iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** IV **Month of publication:** April 2020

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue IV Apr 2020- Available at www.ijraset.com

Comparative Study on Analysis and Design of Roof Tubular Truss for Cricket Stadium

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***Abstract:** In this study the main structural components of the cricket stadium are presented, with the combinations of the superstructure with the priority on the steel roof structure. The cricket stadium comprise shape are considering the elliptical plan, the main purpose of this study to analyze the steel roof tubular truss for under the long span for cricket stadium according to the Indian standards codes IS: 800-2007. The tubular hollow section can be used for this study so as per IS-4923:1997 and design 'Howe truss' can be used. The dead load, live load, wind load and some other combination, wind load can be considering as per IS-875(PART-3):2015. The tubular roof truss is perfect alternate sources of the convenient comparatively optimum specification. Analysis of tubular truss elements was carried out with software program of staad pro and also the manually applying as per Indian standards and ACI-318-14(American concrete standards) and SP-38(S&T).*
***Keywords:** Analysis and Design of Tubular Truss, Tubular roof truss, large span roof truss, Howe truss, Staad pro.*

I. INTRODUCTION

The main structural components or elements of the cricket stadium show with a superstructure the particular components of structure on building structure and top roof structure. Cricket stadium superstructure basically divided into two parts, first is the reinforce concrete frame structure in building components and second is above the reinforce concrete structure above area is of building frame it is completely erected in steel material. The reinforce concrete structure and steel roof structure are combined as a new modern structure created.[1] Now days our country going the fastest developing nation will be converted; our country changes each and every state to the green city and metro city modification can be created. The Nanded city is a new improving modern or green city developed in nation.

The advancing modern state of Nanded infrastructure is most important, infrastructure like high rise building, national highway, airport, established sport complex or convoluted etc. are essential. In international cricket stadium are one of the type infrastructure to show the uniqueness of city, it is not incomparable. Cricket stadium structure itself milestone mark like many of the designs performance previous or past time, cricket is the most famous game in the world. Cricket stadium not only the places emotion and attached with the happiness, attraction also to the cricket fans.

The present day cricket stadium designed to satisfy or accomplish every criteria is including the player comfort, safety, security or surveillance, convenience and crowd management etc. In this study to analysis and design of cricket stadium with elliptical steel roof tubular truss; in intended to understand the structural analysis and design concept of cricket stadium for steel roof tubular truss. The steel roof tubular truss is the analysis and design for cricket top roof portion, tubular truss is basically framed structure connected to the members their end to end connections. The tubular truss is the one type of hollow structural section(HSS) truss of section to arranged the hollow structural section type truss is the triangles and N-type because we can selected for stadium truss analysis and design to decided the "Howe Truss" type is used.

The Howe truss is generally use for long span, that's why the triangular frame and N- type frame arrangement taken for work. N and triangular frame arrangement is considering the axially loaded member and N-type connection properly distributed load acting at downward side is distributed in node to node in whole structure. N-type truss system pattern is stronger than other arrangement for long span. They are more capable to resisting external forces or loads acting on section, to all members nearly uniformly stress. Tubular sections are economical for long span section. The critical study of analysis and design of steel material is equal to other section method is consider.

Analysis and design problem depends on the dimension, environment, economical or convenience. They can used analysis and design for truss is used rectangular hollow section(RHS) and square hollow sections (SHS) is taken in hot-formed section, there is greater stiffness and lateral strength mean they are easier to pickup and sable to erect.

Protective cost is appreciable lower for hollow section truss than other trusses and higher structural efficiency. The small surface are hollow section lower cost for protection against corrosion and general maintains of structure is minimum, hollow section strength to weight ratio of section compared to open section such as I-beam allows lighter structures saving steel and simplifying construction assembly.[2] The analysis and design tubular truss considering Dead load, Live load, and wind load and other combination as per Indian standards used IS-800:2007, IS 4923:1997, SP-38(S&T):1987, ACI-318-14, IS-806:1968 can be used, and Analysis and design of cricket stadium also check with the computer software program named "STAD-PRO".[10]

A. Overview of Cricket Stadium

The cricket stadium is located at Nanded city, total area of stadium is built-up 39471.71m^2 and seating capacity of stadium 30,000spectors. Stadium provided the proper arrangement of each and every small aspect or fractures can be carefully designed because the stadium is extremely milestone unique landmark of structure so international stadium should be provided completely facility.

The stylish modern stadium should be provided spacious and excellent, wonderful dressing room and also providing the proper armament of furniture because heavy kitbags are available in for these settlements of players officials and other match officials room carryout their enterprise in convince and security and safety. Cricket stadium should be converted to protect spectator from the rain and blinding light for strong sunlight. They are some relatively constant steady sunshine is normal, shade provide by roof should be available to all open area at least a certain time or duration of game. The stadium should be design that all parameters are essentially comfortable and secure, it have a perfect view of each and every person of pitch without any obstruction, and have easily accessible to toilets, snack zone, exit to from seating and emergency situation are carefully planned entry to exit area.

The arrangement of seating is provided is continuous the maximum seating can be easily placed in stadium and fireproof capable of withstanding can be maintained carefully. It is most important factor that the whole or total process is not stressful slow arriving at stadium with a ticket for stadium sector area. Most important in stadium in room is IT room, generator room, anti-doping room, matchrefre room and ICC and BCCI chairman room is very essentially planned because not allowed any one outsides in this area of room and also safety, security point of view can be managed every facility.

B. Objective of Study

The main aim of this study provides which method is most economical truss will be analysis and design for stadium method and considering some important parameter is high bending strength, more load carrying capacity and flexural strength by analysis of method.

