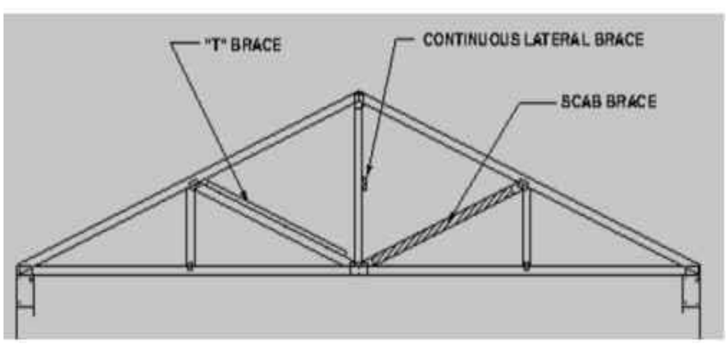


Figure 1. 6 Girder bf

• BRACING

Permanent bracing of individual truss members prevents certain members of individual trusses from buckling under compressive loads. During the design Process of the truss, the members are checked for buckling and for slenderness restrictions. If a member is found to buckle in the narrow direction, a brace is added. If a member is found to buckle in the wide direction, the size of the member is increased. Under normal gravity loads the top chord of a typical truss is in compression and tends to buckle in its narrow direction. The plywood roof sheathing prevents the top chord from bucking sideways. Other members of the truss, such as various web members and the bottom chord may also experience compressive forces under different load conditions. Under certain combinations of member length and magnitude of the compressive force, the member may buckle in the narrow direction. When this combination is reached, bracing of the web member or bottom chord is required.



2- Objectives

• To analyze the various loads acting on the structure.

• To analyze for the different load combinations as per the code.

• To design the industrial warehouse as per its drawing details.

• To calculate the material quantity for the optimized design.

3. Methodology

3.1 Modelling Warehouse is selected for the analysis and all the parameters required for fixing up the warehouse geometry are prepared and presented in Figure-1.

