ANALYSIS & DESIGN OF CONVENTIONAL STEEL SHED

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Abstract— **Conventional steel buildings or sheds are traditional metal structures constructed by rolled steel sections which are designed individually and fabricated at site using welding and cutting. An industrial building with a plan dimension of 20 m x 30 m, and Clear height of 10 m, and roof slopes that are practically viable is taken into consideration for analysis and design in this study. This paper Introduces the Design and Analysis of Conventional steel shed which should be stand for Stability to prevent overturning, sliding or buckling of the structure, or parts of it, under the action of loads. It includes Pratt Type Truss shed design with 5 MT E.O.T Crane loading on the structure and some unpredicted loading, i.e. dead, live, wind & Seismic Loading, and create the model of designed shed geometry. The Designed is carried out as per IS800-2007, for wind load IS875-part III & for Seismic load IS1893-2002 is Considered.**

Index Terms— **Conventional Steel Shed, IS800-2007, IS875-Part III, Pratt type Truss, 5MT E.O.T Crane.**

I. INTRODUCTION

Steel structures are assembly of structural steel shapes joined together by means of riveted / bolted or welded Connections. Steel structures are light weight structures and are extensively used, especially to span large gaps. For single storey industrial buildings, mostly trusses are used as roofs to resist gravity loads. To resist lateral loads and to give lateral stability in horizontal planes, trusses can also be used in walls and horizontal planes. The loads are assumed to be acting only at the nodes of the trusses. Such trusses can be analysed manually by the method of joints or by the method of sections. In this paper whole truss is analysed statically using manual calculations, Excel Design and using Software. Provisions given in IS codes are used to solve the examples. Here focus is only given to truss calculations of Pratt type Truss. In steel structures, a truss is a rigid structure composed of several members joined at their ends. Roof trusses are mostly a part of industrial structures which can be used as auditoriums, workshops, storage houses, ware houses etc. Purpose of providing roof truss is to carry roof dead loads, Live loads and lateral loads due to wind and earthquake. In this study paper, Pratt truss are taken for design. Industrial building is generally classified as braced and unbraced framed structures. In braced buildings, the trusses rest on column with hinges and stability is provided by bracings in three mutually perpendicular planes. The basic function of a bracing is to transfer horizontal loads from frames i.e. loads like wind or earth quake or horizontal surge due to acceleration and breaking of travelling cranes over gantry girders to the foundation. The longitudinal bracing provides stability in longitudinal direction on each longitudinal end provides. The gabble bracing provides stability in the lateral direction. The tie bracing at the bottom chord level transfers the lateral loads (due to wind or earthquake) of truss to the end gabble bracings and similarly the rafter bracing and the bracing system at bottom chords work. Whereas the purlin acts as the lateral bracings to the compression chords of the roof trusses which increases the compression chords design strength. The unbraced frames such as portal frames are the most common type of frames used in industrial building construction because of its simple design, economy, easy and fast erection. This type of frames provides the large utility area with maximum column free space. In such type of structures the inner columns are eliminated, requires considerably less Foundation and its area, the valley gutters and the internal drainage too. The portal frame is a rigid jointed plane made from hot rolled or cold rolled sections, supporting roofing and side cladding.

II. LITERATURE REVIEW

1. **David Alexandre Ferreira Ivo- "Design of a steel structure for a large span roof with emphasis on the verification of bolted connections (July2016)"-** The main objective of the thesis is the conceptual and detailed design of a steel structure for large span roofing by means of lattice girders. These procedures include a conceptual analysis of a proposed roofing system (36x56 meters) as well as the detailed checking of the members and connections in accordance to *EN 1993.* For the purpose of analysis, the structure is modelled with the software SAP2000 as a series of 2D structures, effectively simulating the path of forces in the structure. Regarding the connections, focus is given to detailed design under ultimate limit state of gusset plates as well as spliced plate connections used for chord continuity. Serviceability is evaluated in terms of overall deflection and taking into account the effects of slack recovery.