The objectives of this project study are often shortening as follows:

1) To analysis and design the tubular roof truss for cricket stadium.
2) To optimize the cost of roof truss.
3) Making model of tubular truss for stadium and verifying results with the help of Stadpro software.
4) To design a tubular truss for stadium under wind condition.
5) To study the provision of IS-4923: 1997 & IS- 800:2007, IS- 806: 1968, and SP- 38 (S & T): 1987.
6) To study of wind load design method for stadium structure parameter taken as per IS- 875(part-3):2015.
7) To critical study of effect of wind load on structure.

II. TUBULAR SECTION

The tubular roof truss are generally used in long span construction such as workshop, industrial building, auditoriums, sport complex etc. they used for span as large (25-30m). A truss is essentially to another name of tubular truss is monitors and Hollow sections to admit daylight into the space. The tubular hollow section is type of metal profile with the hollow cross section. The HSS (Hollow structural section) is only composed of structure from codes.[3]

The mainly three type of Hollow section are as follows:-

Rectangular Hollow sections (RHS)

Square Hollow sections

Circular Hollow section

A. Advantages of Hollow Sections

1) Hollow sections there are greater strength as of weight ratio which means the weight of section is less due to this cost is minimum.
2) Hollow sections are very useful as support characteristics and in compression of structural member.
3) The hollow section torsion constant is greater than 200 times in open sections.
4) The maintains cost of hollow section is minimum.
5) Compressive strength and torsion or twisting, because of that tubular is section grater efficiently than conventional steel section.
6) The tubular truss is ease to fabrication and erected as compared to conventional steel sections.

B. Uses of Trusses in Structure:

Tubular trusses are utilized in a wide range of structures, economical, where there is a necessity for large spans, such in airport terminals, aircraft hangers, sports stadium roofs, auditoriums, tall building and other steel structure. Tubular trusses are also utilized to carry hefty loads and are sometimes utilized as transfer buildings, extensively utilized to assist two main functions:

1) To carry the top roof load.
2) To providing horizontal stability.[3]

C. Loading Consideration:

Loads are forces considering effecting and producing deformations and stresses or displacement in steel structure. Cricket stadiums are subjected to several types of loads. They are gravity loads and lateral loads. Gravity loads are some other classified as dead loads and live loads. The two primary lateral loads on cricket stadiums are wind and earthquakes. Design load combinations are also used.

Load Calculations: The different analyses have been using as per Indian standard, the various load combinations considered in the analysis are as follows:

1.5 DL + 1.5 LL
1.2 DL + 1.2 LL +1.2 WL
1.2 DL + 1.2 LL - 1.2 WL
(DL + LL + WL) x 1.2
1.2 DL + 1.6 LL
0.9 DL + 1.0 WL

The as per the different analyses for different geometry and section specifications are compared for optimization of roof tubular truss design.[4]

III. PREPARATION FOR ANALYSIS AND DESIGN CALCULATION

The steel tubular truss has been design as simply supported on column and cantilever portion of truss, analysis of N- type truss has been done on the basis of Indian standards.[7]

The analysis of N-type truss has been done on the basis of relevant Indian Standards for the following different parameters:

A. Span length of N-type trusses = 32 m
B. Spacing between trusses = 5.163m
C. Roof slope=1 in 6
D. Column-1 height = 11 (metres)
E. Column-2 height = 5 (metres)
F. Wind zones = III
G. Terrain category = 4

1) *Truss Configuration:* A configuration which is compound of (a) Howe type of truss (b) N- type truss has been used for N-type truss has been analyzed and design.
2) *Dead Loads:* Dead loads considering of the weight of all material and fixed components incorporated into the stadium structure, as per IS:875 (Part-I) –2015 has been considered to calculate dead load.
3) *Live Loads:* Live loads shall be the maximum loads normal by the intended use or utilized. They may be considering the tentative load taken in fully or partially in place in roof area or not present at every time.

Live load = 750- ((ϴ- 10) x 20)

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4) *Wind Load:* The calculation of wind design force on a stadium structure is basically a dynamic problem because a stadium building will be continually affected by gusts and other aerodynamic force taken.

Required Data in designing for cricket stadium wind load is following:-
IS: 875 (Part III) –2015 has been considered for the calculation of wind loads.
Assuming the life of the stadium building structure to be 50 years and the land to be flat and surrounded by building by small buildings,
k1 = probability factor or risk factor = 1.06 [for Design life of structure in year)
k2 = terrain, height and structure size factor = 0.981 [for terrain of category 4 because structure above the 25m height]
k3 = topography factor = 1 [from 6.3.3.1 apnex for flat topography]
k4 = Important factor for cyclonic region = 1.30
Design wind speed, $V_z = V_b$ x k1 x k2 x k3
V_b = Basic wind speed at Nanded city,
V_b = 39 metre/second
Design wind speed, (V_z)
Design wind pressure, pz = 0.6 $(V_z)^2$
Wind Load on Individual Members – For calculating the wind load as per the Indian standard guidelines on particular member of structural components such as top roof truss, wall and other components of structure, it is mandatory to know the internal pressure as well as the external pressure. Then the wind load *f*, acting in a direction normal to the individual or particular structural element or components unit is:
Then the wind load, F, acting in a direction normal to the particular individual structural element or cladding unit is:
F= (Cpe – Cpi).A.Pz
Where,
Cpe = external pressure coefficient,
Cpi = internal pressure coefficient,
A = surface area of structural element or cladding unit, and
Pz = design wind pressure [6]

IV. MODELLING OF STRUCTURE

A tubular truss is fundamentally a N- type arrangement of straight interlocked structural elements. The common use of tubular trusses is in structures, where assist to top roofs, the floors and inner loading such as services and suspended ceilings, are willingly arranged of the system.

