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EXTENDED ABSTRACT

Investigating the Pattern of Progressive Collapse in Double-Layer Dome Space Trusses

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1. Introduction

Space structures lack non-structural members adding to their stiffness and strength. Also, these structures have lower degree of redundancy, and therefore the loss of an important member in them can result in collapse of the entire structure. Progressive failure in dome structures has been investigated by various researchers (Jihong and Nian 2017; Zhao et al. 2017; Fu and Parke 2018; Gordini et al. 2018; Zheng and Fan 2018). The purpose of this study is to identify the behavior of two-layer dome structures against the occurrence of progressive failure and to determine the relevant failure patterns. The occurrence and pattern of progressive failure in the studied dome is investigated by eliminating the compressive and tensile members as well as the support structures.

2. Methodology

2.1. Geometry

The model used in this study is based on studies by Safari (2016). A two-layer dome space truss with a height of 1.2 m and a radius of 7 m is studied in this paper. Fig. 1 displays the dimensional characteristics of the investigated space truss. Three types of pipe sections have been used in construction of the dome. Section profiles used for structural elements are given in Fig. 2. This figure also shows the group of elements for each type of pipe section.

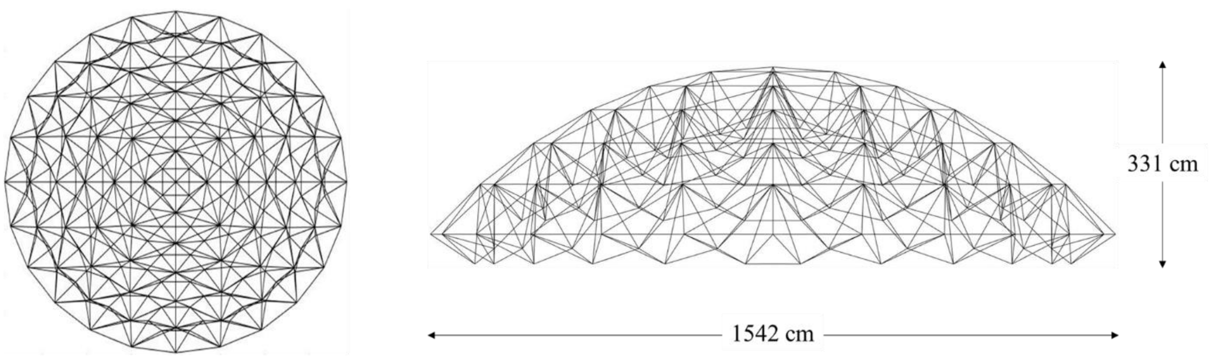

Fig. 1. Dimensional characteristics of the investigated structure

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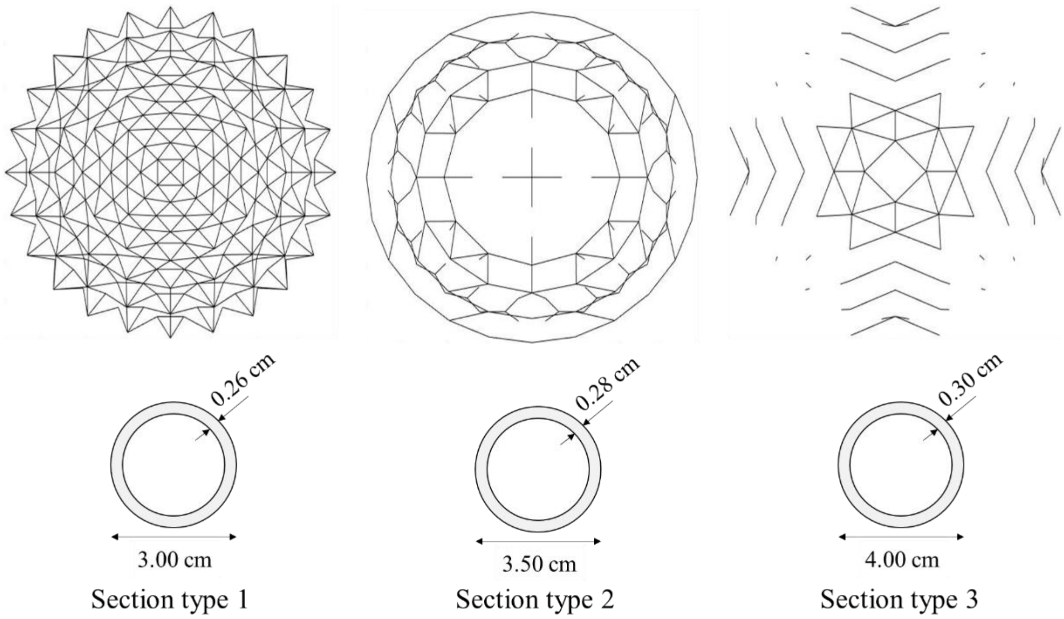