2. **Dr. S. Biswas- "Design of Large Span Roof Truss under Medium Permeability Condition (2018)"-** RCC structures for covering a larger area become heavy and hence uneconomical. In such cases, steel roof trussed building are used and become economical due to its lighter weight. A 20 metre span steel roof truss is considered in this study. IS: 875 (Part I, II and III) have been considered in the calculation of loadings on roof truss. Finally the analysis as well as design of the roof truss has been carried out by STAAD Pro V8i. Limit State Method is adopted here. A suitable fink roof truss is to be designed for covering an industrial building (45 metre long and 20 metre wide). The building is to be built in New Delhi.

Medium permeability condition is used in this study. The trusses are to be spaced at 3 metre intervals. Asbestos cement (AC) sheet is used as roof coverings.

3. **Vivekkumar Vaghela- "Comparative Analysis of Pratt and Howe Truss Considering Different Eave Height and Span"-** In this study paper, Howe and Pratt truss are taken for different spans and eave heights. Four different spans 5m, 10m, 15m and 20 m have taken in to consider with eave height of 5m, 10m, 15m and 20m. Analysis is done using Staad pro software and design for various structural elements like Purlin, Roof Truss, compression member, Tension member etc. were carried out using Microsoft office excel sheet. From various member forces obtained from Staad software, a cost comparison sheet is prepared for pratt and howe truss**.** If height remains constant and span increases, tensile forces and compressive forces are increasing in Howe truss as compared to Pratt truss for Tie beam, Vertical member & Diagonal member.

4. **Vrushali Bahadure, Prof. R.V.R.K. Prasad (January -February 2013)- "Comparison between Design and Analysis of Various Configuration of Industrial Sheds".-** Comparison between various configurations of industrial shed using various types of truss type which gives us that which shed is suitable for the industrial shed and which is more effective in strength and economical point of view. Design of various types of industrial frame by using STAAD-Pro 2007 software which gives us there total design and suitability. A truss is essentially a triangulated system of (usually) straight interconnected structural elements; it is sometimes referred to as an open web girder. The individual elements are connected at nodes; the connections are often assumed to be nominally pinned. The external forces applied to the system and the reactions at the supports are generally applied at the nodes. When all the members and applied forces are in a same plane, the system is a plane or 2D truss. Saw tooth type industrial shed is 65% more economical than portal and A-type frames which means it is economically good.

5. **Milind Bhojkar and Milind Darade (December 2014) on "Comparison of Pre Engineering Building and Steel Building with Cost and Time Effectiveness". International Journal of Innovative Science, Engineering & Technology (IJISET), Vol. 1 Issue 10** They observed that, the Pre-engineered building system is unmatched in its speed and value and that's why they are said to be economical for modern construction. The erection time of the pre-engineered building is 50% of conventional steel building or less than 8 weeks. Clear spans up to 90 meters wide (could be extended up to 150 m in case of Aircraft hangers) and eave heights as high as 30 meters are possible. The cost may be approximate 30% of Conventional steel Building only. The various types of Main frame for the basic supporting component in the PEB systems; main frames provide the vertical support for longitudinal and lateral stability for the building in its direction while lateral stability in the other direction is could be achieved by application of bracing system. The Pre-engineered buildings could be high rise buildings Conventional steel buildings are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof trusses can be used for these structures depending upon the pitch of the truss. For large pitch, Fink type truss can be used; for medium pitch, Pratt type truss can be used and for small pitch, Howe type truss can be used. Skylight can be provided for day lighting and for more day lighting, quadrangular type truss can be used. The selection criterion of roof truss also includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. Several compound and combination type of economical roof trusses can also be selected depending upon the utility. Standard hot-rolled sections are usually used for the truss elements along with gusset plates.

