Progressive Collapse in Tensegrity Systems: An Experimental and Numerical Evaluation

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Abstract
The local collapse due to buckling of struts or rupture of cables in tensegrity systems, which affects a small portion initially, has potential for propagating to other parts of the system and may ultimately cause overall collapse of the system. To better understanding the response of tensegrity systems subjected to the progressive collapse, the experimental and numerical studies were carried out on a 3×3×0.7 *m* prototype. The experimental programme consists of tests on the constituent elements and collapse test on the whole system. Two types of collapse due to sudden rupture of a cable element and buckling of a strut were examined in the tensegrity model under load control. It was found that the most important factors that influence the collapse behavior of the tensegrity model are the imperfection amplitude, damping factors and residual stresses of the buckled struts. Based on the obtained results, the finite element model were adjusted, compared and validated with the experimental results until reliable and robust numerical model were achieved.
Keywords: Tensegrity systems; Snap-through; Sudden cable rupture; Progressive collapse

1. Introduction
It was recognized that the buckling behavior of struts and rupture characteristic of cable elements have a dominant effect on the collapse behavior of these systems. The local collapse due to buckling of struts or ruptures of cables, which affects a small portion initially, has potential for propagating to other parts of the system and may ultimately cause overall collapse of the system. In fact, the member failure in these systems has a dynamic effect on the behavior of the system; and consequently a large amount of kinetic energy is released at a local region of the structure. Therefore, it is important to account for dynamic effects, namely the rapid redistribution of member forces and the inertia forces, caused by the member failure in the evaluation of response of these systems under member failure phenomenon [1, 2, 3].
Important components of tensegrity systems are as follows: struts, cables and ball-bolt joint systems. Regarding the influence of these components on the collapse behavior of the tensegrity systems, the following questions may be arisen. What is the effect of member failure on the stability characteristics of tensegrity systems? When does a local collapse remain contained, that is, it remains local and there is no propagation? Under which conditions, a local instability can propagate over a large area of the system?
To answer these questions, the results of experimental and numerical studies on the collapse behavior of a tensegrity system are presented. Two types of collapse having dynamic effects were examined in the studied model: Local collapse due to sudden loss of a cable element at a specified load level and collapse due to member snap.
The numerical analysis consists of three main steps, namely nonlinear static analysis, linear eigenvalue analysis and nonlinear dynamic analysis. At the first step, a nonlinear static collapse analysis is carried out to find the load-deflection responses of the system using the behaviors of struts and cables obtained by buckling and tensile tests. If the response of the system is a "local collapse with dynamic effects", the subsequent steps can be undertaken. At the second step, a linear eigenvalue analysis is carried out to obtain the natural frequencies of the system in the strained configuration. By doing so, the appropriate time increment for the nonlinear dynamic analysis as well as suitable damping factors can be predicted. The time