International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 06, June-2019

ANALYSIS OF TENSEGRITY DOME STRUCTURE

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Abstract*— Tensegrity is a relatively new concept first introduced by Buckminster fuller in 1962 based on the use of solitary pieces in compression within a continuous tension network, so that compressed elements (usually rods or struts) do not they touch each other and the prestressed tension elements (usually wires or tendons) describe the system in particular [1] [2]. The main objective of this work is to find possible applications for such an unconventional type of structure, despite its particular flexibility and its relatively high deflections. The modeling and analysis of the structure was performed using SAP-2000, with Prestress loading as the most important. After the analysis of the dome, the net deflection of the tensegrity dome should be minimal compared to the stability of the structure. After the analytical testing of the tensegrity structure one more property comes in picture that tensegrity structure can be improved significantly through a minor variation in the potential energy of the tensegrity structure. Consequently, the shape control of module of the tensegrity structure must be economic and safe. The unique side of the research paper is that the presentation of many tensegrities that are light weight however extraordinarily robust. The idea of self-similar structures is employed to seek out a minimum mass subject to a selected instability restriction. The rigidity and strength of those tensegrity structures are determined.

Keywords— **Tensegrity, form-finding, layout, pre-stress force, displacement, applications**

I. INTRODUCTION

The tension structures are created with strut and strings hooked up to the ends of the strut. The strut will resist the compressive force and consequently the strings cannot. Most bar string configurations that would be planned aren't in balance and, if they're designed, they'll truly collapse in an exceedingly completely different approach. solely the configurations of bars and strings in an exceptionally stable balance are referred to as tensegrity structures. If handy, applying forces to a tensegrity structure can deform it in an exceedingly slightly completely different approach in a way that supports the applied forces. Tensegrity structures are terribly special cases of frames, during which members are assigned special functions. Some members of the tensegrity structure are uninterruptedly in tension and strut of structure are constantly in compression. we are going to implement the words "strings" for tension members and "strut" for compression members. (The completely different word choices for recitation tension members as "strings", "tendons" or "cables" are impelled solely by the dimensions of the applications). The struts of a tensegrity structure cannot be connected to every alternative by couples giving couples. the tip of a bar is mounted to string or balls hooked up to alternative bars. The creative person Kenneth Snelson1 (Figure I.) designed the primary structure of tensegrity and his work of art was the motivation for the attention of the first author in tensegrity. Fuller presented the word "tensegrity" from 2 words: "tension" and "integrity". When continuous push and discontinuous pull have a win- win relationship to one another results given by the tensegrity layout. The push is balanced the pull, generates the integrity of compression and tension. This basic layout does not counter, but addition each other to keep up the structure in equilibrium. The design patterns followed in these conditions are:

1. members either carries in pure compression or in pure tension, so that the structure fails only when either the cables relent or the rods buckle.

2. Pre-stress this permits the cables to be in stiff in tension. There is a huge quantity of literature on geometry, the artistic form and the architectural attractiveness of the tensegrity structure, but there is little information on the dynamics and mechanics of these structures [3].

A study was carried out on dual-layer tensegrity networks (DLTG) consisting of triangular prisms subjected to static charges that use a first order linear analysis (small deviations) of prestressed press-point networks based on the flexibility approach [4]. A generalized non-linear static analysis of the 'n-structure' tensegrity systems and the design equations for self-deployable tensegrity systems was derived [5]. Switchable structures based on the concept of tensegrity have been developed for space applications. Several methods have been proposed to find tensegrity structure methods [6]. A detailed investigation was conducted on the origin and on the original patents of the tensegrity structures [7] general methods and corresponding computer codes were proposed to create tensegrity structures [8]. A new technique has been developed for the development of tensegrity structures and their deployment in the field. An experimental and analytical investigation was carried out on the prototype structures to study the behavior of the structure under various parameters.

Fig. I Snelson's tensegrity structure. (From Connelly, R. and Beck, A., American Scientist, 86(2), 143, 1998. Kenneth Snelson, Needle Tower 11, 1969, Kröller Müller Museum. With permission.) [9]

A. Finding of study

First of all, a one circular structural module with a size 10 m diameter is modelled and analysed using FEM-based software. Thus, the investigations extend over a 15 m diameter circular structure. The behaviour of the structure is studied under the application of external loads which vary the prestressing forces in the members. Subsequently, a 20 m diameter structure is modelled and analysed. From the analysis, it is found that the displacement of the structure satisfies the proportional limits allowed according to the previous research values. The member forces were also analysed.

B. *Material and Section Properties of the Structure*

In this Research, for the compression member of the structure were used the galvanized iron (GI) pipes of medium type, conforming to the Indian Standard. And for tensile member of the structure were used a 6 mm nominal diameter mild steel stranded wires of 6 x 19, confirming to Indian Standards. The material properties and section properties of the members are as follows in Tables 1 and 2 respectively.