A truss is basically an N- type system of straight correspond structural components; it is sometimes also mentioned as an open web structure. The particular individual components are connected at joint to joint; the links are often assumed to be nominally pinned. The outer load applied to the arrangement of system and when every the members and applied forces are in a similar plane, the system is plane truss.

The main force in all components in a truss is axial tension or compression. Analysis and design also done using staad-pro software for stimulation of behavior under gravity and wind loading. [8]

A. Problem Statement

A suitable Howe type roof truss is to be analyzed and design for covering a cricket stadium; this is design as per Indian standards. It is located of city at Nanded. Considering following parameters:

B. Geometry of Roof Tubular Truss

Roof truss = Howe type of truss
Span of Truss = 32m
Spacing of Truss = 5.163m
Roof slope = 1:6

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C. Shape and Dimensions of a single Tubular Truss

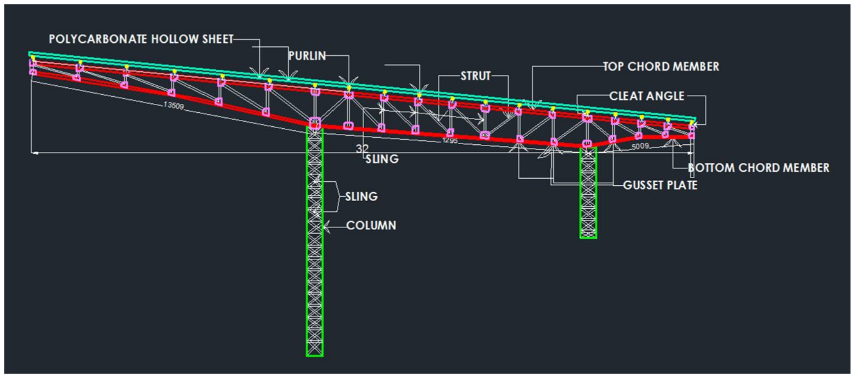


Fig. 1 Section of Truss

Type of roof covering material = Polycarbonate Honeycomb Sheet-18mm thick@29.42N/m²

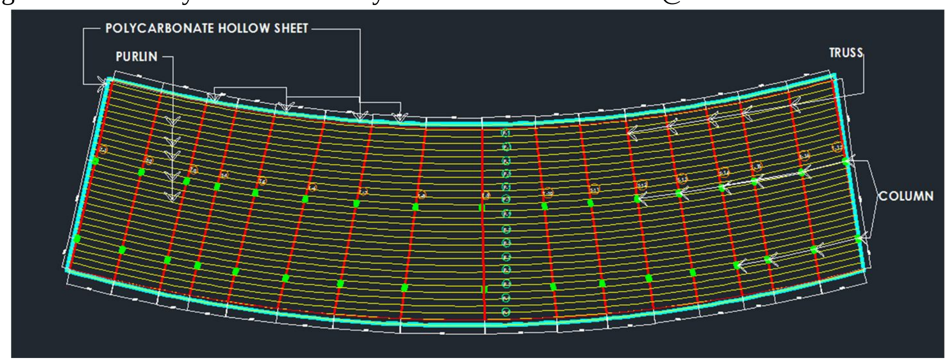


Fig. 2 Plan of Truss

Let ἀ be the inclination of the roof (ἀ)
Tan (ἀ) = rise / half of span
Length of rafter $= \sqrt{(rise)^2 + (span/2)^2}$
= 31.456m
Tan (ἀ) = rise / half of span
ἀ = 18.262^0

D. Dead load on Truss

Weight of sheeting = 0.02942KN /m^2
Weight of Purlin = 0.08 KN /m^2
Weight of Bracing = 0.05 KN/m^2
Weight of truss = (Span /3 +5) 10
= 0.15667 KN/m^2
Self weight of truss = (weight x span x spacing)
= 25.85KN
Self weight of Purlin = 13.218KN
Self weight of Bracing = 8.26 KN
Self weight of sheeting = 4.87 KN
Total Dead load on truss = 52.19KN
Live load on truss = (750- ((Ѳ-10) x 20)
= (750 – ((18.262- 10) x 20
= 584.76 KN/m^2 > 400 KN/m^2