III. OBJECTIVE

The objectives of structural design is to design the structure for stability, strength and serviceability. It must also be economical and aesthetic. The design of a structure must satisfy three basic requirements:
1) Stability to prevent overturning, sliding or buckling of the structure, or parts of it, under the action of loads,
2) Strength to resist safely the stresses induced by the loads in the various structural members.
3) Serviceability to ensure satisfactory performance under service load conditions - which implies providing adequate stiffness and reinforcements to contain deflections, crack-widths and vibrations within acceptable limits, and also providing impermeability and durability (including corrosion-resistance), etc.
4) Design a structure that is not only appropriate for the architecture, but also strikes the right balance between safety and economy.

IV. METHODOLOGY

Analysis of all the investigation procedures and methods is methodology. Methodology depends on the objective of the project. Based on the objective the methodology is decided. In the present case, based on the objective manual calculation is carried out then preparation of model and analysis and design is done.
1. Study of conventional steel Pratt frame, shed is carried out.
2. The necessary data such as height, span, length, type of section is decided based on most construction practices in India.
3. The dead load on the structure is manually calculated using IS 875 (Part1)
4. The imposed load on the structure is manually calculated using IS 875(Part2)
5. The wind load on the structure is manually calculated using IS 875(Part3)

6. Using STAAD Pro. Software models of conventional truss shed is carried out by the mention plan dimension and eave height.
7. Manually calculated loads are applied to the models prepared.
8. Using Indian standard code 800-2007(limit state design) design of frames is carried out.
9. Using STAAD Pro, the steel structure is analyzed and designed by subjecting the frame to various load combinations and frame sections.
10. Check for slenderness is carried out and it is made sure that all the sections are passed in the software.
11. Manual design of purlins will be carried out and checked with the software results.
12. The present study is mainly concentrated on the steel take-off of the conventional Pratt truss shed, including primary and secondary.9. Using STAAD Pro, the steel structure is analyzed and designed by subjecting the frame to various load combinations and frame sections.
10. Check for slenderness is carried out and it is made sure that all the sections are passed in the software.
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V. ANALYSIS AND DESIGN OF STEEL STRUCTURE

5.1 Required data of the shed

1. Plan size - 20m x 30m
2. Clear Height - 10 m
3. Type of sheeting used is Profile sheet or GC sheets
4. Place where the structure is to be constructed is Wardha
5. Width: 20m
6. Length: 30m
7. Bay spacing: 5m
8. Roof angle: 11.30◦
9. Consider Eave height : 11m
8. Roof type: Pitched
9. Slope of Roof: 1:05
10. Considered the building wall Condition is 3.0m brick wall & above sheeting there for the building is design as a enclosed building.
11. Terrain category is consider 3.
12. And the wind internal coefficient as per IS 875 PART III is +0.2 &-0.2.
13. Collateral load =0.2 kN/m2 for solar panel
14. 5 MT E.O.T crane having top of Bracket 6.0m and electrically driven.

5.2. Dead load calculation

1. Galvanized iron sheeting: 0.055kN/m2
2. Purlin wt : 0.05kN/m2
3. Total dead load: 0.11kN/m2
4. As per IS800-2007 the minimum dead load: 0.15Kn/m2
5. Dead load on roof: 0.15*5=0.75kN/m2
6. Dead load of roof: 0.15*5*20=15kN
7. Weight of purlin (assuming 50N/m2) : 0.05*20*5=5kN
8. Welded sheet roof truss weight: 0.125kN/m2
9. One truss frame self-weight: 0.125*5*20 = 12.5kN
10. Total dead load: 32.2kN
11. Number of internal nodes at top chord: 6
12. Intermediate nodal point dead load: 32.2/6 = 5.367kN
13. End nodal point dead load: 5.367/2 =2.683kN

5.3 Live load calculation

1. Since the roof angle is more than 10◦ following reduction is to be considered
2. Live load: 0.75-0.02(11.309^0 - 10^0) = 0.7238kN/m2
3. Total live load: 0.7238*5*20 = 72.38kN
4. Total live load: 0.7238*5= 3.619kN/m2
5. Intermediate nodal live load: 72.38/6 =12.063kN
6. End Nodal point live load: 12.063/2 = 6.03kN

