NCSSM Mini-term 2011

Dr. Bennett

Tensegrity

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Abstract

Tensegrity is an architectural principle in which compression members are bounded to each other via only tensional members. These structures are derived from basic "weaves" to form any polyhedra. Furthermore, these polyhedra can be concatenated to form structures. In my mini-term I designed my own structure and constructed an eight foot tall statue.

1 History

Tensegrity was conceptualized during the 1950's by Buckminster Fuller and Kenneth Snelson. At the time, Kenneth Snelson was doing artistic experimentation at Black Mountain College in North Carolina. He came up with his "X-module" and expanded. However his professor, Buckminster Fuller coined the term "tensegrity" and then continued to do work with geodesic domes, which rely on tensegrity principles. A famous geodesic dome is "Spaceship Earth" at Epcot Disney World. Kenneth Snelson's most famous structure is the "Needle Tower" located in the Hirshhorn Museum in Washington D.C.


2 Fundamentals

Tensegrity is derived from weaving. Each weave either has a right or left handed rotation. Weaving can also be brought into three dimensions. Tensegrity takes these weaves and binds the ends together using tension. Any polyhedra can be formed in this way [1].

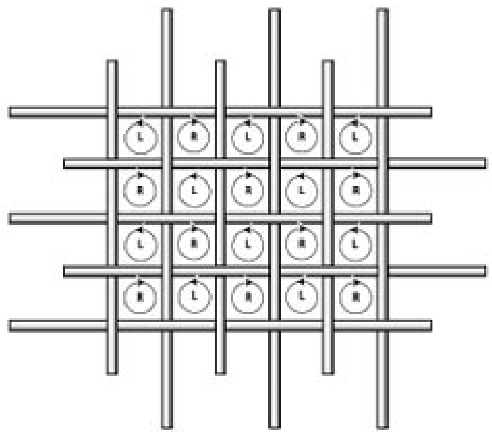


Figure 1: Rotations shown in a typical weaving

Figure 2: 3-D weave vs. 3-D tensegrity of tetrahedron

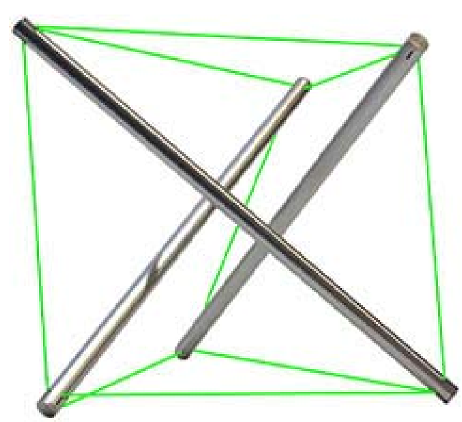


Figure 3: Tensegrity triangular prism

To see how tensegrity manages to be upright and standing, see figure 3. The triangular prism is the most basic structure. The top and bottom triangles force the compression members to come together and increase the height, while the three vertical tension members prevent this from happening.

In order to have rigidity, there must be prestress. In other words the tension members must be taught. The shape of the structure will morph until the forces along the tensions members equalize [3].

All tension members must be present since the whole system is interconnected. If one member is removed, then the whole system loses structural integrity. This creates problems in construction as the whole structure must be completed as the same time. Progressively building does not work.

3 Properties

The unique nature of tensegrity begets numerous properties.

3.1 Aesthetics

The fact that none of the compression members are linked to each other leads to a very unique aesthetic. In all traditional architecture, compression members rely on other compression members. Tensegrity's atypical look is almost alien and creates a very ethereal image.

Figure 4: Kenneth Snelson's "Easy Landing"

The silhouette of a tensegrity structure also preserves some of the weave. For example, from a certain perspective, a tensegrity isocahedron's silhouette looks like a six pointed star.

3.2 Modularity

In a tensegrity polyhedron, we have faces composed of tension members as edges. These faces can be connected such that there is still tension binding all the compression members. For example, in a triangular prism tower, the triangular faces can be connected. However, due to the aforementioned rotation of these structures, we connect pieces that have opposite rotation, so there is little net rotation.

3.3 Flexibility

In a sense, tensegrity structures are tension members that are stretched out by a framework of compression members. The structure will tend towards equalizing all the tension members, that is, the shape and size of structures can be easily changed by manipulating tension. This is easiest to see in rubber band models. Doubling a rubber band will increase the tension and make the affected faces smaller. In this way, we can alter a prisms height and width, or even make it conical. For tensegrity structures using twine or rope, tension is changed by lengthening or shortening segments. This creates flexibility where the shape of a tensegrity structure can easily be manipulated even after the structure is complete.

3.4 Collapsibility

Due to the nature of the constituent parts of tensegrity structures, i.e., rods and rope, materials can be transported quite easily. Furthermore simple structures can be folded into “nets” for transport.

4 Applications

4.1 Aesthetical

For my own project, I designed my own tensegrity structure. The goal was a tree-like object. With this in mind, I used two hexagonal prisms to create a trunk and a flattened tetrahedron for the canopy. The construction was made out of silver spray painted PVC pipe and twine. The structure stands around eight feet tall.

4.2 Practical

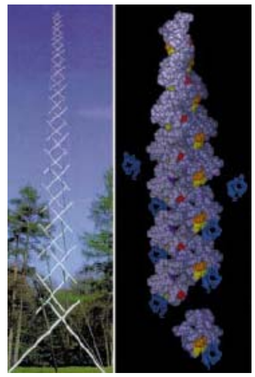
Non-artistic uses of tensegrity are varied.

In architecture, the Georgia Dome, which hosted the 1996 Summer Olympics, was a large tensegrity structure.

Kurilpa Bridge in Brisbane, Australia is a pedestrian and cycling bridge. It spans 470 meters.

Buckminster Fuller uses tensegrity in many of his inventions, such as his many geodesic domes in the world as well as a Dymaxion house which was intended to be a cheap, energy efficient house.

Donald Ingber, founder of the Wyss Institute at Harvard University employs tensegrity to model organic molecules and cell tissue [5].



Gordon Pask, an English psychologist even used tensegrity in his interaction of actors theory [6].

5 Conclusion

Tensegrity is an interesting architectural principle. It relies on rigid tension members to create structural integrity unlike the traditional methods of using the compression strength of materials. This novel idea produces structures that are very atypical yet visually appealing. Furthermore, tensegrity has uses from architecture to biology.

6 References

[1] Snelson, Kenneth. *Tensegrity.* http://www.kennethsnelson.net/category/tensegrity/

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[4] Burkhardt, Robert. *A Practical Guide to Tensegrity Design.* http://www.angelfire.com/ma4/bob_wb/tenseg.pdf

[5] Ingber, Donald. *The Architecture of Life.* http://web1.tch.harvard.edu/research/ingber/PDF/1998/SciAmer-Ingber.pdf

[6] Pask, Gordon. *Interaction of Actors, Theory and Some Applications.* *www.cybsoc.org/PasksIAT.PDF*