TABLE I
Material Properties

Material	**Mass (kg/m)**	**Modulus of elasticity (N/mm^2)**	**Yield stress (N/mm^2)**	**Poisson's ratio**
Galvanised Iron Pipes	1.21	2.05×10^5	240	0.25
High carbon Steel wires	6.09	0.954×10^5	1421.34	0.25

TABLE II
Section Properties

Section	**Material**	**Diameter**
Cable	High Carbon Steel Wires	6 mm
Struts	Galvanised Iron Pipes	In diameter 6 cm Ex. Diameter 6.8 cm

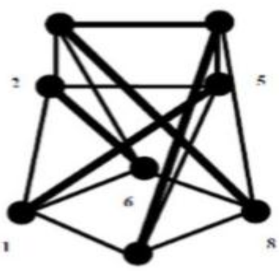

Fig.II Half-cuboctahedron

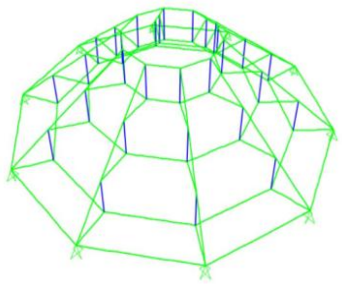

Fig. III 3D view of tensegrity structure module in SAP 2000.

II. ANALYSIS OF THE TENSEGRITY STRUCTURE

A double-layered flat tensile structure for roofing systems using the finite element package was developed and analysed. A basic tensegrity module and a 10 m diameter circular tensegrity structure were developed and analysed to study the mechanism under various prestressing forces. The study has also been extended to a 15 m and 20 m diameter circular tensegrity to study the behaviour of tensegrity structures of large bays. The configuration of the prototype used in this study for the structure of the tensegrity structure is half of a cuboctahedron shown in Figure II.

A. Analysis of the Tensegrity dome structure

A finite model of 10 m diameter circular tensegrity structure has been developed from by half-cuboctahedron modules and analyzed. All members of the strut are defined as truss elements, so that no bending moments develop in any of the members. In the nodes of the lower corner, the degree of freedom is blocked in the three directions of translation and in the upper nodes all degrees of freedom are released. For the central bottom node, all the three degrees of translations and rotations are locked. following are the loading cases for the analysis of the tensegrity structure.

Case 1-Considering a prestressing force of 1.25 kN on the top cables and the corresponding static loads are apply linearly varying ranging 0.2 to 2kN as per previous study done by other author.

Case2: Considering a prestressing force of 1.5kN on the top cables and the corresponding internal member forces are apply as above as mentioned in case 1. For the above cases the structure is analyzed for various static loads. The 3D view of the structure modelled in SAP2000 is shown in Figure III.

III. RESULT AND DISCUSSIONS

The finite model of the 10 m,15 m and 20 m tensegrity structures are well analyzed under different static loads to understand the behavior of all the three models of tensegrity structures. after the analysis of the finite model of 10 m diameter tensegrity structure under various applied loads and prestress force 1.25kN and 1.5kN, the maximum nodal displacement is observed in the top Centre nodes. Figure IV shows the maximum nodal displacements of the 10 m diameter tensegrity structure. The permissible limit for the nodal displacement of structure is L/250 as per previous research done by researcher[10], which is 40 mm for 10 m diameter tensegrity structure is attained even at a uniform nodal load increase up to 800N. Figures V and VI represent the strut forces and maximum cable forces developed in the bottom centre cable in the structure for both the cases respectively.