5.4 Wind load calculation

1. Indian standard 875 part 3 is used for the following wind load analysis
2. Height (h): 11m
3. Width (w): 21M O/O of steel line
4. Length (l): 31m O/O of steel line
5. Roof angle: 11.309◦

STEP 1: Wind data

1. Place where the structure is to be constructed: Wardha
2. As per IS 875 Part3 2015 the basic wind speed: 44m/s

STEP 2: Terrain Category

Terrain category: Category 3

STEP 3: Design Factor

1. Risk coefficient (k1 Factor): 1 (For general building and structures from table 1 Clause 6.3.1 IS875 Part III)
2. Terrain factor or height factor (K2 Factor): 0.92 (For height = 11m ans by interpolation from table 2 clause 6.3.2.2)
3. Topography (k3 Factor) : 1.0 (The upward wind slope less than 3◦)
4. Importance factor for cyclonic Region (k4): 1.0 (All other structures wich is far away from sea coastal area)

STEP4: Permeability of the building

1. Permeability is between 0% to 5%
2. Internal Pressure Coefficient: ±0.2

STEP 5: Design wind pressure

1. Design wind speed Vs : Vb * k1 * k2 * k3 * k4
   = 44*1*0.92*1*1 = 40.48 m/s
2. Wind pressure (pz): 0.6Vz2 = 0.6 * 40.482= 0.983 kN/m2
3. Design wind pressure (Pd): kd *ka *kc* pz

Where, kd= wind directionality factor is 0.9 for triangular, square, rectangular building
ka = 0.86 area averaging factor (from table 4 clause 7.3.3.13)
kc= 1, combination factor (see clause 7.3.313)

The value of Pd, However shall not be taken as less than 0.7pz i.e 672 N/M2

Therefore, Pd= 0.9 * 0.86 * 1 *0.983
= 0.76 kN/m2

STEP 6 : Calculation of Cpe, external wind coefficient

11/20 = 0.55 (h/w ⩽0.5)

Therefore, 1/2 < h/w ⩽ 3/2

&

30/20=1.47 (1 ⩽ l/w ⩽ 3/2)

Table:1.1 The Cpe coefficient for wall is as follows.

Wind angle	Cpe for wall				Local Cpe
Θ (deg)	A	B	C	D	-0.8
0	0.7	-0.25	-0.6	-0.6	
90	-0.6	-0.6	0.7	-0.25	

If h/w=11/20=0.55 (1/2 ≤h/w≤3/2)

Roof Angle =11.309°

Table:1.2 The Cpe coefficient for roof is as follows.

0 (deg)		90(deg)	
EF	GH	EF	GH
-1.1	-0.6	-0.8	-0.8
-1.036	-0.59	-0.8	-0.8

STEP 8: Calculation of wind forces
The Wind forces are calculated by below formula:

F= (Cpe-Cpi)*A*Pd

Where, A = Tributary Area of members

Table 1.3 Wind forces at 0^0, 90^0, 180^0, 270^0 for +0.2 & -0.2 internal coefficient

Direction	**Cpi=+0.2**				**Cpi=-0.2**			
	0^0	**90^0**	**180^0**	**270^0**	**0^0**	**90^0**	**180^0**	**270^0**
WL	1.9	3.42	-1.71	-0.19	-3.04	-1.52	-3.04	-1.52
RL	-4.74	-3.22	-2.99	-1.47	-3.8	-2.28	-3.8	-2.28
RR	-2.99	-1.47	-4.74	-3.22	-3.8	-2.28	-3.8	-2.28
WR	-1.71	-0.19	1.9	3.42	-3.04	-1.52	-3.04	-1.52
LEW	-3.04	-1.52	-3.04	-1.52	1.9	3.42	-1.71	-0.19
REW	-3.04	-1.52	-3.04	-1.52	-1.71	-0.19	1.9	3.42

5.5 Crane Load Calculation & its Design:

Demag Crane data is used to calculate single girder 5MT crane shows in fig1.2

Demag Cranes & Components (India) Pvt. Ltd.