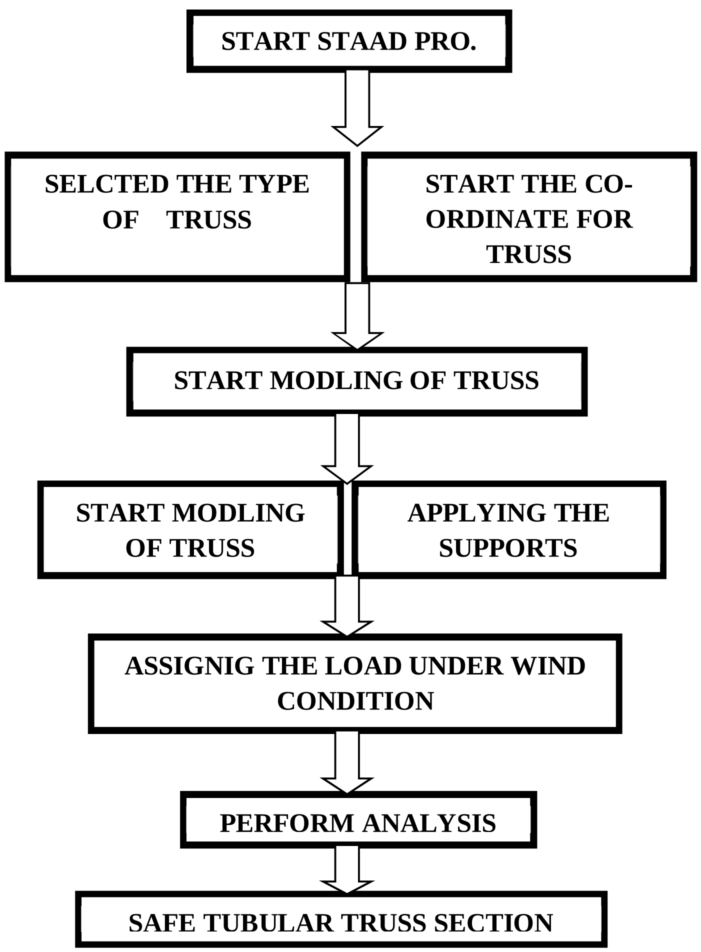
E. Wind Properties

Location = Nanded
Basic wind speed = 39m/s
Height = B
Wind Zone = II (As per IS 875-(part-3):2015)
k1 = 1.06
k2 = 0.981
k3 = 1
k4 = 1.30
Vb = 39 metre/second
Design wind speed, (Vz)
V_z = 39 x 1.06 x 0.981 x 1.252 x 1.30
V_z = 52.7209 metre/second
Design wind pressure, $P_z = 0.6\,(Vz)^2$
$= 0.6(52.7209)^2$
= 2613.6 N/m2
= 2.6136 kN/m2
F= (Cpe – Cpi).A.P_z
P_d = kd x ka x kc x P_z
Where,
kd = 0.90 [for triangular shape]
ka = 0.8 [>100 condition taken averaging]
kc = 0.9 [combination factor for roof surface]
Pd = 0.90 x 0.8 x 0.90 x 2.6136
= 1.7KN/m
b = 119.366 m
a = 32 m
h = 31.457m
a / b = 32 / 119.366
= 0.263
h / b = 31.457 / 119.366
= 1.01
A = 5.163 x 1
= 5.163 m2
Cpe and Cpi value can be selected as per above conditions and ratio from tables; h/b > 1
Cpi = +0.7 [more area will be open]
= - 0.7
Cpe condition ½ < h/w < 3/2
For = Windward coefficient
Cpe = -0.77
= - 0.5
For = - Leeward coefficient
Cpe = -0.8
= -0.6
F= (Cpe – Cpi).A.Pz
Windward side fmax = 140.066 KN
Leeward side fmax = - 142.929KN. [6]

F. Load Combinations

1.5 DL + 1.5 LL
1.2 DL + 1.2 LL +1.2 WL
1.2 DL + 1.2 LL - 1.2 WL
(DL + LL + WL) x 1.2
1.2 DL + 1.6 LL
0.9 DL + 1.0 WL
Load combinations 1:- (DL+LL)
Load combinations 2:- 1.5(DL+LL)
Load combinations 3:- 1.2(DL+LL+ wind load
Load combination 4:- (DL+ LL+ wind load in x+ direction)
Load combination 5:- (DL+ LL+ wind load in x- direction)
Load combination 6:- (DL+ LL+ wind load in z+ direction)
Load combination 7:- (DL+ LL+ wind load in z- direction)
Load combination 8:- (DL+ LL+ wind load in s x+ direction)
Load combination 9:- (DL+ LL+ wind load in s x- direction
Load combination 10:- (DL+ LL+ wind load in s z+ direction)
Load combination 11:- (DL+ LL+ wind load in s z- direction)
Load Combinations (e) are also considered in the design of the roof truss by taking wind in the reverse direction using software also, they are similar to Load Combinations they can consider the IS: 800-2007& 875 (part-1): 2015. [4]

V. METHODOLOGY FOR STAAD – PRO.



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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue IV Apr 2020- Available at www.ijraset.com

VI. ANALYSIS OF RESULTS

The cricket stadium tubular truss will be design manually every checks will be satisfied as per Indian standards and Tubular roof truss will also computerized software Staad Pro. Compare the results with every dead load, live load, and wind load parameters consideration with wind zone-III. Above Howe-types of truss are analyzed for zone III by Limit State Design Method.

These tubular truss models are analyzed and designed as per the specifications of Indian Standard codes IS 800:2007 IS and IS 806:1968, SP-38(S&T):1987, ACI-318-14. [10]

