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Numerical simulation study on structural behavior of Tensairity domes with annular airbags

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ABSTRACT

Tensairity dome is a lightweight spatial structure composed of struts stabilized by cables and airbags inflated by low pressurized air. Two forms of Tensairity domes with annular airbags, stiffened with central cables or webs placed between the upper and lower chords, were proposed based on the Tensairity concept. The zero-stress state, the initial state and the loaded state were successively simulated to investigate the static behavior of the structures, respectively. The results indicate that both two forms of structure have good static performance and the internal pressure in the airbag at about 1000–4000 Pa can ensure the stabilizing role of the inflated airbag. The investigation reveals the subtle interplay between the internal pressure and external loads in the load state, and the tremendous effect of temperature change on overall structure is predicted. The comparisons also show the benefits of webs in the structure for all load cases. Finally, the results show the attractive advantages of Tensairity dome in comparison with conventional structures in terms of structure weight and overall stiffness.

1. Introduction

Air inflated membrane structure is a type of spatial structure composed of membrane members and pressurized internal air, of which the major advantages are light weight, low cost and able to accommodate large spans, leading to wide applications ranging roof structures to military facilities [1–3]. But the relatively poor load-bearing capacity drastically limits their application in structural engineering. However, this restriction is overcome by the Tensairity concept [4], of which most previous researches focused on Tensairity beams or columns. Tensairity is a synergetic combination of struts, cables and an airbeam. The airbag pretensions the tension element and stabilizes the rigid element against buckling. The upper chord of rigid member could greatly reduce the wind sensitivity of membrane structures and increase the resistance capacity of the external load, and the whole structure can be prestressed by the air pressure instead of tensioning device, which can also improve the convenient construction quality and efficiency significantly. Several structural applications have already been realized so far with Tensairity, including the roof of a parking garage with a span of 28 m in Montreux [5], a skier bridge with 52 m span in Lanslevillard and a tennis court cover in Rouhampton.

Investigations of the structural behavior of different shape Tensairity structures revealed their reliability as beams without and with internal fabric webs or cables [6–12]. Plagianakos [13] and Wever [14] studied the static performance of spindle shaped Tensairity structures under axial compressive loads, revealing their potential as columns. Breuer and Luchsinger [15] applied the Tensairity concept to inflatable wings, overcoming the small load-bearing capacity of such structures. Recently, Tensairity arches were developed and investigated, showing that the Tensairity concept could bring many solutions for inflatable arch structures [16].

Based on this structural concept, Tensairity dome is proposed as a type of spatial structure, which is designed to transform two-dimensional force into three-dimensional force. In this paper, two forms of tire-shaped Tensairity domes with the same geometry, stiffened with central cables or webs placed between the upper and lower chords, are studied numerically, and this study is devoted to the investigation of the static response of Tensairity dome to different types of load cases. For each load case the behaviors of both domes are compared with each other, and the influence of the internal pressure on the stiffness of Tensairity dome is discussed. In particular, the interaction between the internal pressure and external loads as well as the effect of temperature change on the structure is taken into account.

2. Structure design

Two kinds of Tensairity domes with a span of 80 m are designed, which are called c- and w-dome, respectively, and the compositions of

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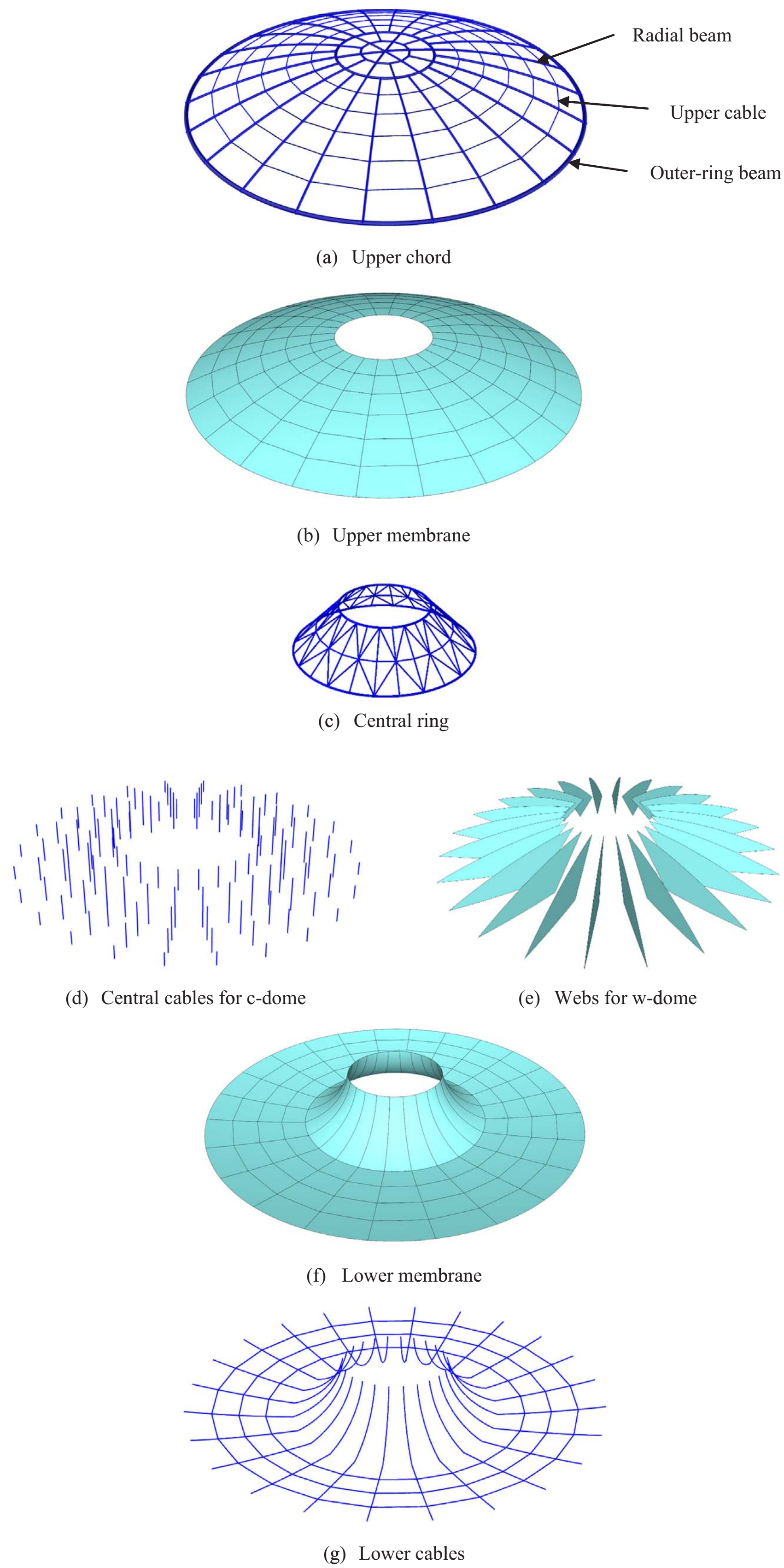

Fig. 1. Composite members of Tensairity domes.