Fig. 2. Section profiles used for structural elements

2.2. FE modeling and validation

The studied structures are modeled and analyzed using the nonlinear dynamic analysis in opensees software. Members are modeled using “dispBeamColumn” element with an L/1000 imperfection at the mid-length. “Steel02” uniaxial material is used to define stress-strain relationship. Modulus of elasticity and the yield stress for steel material is assumed to be 200 GPa and 250 MPa, respectively. To validate the models, a double-layered grid space truss whose test results were available in the literature (Parke 1989) was used at different levels of gravity loads. The geometry of the structure used for verification and comparison of results are shown in Fig. 3. According to the figure, it can be seen that there is a good agreement between experimental and numerical curves.

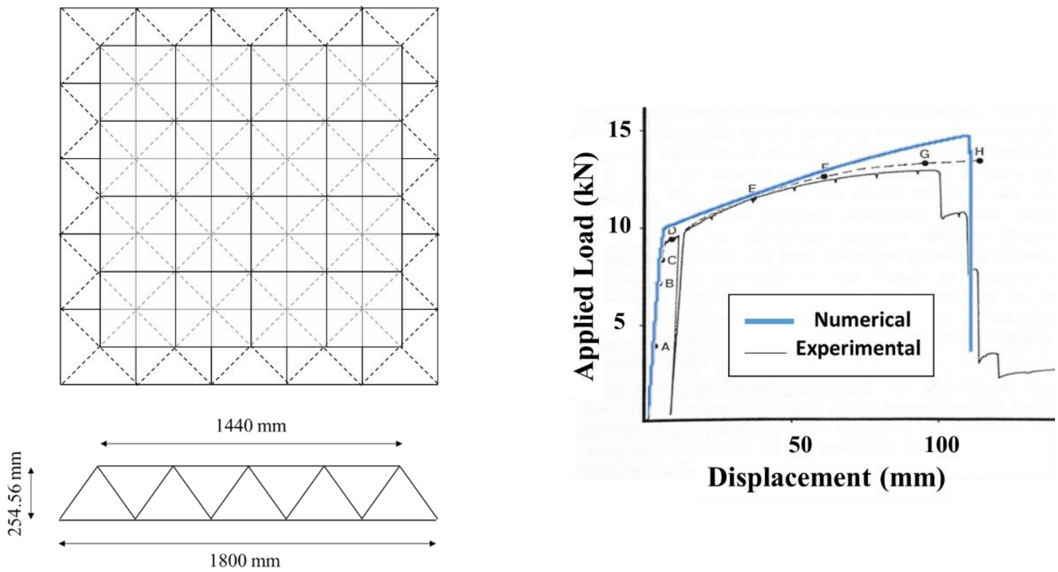

Fig. 3. Structure used for verification and comparison of results

3. Results and discussion

3.1. The occurrence of progressive collapse

For the considered dome structure under design loads (100% of the gravity loads) the progressive collapse occurs only by eliminating four compressive members located at the farthest points on four sides of the dome.

Fig. 4 displays vibration of the vertex of the dome after removing one of these compressive members. By increasing the gravity load to 140%, elimination of twelve tensile members and eight support nodes result in triggering the progressive collapse. Fig. 5 displays the location of members and supports which their elimination cause progressive collapse at 140% of the gravity loads.