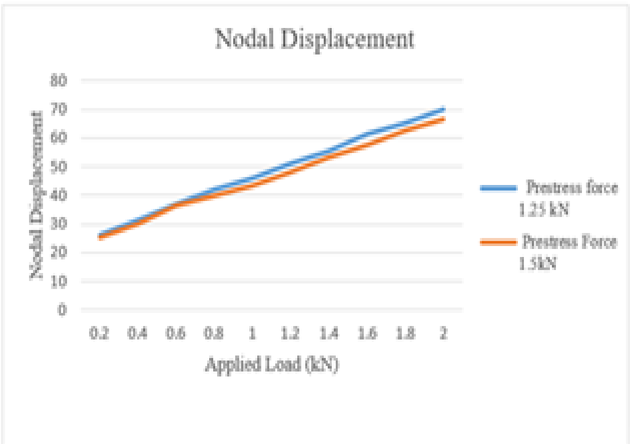

Fig. IIII Maximum nodal displacement of the 10 m dia. tensegrity structure

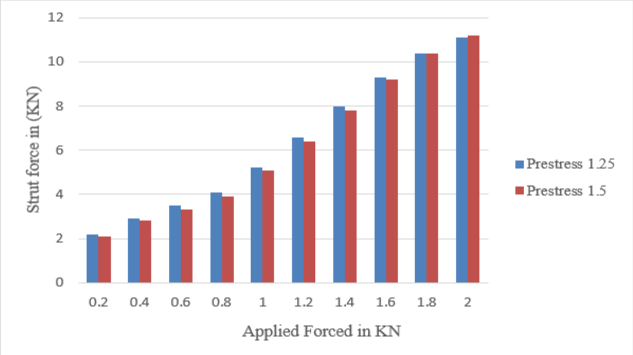

Figure IV. Strut Force for10 m tensegrity structure

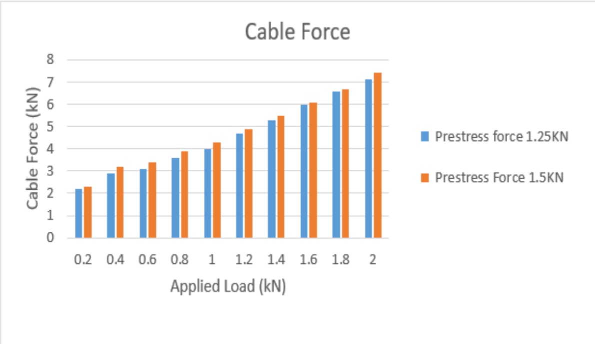

Figure VI. Cable Force for10 m tensegrity structure

A. Behaviour of the Tensegrity Dome Structure

Based on the 10 m diameter tensegrity structure, the 15 m and 20 m diameter tensegrity structures have been modeled and analyzed. Figure 7 and Figure 8 show the maximum nodal displacements observed respectively in the case of 15 m and 20 m diameter tensegrity structure. In Figure VIII, it can be seen that the allowable displacement of 40 mm (i.e. L / 250) for the 15 m tensegrity structure is obtained with a nodal load of 1000N. In Figure 8, it can be seen that the admissible displacement of 60 mm (i.e. L / 250) for a 20 m tensegrity structure is obtained with a nodal load of 1800N.

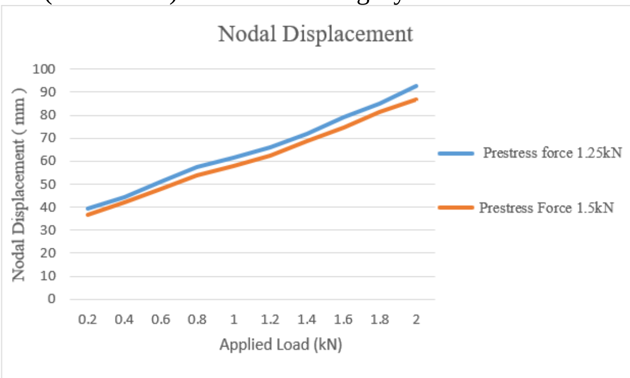

Figure VIIII Nodal displacement Force for 15 m tensegrity structure

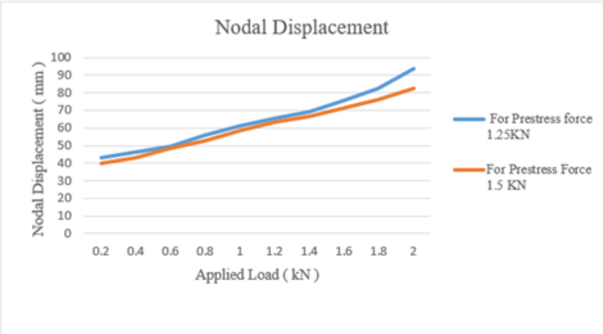

Figure VIIIIII. Nodal Displacement for 20 m tensegrity structure

IIX. CONCLUSIONS

In this research paper, the feasibility of a temporary roof shelter for a large structure was explored. The large tensegrity structure formed by the group of uprights that float in the air consist of very thin cable elements that make the system attractive. Portability and storage in the compact volume are the additional advantages of the deployable tensegrity structure that makes the facility feasible for temporary shelters. The 10 m tensegrity structure develops like two cables as it connects to the one strut likewise all configuration of structures is developed. Based on the 10 m tensegrity structure, the 15 m and 20 m diameter tensegrity structure have also been developed and analyzed. From the results, it can be concluded that the tensegrity structures of greater tension member are more feasible.

Nodal displacements decrease significantly with increasing internal self-stress forces. if the value of its self-stress is close to zero, the displacements tend to infinity. Furthermore, the influence of geometric non-linearity is clearly visible. The effect of non-linearity is the most significant at low values of self-stress forces. The tension stabilizes the structure and increases its rigidity. The tension components acquire rigidity when the structure is loaded. By increasing the use of tension elements, it is possible to obtain the most durable structure.

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