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Comparisons of Tensile Structure with Conventional Steel Structure

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Abstract: *Tensile structures represent a new chapter in the history of building structures. Non-linear material behaviour, large strains and displacements and the use of fabric action to resist loads require a fundamentally different approach to structural analysis and design compared to steel structures. The analysis consists of temporary rectangular shed for steel structure and tensile structure, to carry out the form finding and load analysis of each structure and report key values of stress, deflection and reactions. The results show very high levels of variability in terms of stresses, displacements, reactions and material design strengths, and high light the need for future work to harmonise analysis methods and provide validation and benchmarking for fabric analysis software .The procedure is incorporated into the RFEM Software and the results of some analyses are given.*

Keywords: Tensile fabric Structures, Shape, Form-Finding, Analysis, Dlubal RFEM

I. INTRODUCTION

A tensile structure is a construction of elements carrying only tension and no compression or bending. Tensile structures are the most common type of thin-shell structures. A tensile membrane structure is most often used as a roof, as they can economically and attractively span large distances. Most tensile structures are supported by some form of compression or bending elements, such as masts, compression rings or beams. steel structure is a metal structure which is made of structural steel components connected to each other to carry loads and provide rigidity. Because of the high strength of steel, these structures are require more raw material than some other types of structure such as tensile structure. They can maintain high ratio of applied load to self –weight, as compared to steel and concrete structure for same span.

Fabric structures possess several advantages over conventional steel structures. Perhaps most importantly, fabric can span large distances without incurring much weight on supporting structure or foundation. They are capable of carrying large applied loads while weighing very little in comparison to steel or concrete structures of the same spans. This reduction in weight and material translates into shorter construction schedules and overall cost savings.

II. SHAPE AND FORMS OF TENSILE STRUCTURE

These shapes were discovered by Otto and Berger during their investigation of natural forms such as soap bubbles. There are two types of general shapes: anticlastic and synclastic shapes. Anticlastic shapes are created by having the radii of the principal curvatures on opposite sides of the tension fabric surface. Some examples of anticlastic shapes are saddle, cone, etc. synclastic shapes are characterized by having the radii of the principal curvatures on the same side of the fabric like a dome.

1)	Conic	2)	Double cone	3)	Saddle Forms
4)	Hyper	5)	Skylark	6)	Ridge-and-Valley Forms
7)	Barrel vault	8)	Inverted cone	9)	Hybrid Forms
10)	Inflatable	11)	Hanging	12)	Dome

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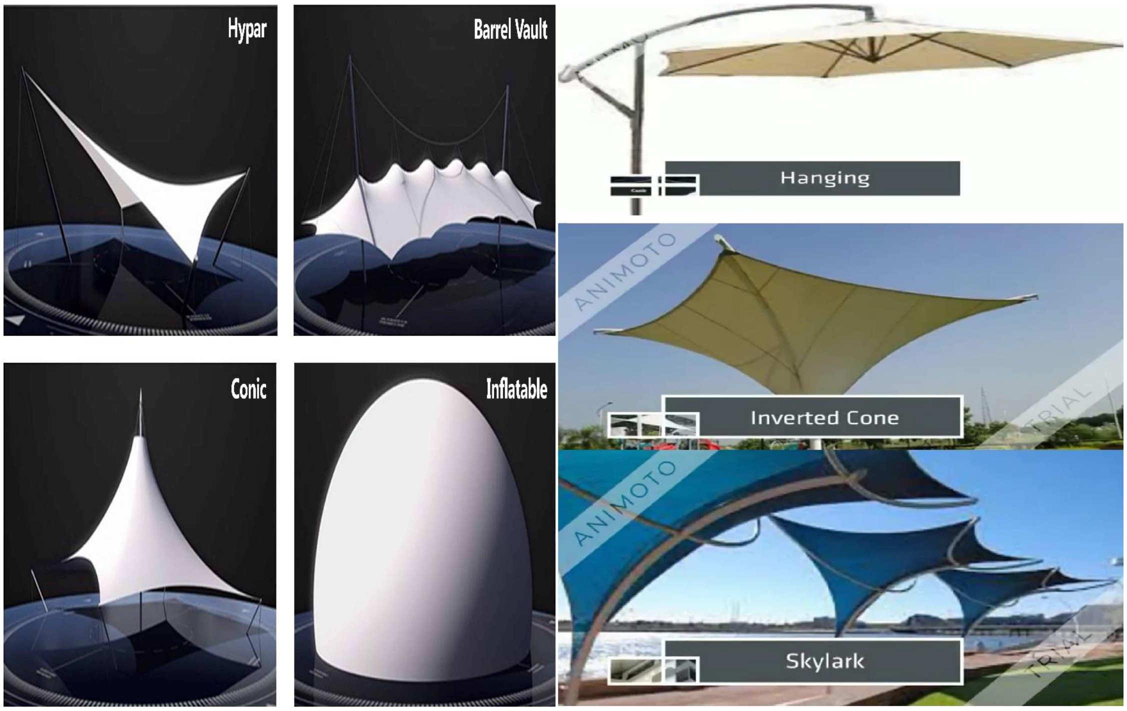

