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Design of Industrial Warehouse

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***Abstract*— In India, due to rapid growth of industrialization, there arise a need of storage and manufacturing of goods which can be fulfilled by proper designed industrial warehouse. This study gives an idea to carry out the design of an industrial warehouse. This topic of work is decided as to know the different types of force/load effects to be considered while designing industrial warehouse with the help of literature review. This structure is proposed to design according to IS 800:2007 and the dead, live, the wind load analysis is done according to IS 875:1987 (Part-I, Part-II, Part-III). The area for 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.**

Keywords*— Warehouse, Load Combination ,Dead Load, Live Load, Wind Load, Nodes.

I. INTRODUCTION

An industrial shed is any building structure used by the industry to store raw materials or for manufacturing products of the industry is known as an industrial building. Industrial buildings may be categorized as Normal type industrial buildings and Special type industrial buildings. Normal types of industrial building are shed type buildings with simple roof structures on open frames. These buildings are used for workshop, warehouses etc. These building require large and clear areas unobstructed by the columns. The large floor area provides sufficient flexibility and facility for later change in the production layout without major building alterations. Special types of industrial buildings are steel mill buildings used for manufacture of heavy machines, production of power etc. The function of the industrial building dictates the degree of sophistication. A structure is a collective result of idea, design, material, man power, time, finance etc. As need is the mother of invention, similarly, type of construction and its proper required design is a necessity.

A. General

Typically the bays in industrial buildings have frames spanning the width direction. Several such frames are arranged at suitable spacing to get the required length. Depending upon the requirement, several bays may be constructed adjoining each other. The horizontal and vertical bracings, employed in single and multi-storey buildings, and also trusses are used primarily to resist wind and other lateral loads. These bracings minimize the differential deflection between the different frames due to crane surge in industrial buildings. They also provide lateral support to columns in small and tall buildings, thus increasing the buckling strength. Sheeting, purlin and supporting roof trusses supported on column provide common structural roof system for industrial buildings (Fig.I). Truss includes members such as Top Chord, Bottom Chord, and Web Member.

B. Loads and load combinations

- *Dead load*

Dead load comprises of self-weight of the structure, weights of roofing, G.I. sheets, gantry girder, crane girder, purlins, sag rods, bracings and other accessories.

- *Live load*

According to IS : 875 (Part 2) – 1987, for roof with no access provided, the live load can be taken as 0.75 kN/m^2 with a reduction of 0.02 kN/m^2 for every one degree above 10 degrees of roof slope.

- *Wind load*

Wind load is calculated as per IS: 875 (Part 3) – 1987. The basic wind speed for the location of the building is found to be 15km/h. The wind load over the roof can be provided as point loads acting outward over the CSB panel points.

- *Load combinations*:-

Following codes are used for deciding load combinations and for designing members according to it.

IS CODE-

1. IS 875-1987 for load calculation

3. IS 800:2007 for load calculation

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II. LITERATURE STUDY

This section discusses the literature reviewed related to design of industrial warehouse.

M. Suneetha completed a numerical study and concluded that Weight of single Truss utilizing Angle and Pipe both is less compared to PEB yet because of Weight of Channel Purlin, Weight of Steel Truss Building is on higher side.

Vaibhav B. Chavan, determined optimum span length for economy.

Author C.M. Meera made a comparative study between Pre-Engineered Building (PEB) and Conventional Steel Building (CSB) and analyzing the design frames using structural analysis and design software STAAD PRO.

Subhrakant Mohakul designed an Industrial warehouse and did a thorough study of behaviour of members due to effect of failure at connecting joints.

Manan D.Maisuri stated that the consumption of steel of whole industrial building can be reduced by deciding appropriate geometry of truss and by using hollow steel section with compare to conventional steel section. Thus stating tube sections are most economical.

Research paper by Shaiv Parikh emphasis on the importance of compression members and gives brief description about the characteristics and the behaviour of steel compression members.

A.Jayaraman presents a study on behavior and economical of roof trusses and channel section purlins by comparison of LSM and WSM.

Yash Patel states the importance of tubular sections and concludes the economic advantages of tubular sections.

III. OBJECTIVE OF STUDY

- To identify various loads and load combinations acting on the structure.
- To design the industrial warehouse as per its drawing details.
- To check the structure as per is code, with all the members as per the drawings.

