Tensegrity System by Pantadome and Its Units

Zhihua Chen Mamoru Kawaguchi

Department of Architecture
Hosei University
3-7-2 Kajino-cho, Koganei-shi
Tokyo 184
Japan

Tel: +81 42 387 6333
Fax: +81 48 258 8146
Email: chen@archi.arc.hosei.ac.jp

Abstract

Philosophy of tensegrity systems has got a great development and the principle of tensegrity has been adopted in several effective structural systems, such as cable dome and suspendome structures. Yet no pure tensegrity structures of large scale has been completed, according to Fuller's definition. By making use of the three-bar or four-bar-prism units, the periphery beam of cable dome can be changed to a tensegrity system. Thus, a kind of pure tensegrity system can be produced. To improve the rigidity of the pure tensegrity dome, radical ribs or longitudinal ribs made up of units can be utilized. When a two-circle ribs were adopted, a pantadome configuration emerged, Thus the so-called panta tensegrity dome. Important element of this system-the tensegrity units were then analyzed and experimented to test their structural features. With the advantages of simple joint system and the pushing up process being utilized as the process of prestressing, the panta tensegrity system will be expected to have high structural efficiency..

1. Tensegrity Systems

It is near forty years since Fuller coined the word tensegrity. Although the philosophy of tensegrity has got a great development, no engineering application of large scale by pure tensegrity system has completed yet. The concept of tensegrity was not able to be applied until late 1980's, when D. Geiger established his cable dome in the Korean Olympic game buildings. Later on, cable dome structures have realized in six large buildings world wide with the same configuration. Different from Geiger's radical-grid cable dome, a triangulated cable dome by M. Levy was adopted in another Olympic Game building in Georgia Atlanta by 1996.

Principle of tensegrity was also adopted in some other effective structural systems, such as suspendome system by M. Kawaguchi, five-bar-unit structure by Y. Hangai and so on. A lot of tensegrity configurations can also be found in R. Motro's work, where shows the various aspects of these innovative structural systems. Knowing that calculation methods are feasible by those of flexible systems, the main tasks to develop pure tensegrity structures lie in the morphology and the practical technical problems.

2. Pure Tensegrity

From the natural law of continuous tension and isolated compression, Fuller named tensegrity systems as: A tensegrity system was established when a set of discontinuous components interacts with a set of continuous tensile components to define a stable volume in space, where three main factor were mentioned, continuous tension, discontinuous compression and a stable volume. By the expression of a stable volume, tensegrity systems are meant to be in self-stressed and self-equilibrated state.

Although cable dome systems come from tensegrity, they are not pure tensegrity ones for their different prestressed and equilibrated manner, i.e., they are not stable volumes in space, they don't work without the periphery beams. Also for this reason, the construction methods are limited. The other structural systems mentioned above often have bar to bar connection, which are conflict to one of the three main rules for tensegrity , i.e. isolated compression.

Early models of tensegrity units from polyhedra by Fuller are self-equilibrated, but trying to make use of the inner space of the units led to cable domes. While A. Hanaor has been doing research on assembling original tensegrity units to approach real tensegrity systems in which the compression members do not contact strictly. Even though the problem of long compression members exists, the members in compression can be as less as one fourth of total members, the completed tensegrity systems will still have their advantages as well as in the aspect of construction.

Fuller's single-layer pure tensegrity domes, developed from polyhedra, are difficult to realize in practice, while cable domes have been completed with the help of periphery beams. Through Hanaor's double layer tensegrity structures, roof area can be covered, and of course structures could be spanned in form of beams. Thus, we use tensegrity beams, which are assembled by polyhedron tensegrity units, instead of the concrete beam in cable dome structures, pure tensegrity domes can be designed.

3. Tensegrity Units

In constituting the tensegrity beam instead of a concrete one, not only the configuration , but also the feature of the units are found to be of important role. The three-bar-prism unit and four-bar-prism unit were designed and fabricated, then by load experiment, the structural features of those units were studied. For the test models, the joint structures were discussed first. The same as that a type of a joint structure means a kind of commercial space grid system, the joint can be designed and produced in very different ways. Among end hole joint, Mero joint, bolt piece joint, plate tube joint, suspendome joint and other joint structures, the effective factor were absorbed and a kind of hemisphere joint was designed.

By the hemisphere joint, two tensegrity units were tested. The result showed that non-linear feature for the load-displacement at the beginning and a load strengthen characteristic with the increasement of the load level. Also the value of prestress had large influence on the load displacement curve, which became to be more linear to higher prestress, meaning rigidity of the structures depends on the internal force to a large extent. While the load capacity would reduce with respect to large prestress, all of which showing consistent with the theoretical analysis.

For the two kind of test models by three and four-bar-prism units, the kinematics freedom under symertrically vertical load was only one in the according direction. With the stress strengthen feature, two kinds of unit showed to be suitable to be used in large scale tensegrity structures. The combination of those units could be arranged in various patterns, among which strictly tensegrity ones may be in several categories.

4. Panta Tensegrity Systems

The same as other tension structures, tensegrity systems do not have rigidity before they are prestressed, they are geometrically flexible and have inner mechanisms. To improve the rigidity of the pure tensegrity system by cable dome and tensegrity units, ribs can be added to the structure, where the ribs will also be constituted by tensegrity units. The ribbed units can be arranged either in radical direction or in longitudinal direction.

Although the longitudinally ribbed ones would have higher rigidity than those radically ribbed structures, when a two-circle-rib pattern was adopted, the ribbed structure would exactly be a Pantadome configuration and thus a panta tensegrity.

Even if theoretically a structural system is feasible, it will not be a sound structural system without suitable considerations of construction, especially in space structures. To achieve the above suggested tensegrity domes, theory of the patented structure-Pantadome system is worth to be introduced in. Pantadome is an optimum structural system, in which the hoop action of a dome is partially removed to make the structure a one-directional mechanism, so the dome can be assembled at a lower level near ground, then pushed up to the final position, thus the erection can be completed more safely, quickly, precisely and economically.

Pantadome structures are usually divided into three parts and connected together by two articulated joint lines, then one more articulated line will connect the dome to the supporting structures. Let's say that the three part of the Pantadome are as surrounding shell, middle shell and the central dome. By the idea of pure tensegrity dome, the central dome can be easily constituted. The surrounding shell and the middle shell, need not only the periphery tensegrity beams as the central dome, but also inner ones to form stable volume before lift-up. The two tensegrity beams at a articulated joint line inside the dome area, can be arranged to the configuration of a double layer tensegrity grids structure by three-bar-prism unit or four-bar-prism unit. So the completed pure tensegrity dome is composed of three tensegrity units parts and three cable domed structural parts.

There are still two advantages for the pure tensegrity dome systems in Pantadome forms, one is that the simple joint structure will make the erection more convenient and cheap, another is that the lift-up process can be used as the process of the prestressing because the roof is light and the jacks are of high load capacity.

3. Conclusion

A kind of pure tensegrity dome systems (Panta tensegrity system) was proposed on the basis of cable dome system and polyhedron tensegrity units. By the principle of Pantadome, when the pure tensegrity dome was constructed to the form of Pantadome patterns, the vertex of the inner units in some four-bar-prism units configuration happened to be the starting points of the cable dome structures. On the basis of simple joint structure and simple prestress process, then by further analysis on the mechanical features, panta tensegrity domes are expected to be used in large span light structures providing quality improvement, cost benefits and increased safety.

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