Figure 1 Forms of tensile structure

III. ANALYSIS

The Finite Element Method (FEM) is a numerical technique for calculating approximate solutions to partial differential equations. FEM aids in the visualization of stiffness and strength in a structural simulation. It also aids in the reduction of material weight and the cost of construction. RFEM is structural analysis software that uses the finite element approach. RFEM was utilized in this project to model and solve composite tensile structure and compare result with steel structure. The proposed tensile structure is located in Vadodara. The structure is made up of mild steel tubular sections. The structure provides roof to rectangular temporary shed using tensile structure and steel structure. Rectangular dimension 4 x 4.5 m and 4.5m clear height at eave level and 6m is total height at ridge level and 2mm thickness of fabric material.

- Design fabric material as per ASCE 55-10 and loading as per IS 875
- Fabric type is PTFE and The elastic constants provided are Ex = 634 kN/m, Ey = 213 kN/m, Vxy = 0.29 and Vyx = 0.87.
- The material for steel section selected is Steel IS 513 D | IS 800:2007.
- Design steel member according to IS 800:2007.
- IS 1161: 1998 Hollow Steel Section for Structural Use.
- IS 4923:1997 Hollow Steel Sections for Structural Use-Specification.

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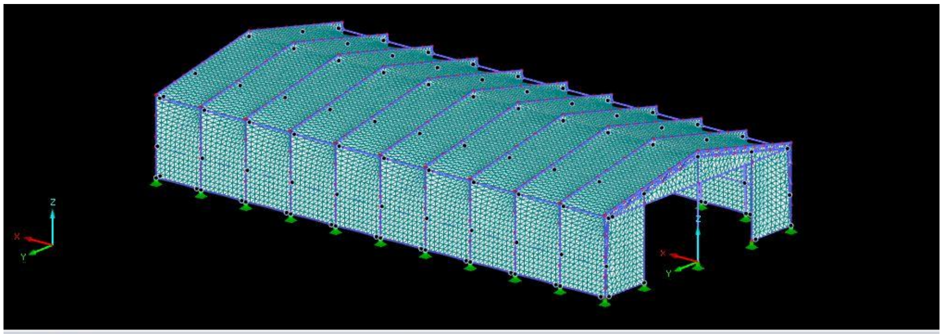


1.13 Cross-Sections

Section No.	Cross-Section Description [mm]	Material No.	Moments of inertia [mm⁴] Torsion J	Bending I_y	Bending I_z	Cross-Sectional Areas [mm²] Axial A	Shear A_y	Shear A_z	Principal Axes α [°]	Rotation α' [°]	Overall Dimensions [mm] Width b	Depth h
1	RO 127x5.4 | IS 1161-1998	2	7640820.0	3820410.0	3820410.0		1028.9	1028.9	0.00	0.00	127.0	127.0
2	RO 114.3x5.4 | IS 1161-1998	2	5490777.5	2745388.8	2745388.8	1847.4	921.7	921.7	0.00	0.00	114.3	114.3
3	RO 114.3x5.4 | IS 1161-1998	2	5490777.5	2745388.8	2745388.8	1847.4	921.7	921.7	0.00	0.00	114.3	114.3
4	RRO 100x50x4 | IS 4923-1997	2	1124320.3	1341400.0	449500.0	1095.0	249.0	705.2	0.00	0.00	50.0	100.0
5	Round 12	4	2035.8	1017.9	1017.9	113.1	95.0	95.0	0.00	0.00	12.0	12.0