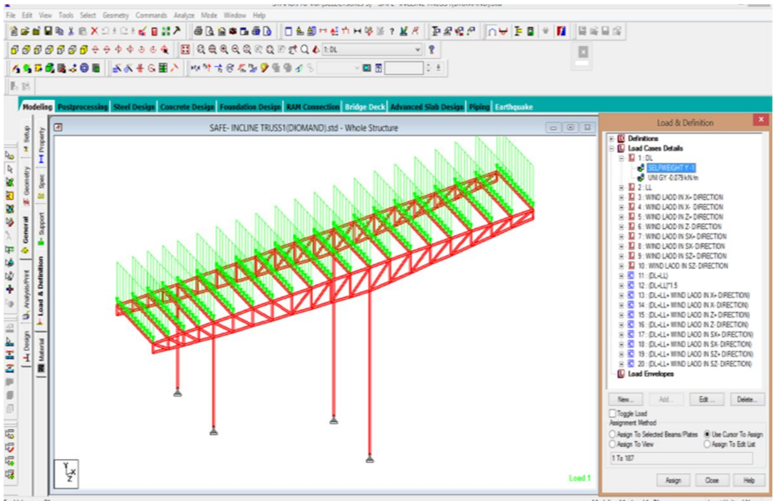

Fig. 3 Self Weight Of Truss

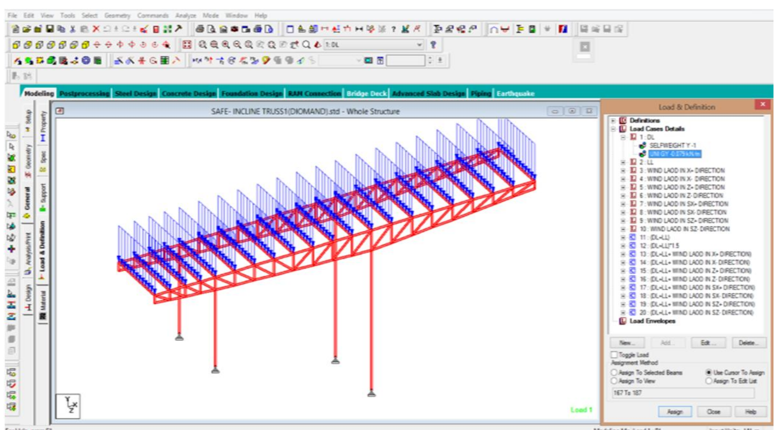

Fig.4 Dead load of truss

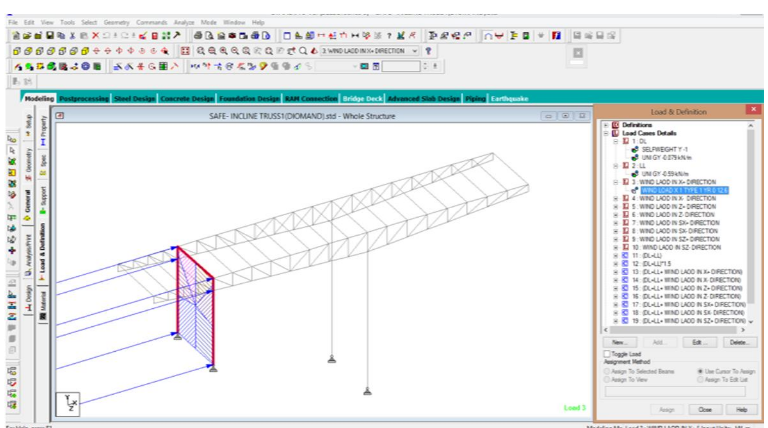

Fig.5 Wind Load in Acting on Structure X+ Direction

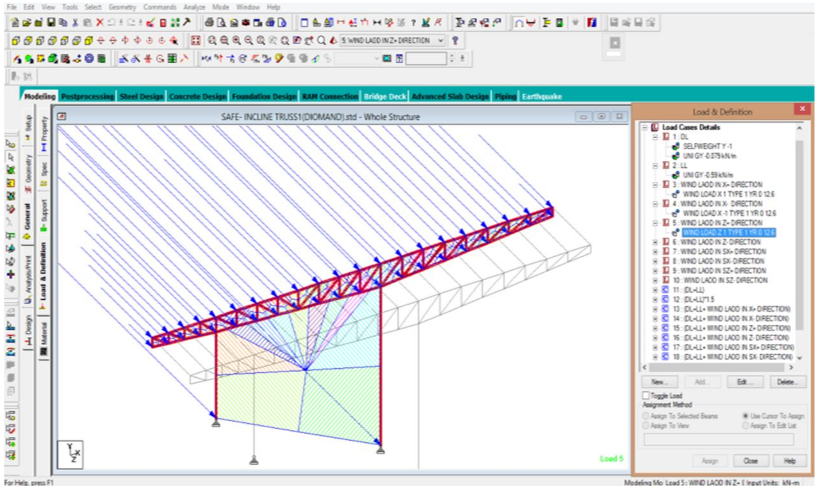

Fig.6 Wind Load in Acting on Structure Z+ Direction

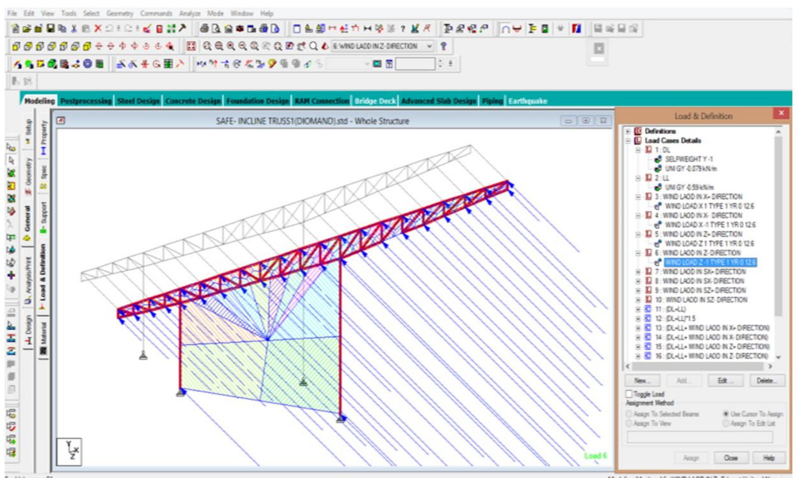

Fig.7 Wind Load in Acting on Structure Z- Direction

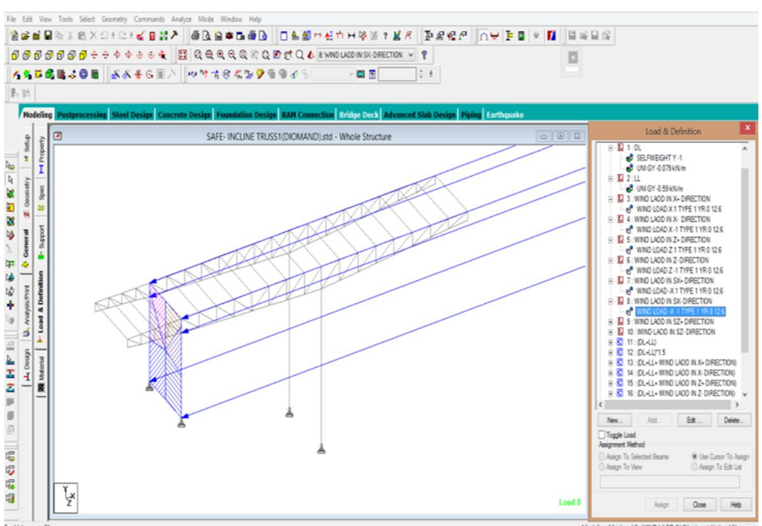

