

“Deployment analysis of a pentagonal tensegrity-ring module”

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Tensegrity structures are spatial systems composed of tension and compression components in a self-equilibrated prestress state. Although the concept exists since 1950, few examples have been used for engineering purposes. Tensegrity-ring modules are deployable modules composed of a single strut circuit that when combined create a hollow rope (Motro et al. 2006). The hollow-rope concept was shown to be a viable system for a tensegrity footbridge (Rhode et al. 2010). This paper focuses on the deployment of pentagonal ring modules that compose the tensegrity footbridge (Figure 1).

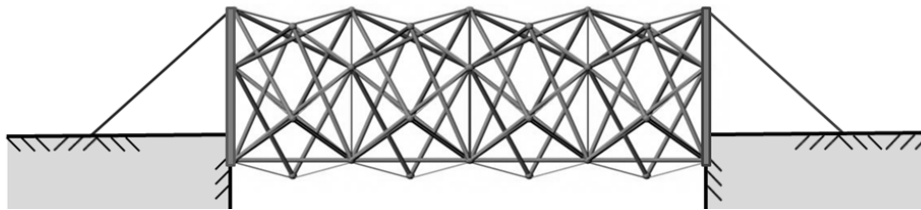


Figure 1: The structural system of the tensegrity pedestrian bridge

The deployability of the module is assured by special characteristics of the tensegrity-ring module topology. Both unfolding and folding occur through cable-length changes. Deployment is first studied geometrically for a single module in order to identify potential deployment paths. A highly compacted structure is obtained when both relative translation and rotation between the pentagonal faces of the module occur. Figure 2 shows the deployment solution space defined by the module length and the transverse rotation. The allowable space (white) is delimited by strut contact (grey).

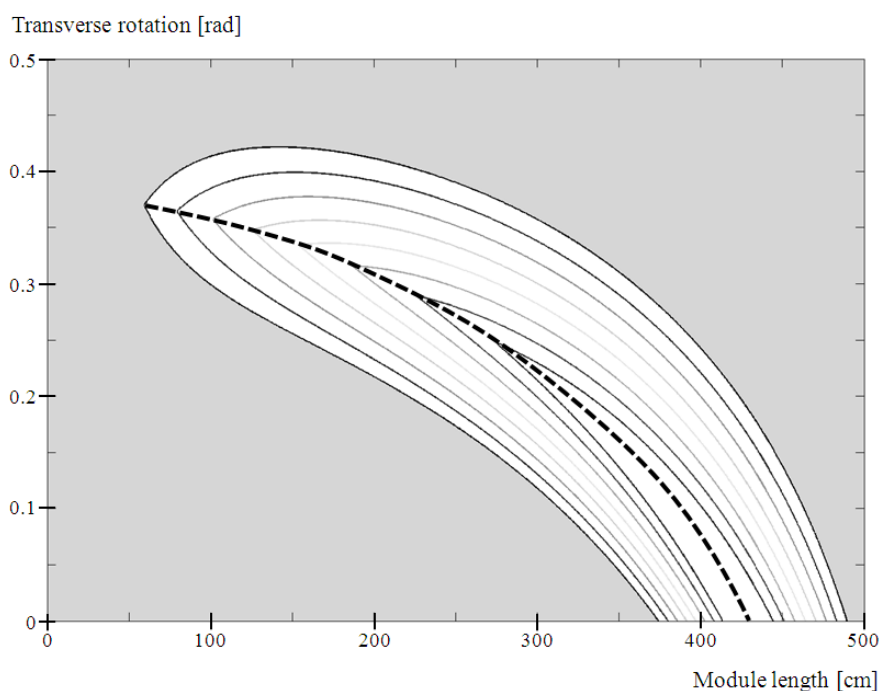


Figure 2: Space of geometric allowable deployment paths and the path with minimum contact risk

An analysis algorithm was conceived for the deployment of tensegrity modules. The algorithm is based on the actuation required for deployment. Static equilibrium configurations with modified module length are determined employing the dynamic relaxation method. Therefore, deployment can be analyzed with or without loading. Cable-length changes are applied first to create mechanisms allowing deployment and then to find new equilibrium configurations. Cable actuation is implemented as a decrease or increase of the length. The algorithm provides a description of the deployment path (module length and rotation) with an illustration of the movement. Internal forces and nodal displacements are provided for all configurations of unfolding and folding. The analysis stops if strut locking occurs. Additional constraints can be implemented if required.

A model of the deployable tensegrity-ring module was constructed (Figure 3). The model has a total length of 80 cm and it is made of aluminum struts and steel cables. Actuated members are implemented with the use of adjustable length cables and spring elements. The joints were designed according to service ability and deployment specifications. Therefore, they allow all required movements for deployment while providing the necessary strength and stiffness for static loading. Deployment paths and internal forces were validated experimentally on a physical model.

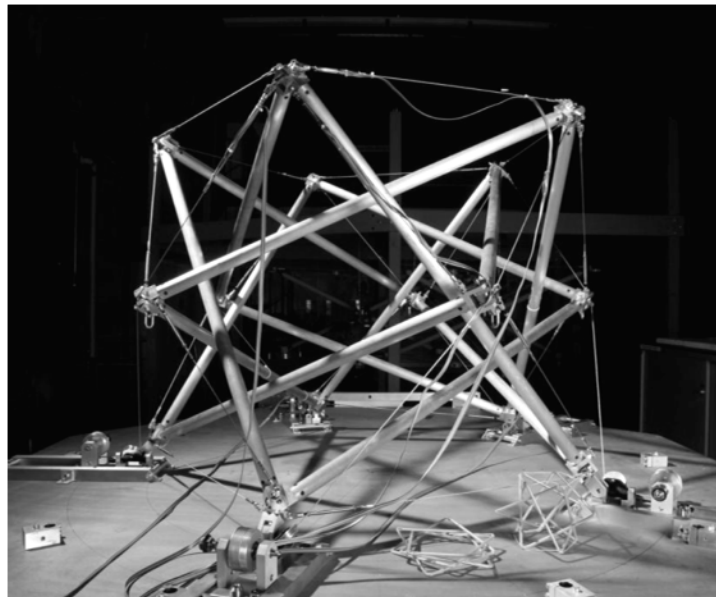


Figure 3: Small scale deployable tensegrity-ring module

References:

- Motro R, Maurin B, Silvestri C. Tensegrity Rings and the Hollow Rope. IASS Symposium 2006, New Olympics, New Shells and Spatial Structures. Beijing 2006:470-1.
- L. Rhode-Barbarigos, N. Bel Hadj Ali, R. Motro and I.F.C. Smith, "Designing tensegrity modules for pedestrian bridges," *Engineering Structures*, Vol.32, No.4, 2010, pp 1158-1167.