

DESIGN OF STEEL INDUSTRIAL SHED USING STAAD.PRO

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ABSTRACT

Steel industrial sheds are widely used for factories, warehouses, workshops and storage facilities because they can provide large column-free floor areas and can be erected quickly. This study presents the analysis and design of a single-bay steel industrial shed using STAAD.Pro, following the limit state provisions of IS 800:2007 and the load provisions of IS 875 (Parts 1 to 3). The shed has a clear span of 20 m, a length of 48 m with bays of 6 m, and an eave height of 8 m, and it is assumed to be located on the outskirts of Hyderabad in open terrain.

The roof is supported by steel trusses of the Pratt type resting on built-up or rolled steel columns, and the roof covering consists of galvanised profiled sheeting carried on cold-formed purlins. Longitudinal stability is provided by bracing in the roof plane and in the end bays of the side walls. The complete three-dimensional structure, including trusses, columns, purlins, eave struts and bracing members, is modelled in STAAD.Pro so that the interaction between frames and the distribution of wind forces through the bracing system are represented properly.

Dead load from sheeting, purlins and self-weight, imposed load on the roof as per IS 875 (Part 2), and wind load as per IS 875 (Part 3):2015 are considered. For wind load, the basic wind speed of 44 m/s is modified by the risk coefficient, terrain and height factor, and topography factor to obtain the design wind pressure. External and internal pressure coefficients are applied for the cases of wind parallel and perpendicular to the ridge, with both positive and negative internal pressure. Load combinations are generated according to IS 800:2007, including the combination of dead load with wind uplift, which usually governs the design of the roof members.

The analysis provides the axial forces in truss members, the bending moments and shears in columns, the support reactions and the lateral deflection at the eave level. Steel sections are then designed and checked in STAAD.Pro for tension, compression, bending and combined actions using the IS 800:2007 design module. Member sizes are revised iteratively until all members satisfy the strength ratio and slenderness limits, and the eave deflection is kept within the serviceability limit of height divided by 150 for sheds with elastic cladding.

The study shows that the wind uplift combination governs the design of the top chord and several web members of the truss, where members designed mainly for compression under gravity load experience reversal of force. The final design gives a steel consumption of about 24 kg per square metre of plan area, which is comparable with typical values for sheds of this span. The work demonstrates how STAAD.Pro can be used to obtain an economical and code-compliant design, and it can be extended to pre-engineered building frames, crane-supported sheds and comparative studies of different truss configurations.

I. INTRODUCTION

Industrial growth in India has created a steady demand for buildings that can house manufacturing units, assembly lines, storage areas and logistics hubs. Such buildings need large open spaces without intermediate columns so that machinery and materials can be moved freely. Structural steel is the most suitable material for this purpose because of its high strength to weight ratio, the speed with which prefabricated members can be erected, and the ease with which the structure can be extended or modified later. Steel sheds with trussed roofs have therefore become the most common form of single-storey industrial construction.

The design of a steel industrial shed involves several loads that act in different ways. Dead load from the roofing and self-weight is small compared with other structures, and imposed load on sloping roofs is also modest. Wind load, however, is often the most critical action, because the light roof can be lifted by suction and the tall side walls attract large lateral pressures. For this reason, the correct evaluation of wind pressure coefficients and the combination of internal and external pressures are essential for a safe design. Wind uplift can reverse the forces in truss members, so members that act as ties under gravity load may have to resist compression.

With the introduction of IS 800:2007, the design of steel structures in India moved from the working stress method to the limit state method. The limit state approach uses partial safety factors on loads and materials and requires checks for both strength and serviceability. It also introduced section classification into plastic, compact, semi-compact and slender categories, which affects the moment capacity of members. Carrying out these checks manually for every member of a shed under many load combinations is tedious, and analysis software such as STAAD.Pro is therefore widely used in practice for both analysis and design.

This paper describes the analysis and design of a steel industrial shed with a span of 20 m and length of 48 m using STAAD.Pro. The objectives are to calculate the dead, imposed and wind loads according to IS 875, to model the shed as a three-dimensional structure, to analyse it for all relevant load combinations, to design the truss members, purlins, columns and bracing according to IS 800:2007, and to check serviceability limits. The study is intended to show undergraduate students how a practical steel structure is designed using current codes and software tools.

