Development & Analysis of a Prototype Dismountable Tensegrity Structure

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Abstract- *The tensegrity structure is a low weight structure which is constructed by tension and compression member. Then characteristics advantages and disadvantages of these structures are discussed in detail, followed by a review of little simple tensegrity structure. This paper presents a new technique for development of tensegrity structure and their deployment in field, in two different modes-struts based and cable based.*

Key Words: Tensegrity, Light-Weight, Analysis, Deployable, Controllable, Energy-Efficient, Dismountable.

1. INTRODUCTION

The word tensegrity comes from the construction of tension and integrity. a tensegrity structure consists of a set discontinuous compression members tied together by continuous tensile member, generally cables. Tensegrity structure essentially consist of bars and strings which are attached to the end of the bars. the bars are always in compression whereas the strings are always in tension. They are lightweight, adaptable, deployable, and space efficient structure in which the struts appear to be floating in the air. The basic property of tensegrity structure is that they acquire their rigidity by the application of tension on cables. From engineering point of view, it is also defined as statically indeterminate reticulated system. This type of structure uses many interesting structure property, because their composition, they are relativity light weight.
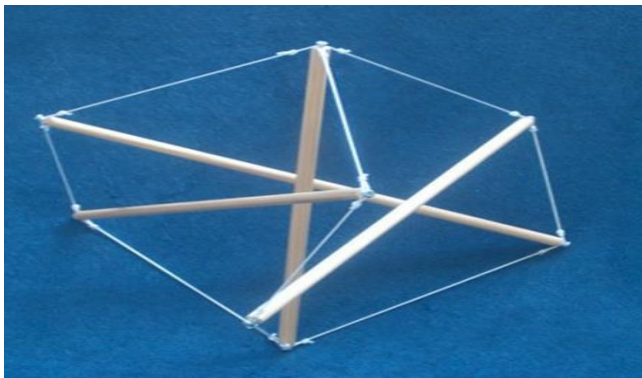

Figure 1: Prototype Tensegrity Structure

1.1 Definition

TENSEGRIY = TENSION + INTEGRITY

TENSEGRIY, tensional integrity or floating compression is a structural principle based on the use of isolated components in compression inside a net of continuous tension, in such a way that the compressed members (usually bars or struts) do not touch each other and the pre stressed tension members (usually cables or tendons) delineate the system spatially.

1.2 Concept of Tensegrity Design

Tensegrity structures are structures based on the combination of a few simple design patterns:

- Loading members only in pure compression or pure tension, meaning the structure will only fail if the cables yield or rods buckle.
- Preload or tensional pre-stressed which allows cables to be rigid tension.
- Mechanical stability, which allows the member to members to remain in tension/compression as stress on the structure increase.

Because of the patterns, no structural member experiences a bending moment. This can produce exceptionally rigid structures for their mass for the cross section of the components.

2. BENEFIT OF TENSEGRITY STRUCTURE

a) Tension stabilizes the Structure.
b) Tension structures are Efficient.
c) Tensegrity structures are Deployable.
d) Tensegrity structure are easily Tunable.
e) Tensegrity structures can more Reliable Modelled.
f) Tensegrity structure can perform Multiple Function.

3. MATERIAL CHARACTERIZATION

Tensegrity structures generally consist of soft members (cables) and hard members (struts). It is essential to

determine the material properties i.e. the Young's modulus (E), yield strength and the ultimate strength of both the tension and the compression members before they can be employed for fabrication. In this study Indian Standards IS 1239-I (1990), were used as compression members. The market confirming to IS 3459 (1977), were used as tensile members. The GI pipes

Table -1: Properties of GI pipe as per IS 1239

PARAMETER	VALUE
Nominal bore diameter	15 mm
Thickness	2.6 mm
Mass	1.21 kg/m
Maximum outside diameter	21.8 mm
Minimum outside diameter	21
Tolerance in thickness	-10% to + unlimited
Minimum tensile strength	320 N/mm^2

Table -2: Properties of Stander Wire as per IS 3459

PARAMETER	VALUE
Nominal diameter	4mm
Construction	6*19(12/6/1)
Approximate mass	Round
Minimum breaking load	6.09 kg/100
Tolerance in thickness	9.4 KN for 1770 grade steel
	10.4 KN for 1960 grade steel
Tolerance in thickness	+ 6% to -1%

were tested in the universal testing machine (UTM) of 100t capacity. Four strain gauges of 5mm gauge length, manufactured by Tokyo Sokki Kenkyujo Company Limited (TML, 2005), were surface bonded in the middle portion along the circumference of the GI pipe using Cyanoacrylate (CN) adhesive. The strain gauges were connected to the data logger card fixed on a personal computer for automatically recording the strains using strain smart data system, version 3.1. The average strain was considered for determining Young's modulus of the pipe. The internal and external diameters of four pipes were measured and the average inner and outer diameter was

Figure 2: Eye bolt

Figure3: Eye bolt joint with GI pipe

Figure 4: Stranded weir

found as 15.9 and 21.375 mm respectively and the cross sectional area was calculated as 160.284mm2. Three pipes were tested and the stress strain curve. The average value of Young's modulus was computed as 2.05×10^5 N/mm2. The average breaking load was 65727 N and the corresponding ultimate stress was 410 N/mm2. Hence, the GI pipes confirms to 240 grade as per IS 1161 (1998) and the yield stress is 240 N/mm2.