Figure 2 Rectangular shed modal

IV. LOAD ASSUMPTIONS (AS PER IS 875)

Units

All units are specified in SI system for solving equations. Forces are in Kilo Newton and moments in KN-m.

Sign conventions

Positive signs indicate compression and negative signs indicate tension.

Dead Weight

The dead weight is assumed including all the fittings. Absorption of liquid is not possible, so any addition in the dead load due to water ingress is not possible.

Imposed Loads

Referring to the table 2 Clause 4.1 of IS875 (Part 2)
With slope greater than 10 degree imposed load is calculated as given below
Angle of the line joining top and bottom end is 11.3 degree.
Therefore, 0.75 – 0.02 x (11.3-10) = 0.724 KN/m^2 .
Minimum live load 0.4 kN/m^2 for tensile structure.

Wind loads

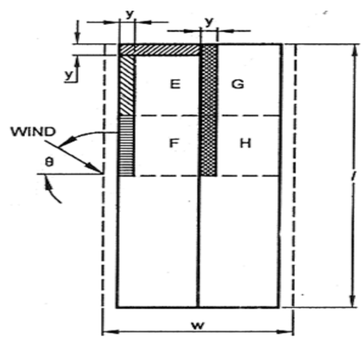
Design Wind speed,
For vadodara
Vb=Basic wind speed (m/sec) = 44 m/sec (As per Appendix A of IS 875 (Part 3)- 2015.
K1=Risk coefficient (Table 1 of IS 875 (Part 3)-2015)= 0.73
K2= Terrain & height factor (Table 2 of IS 875 (Part 3)-2015). For Terrain category 3 and for height 6m
K2=0.91
Topography : Plane
K3=Topography factor (Clause 6.3.3 of IS 875 (Part 3)-2015)
For slope 3◦ < □ ≤17◦ (Annex C) and Clause 6.3.3 of IS 875 (Part 3)-2015
K3 = 1.0.
K4 =Importance factor for Cyclic Region=1.15
Nature of site : Non cyclic Structure Type : (industry structures) –

K4= 1.0 (clause 6.3.4 of IS 875 part 3-2015)
Design Wind speed Vz= Vb K1 K2 K3 K4
Vz = 44 x 0.73 x0.91 x 1.0 x 1.15 =33.61m/s

Design Wind Pressure,
Pz=0.6 x Vz^2 = 0.677 Kn/m^2
pd= Kd Ka Kc pz
where Kd= Wind directionality factor for buildings as per clause 7.2.1 of IS875 part3- 2015 =0.90 Ka=area averaging factor Tributary area of a panel TA= Column spacing x storey height=4 x 4.5=18m2 For TA =18m2 As per table 4 of iS875 part 3- 2015
Ka for 10 to 25 m2 is 0.90
Combination factor = Kc as per clause 7.3.3.13 for frames over the building envelope when roof is subjected to pressure and internal pressure is suction or vice-versa=0.90
pd= Kd Ka Kc pz
pd= 0.90 x 0.90 x0.90 x 0.677
=0.49 kN/m^2

Internal Pressure Coefficients C_{pi}

The **internal pressure coefficients** C_{pi} can be determined from 7.3.2 of IS 875-3:2015. For this structure, it is assumed the total opening on the wall is less than 5 to 7 percent of the total wall area. Therefore, the C_{pi} values for this example are **+0.5**and **-0.5**.