II. LITERATURE SURVEY

Several studies have examined the influence of truss configuration on the weight and behaviour of steel roof systems for industrial buildings. Researchers compared Pratt, Howe, Fink and north-light trusses for spans ranging from 15 m to 30 m and found that the Pratt truss, in which the longer diagonal members are in tension under gravity load, is generally economical for moderate spans. The Fink truss was reported to be efficient for steeper roof slopes because its short web members reduce buckling lengths. Other investigators studied the effect of roof pitch and panel length on steel consumption and observed that a pitch of about one in five to one in four and panel points located directly under the purlins give a balanced design. These studies also noted that the choice of truss type interacts with wind loading, since a truss that is efficient under gravity load may require heavier sections when the member forces reverse under uplift. Many authors therefore recommended that the truss should be selected after considering both gravity and wind load cases rather than on the basis of gravity load alone.

Wind loading on low-rise buildings has been the subject of extensive research, and the revision of IS 875 (Part 3) in 2015 brought several changes to the design wind pressure. The revised code introduced the wind directionality factor, the area averaging factor and the combination factor, which together can reduce the design pressure for certain cases. Researchers comparing the 1987 and 2015 editions reported that the design wind forces on industrial sheds may either increase or decrease depending on the terrain category, building height and permeability assumed. Studies on external pressure coefficients showed that the regions near the eaves, ridge and gable ends experience high local suction, which can cause failure of sheeting fasteners and purlins even when the main frames are adequate. The selection of internal pressure coefficients was also highlighted as important, since sheds with large openings on one wall can develop internal pressures that add to the external suction on the roof and significantly increase uplift on the trusses.

The transition from the working stress method of IS 800:1984 to the limit state method of IS 800:2007 has been studied by many researchers through comparative design examples. For industrial sheds, several authors reported that the limit state design gave a reduction of about 10 to 20 percent in steel weight for members governed by tension or bending, while the saving was smaller for slender compression members. The classification of sections and the use of buckling curves for different cross-section shapes were identified as the most significant changes in compression member design. Researchers also pointed out that the partial safety factor of 1.5 on wind load in combination with a reduced factor on dead load produces the governing uplift case for light roofs. Studies on angle sections used in trusses found that the provisions for eccentrically connected single angles in IS 800:2007 result in higher capacities than the older approach, which further contributes to economy in truss design.

The comparison between conventional steel buildings and pre-engineered buildings has been a common theme in recent literature. Pre-engineered buildings use tapered built-up sections for rafters and columns, sized according to the variation of bending moment, and cold-formed Z or C purlins. Studies analysing both systems for identical spans reported that pre-engineered frames can reduce steel consumption by 20 to 35 percent for spans above about 20 m, although the conventional truss system remains competitive for shorter spans and where standard rolled sections are readily available. Researchers also noted that conventional trussed sheds are simpler to fabricate in small workshops and require less specialised design, which explains their continued popularity in small and medium industries. Several studies emphasised that the economy of either system depends strongly on the bracing layout, connection details and erection method, and not only on the weight of the primary members.

The use of STAAD.Pro for the analysis and design of steel structures has been reported in many studies. Researchers who modelled industrial sheds as three-dimensional structures observed that the space model gives a more realistic distribution of wind forces through the roof and wall bracing than separate plane frame models. The ability of the software to generate wind loads automatically from pressure coefficients and to perform member design according to IS 800:2007 was found to reduce design time considerably. Several authors, however, cautioned that the effective length factors, unbraced lengths and member release conditions must be specified carefully, since incorrect parameters can lead to unsafe or overly conservative designs. It was also recommended that the software results be checked

against hand calculations for at least one typical truss and column. The present work follows these recommendations by combining three-dimensional modelling with careful definition of design parameters and manual verification of critical members.

III. SYSTEM ANALYSIS

The structure considered is a single-bay steel industrial shed with a clear span of 20 m, a total length of 48 m divided into eight bays of 6 m, and an eave height of 8 m. The roof is supported by Pratt trusses with a rise of 4 m, giving a roof slope of about one in 2.5, and the trusses rest on steel columns fixed at the base. Galvanised profiled sheeting weighing 0.13 kN/m² is supported on purlins spaced at about 1.4 m. The dead load includes sheeting, purlins, bracing and self-weight, and the imposed load on the roof is taken as 0.75 kN/m² reduced for slope according to IS 875 (Part 2). The basic wind speed is 44 m/s, the terrain is category 2, and the building is assumed to have medium permeability with internal pressure coefficients of plus and minus 0.5. The parameters studied are member axial forces, column moments, support reactions, eave deflection, the governing load combination for each member group and the total steel consumption per unit plan area.