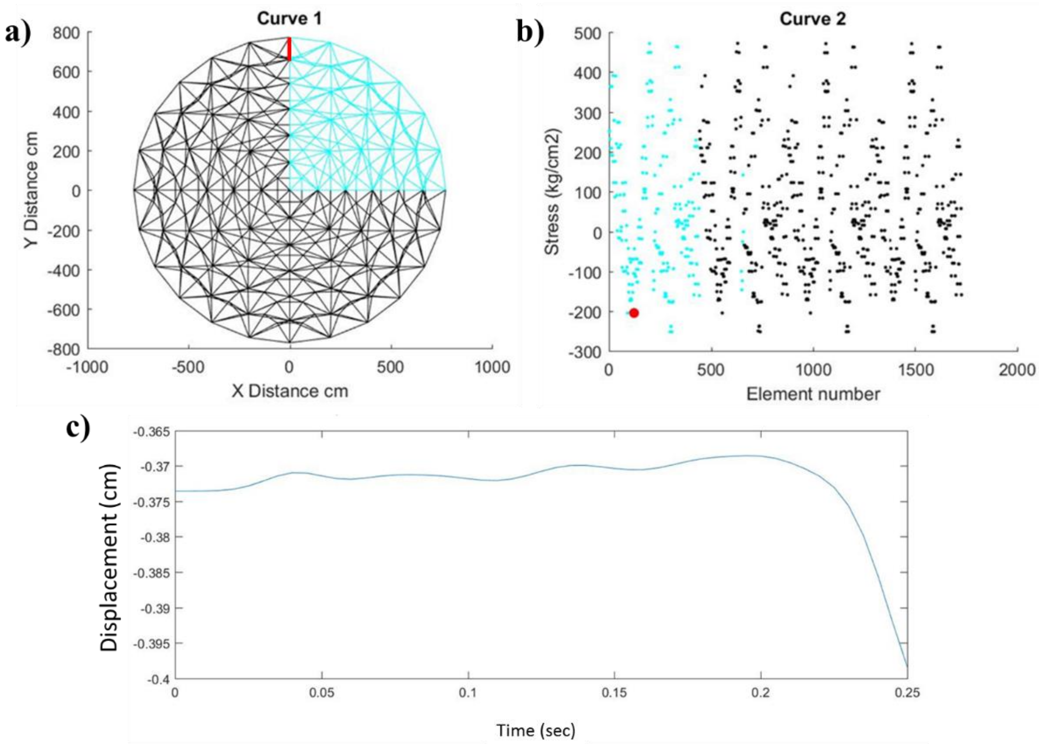

Fig. 4. Vibration of the vertex of the dome after removal of member 123: a) location of the removed element, b) stress level at removed element, c) Vibration of the vertex of the dome

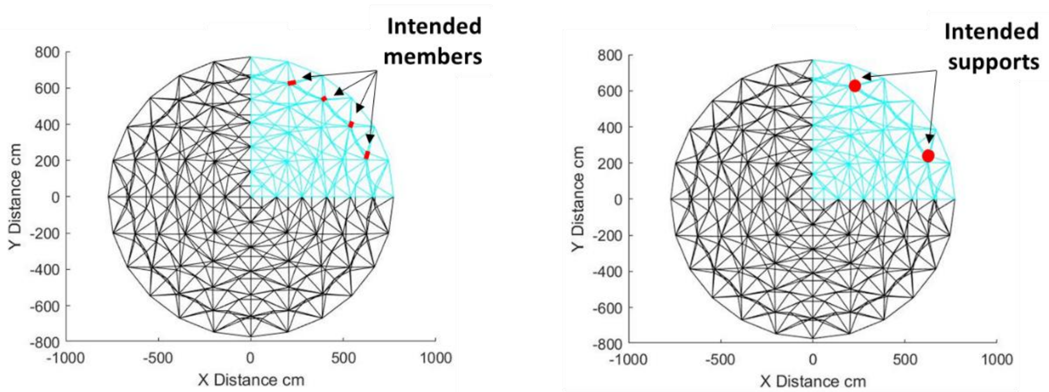

Fig. 5. Members and supports which their elimination cause progressive collapse at 140% of the gravity loads

By applying 150% of the gravity load or more, the progressive collapse occurs by eliminating every member (compressive or tensile) or support of the structure. Fig. 6 displays Pattern of progressive collapse for elimination of compressive members, tensile members and support nodes. For compressive and tensile members, elimination of one central and one side member is displayed. According to the figure, the progressive collapse occurs in the outer ring of the dome where the members are attached to the support nodes. Also it can be seen that, the more closer the removed member is to the center of dome, the more extensive the propagation of progressive collapse will be.