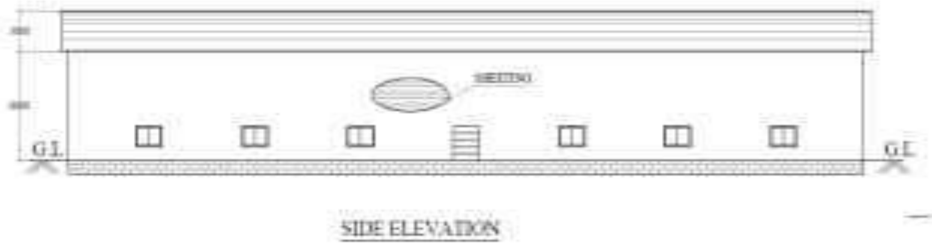


Figure-1 Plan at Plinth level and side elevation

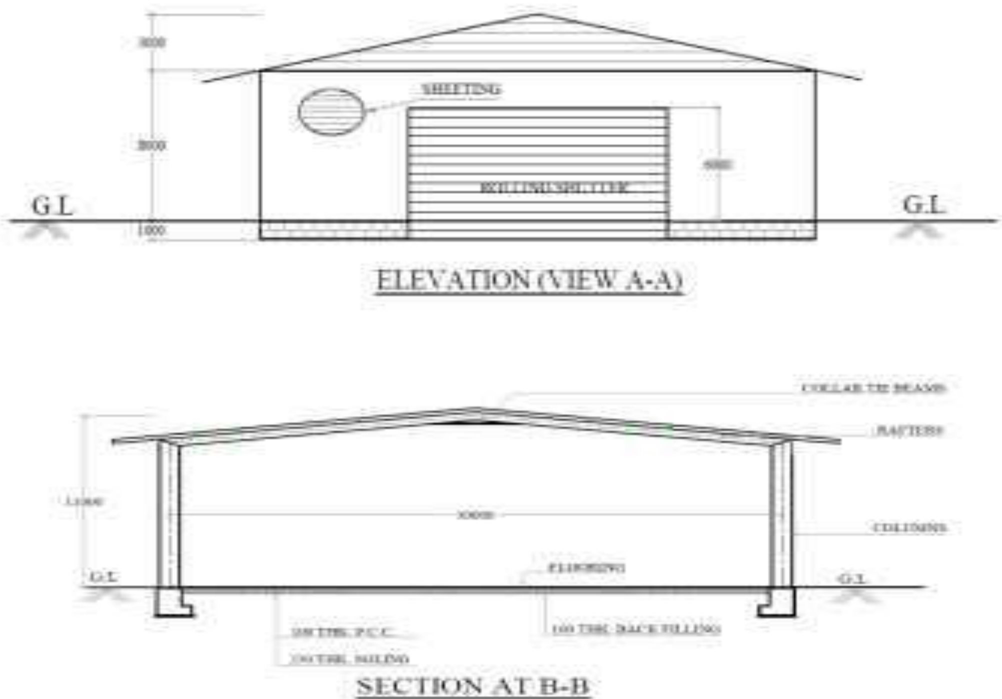


Figure-2 Elevation (View A-A), Section at B-B, Section at gable end.

Figure-3 Model of warehouse in STAAD Pro.

3.2 Loads

Loads and load combinations are considered in reference with the IS codes, IS-875 part 5.

3.2.1 Dead loads

* Weight of metal sheeting = 0.131KN/m2

* Weight of fixings =0.025KN/m2

Total load = 0.156KN/m2

Total load per meter run = 0.156*4 = 0.624 KN/m run.

* Dust load = 6.85 KN/m

Dust load per panel of roof = = 0.112 KN/m2 = 0.112KN/m

* Dead load on intermediate rafter beams = 0.736 KN/m2

* Dead load on gable end rafter beams = = 0.368 KN/m2

3.2.2 Live loads According to IS 875-1987 part-b the live loads for an industrial storage building.

* Point load = 7.0KN

Point load per meter run = = 0.46 KN/m

* Uniformly distributed load = 7.5 KN/m

Total live load = 0.46KN/m + 7.5 KN =7.96 KN/m

* Live load on intermediate rafter beams = 7.96 KN/m

* Live load on gable end rafter beams = = 3.98 KN/m

3.3 Analysis of the Structure using STAAD Pro. Analysis of the steel warehouse structure using sap2000 for shear force, bending moment, deflection.

Figure-4 Louding on the structure in STAAD Pro .

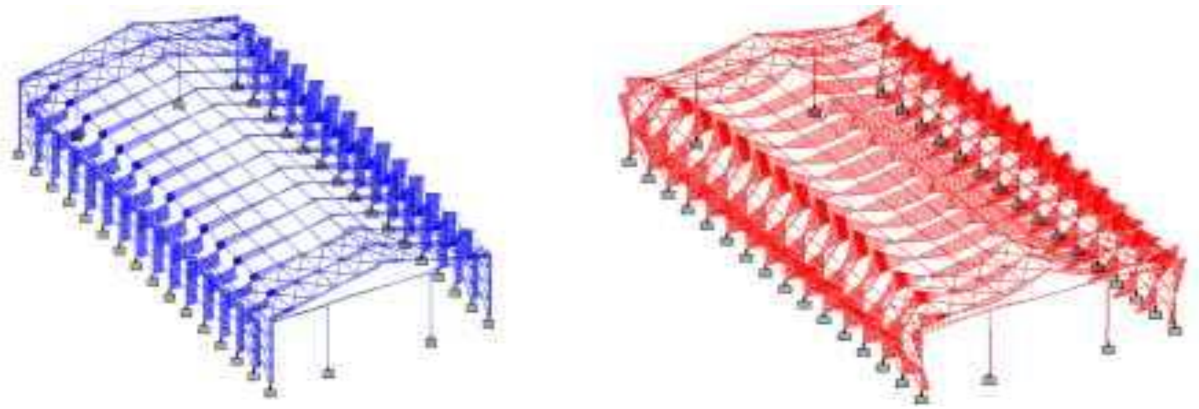


Figure-5 Shear force and Bending moment diagram after analysis.

3.4 Design of Components of the Steel Warehouse Design of structural elements like principal rafter, column, column base and purlins etc as per IS 800-2001. Components are designed for the maximum load, maximum bending moment and shear force.