IV. METHODOLOGY ADOPTED

In this research, the region for proposed structure and dimensions were fixed according to the requirement and considering different parameters like storage space required, adequate lighting, etc. The details about warehouse are given below;

TABLE I: DETAILS OF WAREHOUSE

Sr.no.	Particulars	Description
1.	Type of building	Container Warehouse
2.	Type of structure	Single Storey Industrial Structure
3.	Location	Mumbai
4.	Area of site	7875sq.m. (84766.5 sq.ft.)
5.	Type of building	Steel Building
6.	Area of building	5400sq.m. (58125.6 sq.ft.)
7.	Eave height	12m
8.	Number of spans	2
9.	Single span width	30 m
10.	Total span width	60 m
11.	Number of bays	15
12.	Single bay length	6 m
13.	Total bay length	90m

A plan according to requirement and considering architectural aspects was prepared. The plan for the proposed industrial warehouse is given in Fig.III.

Trapezoidal truss was adopted with roof slope 1:5. For this span length, the trapezoidal trusses would be normally efficient and economical. Approximate span to depth ratio is about L/8 to L/12. Truss Spacing may be in the range of $1/4^{th}$ to $1/5^{th}$ of the span length. Depth of truss, spacing of trusses, spacing of purlins were decided according to specifications.

Size of GI sheeting varies from 8 to 11 corrugations per sheet. The weights of sheet varies from 50-156 N/m^2. Selection of gravity loads generally control the bay size. For buildings without cranes, a 9m bay is the most suitable and economical choice. Function of bracing is to transfer horizontal loads from the frames to foundation. Purlins acts as lateral bracings to the compression chords. The lateral ties provide similar functions to the bottom chord members when they are subjected to compression due to reversal of loading. Purlin is a part of roof bracing system. The weight of purlin in the total weight of steel structure could vary from 10-25%. The weight of purlin may be equal to or greater than the weight of the trusses. Spacing of purlin depends largely on the maximum safe span of roof covering and the glazing sheets. The purlin spacing may vary from 1.5-1.75m. The depth of the truss determines its stiffness in relation to its span and also its economy. Roof depth range from 1/12 to 1/8 of the span for continuous trusses.

Loading consideration is as follows: dead load calculation includes GI sheeting weight, fixings, services, roof dead load, weight of purlin, and self-weight of one truss. Then calculation is carried out for nodal dead loads. As per IS 875 (Part 3)-1987 wind load calculated by considering basic wind speed in Mumbai=44m/s. Wind load F on roof truss by static wind method is given by (clause 6.2.3.2 of IS 875) as follows:

$$F=(C_{pi}-C_{pe})*A*P_d$$

After getting wind load, calculation of wind pressure were carried out and results are tabulated. (Table II). For designing one should consider critical wind pressure/loads given in Table III. After calculations of all the loads, load combinations adopted are as follows:

(Clause 3.5.1 and 5.3.3 IS 800: 2007)

(DL*1.5)+ (LL*1.5)

(DL*1.5)+ (WL*1.5)

In the design of any industrial shed design of truss member is most important part. There are various types of truss:- King Post Truss, Pitched Pratt Truss, Fan Truss, Queen Post Truss, Trapezoidal Truss, Mansard Truss, Cambered Truss, etc. For span of 30m trapezoidal truss is most economical. Hence trapezoidal type of truss was adopted (fig. II and III).

Truss consists of members that are: Top chord member, bottom chord member, web member, side runner, tie runner, etc. Before actual design of members, analysis of truss were carried out by simple manual procedure. Truss members can carry compression or tension force, after analysing maximum force is considered for design. The members of the trusses are made of either rolled steel sections or built-up sections depending upon the span length and intensity of loading. Rolled steel single or double angles, T sections, hollow section, square or rectangular sections (Fig. IV) are used in roof trusses

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of industrial buildings. Each member is designed and checked as per IS 800.

Columns are designed as a compression member carrying loads coming from the roof structure. After all component members of warehouse connections were designed to join column to truss and internal connections between truss, etc.