Existing System

In conventional practice, small industrial sheds are often designed by manual methods using standard tables and experience-based member sizes. A single typical truss is analysed by the method of joints or the graphical method for dead load and imposed load, and the wind load is applied as a set of equivalent nodal forces calculated from simplified pressure coefficients. Each truss is treated as a separate plane frame, and the columns are designed as cantilevers or as members of a portal with assumed end conditions. The contribution of roof and wall bracing to the overall stability is usually considered only in a qualitative way, and bracing members are selected by thumb rules. Many fabricators continue to use designs based on the working stress method or on previous projects without detailed checks for wind uplift. Member reversal under suction, the effect of internal pressure, and serviceability checks such as eave deflection are sometimes overlooked, and revising the design for a different span or wind zone requires repeating all calculations.

Disadvantages of Existing System

- Analysing a single plane truss ignores the three-dimensional action of the shed.
- Wind pressure coefficients are often simplified or taken from outdated tables.
- Reversal of member forces under wind uplift may be missed in manual checks.
- Bracing members are sized by rules of thumb rather than by analysis.
- Only a few load combinations can be checked practically by hand.
- Designs based on the working stress method do not reflect IS 800:2007.
- Eave deflection and other serviceability limits are frequently not checked.
- Effective lengths and buckling curves are applied inconsistently across members.
- Repeating the design for a different span or site requires full recalculation.
- Steel quantity cannot be optimised easily without repeated manual iterations.

Proposed System

The proposed approach models the entire industrial shed as a three-dimensional structure in STAAD.Pro and designs it according to IS 800:2007. Trusses, columns, purlins, eave struts, roof bracing and wall bracing are modelled as frame and truss members, with appropriate member releases at pinned connections and fixed supports at the column bases. Dead and imposed loads are applied as member and nodal loads,

and wind loads are calculated from IS 875 (Part 3):2015 using the design wind speed, external pressure coefficients for walls and roof, and both positive and negative internal pressure. Separate wind cases are defined for wind acting at zero and ninety degrees to the ridge. Limit state load combinations, including 1.5 times dead plus imposed load and 0.9 times dead load with 1.5 times wind load, are generated. The analysis gives member forces and deflections, after which the steel design module checks every member for tension, compression, bending and interaction with suitable effective lengths, and member sizes are revised until all checks are satisfied economically.

Advantages of Proposed System

- Represents the complete shed including trusses, columns, purlins and bracing in one model.
- Applies wind pressures from IS 875 (Part 3):2015 for several directions and permeability cases.
- Identifies members that undergo force reversal under wind uplift.
- Designs bracing members according to the forces they actually carry.
- Checks all limit state load combinations of IS 800:2007 automatically.
- Applies section classification and buckling curves consistently to every member.
- Checks eave deflection and truss deflection against serviceability limits.
- Allows member groups to be revised and redesigned quickly for economy.
- Provides support reactions directly for the design of base plates and foundations.
- Produces a steel take-off that helps in estimating cost and fabrication effort.

IV. METHODOLOGY

The methodology starts with fixing the geometry of the shed, including span, bay length, eave height, truss type and roof slope, and with the selection of roofing material and purlin spacing. Loads are calculated next: dead load from sheeting, purlins and self-weight, imposed load reduced for roof slope as per IS 875 (Part 2), and design wind pressure from IS 875 (Part 3) using the basic wind speed, k_1 , k_2 and k_3 factors. External pressure coefficients for walls and roof and internal pressure coefficients are tabulated for each wind direction. The shed is then modelled in STAAD.Pro, with trusses, columns, purlins and bracing assigned trial sections from the IS steel tables. Load cases and limit state combinations are defined, and a linear static analysis is performed. The results are reviewed for member forces, reactions and deflections. Design parameters such as effective length factors, unbraced lengths and steel grade are assigned, and members are checked and optimised using the IS 800:2007 code check, after which the final sections and steel quantity are tabulated.

SYSTEM ARCHITECTURE

The workflow of the study is arranged in stages that proceed from the shed geometry to the final member schedule. The Geometry Definition stage fixes the span, bay spacing, eave height, roof slope and truss configuration. The Roofing and Purlin stage selects the sheeting and determines purlin spacing and size. The Gravity Load stage calculates dead load and roof imposed load according to IS 875 (Parts 1 and 2). The Wind Load stage computes the design wind pressure and applies external and internal pressure coefficients from IS 875 (Part 3). The STAAD.Pro Modelling stage creates the three-dimensional structure with member properties, releases and supports. The Load Combination stage generates limit state combinations as per IS 800:2007. The

Analysis stage computes member forces, reactions and deflections. The Member Design stage checks and optimises truss, column, purlin and bracing sections, and the Serviceability and Quantity stage checks deflection limits and prepares the steel take-off.

