Digital Modelling Analysis and Fabrication of Deployable Structures for Kinetic Architecture

As a result of the human mobility needs and the progressive technological advances over time, varied deployable structures utilising scissors and sliding mechanisms have evolved for transformable and transportable functionalities. In recent decades, this topic has piqued the interest of professionals within several fields - the Arts, Industrial Design, Architecture and Engineering - leading to an extensive database of publications in journals, conference proceedings, books, and patents. Gaps between theory and practice can sometimes restrict prospective applications due to structural complexities compromising the material capacities during installation, service, or dismantling.

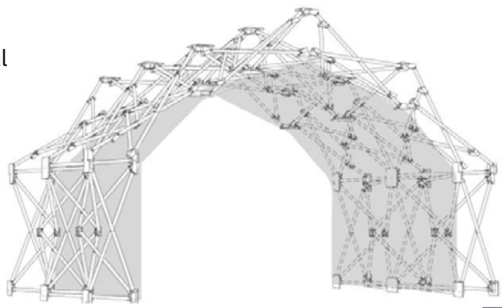
In 2016 the Colombian Administrative Department of Science, Technology, and Innovation COLCIENCIAS (forgivable educative loan for supporting doctoral studies abroad: Call No 728 of 2015) funded a PhD research project to develop alternative solutions for stabilising the angular distortions of quadrangular expandable grids, controlling the deflection limits, and enhancing the structural behaviour of large-span constructions requiring transitory processes, with a rapid installation or a frequent relocation.

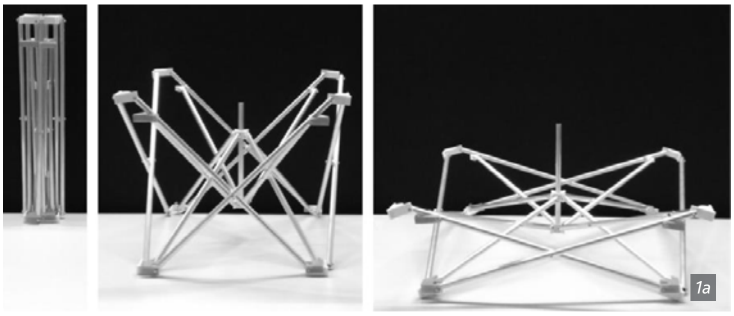
The research was carried out by Daniel Enrique Gómez Lizcano at the University of Nottingham under the supervision of Dr. Paolo Beccarelli, Dr. Davide De Focatiis and Prof. John Chilton. The work employed the latest digital modelling tools to evaluate complex projects from the early design phases, collecting real-time data from parametric environments, movement simulations, and simplified structural predictions. In addition, physical to-scale models have been created by additive manufacturing and standard portable tools, granting rapid testing. A holistic and reciprocal approach was adopted to obtain an overall spatial evaluation, validity, and reliability. The study identified eight cases to study the viability of achieving structural strength, stability, and rigidity through diagonal stress-free mechanisms, rectifying the primary instabilities during the size and shape transitions.

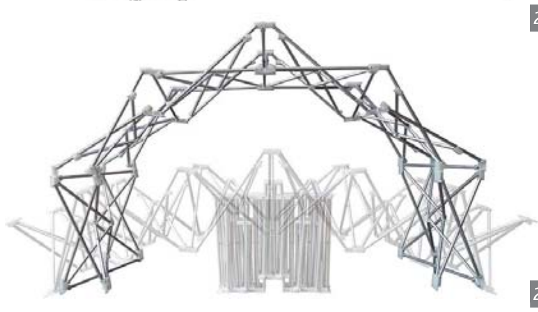
The results have been validated through a hypothetical transportable tent used to compare the stabilisation of diagonal scissors and triangulations by passive cables.

Tensioned locking devices aim to control the deflection limits of span/250, according to Eurocode, at the deployed position associated to weather loads.

The research resulted in the successful development of a complete design process for mobile architectural applications which maintain a degree of freedom. After discussing the efficiency of the setting-up procedures, the suggested active-cables outline demonstrated superior structural performance under each loading scenario, preventing time-consuming tasks required by manual locking and facilitating the components adjustment from the ground level. Transformable umbrellas may adopt the proposed structural analysis methodology; however, researchers should correlate detailed engineering studies and full-scale testing to validate practical results.


2a


1a


2b


1b


2c

3

Figure 1a. Manufactured sample of a stress-free trapezoidal cross-section prism with double diagonalisation.
Figure 1b. Manufactured sample of a stress-free trapezoidal cross-section prism with a single diagonalisation and the membrane attached.
Figure 2a. A deployable single curvature tent from case study 1, 3 and 4.
Figure 2b. Scale model of a deployable single curvature tent from case study 1, 3 and 4.
Figure 2c. Scale model of a simplified case study 4
Figure 3. Experimental scale model load deflections: (a) symmetric, (b) asymmetric.

Daniel Gómez Lizcano
Universidad de la Costa,
Barranquilla, Colombia
danielgomezlizcano@gmail.com