Comparison of Tensegrity Towers of Two Different Compartment Heights

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Abstract— The objective of the present study is to compare the tensegrity towers of compartment height of 4 meter and 5 meter for node deflection at various heights and their respective deflection diagram and Beam stresses. Tensegrity tower is of 20 meter height and it is analyzed using STAAD pro V8i. The analysis was based in the terrain category two. Lucknow city in the state of Uttar Pradesh, India is selected as the place for analysis and the respective data is used for wind speed, seismic zone et cetera. Tensegrity towers provides better alternative for the conventional structure and can be used for better efficiency. The result of the present study shows that the compartment height of 4 meter shows better results in terms form-finding and stresses developed.
Key words: Tensegrity Structures, Compartment height, Finite Element Analysis, STAAD.Pro V8i.

I. Introduction

Tensegrity is relatively new field, which incorporates Scupper, lightweight and unique structures, giving the impression that the struts are floating in air. Tensegrity is the combination of two words tensile and integrity. Which means that the tensile members play active role in the structure and are the one that transfers the load from the point of application to the foundation of the structure Buckminster Fuller started the word'Tensegrity' and relative discoveries were made in the year 1950.There are many definition provided by the researchers for tensegrity structures. As per the view of Fuller tensegrity structures are "islands of compression in an ocean of tension". Tensegrity can be understood as a system of continuous 'pull' and discontinuous 'push' and this pull and push work in tandem producing the integrity of tension and compression [1-3]. The word tensegrity is a contraction of 'tension' and 'integrity'. A Tensegrity structure usually consists of bars (Struts) and strings (Cables). Struts are the discontinuous compression member that seems to be floating in the web of cable, which is in tension and is continuous. It is stabilized by introducing member forces (tension and compression) to the structure. In the original and strict definition of tensegrity structures, no strut that is in compression makes any sort of contact with other struts [4,5]. The ideal approach to see how a tensegrity framework functions is to observe a model or, far better, to construct one. Kenneth Snelson was probably the first person to build a tensegrity system in 1948 which is known a 'X piece', a wooden structure in which two pieces are not in contact with each other and are balanced out by an arrangement of tension members (strings) Fig 1.

Fig. 1: The "X-piece" made by Kenneth Snelson in the winter of 1948

A. Types of Tensegrity Structures:

Self Stressed Structures: Self-stressed structures are freestanding so that they can maintain their self-equilibrium states without any support.

Prestressed Structures: These structures such as tensegritic domes, cable nets and membrane structures should be attached to supports to retain equilibrium.

B. Properties of Tensegrity Structures:

1) In tensegrity structures, the tension is continuous and plays active role in stabilizing the structure. The tensile strength of a longitudinal member is larger as compared to its buckling strength. Hence, a large stiffness-to-mass ratio can be achieved by increasing the use of tensile Members. A compressive member loses stiffness under loading, whereas tensile member gains stiffness when loaded.
2) The tensegrity structures are light in weight than the conventional structures and permits the more efficient use of the materials. Tensegrity structures use longitudinal members arranged in exceptionally bizarre patterns to achieve strength with small mass.
3) Tensegrity structures are Deployable. As they are lightweight so they can be made easily at, the factory transported to the site and can be assembled there using simple tools such as wrenches.
4) Tensegrity structures are Tunable. An existing structure can be fine tuned like a musical instrument to make some adjustment in the loaded state to change a certain member or apply extra load onto it.
5) All individuals from a tensegrity structure are axially loaded. The best feature of tensegrity structures is that, even though the whole structure bends with external static loading, none of the individual member of the tensegrity structure experience bending moments.
6) Tensegrity structures can be more precisely controlled as compared to other structures. Hence, they find vast use from microsurgery to antennas, to aircraft wings, and to robotic manipulators.

C. Some Disadvantages:

1) Tensegrity arrangements suffer the problem of bar congestion. As some designs become larger (thus, the arc length of a strut decreases), the struts start running into each other.
2) The same author stated, after experimental research, “relatively high deflections and low material efficiency, as compared with conventional, geometrically rigid structures.
3) The fabrication complexity is also a barrier for developing the floating compression structures. Spherical and domical structures are complex, which can lead to problems in production.
4) In order to support critical loads, the pre-stress forces should be high enough, which could be difficult in larger-size constructions

II. EXPERIMENTAL PROGRAMME

The models of tensegrity and steel towers are modeled and designed using the STAAD Pro V8i and are tested under various loading as per the specification of the Indian Codes and Uttar Pradesh Power Transmission Corporation Limited.