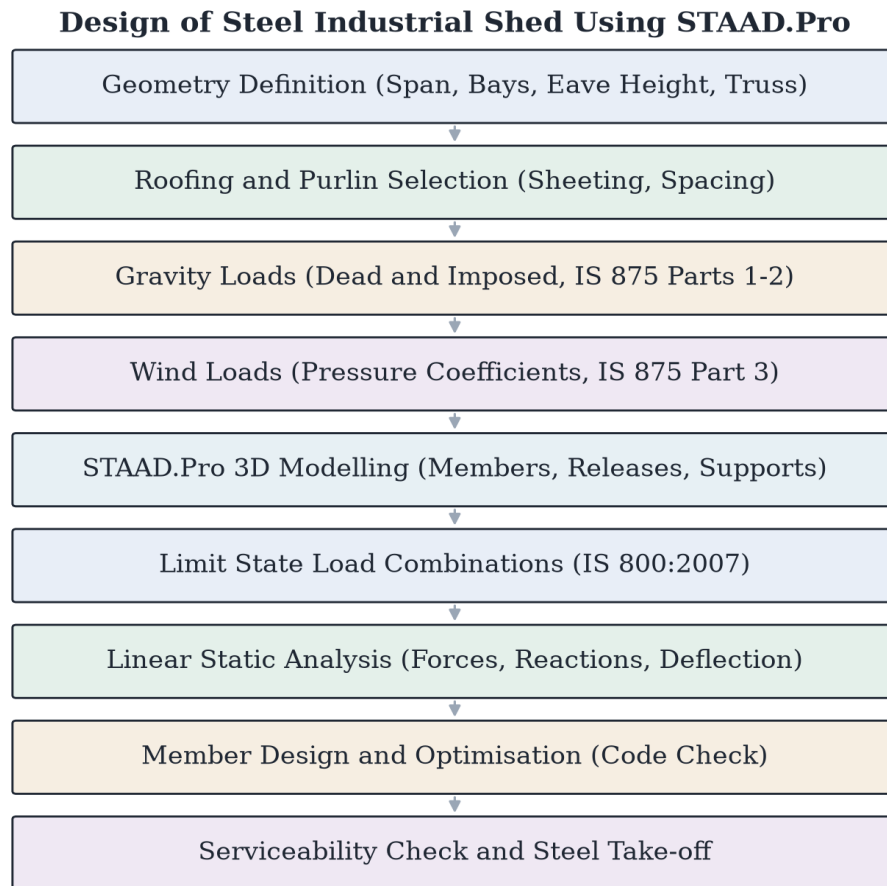


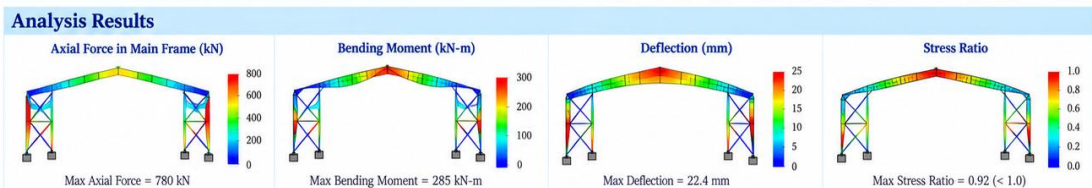
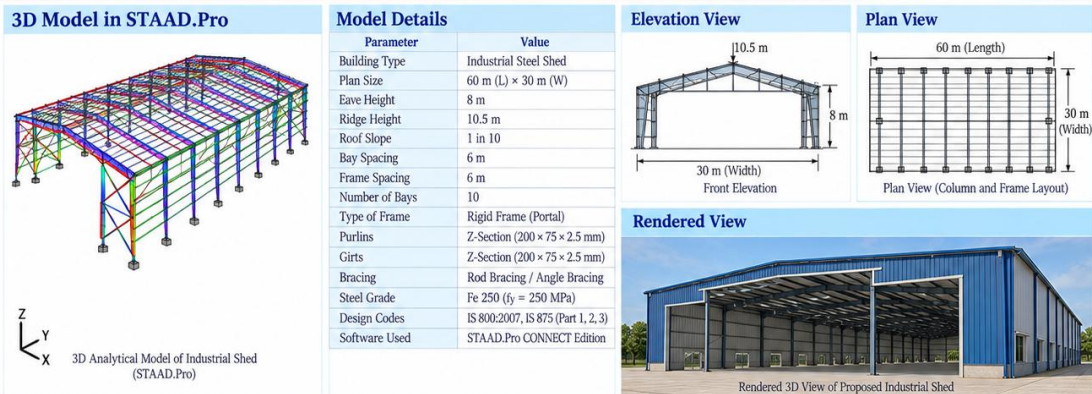
Fig. 1 System Architecture

