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Sensitivity of Plane Tensegrity Systems to Tension-Only Member Loss

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Abstract

Tensegrity systems are self-stressed equilibrate spatial structures composed of compressed struts connected to cables in tension. The initial stresses contribute to the system's rigidity and stability. These systems typically contain a large number of members, and possess a high degree of statically indeterminacy. However, a number of members are critical to system integrity, with the loss of any of them likely to produce serious strength reductions. Furthermore, when these members are lost suddenly, their forces are shed into the structure in a dynamic manner, leading to yet more severe damage. This paper presents a numerical study on the sensitivity of plane tensegrity systems to both gradual and sudden member losses, taking into account both geometric and material nonlinearities. Other parameter that was also considered in this work includes the self-stress level. The conclusions drawn from such a study can in turn, lead to the suggestion of some simple guidelines for the design of such systems.

Keywords: tensegrity systems, self-stress levels, system integrity, collapse mechanisms.

1. INTRODUCTION

Tensegrity systems are innovative systems in Civil Engineering submitted in the 50's by sculptors and architects. These systems are a class of truss structures consisting of a continuous set of cables (tension members) and a set of struts (compression members). Further, these systems exist under pre-stressed (self-stressed) configurations. These initial stresses contribute to the system's rigidity and stability. Self-stress is created by shortening the cables and/or lengthening the bars starting from geometry with no self-stress.

Until recently, many studies have been carried out on tensegrity structures. A great amount of these researches has been done on geometrical basis, the so-called definition, form-finding on these systems. There are few studies undertaken on the effect of cable rupture on tensegrity systems. In this regard, we can refer to the "effect of cable rupture on tensegrity systems" which was performed by Ben Kahla and Moussa [1]. In which, the behavior of a beam-like tensegrity system was investigated without applying external loads. The effect of member loss on space trusses was also studied by many researchers as Smith [2], El-sheikh [3] and Malla [4]. It was illustrated that a loss of a member in a critical truss area was more serious than a loss in another area. Further to this, it was indicated that when a truss member buckled, it snapped through to a low post-buckling load. And since this phenomenon was rapid, dynamic effects could develop, leading to a further damage in the space truss. Nevertheless, so far no study was conducted to confirm and examine the effect of tension-only member loss on nonlinear behavior of double layer tensegrity systems under external loads.

Tensegrity systems are statically and cinematically indeterminate systems. They typically contain a large number of members, and possess a high degree of statically indeterminacy. It may be mistakenly believed that this inherent redundancy provides a large measure of safety against collapse. However, a number of members are critical to system integrity, with the loss of any of them likely to produce serious strength reductions. Furthermore, when these members are lost suddenly, e.g. due to the failure of a faulty connection, their forces are shed into the structure in a dynamic manner, leading to yet more severe damage.
In practice, members of a tensegrity system may be lost due to a poor member node connection. In spite of the high standard of manufacture and assembly normally adopted, having one or more faulty connections in a structure that contains hundreds of connections is a realistic possibility. The existence of geometric imperfections (e.g. lack of fit) may cause this to occur prematurely under a small portion of the total design load. In such a case, it can be argued that this member has in effect been lost.