Single Girder EOT Crane.

DEMAG Cranes & Components

20.05.2002

SWL (KG)	Span Lkr Mt.	Dead Wt Of Crane (KG)	Max Wheel Load-Rmax (KG)	Min Wheel Load-Rmin (KG)	Dimensions (Refer Enclosed GA) (in mm) X1	d	e kt	L e kt	b	Hoist Wt (KG)
5000	10	2250	2875	750	1100	112	2000	2416	200	470
	15	3100	3200	850	1200	112	2000	2416	200	470
	20	4750	3650	1225	1350	125	3150	3586	200	470
	24	7250	4300	1825	1500	125	3150	3586	200	470
10000	10	3700	5600	1250	1100	160	2000	2492	200	1190
	15	5200	6200	1400	1250	160	2000	2492	200	1190
	20	7000	6750	1750	1350	160	3150	3682	200	1190
	24	9200	7350	2250	1500	160	3150	3682	200	1190

FIG. 1.1 Demag Crane data

STEP 1 :Load Generation

= (legth of beam-e^{kt})/0.1

=(3*5-3.15)/0.1=119 no.

STEP 2: Maximum wheel load =32*1.5=48KN

Minimum wheel load =12.25*1.5=18KN

hoist wt=4.7KN

STEP 3: Lateral Surge

= (hoist wt+Crane capacity)*20%

=(4.7+50)*20%

=11KN

Fxmax=0.7*lateral surge=8KN

Fxmin=0.3*lateral surge=3KN

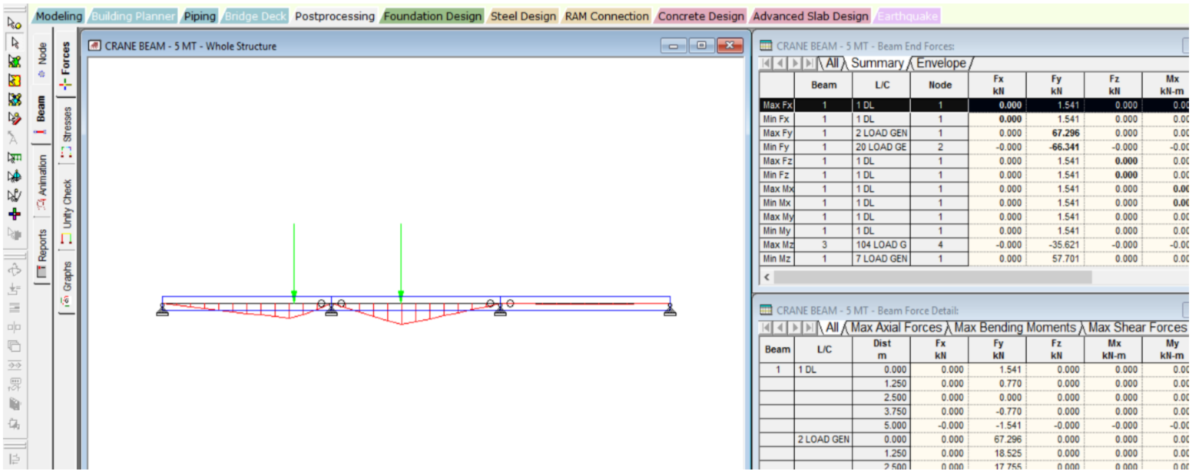

Fig.1.2Crane beam Design check in Staad pro

STEP 4: Vertical Forces:

Fymax=0.7*lateral surge=67 KN

Fymin=0.3*lateral surge=30 KN

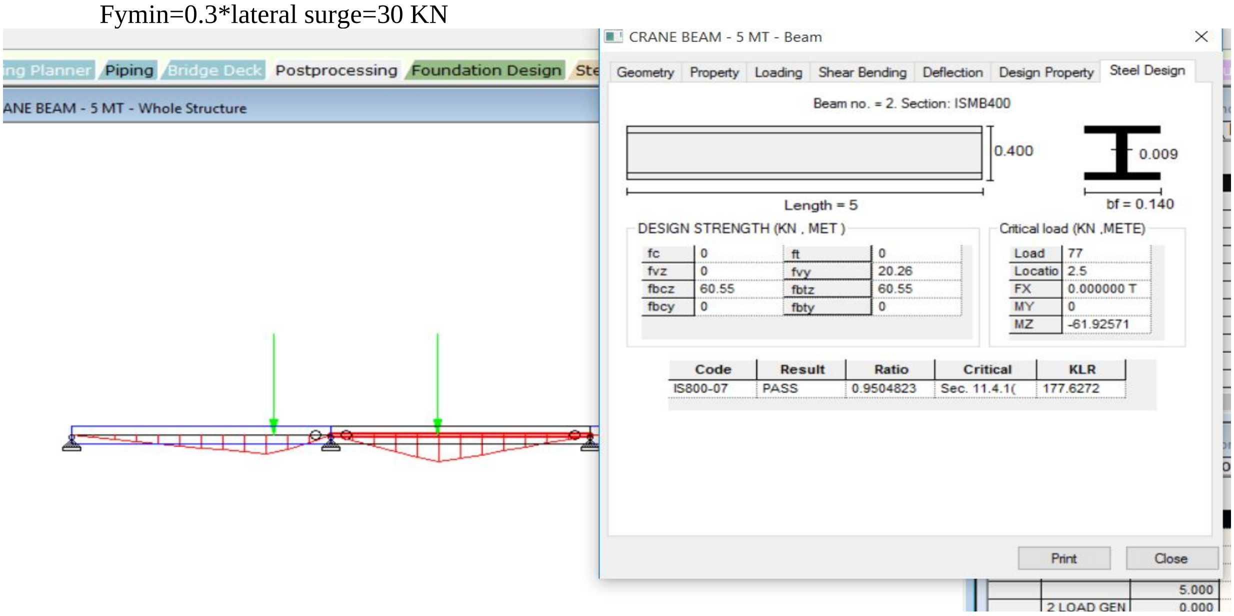

Fig. 1.3 Crane beam size ISMB 450

5.6 Seismic loading:

As wardha location have seismic Zone II & Soil is considered medium

STEP 1: Design Acceleration Spectrum

Ah= (Z/2)*(sa/g) / (R/I)

= (0.1/2)*(2.5)/(5/1)

=0.025

Where, Z= 0.1, Seismic zone factor given in table 3 of IS1893-2002..

I= 1, Importance factor given in IS 1893-2002

R=5, Response reduction factor (for steel building with SMRF)

(sa/g)= Design acceleration coefficient

STEP 2: Time period=0.085*h0.75 (for steel MRFbuilding)

=0.085*110.75

= 0.513 Sec.

STEP 3: Later force Calculation:

:. VB = Ah w

Where, VB-Lateral forces

W- Self weight of building

VB min for zone II = 0.7% of wt

{note: as per IS1893-2002, damping ratio is 5%}

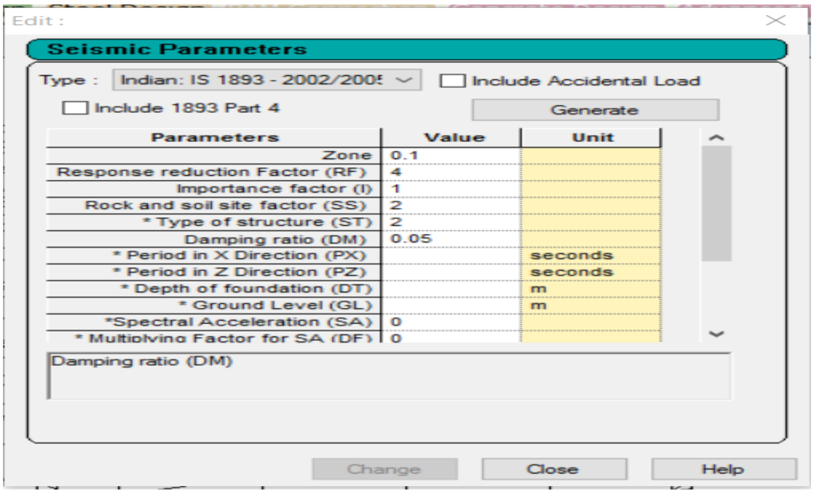

Fig. 1.4 Seismic data for wardha location.

5.7 Load Combination:

A load combination results when more than one load type acts on the structure. Building codes usually specify a variety of load combinations together with load factors (weightings) for each load type in order to ensure the safety of the structure under different maximum expected loading scenarios.

IS 800-2007
Limit state of serviceability
DL+LL)
(DL+WL/EL)
(DL+LL+CL)
(DL+0.8*LL+0.8*CL+0.8*WL/EL)
Limit state of strength
1.5(DL+LL)
1.5(DL+WL/EL)
0.9*DL+ 1.5*WL/EL
(1.5*DL+1.5*LL+1.05*CL)
(1.5*DL+1.05*LL+1.5*CL)
(1.5*DL+1.05*LL+1.5*CL)
(1.2*DL+1.2*LL+0.6*WL/EL+1.05*CL)
(1.2*DL+1.05*LL+0.6*WL/EL+1.2*CL)