Fig.8 Wind Load in Acting on Structure SX- Direction

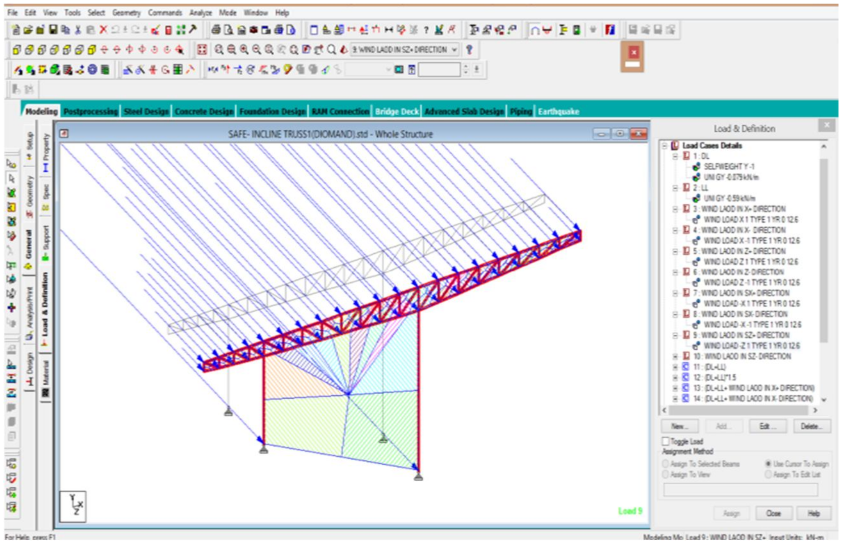

Fig.9 Wind Load in Acting on Structure SZ+ Direction

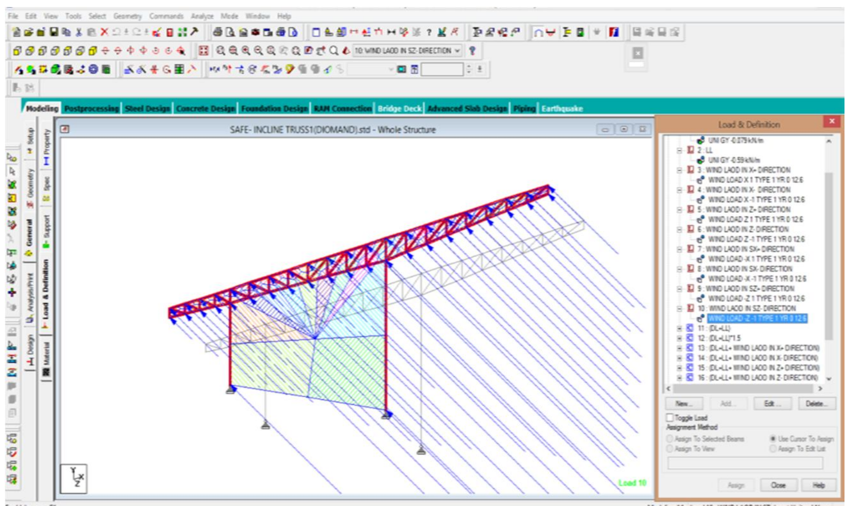

Fig.10 Wind Load in Acting on Structure SZ- Direction

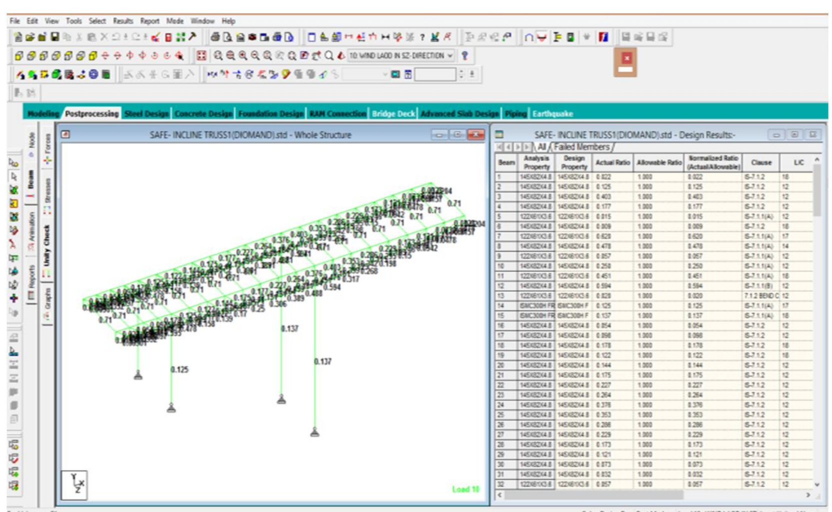

Fig.11 Unity checks of truss with safe section

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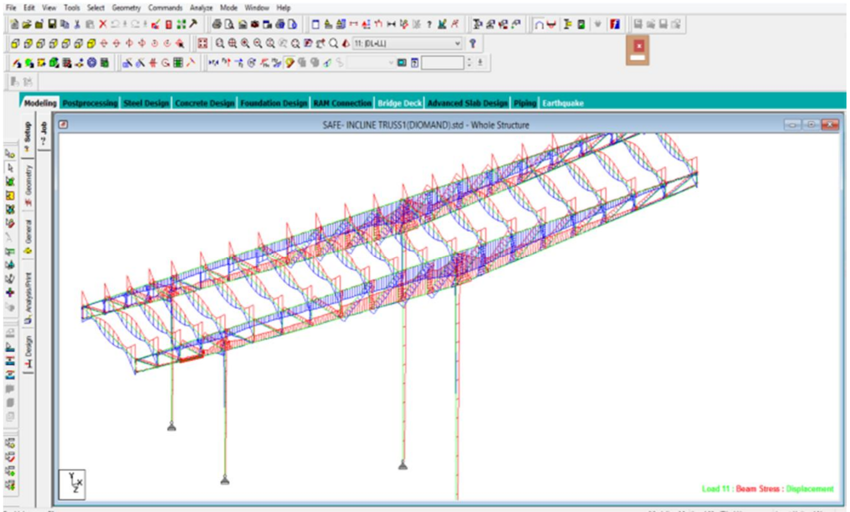