3.4.1 Design of Beams Maximum load = 15.009 KN/m

Maximum bending moment = 438.60 KN/m

Maximum shear force = 114.74 KN Check for shear:

* Design shear strength

$$\text{Vd} = 0.6\,[\ \frac{f_y}{\sqrt{3}*\gamma_{mo}}\ \text{A} \quad \text{v}\ ] \quad \text{Vu}$$

$$= 0.6\,[\ \frac{250}{\sqrt{3}*1.1} \quad 250 \quad 21.3]$$

$= 419.23$ KN 114.74 KN   Hence it is safe.

Check for moment of resistance :

$$\text{Md} = \frac{\beta_b \times Z_p \times f_y}{\gamma_{mo}}$$

Here, $= \frac{b}{t_f} = \frac{250/2}{21.3}$ 5.86 mm 9.4

$$\frac{d}{t_w} = \frac{(h-2t_f)}{t_w} = \frac{(600-(2\times 21.3))}{11.8} = 47.23 \quad 84$$

Therefore, the section is in plastic condition.

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For plastic condition, $\beta_b = 1$

Plastic modulus $Z_p = 3986.66 \text{ cm}^3 = 3986.66 \;\; 10^3 \text{ mm}^3$

$$M_d = \frac{1 \times 3986.66 \times 10^3 \times 250}{1.1}$$

$= 906.05$ KN m 438.60 KN m   Hence it is safe.

Check for deflection(∇) :

$$\text{Deflection}(\nabla) = \frac{5wl^4}{384\,EI} = \frac{5 \times 10.006 \times 15290^4}{384 \times 2 \times 10^5 \times 106198.5 \times 10^4} = 33.52 \text{ mm}$$

$$\text{Maximum permissible deflection} = \frac{\text{span}}{250} = \frac{15290}{250} = 61.16\text{mm} \;\; 33.52\text{mm}$$

Hence it is safe

Check for web crippling :

Design of bearing strength

$$F_w = (b1+n2) \times t_w \times \frac{f_y}{\gamma_{mo}} > Vu$$

We have assumed bearing b1 = 200mm

$n_2 = 2.5\,(\,tf + rmin\,) = 2.5\,(\,21.3+52.5\,) = 184.5$ m

$$F_w = (200+184.5) \times 11.8 \times \frac{250}{1.1}$$

$F_w = 1031.15$ KN > 114.74 KN

Hence it is safe.

Check for buckling :

Buckling strength

$F_{wb} = (b_1 + n_2) \times tw \times fc$

Assume bearing $b_1 = 200$mm

$$n_2 = \frac{h}{2} = \frac{600}{2} = 300\text{mm}$$

To calculate fc

We know that slenderness ratio,

$$\text{Slenderness ratio} = 2.50 \times \frac{d}{t_w} = 2.50 \times \frac{(h-2t_f)}{t_w}$$

$$= 2.50 \times \frac{(600-(2\times21.3)}{11.3} = 118.09\text{mm}$$

By knowing the value of fy = 250N/mm2

For slenderness ratio 118.09mm, fc = 85.78

Fwb = (200+300) 11.8 85078 = 506.10 KN > 114.74 KN

Hence it is safe. Hence we have chosen the beam section ISWB-600@ 133.7 kg/m is safe again for the loading. After checking for shear, moment of resistance, deflection, web crippling, buckling, we have chosen the beam section ISWB-600@ 133.7 kg/m is safe again for the loading.

3.4.2 Properties of the components The steel sections adopted to the warehouse for the design of the structure for maximum loads, maximum bending moment, maximum shear force. Sections adopted for different components are as follows,

BEAMS- ISMB-600

COLUMNS- ISHB-450

PURLINS-ISMC-250

BRACINGS- ISLC-150

3.5 Steel take-off

The weight of the steel sections (Table-1) is the total weight of the total length required.

Table-1 Weight of Steel Sections.

PROFILE	LENGTH (m)	WEIGHT (KN)
ISWB600	861.51	1125.068
ISMC400	1247.89	611.601
ISLC150	360	50.885
IPA200*200*25	86.61	125.222

4. Conclusions

The following are the major observation and conclusion drawn from the present project work.

* The steel warehouse is analyzed for the respected loads acting on the structure as per the codes. * The warehouse structure is analyzed for the different load combinations.

* The materials quantity is calculated for the optimized design of the structure .

* Time saving design with respect to computer aided design of structure (CADS).

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