Fig.1.5 Load combination as per IS800-2007

5.8 Design Parameters:

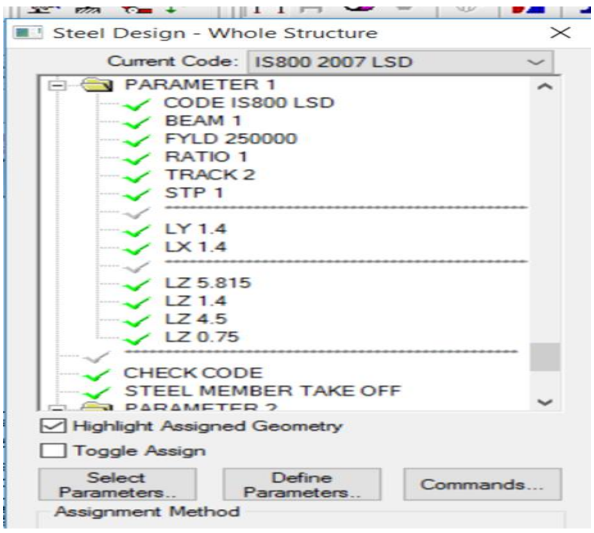

Fig.1.6 Parameters apply in staad-pro

5.8 Analysis Result from staad-pro:

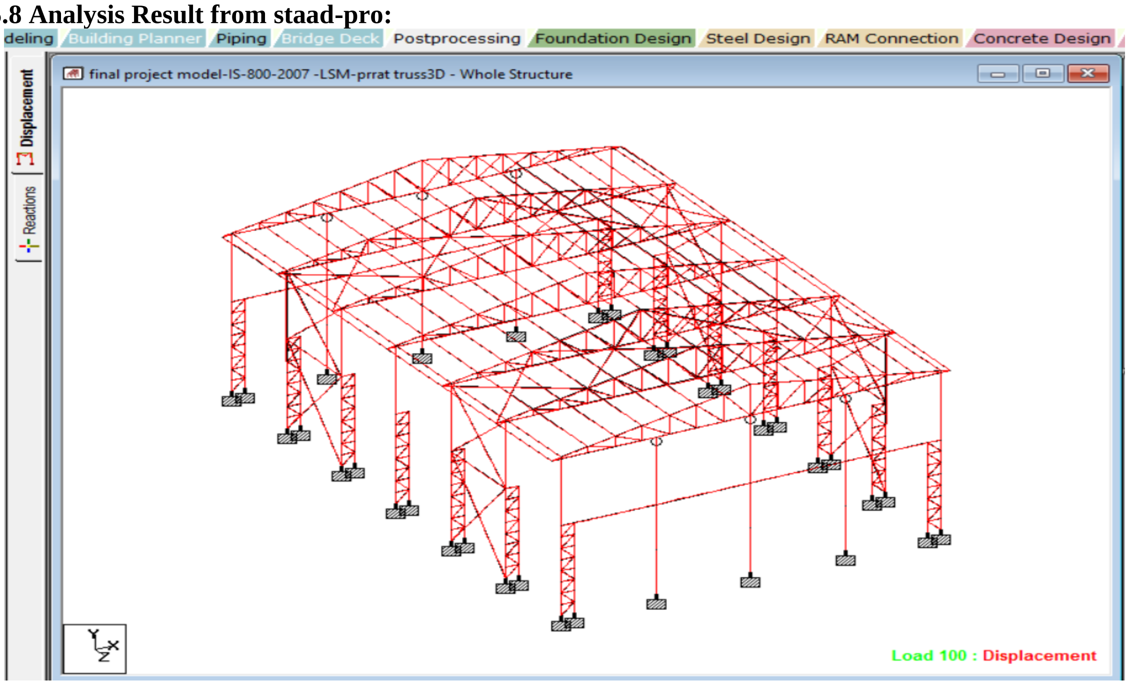

Fig.1.7 Analysis in staad-pro

VI. RESULT AND CONCLUSION

- After numbers of trial and error the final optimize structure sizes are passed with safe utility ratio and steel take off obtain is as follows:
- The steel take off obtain is 196.515 Kn that is 20044.53kg.

TOPAND BOTTOM CHORD	RHS200X100X5
INNER TRUSS MEMBERS	SHS 100X100X5
COLUMN	ISMB 250 & ISMC125
INNER TRUSS MEMBERS IN COLUMN	ISA 50X50X5
PURLIN	200Z1.6
BRACING	ISA110X110X10LD

Table 1.5 Section sizes used in staad

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STEEL TAKE-OFF
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   PROFILE                    LENGTH(METE)       WEIGHT(KN   )

856. 144 TO 146 150 TO 152 156 TO 158 162 TO 175 177 179 180 183 TO 188 -
857. 192 TO 196 200 TO 207 211 TO 218 221 TO 234 236 237 239 TO 253 255 TO 267 -
858. 269 TO 274 280 281 285 TO 294 299 TO 377 379 TO 406 408 TO 413 416 TO 419 -
859. 424 TO 433 438 TO 516 518 TO 545 547 TO 552 555 TO 566 571 TO 649 -
860. 651 TO 678 680 TO 685 688 TO 699 704 TO 782 784 TO 811 813 TO 818 -
861. 821 TO 832 837 TO 915 917 TO 944 946 TO 951 954 TO 965 970 TO 1048 -
862. 1050 TO 1077 1079 TO 1084 1087 TO 1090 1095 TO 1101 1234 1236 TO 1238 1240 -
863. 1277 TO 1280 1298 TO 1304 1306 1308 1311 1313 1315
ST   ISMB250                      210.00              76.789
ST   200X100X5.0RHS               212.18              46.225
ST   ISMB450                        9.80               6.949
ST   ISMC125                       87.43              11.149
ST   ISA50X50X5                   183.49               6.752
ST   100X100X5.0SHS               344.95              48.652
                                         ----------------
                                TOTAL =           196.515
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Fig.1.8 Steel take off in staad-pro

References

[1]]David Alexandre Ferreira Ivo- "Design of a steel structure for a large span roof with emphasis on the verification of bolted connections (July2016)"

[2] Dr. S. Biswas- "Design of Large Span Roof Truss under Medium Permeability Condition (2018)"-

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[15] IS801 For cold form member design

[16] I811 -1987 Cold form member section table