Fig.12 Stress of Truss

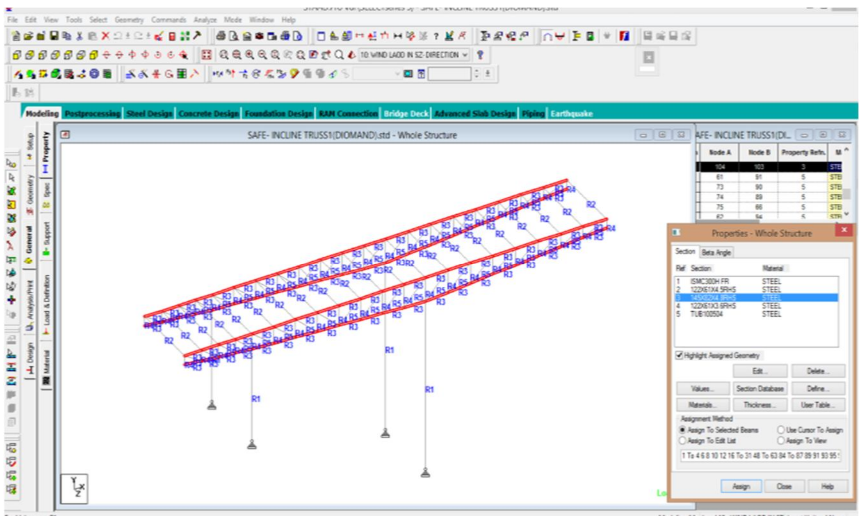

Fig.13 Top & Bottom Member of Truss

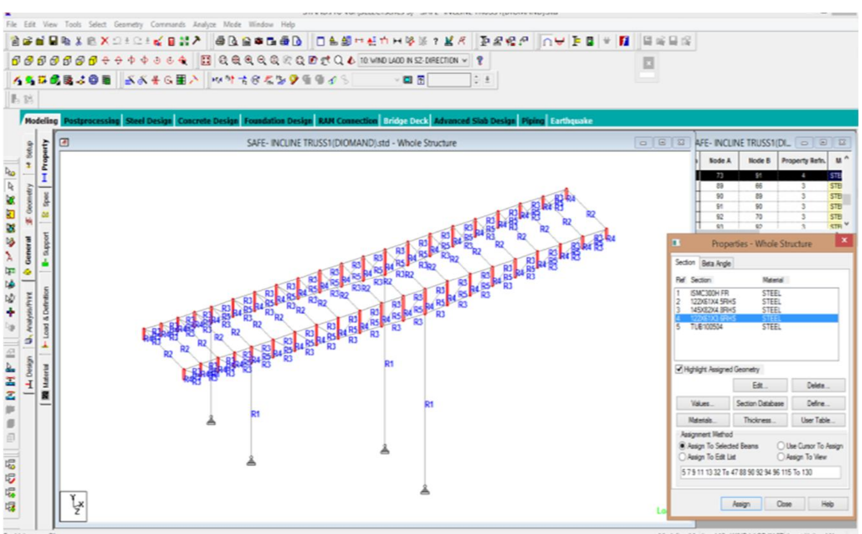

Fig.14 Vertical Member of Truss

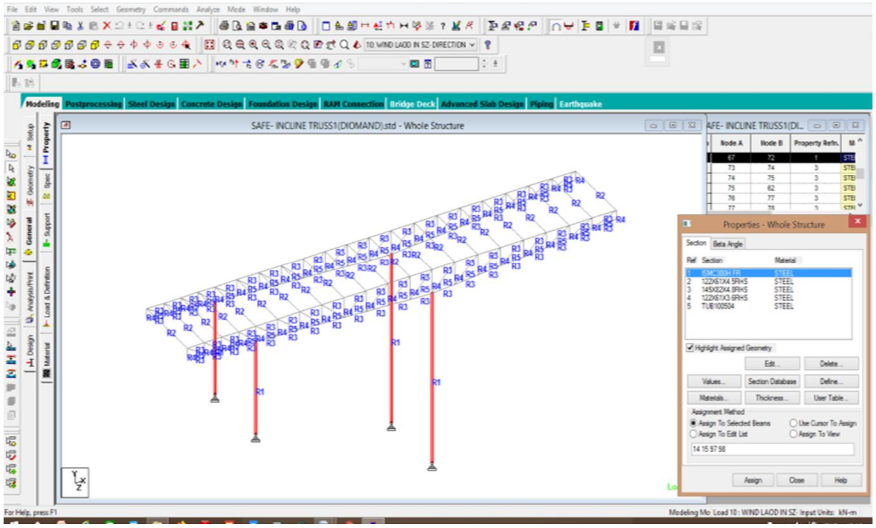

Fig.15 Column Member of Truss

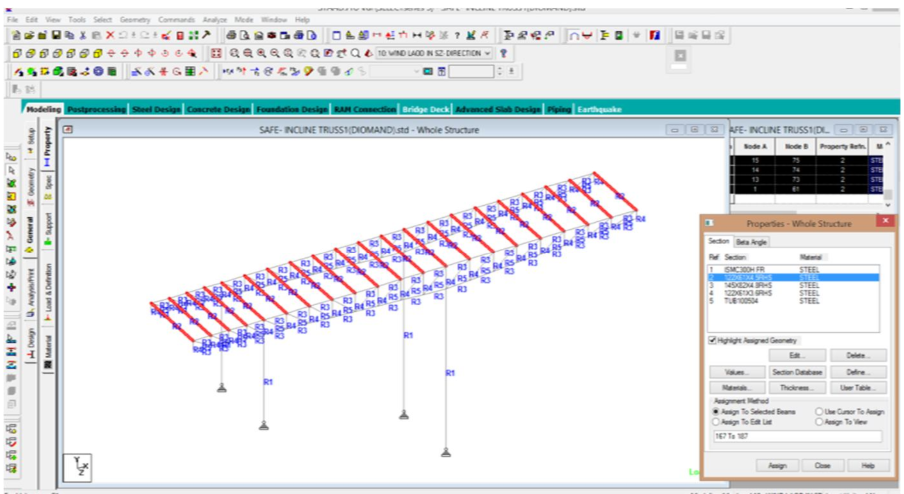

Fig.16 Purlin Member of Truss

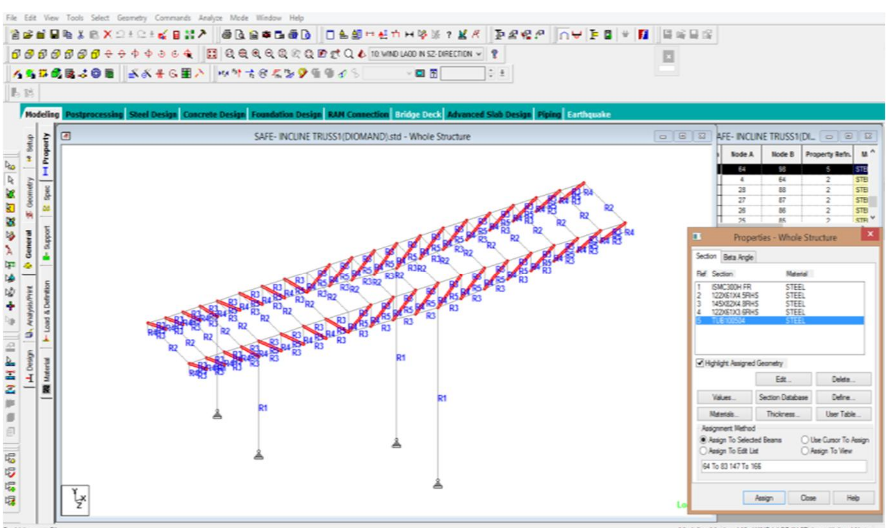

Fig.17 Diagonal Member of Truss

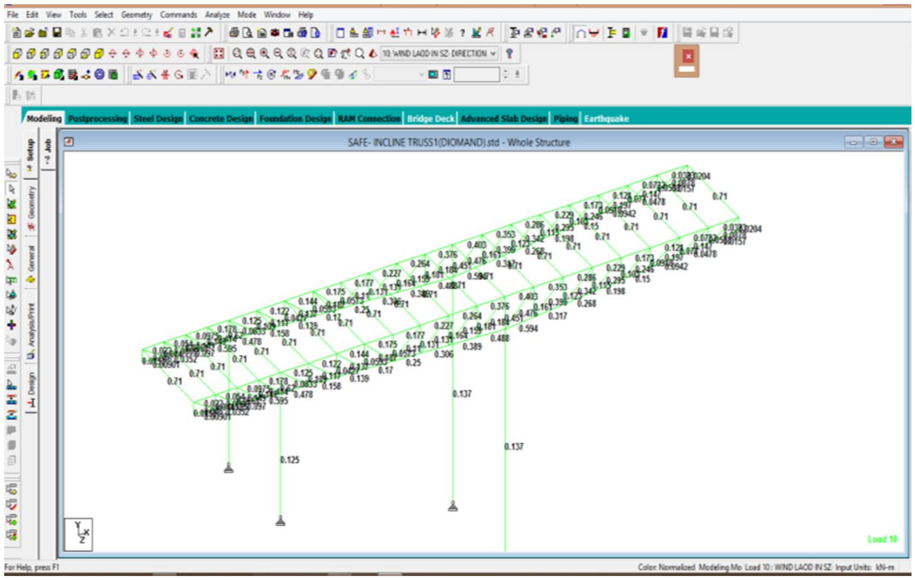

Fig.18 Safe Section Show on Staad-Pro

A. Tubular Section Property

1) Purlin = 122 x 61 x 4.5
2) Top & Bottom Member = 145 x 82 x 4.8
3) Vertical Member = 122 x 61 x 3.6
4) Diagonal Member = 100 x 50 x4
5) Column- 1& 2 = ISMC300. [3]

VII. CONCLUSION

1) We can seen the long span truss configurations and there analysis and investigation, comparison the tubular roof truss provide a long span to tubular truss of the structure analysis.
2) The studies reveal that the tubular truss provides along span required less material as compare to manual calculation and Stadpro software.

A. Check for Deflection

1) Maximum deflection in the 32 metre span tubular roof truss due to Dead Load, Live Load and Wind Load in working condition is 1.002 mm.
2) Allowable deflection for the roof truss is L/250 = 32000/250 mm = 128 mm > 1.002 mm.
3) All loads for the 32 metre span roof truss have been calculated by considering IS:875 (Part I, II and III), SP-38:1987 & IS:800-2007 and some other Indian standards the tubular truss analysis and design for the same have been carried out by STAAD-Pro. V8i.

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