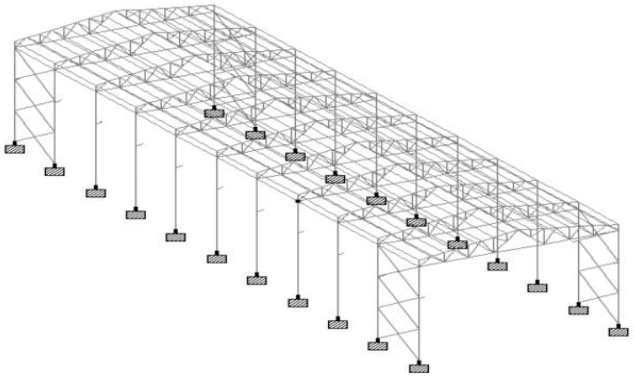

Fig. I. *Truss and column design*

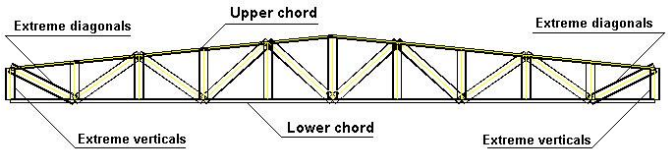

Fig. II. Component parts of Trapezoidal Truss

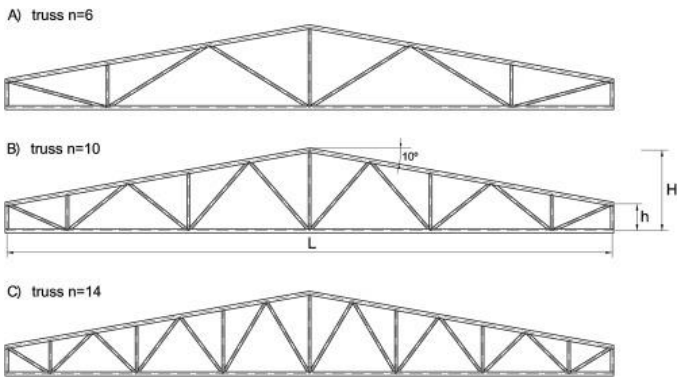

Fig. III. Trapezoidal Truss

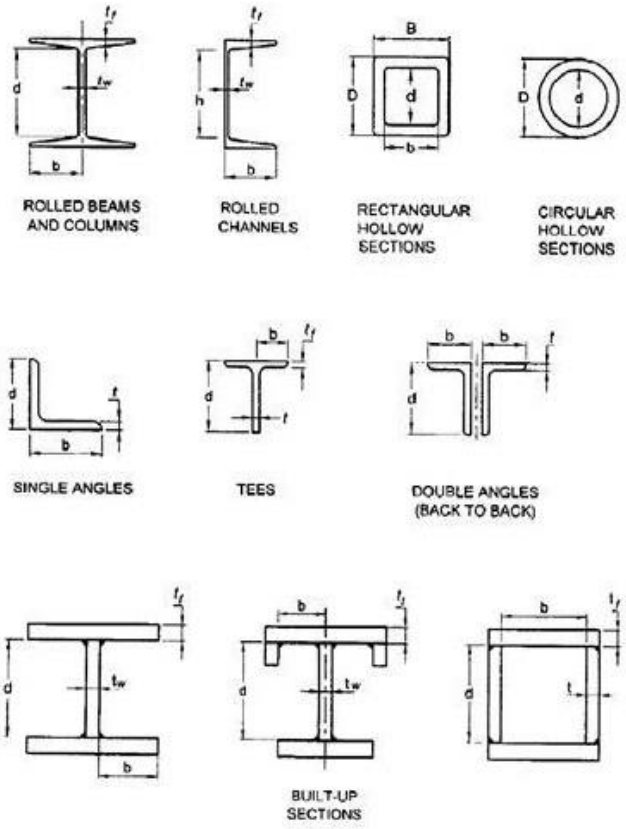

Fig. IV. Various types of steel section

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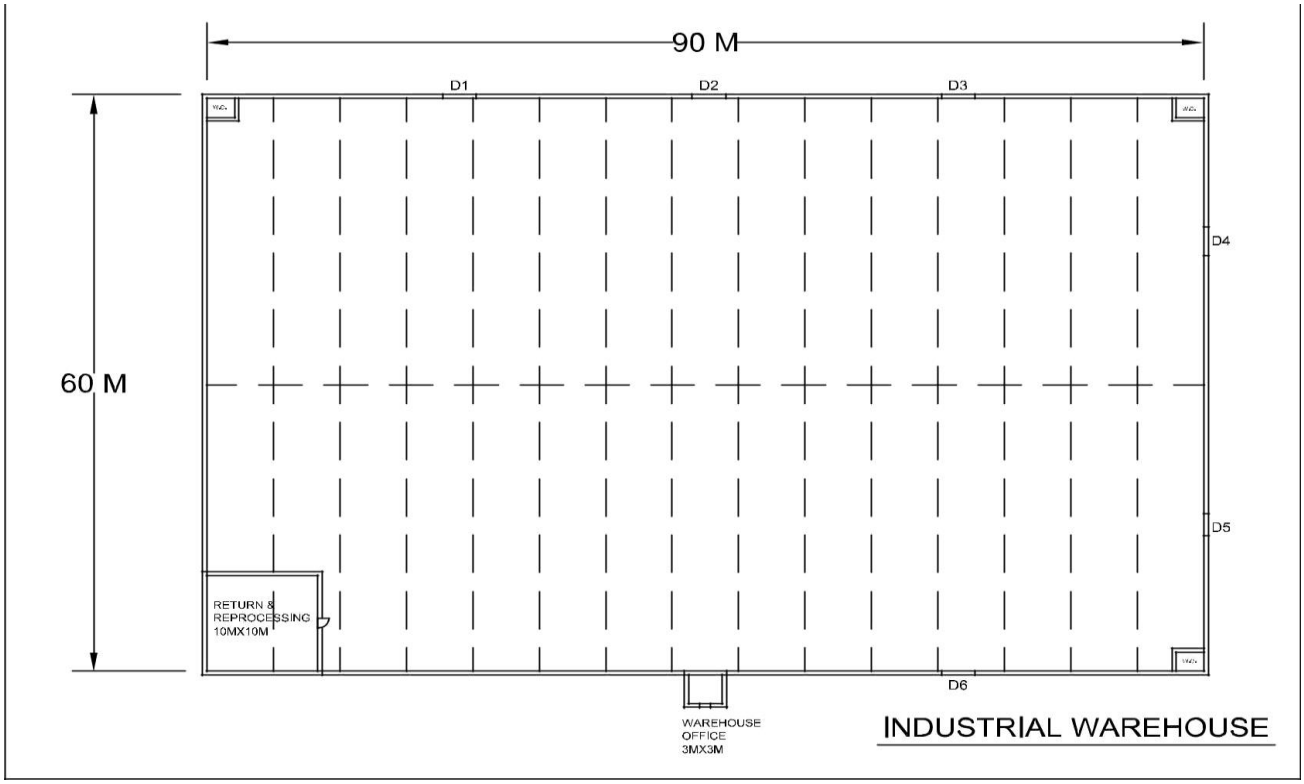

FIG. V. AUTOCAD PLAN

TABLE II. WIND LOAD ON ROOF TRUSS

Wind angle	Pressure coefficients			Cpe ± Cpi		A* Pd	Wind load (KN)	
	Cpe		Cpi					
	Windward	leeward		Windward	Leeward		Windward	Leeward
0°	-1.1	-0.4	-0.5	-1.6	-0.9	15.31	-24.624	-15.779
			0.5	-0.6	0.1	15.31	-9.186	-0.9186
90°	-0.79	-0.79	-0.5	-1.29	-1.29	15.31	-19.749	-19.744
			0.5	-0.29	-0.29	15.31	-4.439	-4.439

TABLE III CRITICAL WIND LOADS

Wind angle	windward side		Leeward side	
	Intermediate nodes(w_3)	End and apex nodes($w_3/2$)	Intermediate nodes (w_4)	End and apex Nodes($w_4/2$)
0°	-24.624	-12.312	-13.779	-6.8895
90°	-19.749	-9.8749	-19.749	-9.8745

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V. ABBREVATIONS

IS = Indian Standard

D_l = Dead load

L_l = Live load

W_l = Wind load

C_{pi} = Internal pressure coefficient

C_{pe} = External wind coefficient

A = Area

P_d = Design wind pressure

VI. RESULTS AND DISCUSSION

All members are designed according to the loads coming on the structure and as per IS code specifications. Results obtained are as follows:

TABLE IV. SUMMARY OF RESULTS

Member	Section provided
Top chord	2ISA 200*200*24
Bottom chord	2ISA 110*110*8
Web member	2ISA 150*150*18
Column 1	ISHB 450@87.2 kg
Column 2	ISWB 600@145.1 kg
Rafter bracing	ISA 90*90*6
Purlin	ISMC 100

VII. SCOPE AND APPLICATIONS

Purchase of raw material is an integral part of any business. These raw materials need to be kept in a safe place, hence in order to rectify this need warehouse are constructed. In future due to rapid growth in industrialization there will occur a great need to construct economically efficient warehouses. The design will serve the purpose of storage of goods.

Applications:

- Various industries requires warehouse to store their goods such as packing warehouses, Railway warehouses, Canal warehouses, Cool warehouses and cold storage.
- The calculations and design is executed considering economy and safety factors.. The factors and steps highlighted while execution of project is important to design any other industrial shed.
- Efficient designing and analysis for any similar industrial shed which is to be constructed.
- Getting to know factors affecting the construction.

VIII. CONCLUSION

In this dissertation, Numerical study was completed considering Mumbai Region, the necessary and appropriate loads and loading combinations were adopted. AUTOCAD plan was prepared followed by load calculations. 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.

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