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Prototyping Structures in Architecture

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The 9th issue of the **archiDOCT** e-journal contains papers that explore the design, analysis and development of prototype structures in architecture per se, as well as the processes followed for the creation of innovative structural solutions within contemporary architecture. Prototype structures may address aesthetic, form, material, system, fabrication or even energy efficiency related aspects in achieving innovation and advancement in contemporary architecture. Related developments are most prevalent since the initiation and application of numerical methods of analysis that revolutionized architectural technology and engineering in the early 70s, and which distinguished -throughout design and computational analysis- design optimization and automated manufacture and open-loop multivariable system performance-based design. While computational analysis initially led to a discretization of the disciplines involved, in the processes of form creation, primarily derived from abstract aesthetic and functional reasoning on the one hand, and numerical calculation and optimization on the other, advances of digital design technology enabled through linear, sequential developments of form, design and construction single or multi-objective optimization processes to be achieved following any intermediate design results. At the same time, digital technology opened many possibilities for the integration and shift from mass-production to mass-customization in an effort to relate the principles of the former with the advantages of bespoke fabrication. Meanwhile, computational platforms of operation and real-time performance simulators enable iterations of system simulation, numerical verification and optimization, and may even shift the focus of design towards bottom-up processes primarily influenced by aspects of structural geometry, morphology, material and performance. Thus, open loop developments in multivariable, transformative systems may be achieved from early conceptual designs to fabrication through respective research-based design processes.

In exemplifying the aforementioned developments in design and analysis, the paper "Design and analysis of form-active systems. Spanning from tensile to hybrid bending-active structures" written by the Guest Editor of the issue, **Marios C. Phocas**, reviews historical milestones in design and computational analysis based on the realization of the roof structure of Munich 1972 Olympics-Arenas and the initiation of numerical methods of structural analysis, while it discusses aspects of design optimization and automated manufacture. In addition, it examines form-active systems' integral form-finding and load-deformation processes from a bottom-up design approach, based on three prototype case examples of hybrid bending-active structures.

This **archiDOCT** issue includes doctoral research activities focusing on aspects of design, simulation, analysis, experimentation and fabrication of individual prototype structures, as well as on integrated interdisciplinary modes of operation in generating new, innovative and transformative structure design solutions in architecture.

Annie Locke Scherer, Ph.D. student at KTH Royal Institute of Technology in Stockholm, outlines design methods in her research on "Concrete Form[ing]work: Integrating patterns

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in flexible formwork for cast concrete" and contextualizes these within design research. The presented techniques to custom-tailor fabric for casting include traditional hand smocking, as well as custom knit structures that can react and transform in response to heat, water, or electrical currents. The integration of such methods advances new possibilities of fabrication techniques with regard to what can be achieved with state-of-the-art fabric formwork. It also conveys perspectives for respective application of robotics in improving repeatability, scale, and economy.

Beatriz Arnaiz, Ph.D. student at the Polytechnic University of Catalonia-Barcelona Tech, in her paper "Ephemeral tensile structure: Membrane house" discusses the design, analysis and construction process of a membrane prototype. Design and realization of the prototype are presented in respective separate phases of development, which prove to be interdependent with regard to the final outcome. The space truss prototype comprises of hinge connected timber beam sections and triangular membrane patterns. The temporary structure contributes to the development of space trusses with tensile structural envelope components, as well as to the creation of social space in public areas.

Andreana Papantoniou, Ph.D. student at the University of Patras, with her research on "Parametric models of tensegrity structures with double curvature", aims at enriching respective typological configurations and at developing processes that will facilitate their full-scale application. Her paper presents parametric models for a double-layer tensegrity structure of spherical and ellipsoidal surface, composed of square-base units, of variable sizes, while the geometric approach followed permits the concurrent arrangement of the bases of the tensegrity units, on the two layers of the structure. Furthermore, the paper addresses the applicability of the developed methods on minimal surfaces. Future activities refer to ellipsoids with changing dimensions and free-form surfaces, as well as relevant form optimization methods.

Ana Laura Rocha Peña, Ph.D. student at the Polytechnic University of Catalonia-Barcelona Tech, in her research on "Shell structure: Analysis of hyperbolic paraboloid in paper", evaluates the use of paper as building material for shell structures. The structural behavior of the material improves through respective shaping. A hyperbolic paraboloid with two pinned supports is simulated based on the finite-element method for analyzing its mechanical behavior. The investigation includes a static linear, an elastic nonlinear and a plastic nonlinear analysis of the system. The analyses results obtained indicate the feasibility of using paper as a building material, opening up further research on ways to increase the material strength, decrease its humidity content and enable automated manufacture.

Kristis Alexandrou, Ph.D. student at the University of Cyprus, in his paper "Bending-active systems: On exploring morphological configurations through coupling with tension-only members" refers to the development of elastic member systems with enhanced controllability in the active formation process and structural stability and capacity in the post-strained state, through hybridisation with tension-only elements. The paper investigates hybrid structural configurations of single and coupled elastic strips and interconnecting cables of variable length. The finite-element analyses conducted demonstrate that activation of the cables induces deformations to the primary elastic members and provides various controlled system configurations. Thus, the control concept constitutes a promising alternative for lightweight reconfigurable structures.