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Structural behavior and design methods of Tensegrity domes

Feng Fu*

Ph.D. Candidate, School of Civil Engineering, University of Leeds, LS2 9JT Leeds, UK

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Abstract

A comprehensive study on the structural behavior and structural types of Tensegrity domes is presented. The numerical analysis method of Tensegrity structure is also discussed. The first Tensegrity dome–Georgia Dome is analyzed as a prototype through a non-linear software using the numerical method presented in the paper. Based on the analysis, the structural behavior of the Tensegrity dome is summarized and therefore, some design methods for the Tensegrity dome are proposed. Based on the above studies, several new types of Tensegrity domes with different geometric grids are proposed by the author. A comparison of the structural behavior between the Georgia Dome and the domes proposed by the author is also made.

Keywords: Tensegrity; Non-linear; Equilibrium; Static

1. Introduction

In the process of designing long span space structures, the way to reduce the self-weight of the structure and consequently the cost of the building is the key issue. Among different types of structures, the ‘Tensegrity system’, that is a self-equilibrium system composed of continuous prestressed cables and individual compression bars, is one of the most promising solutions.

* Tel.: +44 113 2332319; fax: +44 113 3432243.
E-mail address: cenffu@leeds.ac.uk.

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The concept of 'Tensegrity' was first conceived by Fuller [2], which reflected his idea of 'nature relies on continuous tension to embrace islanded compression elements'. Unfortunately, his 'Tensegrity dome' has never been executed in an engineering project.

It was Geiger et al. [3], who made use of Fuller's thought and designed an innovative structure 'cable dome'. It has been successfully put into practice in the circular roof structures of Gymnastic and Fencing Arenas for the Seoul Olympic Games in 1986. However, it is could not be considered as an actual Tensegrity system, because the compressed ring is not inside the set of cables.

In 1992, Levy [6,7] further improved the layout of the cable dome and built the Georgia Dome in quasi-elliptical shape for the Atlanta Olympic Games. Motro [8], (2002) and Hanaor [4] did much research on a double layer grid Tensegrity system. Some researchers also proposed a kind of RP system for the Tensegrity dome grid. The dome is made of self-stressed equilibrium reciprocal prisms. Base on this idea, Wang [11] proposed his own RP grid dome. Rebielak [9] proposed several new structural systems of cable domes shaped by means of a simple form of spatial hoops.

In addition to the above research toward the geometry grid of the system, some researchers also did some research on the numerical analysis of the system. Kebiche et al. [5] performed the geometrical non-linear analysis of Tensegrity systems. Sultan et al. [10] discussed the prestressability problem of Tensegrity structures. Williamson et al. [12] discussed the equilibrium conditions of a Tensegrity structure. Through the research of the researchers, an algorithm considering the geometrical non-linearity is widely developed, and the dominant role of initial equilibrium state and prestressed force is also widely recognized.

Among the domes in the Tensegrity system built to date and the domes proposed by the researchers, there exists different variations of the network geometries. For designers, it is interesting to know the correspondent structural features with different layout of the network, which will influence the weight and the cost of the structure. For application purpose, the way to design the Tensegrity dome also becomes necessary.

In this paper, the design methods of such a kind of dome are discussed. Several structural types of Tensegrity domes with different geometric grid are proposed by the author. The numerical analysis method of Tensegrity structure is also discussed. The first Tensegrity dome–Georgia Dome is analyzed as a prototype through a non-linear software using the numerical method presented in the paper. Based on the analysis, the structural behavior of the Tensegrity dome is sumarized and some design methods for the Tensegrity dome are proposed. A comparison of the structural behavior between the Georgia Dome and the domes proposed by the author is also made.

Since most long span sports halls are non-circular in plan and usually have the configuration in an oval shape, the layouts of domes proposed in this paper are all presented as elliptical.

2. Numerical analysis method

The Tensegrity structure is a geometrical non-linear system, the structural analysis can be divided into two phases: the first phase is the initial equilibrium; the second phase is