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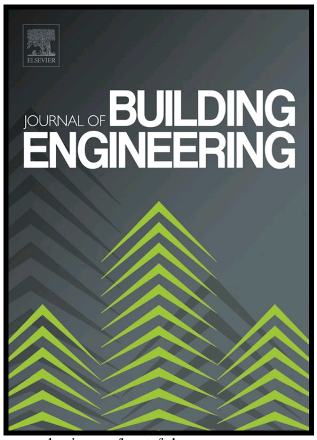

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PII: S2352-7102(17)30624-1
DOI: https://doi.org/10.1016/j.jobe.2018.01.013
Reference: JOBE401

To appear in: *Journal of Building Engineering*

Received date: 14 October 2017
Revised date: 16 January 2018
Accepted date: 29 January 2018

Cite this article as: Maria Matheou, Marios C. Phocas, Eftychios G. Christoforou and Andreas Müller, On the Kinetics of Reconfigurable Hybrid Structures, *Journal of Building Engineering,* https://doi.org/10.1016/j.jobe.2018.01.013

On the Kinetics of Reconfigurable Hybrid Structures

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Abstract

The paper refers to a basic reconfigurable structural typology of hinge-connected members forming of an *n*-bar planar linkage and a secondary system of struts and cables. The system aims at providing both structural stability and transformability. For realizing reconfigurations of the system, the 'effective 4-bar' concept is applied, using a sequence of 1–DOF motion steps that involve selectively locking (*n*-4) joints of the primary members and appropriately tensioning the cables. The control system includes two motion actuators associated with the two cables, which are located at the structural supports, as well as brakes installed on each individual joint. The numerical studies involve three similar arch-like configurations of 8, 9 and 10-bar linkages. Several feasible reconfiguration sequences are considered for the system, in order to change between an initial and a target configuration. The numerical studies provide insight into the characteristics of the hybrid structure and the practical implementation of the reconfiguration approach. The structural concept supports the realization of temporary buildings with adaptive characteristics as to varying external conditions or application requirements.

Keywords:

Hybrid structures, Reconfigurable structures, Multi-link mechanisms, Cable actuation, Motion planning.

1. Introduction

Traditional buildings have been fixed-shape structures, providing limited flexibility for adjustments to new or changing requirements. Nowadays, technological developments allow for a new generation of responsive building structures, whose shape can be modified, in order to adapt to changing functional, structural loading or environmental conditions. Adaptive architecture presents new opportunities as well as challenges within the wider field of building engineering. In response to this possibility, kinetic structures of different typologies and mechanisms have been developed in recent years, primarily in terms of deployable structures, in relation to requirements of temporary environments and aerospace applications [1]. In this frame, the use of scissor-like elements, tensegrity and hybrid systems of beams, struts and cables has been proposed to allow transformability.

Planar and scissor-like elements can provide an interrelated form and function, while being capable to expand in both, the horizontal and the vertical direction. Initially, Pinero conducted comprehensive studies on scissor-like system typologies with emphasis on aspects of scale and standardization. His patent on 'Three-Dimensional Reticular Structure' initiated the design and construction of a mobile, deployable theatre roof structure of compression and tension members [2, 3]. This particular structural typology was further developed with regard to stabilization members and locking mechanisms [4-6]. Alternatively, self-stable structures can be achieved through additional inner scissor-like elements. A considerable advancement in the design of such systems was made with the development of a simple angulated element and its geometrical principles [7-9]. Addressing the disadvantage of scissor-like elements, which are not capable of providing extensive flexibility since the systems' configurations are limited between an open and closed state, a novel planar and spatial scissor-hinge mechanism was proposed in [10, 11].

Tensegrity structures, i.e., self-stressed systems composed of tension and compression members, provide opportunities for embedded active control. This typology comprises autonomous and self-supported systems in all stages of transformation, from the initial to the target one, especially in the intermediate ones, while effectively transferring the loading [12]. Shape control and stress analysis of tensegrity structures are presented in [13-16]. In principle, the transformation of 'static tensegrities' in kinetic systems is based on the replacement of compression members with linear actuators, or the use of tension members with variable length [17, 18]. An investigation of the optimum deployment of a tensegrity structure controlled by cables is presented in [19]. Shape control and design of deployable tensegrity structures is further examined in [20]. A representative example is the actively controlled planar truss with variable geometry that responds dynamically to seismic excitations through integration of hydraulic actuators in place of diagonal members and loading sensors [21]. Six hinge-connected trapezoid prisms with decreasing dimensions over the height comprise the core of the so-called 'Muscle Tower' [22]. The continuous compression members of the structure are