A. Tower Properties and Data:

- Height 20 meter
- Material Used Steel Pipes
- Terrain Category 2 (As per IS 875 part 3)
- Seismic Zone III (As per IS 1893 (2002))
- Bay/compartment Length 4 and 5 meter
- Type Of Electric line 132 KV
- Span Length 500 meter
- Conductor ACSR 'Special Panther' (As per UPPTCL)
- Weight of Conductor 622 Kg per KM

B. Loads on Towers:

- Dead Load
- Live load on tower due to conductor - 155.5 kg
- Wind Load As Per IS 875 Part 3
- Seismic Load As per 1893 2002

III. RESULTS AND DISCUSSION

The Tensegrity towers of 4 and 5 meter height are analyzed using the software STAAD pro and their desired outcomes are analyzed and listed. They are compared on various property and they are listed below in the table and the required diagrams are also attached here within the paper

S.No	Attribute	Tensegrity Tower 4 meter	Tensegrity Tower 5 meter
1	Weight (KG)	796.8	796.8
2	Maximum Node Reaction (KN)	63.5	79.5
3	Maximum Node Moment (KN-m)	1.07	1.4
4	Maximum Axial Force (KN)	69.8	87.9
5	Maximum Shear Force (KN)	.5	.7
6	Maximum Bending Moment (KN-m)	.8	1.4

Table 1: Table of Comparison

A. Deflection Diagram:

Since the weight of the tower of compartment height of 5 meter is more as compared to that of 4 meter. Thus the deflection diagram of tensegrity tower of 5 meter is more tilted as can be seen in the diagram.

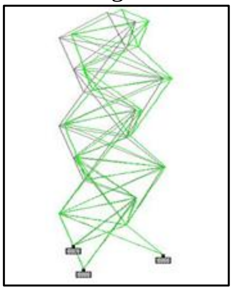

Fig. 3.1: Tensegrity Tower of 4 meter compartment height

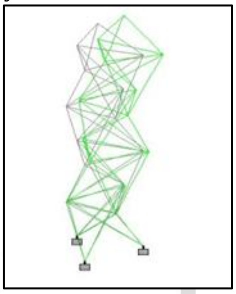

Fig. 3.2: Tensegrity Tower of 5 meter compartment height

B. Beam Stress Diagram:

The beam stress diagrams shows that the compression member of the tensegrity tower of 5 meter compartment height experience more stresses than the tower of 4 meter height

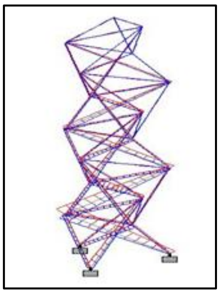

Fig. 4.1: Tensegrity Tower of 4 meter compartment height

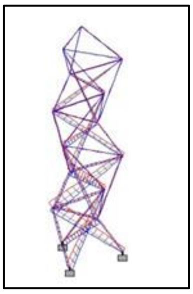

Fig. 4.2: Tensegrity Tower of 5 meter compartment height

IV. CONCLUSION

From the acquired results, it is evident that to acquire more efficiency for tensegrity tower to as minimum as possible so that the stresses and the deflection of the structure is not much. On the same hand we should also take care that we did not decrease the compartment height to such degree that it becomes too complex a structure. Thus from the above analysis it can be said that compartment height from 4 meter and 5 meter, 4 meter suits better to the structure. Thus it is recommended to do a thorough study before selecting the compartment height of the structure.

V. FUTURE SCOPE

The field of tensegrity is relatively new and there is much scope for the researchers into it. In future the researchers can check the tensegrity tower for ther compartment heights. Additionally these towers can also be checked for higher transmission lines such as 220 KV 400 KV and 800 KV. Other shapes of tensegrity tower such as rectangular or octagonal can also be used.

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