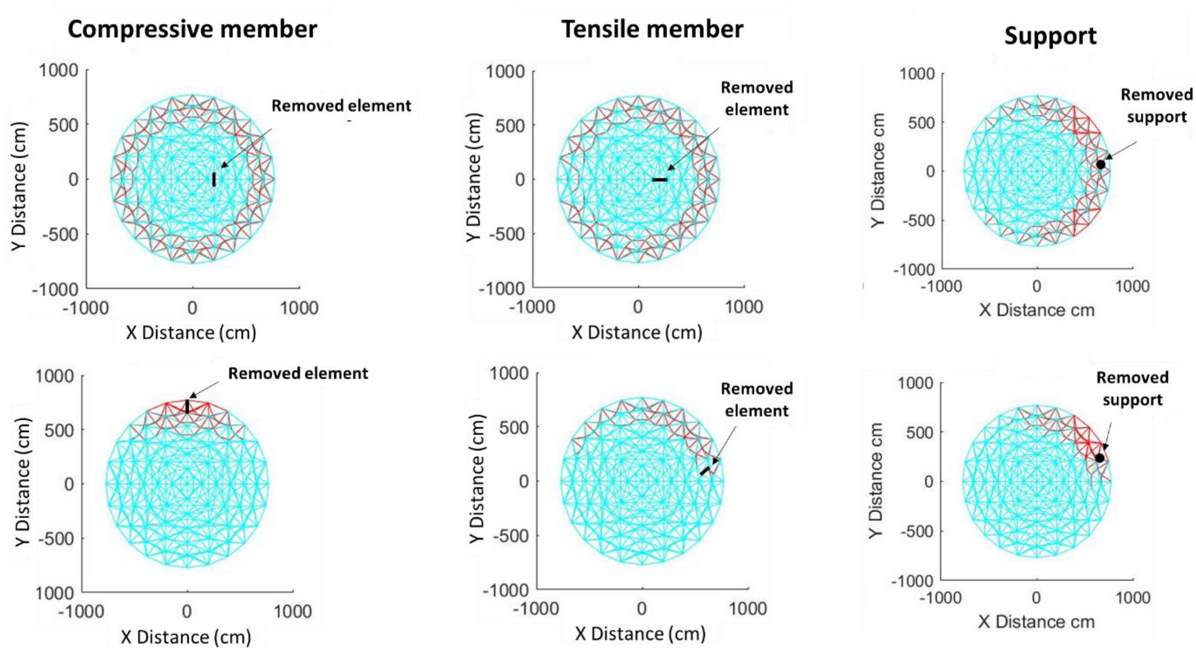

Fig. 6. Pattern of progressive collapse for elimination of compressive members, tensile members and supports

4. Conclusions

The occurrence and pattern of progressive failure in the studied dome is investigated by eliminating the compressive and tensile members as well as the support structures. Based on the results:

- By applying 100% to 140% of the gravity load, the progressive collapse occurs only by eliminating four compressive members located at four sides of the dome. However, by applying 150% of the gravity load or more, the progressive collapse occurs by eliminating every compressive member.
- By applying 100% to 130% of the gravity load, removing none of the tensile members results in occurrence of progressive collapse. By increasing the gravity load to 140%, elimination of twelve tensile members result in triggering the progressive collapse. However, by applying 150% of the gravity load or more, the progressive collapse occurs by eliminating every tensile member.
- By applying 100% to 130% of the gravity load, removing none of the supports results in occurrence of progressive collapse. By increasing the gravity load to 140%, elimination of eight supports and for more gravity loads elimination of every support result in triggering the progressive collapse.
- In most cases, the progressive collapse occurs in the outer ring of the dome and then propagates to other parts. In general, the more closer the removed member is to the center of dome, the more extensive the propagation of progressive collapse will be.

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