frontiers | Frontiers in Built Environment

TYPE Editorial
PUBLISHED 20 June 2023
DOI 10.3389/fbuil.2023.1238675

OPEN ACCESS

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RECEIVED 12 June 2023
ACCEPTED 14 June 2023
PUBLISHED 20 June 2023

CITATION
Phocas MC and Matheou M (2023), Editorial: Transformable structures and envelopes in architecture and civil engineering.
Front. Built Environ. 9:1238675.
doi: 10.3389/fbuil.2023.1238675

Editorial: Transformable structures and envelopes in architecture and civil engineering

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KEYWORDS

transformable architectural systems, adaptive structures, transformable building envelopes, kinematics, parametric design, numerical analysis, optimisation

Editorial on the Research Topic
Transformable structures and envelopes in architecture and civil engineering

The achievement of CO_2 neutral construction constitutes the most important challenge for the building industry in the 21st century. Speed, durability and resource efficiency are of increasing importance in meeting the challenges of global population growth and climate change. The conceptualization and development of new innovative structures and materials towards a minimization of energy consumption and fossil resources, as well as sustainable solutions by means of reduced footprint and resource optimization gain significance. In this framework, transformable structures in architecture and civil engineering offer a promising solution to massive building structures and fixed-shape components realized in a particular context and time.

In the creation of a sustainable built environment, aspects of flexibility, modularity and structural efficiency enable transformability of the buildings and their components at different levels. Transformable structures applied at the building, envelope and elements level may have reconfigurable, deployable, adaptive and intelligent attributes. They are capable to transform into differing shapes and/or adapt in response to varying functional, environmental or loading conditions. From a functional perspective, shape transformations contribute towards better space utilization; from an environmental perspective, optimal comfort levels for the occupants and renewable energy Research Topic become possible. Transformability and adaptivity enable minimization of external loading and structural performance optimization respectively. Different typologies and related mechanisms have been developed in recent years for architectural and other engineering applications, such as tensegrity, scissor-like, rigid-bar linkages and origami inspired systems, as well as control systems and elements. Such developments are often assessed based on their constructability and maintenance, modularity and assembly, fabrication and construction design, material properties, kinematics, control components design and integration, structural performance, environmental performance, as well as energy performance during actuation.

At the architectural level, the spatial, aesthetic, and technical characteristics of transformable buildings and elements are explored for the characterization and perception of architectural space in Akgün et al. In particular, the interrelation of architectural space, tectonics and transformation of architectural elements is classified and further exemplified on a case study of The Shed in Hudson Yards in New York

City. The case study highlights the significance of tectonics in kinetic buildings and contributes to the understanding and conceptualization of transformable architecture.

At the structural level, improved flexibility and controllability with minimum self-weight of the building structure is achieved with reduced actuation components, only positioned at the ground supports. A kinematics principle based on the effective 4–bar and the effective crank–slider approach is applied in a multistep transformation process of a torus-shaped spatial structure of planar interconnected linkages in Matheou et al. The kinematics approaches are exemplified using parametric associative design for a selected motion sequence pattern. The case study demonstrates the applicability of the approach in the spatial structures domain, as well as the investigation of the system kinematics at a preliminary design stage through digital parametric design.

At the structural elements level, the role of structural stiffness in the design of displacement controlled structures that comply with serviceability requirements, is clarified in Trautwein et al. A design methodology is implemented to minimize the control effort by designing the structure as stiff as possible against external loads and as flexible as possible to minimize actuation energy for displacement control. The investigation includes simple analytical and numerical case studies of typical structural elements, such as beams and a ribbed slab. Thus, the approach of pursuing a trade-off between stiffness *versus* load and flexibility *versus* actuation is demonstrated for designing efficient adaptive structures.

At the structural kinematics level, a method of equilibrium path and stability analysis of equilibrium state for a rigid origami is presented in Hayakawa and Ohsaki. The origami system considered consists of rigid flat faces connected by straight crease lines, modelled as frame elements. The method is suited for deployable structures and transformable building envelopes. Equilibrium path analyses are carried out and bifurcations of the equilibrium paths are investigated in cases of waterbomb cell patterns.

Contemporary technological advancements have increased the significance of transformability relevant to various architectural and engineering contexts of our built environment. The Research Topic has demonstrated that transformability involves multidisciplinary research and applications that directly influence the aesthetics, operation and performance of new and existing buildings and contribute to a sustainable development while providing versatility and allowing for innovation with minimum means and material. In this framework, an integrated interdisciplinary development of transformable building structures and envelopes following from early phases nonlinear processes of design and optimization can only provide intelligent solutions of transformable systems that are economically affordable and energy-efficient in their operation, as well as capable of improving the quality and operation of the buildings and related adverse environmental impacts caused by the construction industry. The Research Topic promises for further interdisciplinary advancements in terms of advanced performance-based research on transformable and adaptive structures and technology transfer for achieving energy-efficient and optimized large-scale applications.

Author contributions

MP and MM curated this Research Topic and drafted the editorial. MP and MM approved the submitted version of the editorial. All authors contributed to the article and approved the submitted version.

Acknowledgments

The editors would like to thank all contributors to this Research Topic as well as the reviewers and Frontiers Editorial Team.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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