IASS Annual Symposium 2019 – Structural Membranes 2019
Form and Force
7 – 10 October 2019, Barcelona, Spain

Element location and classification following a damage event of a near-full-scale deployable tensegrity structure

Ann C. SYCHTERZ[a]* and Ian F.C. SMITH[b]

[a]* Deployable and reconfigurable structures
Civil and Environmental Engineering
University of Michigan
GG Brown, 2350 Hayward, Ann Arbor 48105
ann@sychterz.com

[b] Applied Computing and Mechanics Laboratory (IMAC)
School of Architecture, Civil and Environmental Engineering (ENAC)
Swiss Federal Institute of Technology (EPFL)
Station 18, EPFL, 1015 Lausanne

Abstract

Current infrastructure is designed and built such that it must resist all possible loads. This leads to overdesigned structures that are inefficient in terms energy and cost. A structure that can self-identify damage, adapt, and learn for future events results from research into the emerging field of intelligent infrastructure and structural health monitoring.

Two halves of a "hollow-rope" tensegrity structure deploy from supports to join at midspan by controlling the length of active cables on each half of the structure. These active cables are continuous through the length of the half-structure, guided by intermediary joints where cables slide. Springs along the circumference of the structure facilitate deployment due to increasing the diameter of the structure when folding and subsequent decreasing during deployment.

Although previous work has addressed damage location and mitigation of ruptured cables when the cables are the load-critical elements of the structure, this work has not studied the classification of the type of element that is damaged, element location and damage mitigation.

This paper presents work on element classification, detection, and location of damaged elements in a deployable tensegrity footbridge. The footbridge is studied through monitoring dynamic behavior. Displacement and strain values are measured before, during, and after cable breakage. Natural frequencies in healthy and damaged states are compared. Free-vibration dynamic behavior of the tensegrity structure are characterized for two situations, deployment and in-service. Examination of ambient vibrations for the half structure and forced vibrations for the full structure successfully led to detection of ruptured cables. Correlation methods using strain measurements also successfully detect and locate a ruptured cable.

Detection of a buckled strut and a ruptured cable is successful by observing differences of natural frequencies between healthy and damaged states. Location of a damaged element is successful using nodal-position measurements through excluding possible damage scenarios and using strain measurements to identify elements of significant changes in eigenvector coefficients using principal component analysis. Therefore, excluding scenarios from a population for damage identification is effective for highly-coupled structures that are capable of large shape changes. These methods reveal the potential for damage identification of complex sensed structures.

Classification and location of a damaged element on a complex near-full-scale structure is successful using nodal position measurements through excluding possible damage cases and using strain measurements to identify elements of significant changes in eigenvector coefficients using principal component analysis. Implementing error-domain model falsification to exclude possible scenarios for location of damaged elements successfully reduced the number of probable cases of damage location. Paterns of influence from damaged cables and struts are useful to classify the type of element that is damaged. Therefore, the methodology involving error-domain model falsification (EDMF) for damage location is useful for closely-coupled structures that are capable of large shape changes.