KEY PLAN

External Pressure Coefficients C_{pe}

The **External Pressure Coefficients** C_{pe} depend on certain parameters such as height, width, length, roof angle, and roof profile.

For this structure, since the roof profile is gable or duopitch, the roof external pressure coefficients will be calculated based on Table 6 of IS 875-3:2015. For this example since $h/w = 0.3$, and the roof angle is **11.3°**, the C_{pe} values will be interpolated using the following values.

For wind angle = 0 degrees:

Roof angle	Zone EF – Windward	Zone GH – Leeward
10°	-0.9	-0.4
11.3°	**-1.18**	**-0.4**
20°	-1.2	-0.4

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For wind angle = 90 degrees:

Roof angle	Zone EG – Crosswind	Zone FH – Crosswind
10°	-0.8	-0.6
11.3°	**-0.78**	**-0.6**
20°	-0.7	-0.6

Table 1: Combined internal and external pressures

Zone	CPe	CPi	CPe-CPi	(CPe-CPi) Pd Kpa
Zone EF – Windward	-1.18	0.5	-0.68	-0.33
		-0.5	-1.68	-0.83
Zone GH – Leeward	-0.4	0.5	0.1	0.049
		-0.5	-0.9	-0.44
Zone EG – Crosswind	-0.78	0.5	-0.28	-0.13
		-0.5	-1.28	-0.63
Zone FH – Crosswind	-0.6	0.5	-0.1	-0.049
		-0.5	-1.1	-0.54

V. RESULT

The Design of Steel structure and tensile structure was completed using RFEM Software and the results are tabulated from the Analysis Report. Design of both the Structures was optimized for all the governing factors. The Design of both structures was used to derive the steel out-take, economic liability and material specification. It was concluded through statistical and graphical analysis that the tensile canopy outclassed the conventional steel space frame on the parameters such as steel required and cost effectiveness.

Global deformation of Tensile structure

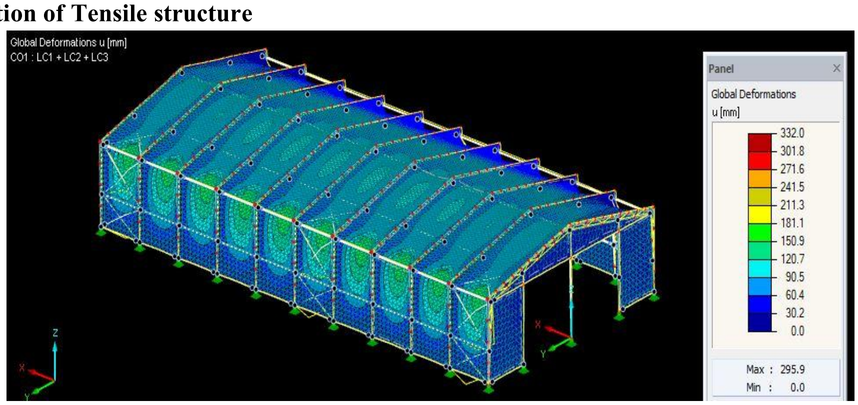

Figure 3 Global deformation of Tensile structure

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Global deformation of Steel structure