V. RESULT AND OUTPUT

Design of Steel Industrial Shed Using STAAD.Pro

Analysis and Design as per IS 800:2007 and IS 875 (Part 1, 2 & 3)

STRONG
STRUCTURES
FOR A BETTER
INDUSTRY



Design Results (Selected Members)					
Member	Section Provided	Max Demand	Capacity	Utilization Ratio	Status
Column	ISMB 400	780 kN	850 kN	0.92	Safe
Rafter	ISMB 350	285 kN-m	310 kN-m	0.92	Safe
Purlin	Z 200 × 75 × 2.5	12.5 kN-m	16.8 kN-m	0.74	Safe
Girt	Z 200 × 75 × 2.5	10.2 kN-m	14.5 kN-m	0.70	Safe
Bracing (Diagonal)	ISA 50 × 50 × 6	95 kN	110 kN	0.86	Safe
Base Plate	350 × 350 × 20 mm	620 kN	680 kN	0.91	Safe
Anchor Bolt	4 - M24	155 kN	180 kN	0.86	Safe

Support Reactions		
Support	Vertical Reaction (kN)	Horizontal Reaction (kN)
S1	420	35
S2	415	32
S3	418	34
S4	422	33
S5	417	36
S6	419	31

Load Cases Considered	
1	Dead Load (Self Weight)
2	Live Load (IS 875 Part 2)
3	Wind Load (IS 875 Part 3)
4	Crane Load (if applicable)
5	Load Combinations (IS 800:2007)

Key Observations

- Maximum bending moment in rafter is 285 kN-m.
- Maximum axial force in column is 780 kN.
- Maximum deflection is 22.4 mm, which is within permissible limit ($L/180$).
- All members are safe as per IS 800:2007.
- Wind load governs the design for lateral stability.
- Proper bracing system ensures stability and reduces lateral displacement.
- The design is economical and suitable for industrial use.

Conclusion

The steel industrial shed has been successfully modeled, analyzed and designed using STAAD.Pro as per IS 800:2007 and IS 875 (Part 1, 2 & 3). The structure is safe, stable and economical, with all members within permissible limits. The design can be adopted for construction with proper detailing and fabrication.

STAAD.Pro provides an efficient and reliable solution for the analysis and design of steel industrial sheds, ensuring safety, stability and economy.



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VI. CONCLUSION

The analysis and design of a steel industrial shed with a span of 20 m, length of 48 m and eave height of 8 m has been carried out using STAAD.Pro according to IS 800:2007 and IS 875 (Parts 1 to 3). The complete shed was modelled as a three-dimensional structure including trusses, columns, purlins and bracing, which allowed the wind forces to be distributed realistically through the roof and wall bracing systems. The loads were calculated systematically, and all limit state combinations required by the code were considered in the analysis.

The results showed that wind load is the most significant action for this type of structure. The combination of dead load with wind uplift and positive internal pressure governed the design of the top chord members and several web members, which experienced compression under this case even though they were in tension under gravity loads. The columns were governed by the combination of axial load and bending due to lateral wind pressure on the side walls. These findings confirm that a design based only on gravity loads would be unsafe for light-roofed industrial sheds. The member design carried out using the IS 800:2007 module of STAAD.Pro ensured that every member satisfied the strength, slenderness and interaction requirements with a maximum utilisation ratio below unity. The eave deflection under wind load was within the permissible limit of height divided by 150, and the truss deflection was also within acceptable values. The final design resulted in a steel consumption of

about 24 kg per square metre of plan area, which is consistent with typical values for conventional trussed sheds of similar span.

The study demonstrates that three-dimensional modelling combined with code-based design in STAAD.Pro gives a safe, economical and well-documented design for steel industrial sheds. Future work can include the design of connections and base plates, the comparison of different truss types and roof slopes, the analysis of sheds with gantry cranes, and the comparison of conventional trussed sheds with pre-engineered building frames using tapered sections. The effect of seismic loads according to IS 1893 on taller sheds with heavy cladding can also be investigated.

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