Figure 5: Different Stages of Deployment of Tensegrity Structure in Cable Mode,
(a) Stage 1, (b) Stage 2, (c) Stage 3

4. OBJECTTIVE

The qualities of tensegrity structure, which make the technology attractive for human use, are their resilience and ability to use materials in a very economical way. The design of tensegrity structure is complex and iterative process. Hence this research mainly focused on development of dismountable tensegrity structure, the main objective of this research can be summarized.

1. To develop a dismountable single tensegrity structure module (1m x 1m) based on half cuboctahedron configuration.
2. To extend it to a 2m x 2m dismountable tensegrity structure grid (by joining four single modules) on half-cuboctahedron configuration for shelter purpose.
3. Development of new design approach using artificial neural network(ANN).

5. METHODOLOGY ADOPTED

The design of tensegrities is divided into three distinct steps
1. From-finding tensegrity
2. Structural stability tensegrity
3. Load analysis tensegrity

Form-Finding is an essential problem in the design of tensegrity systems, since the Fulfillment of stability requirements depends on both the shape and geometry. The solution requires simultaneously solving the geometry and self-stress. Thus, any form finding method would be either based on geometry or mechanics, but both aspects still need to be taken into account that two main methods are available, namely form-controlled and force controlled. The first aspect of the form-finding problem is determining the arrangement and connectivity of the system, such that it is capable of structural stability.

6. ADVANTAGES AND DISADVANTAGES

6.1 Advantages

• Due to the ability of the structure to respond as a whole, it is possible to use materials in a very economical way, offering maximum amount of strength for a given amount of building material. The construction of towers, bridges, domestic. employing tensegrity principles will make them highly resilient and, at the same time, very economical.
• Tensile forces naturally transmit themselves over the shortest distance between two points; hence the members are precisely positioned to best withstand stress.
• The fact that these structures vibrate readily means that they transfer loads very quickly, so the loads cannot stress the structure locally. This is very useful in terms of absorption of shocks and seismic vibrations.
• The spatial definition of individual tensegrity modules, which are stable by themselves, permits an exceptional capacity to create systems by joining them together. This conception implies the option of the endless extension of the assembled piece.
• For large tensegrity constructions, the fabrication process would be relatively simple to carry out, since the structure is self-scaffolding.

6.2 Disadvantages

• Tensegrity arrangements sometimes face the problem of bar congestion.

• Several experts do not prefer tensegrity structures due to large deflections

• The fabrication complexity is also a barrier for developing the floating

Compression structures. Spherical and domical structures are complex, which leads to problems in production.

• The absence of adequate commercial design tools has also been a limitation until now. There was a lack of design and analysis techniques for these structures.

7. APPLICATIONS

Tensegrity structures are attractive solutions under following circumstances:

I. Portable and foldable structures: such as for disaster struck areas, nomadic communities and field hospitals.

II. Superstructures for embedded substructures in order to escape terrestrial confines (e.g. in congested or dangerous urban areas, flood plains or irregular, delicate or rugged terrains).

III. Tensegrity Towers can be used as Lightning conductors. In situations where large displacements are not a matter of concern or considerable displacements are acceptable, tensegrity towers can be employed to support antennas, receptors, radio transmitters, mobile telephone transmitters, etc.

IV. Refugee or hiking shelters.

V. Foldable reflector antennas and masts for large retractable appendages in spacecraft.

VI. Frames over large areas for environmental control, energy transformation and food production

VII. Tensegrity systems can be used to make economical furniture like chairs, tables, lamps etc.

VIII. Exclusion or containment of flying animals or other objects.

8. CONCLUSION

Tensegrity structures in real life can be monitored online using wireless technology and the damage can be detected by comparing the frequencies in intervals. It is observed the damage in both cables and struts can be detected by bonding a single PZT patch on a strut member. The frequencies undergo greater change for damage in the strut than the cable. Low frequency technique is suitable for detecting global damage in the single module as well as grid structure where as high frequency technique (EMI technique) is able to detect localized damage i.e. on individual member. Hence, it is possible to detect damage in the tensegrity structure in field by bonding a single piezo sensor. A single piezo sensor bonded to a strut also provides information regarding damage occurrence with respect to nodes of the tensegrity

structure. Further theoretical and experimental studies are required for locating damaged elements of tensegrity structures.

This thesis reviews the definitions, different form finding methods, static and dynamic analysis, design and deployment of tensegrity structures in detail. Further, the main properties, advantages, disadvantages and potential applications of tensegrity structures have been highlighted. The research mainly highlights on fabrication and testing of dismountable tensegrity single module and tensegrity grid structure based on half cuboctahedron configuration. Numerical models of the structures have been validated experimentally. The dismountable tensegrity grid is easy to fabricate and assemble/dismantle and does not require lifting machine and equipment's. Further, no skilled labour is required for restressing. Hence, the proposed structural system is ideal for field deployment. The structure requires less space for storage and is easy to transport. The tensegrity grids reported so far in the literature require mechanization in field application, which is likely to bring up the overall operational cost. In addition, the proposed method reduces the number of cables. Artificial neural network is employed as an alternate design approach for the proposed structural system. To the best knowledge of the researcher, this is the first time such a structure has been comprehensively monitored using conventional as well as smart sensors.

9. REFERENCE

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