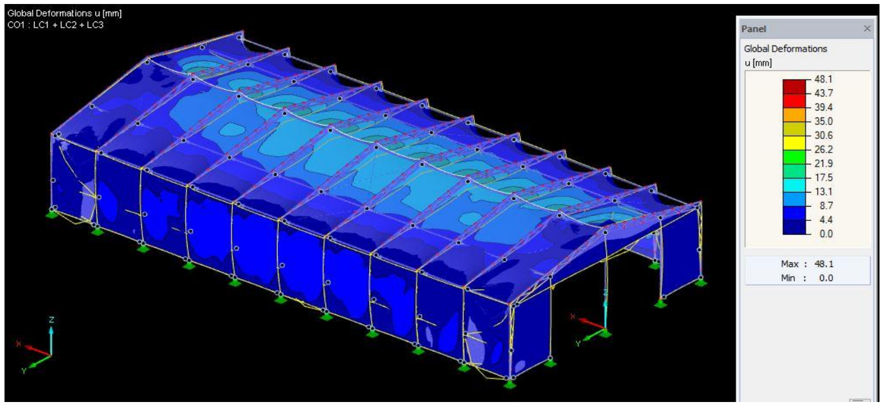
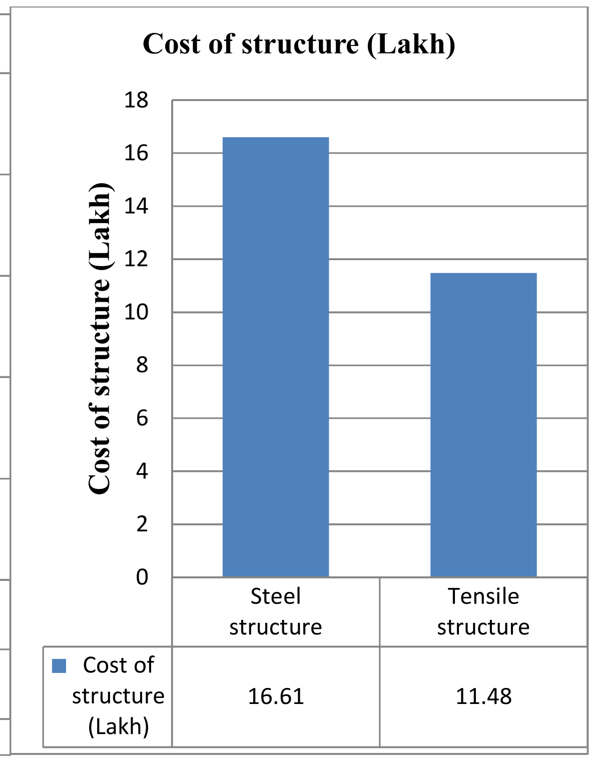


Figure 4 Global deformation of steel structure



Graph 1 Amount of steel tonne for Graph 2 Cost of structure in Lakh for steel structure and tensile structure steel structure and tensile structure

VI. CONCLUSION

1. Results show very high levels of variability in terms of stresses, displacements, reactions and material design strengths. For most output parameters there is a wide spread of values. It is difficult to generalise but the standard deviation and the interquartile range are both commonly 25–50% of the mean value.
2. Tensile structure allow for higher energy savings, a consideration that is becoming ever more important to the green building industry.
3. Tensile structure structures employing polyester or other material subject to creep strain under prestress, retensioning may be carried out in conjunction with inspection 6 to 12 months after completion and for steel structure not need to prestress.
4. Wind loads are the main consideration for membrane structures and steel structure.

5. Point loads should be avoided on the membrane component of the structural system. The necessary heavy point loads should be set on the supporting compression structure at all times possible.

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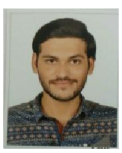
REFERENCES

[1]. Space Structures : Principles and Practice, N. Subramanian, Volume 1, Multi- Science Pub., 2006
[2]. The US-American design standard ASCE-SEI 55-10 [Am10],.
[3]. IS 800:2007 GENERAL CONSTRUCTION IN STEEL - CODE OF PRACTICE
[4]. IS 806-1968 CODE OF PRACTICE FOR USE OF STEEL TUBES IN GENERAL BUILDING CONSTRUCTION
[5]. IS 1161:1998 STEEL TUBES FOR STRUCTURAL PURPOSES
[6]. IS 3601:2006 STEEL TUBES FOR MECHANICAL AND GENERAL ENGINEERING PURPOSES
[7]. IS 4923:1997 HOLLOW STEEL SECTIONS FOR STRUCTURAL USE-SPECIFICATION
[8]. IS 1732 : 1989 DIMENSIONS FOR ROUND AND SQUARE STEEL BARS FOR STRUCTURAL AND GENERAL ENGINEERING PURPOSES
[9]. SP : 6(l) – 1964 HANDBOOK FOR STRUCTURAL ENGINEERS (STRUCTURAL STEEL SECTIONS)

BIOGRAPHY



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