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Constructing structural concepts by means of physical models

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Abstract
Faced with a pronounced shortage of conceptual synthetic competences, a track emphasizing on the creative component of structural studies has emerged in academia in recent years, both in the engineering and architectural realm. The present work seeks to be part of this discourse by unfolding a proposition by the Chair of Structural Design of the Department of Architecture of the ETH-Zurich; discussing structural concepts within an inclusive design perspective. This educational strategy tries to extend the learning-by-doing pedagogy to a projective modality by activating the mode of inquiry of the design culture into the structural realm. Playful active-learning practices by means of material constructs are employed to explore structural concepts beyond typological boundaries. Furthermore, the incorporation of multiple design objectives beyond mere structural optimization, introduces an extended understanding of the structural concept that encompasses both formal and relational interpretations.

Keywords: structural concept, structural design, structural education, architectural education, physical model, equilibrium

1. Context of work
While the creative conceptual schemes of prominent structural designers have been celebrated in discrete instances, a shortage of conceptual synthetic competences is often noted both in practice and education. Faced with this deficiency, a track emphasizing on the creative component of structural studies has emerged in academia in recent years, both in the engineering and architectural realm. In civil engineering curricula, this initiative adopts an exploratory pedagogy via problem-solving scenarios and hands-on activities to expand the analytic skills of the engineer to the synthetic realm (CST [1]); the approach advocates that engineering design involves discipline and play - a term popularized by Billington (Billington [2]) - where discipline stands for technical skills and play relates to creative and aesthetic exploration. In architectural education, the necessity to integrate structural questions in the design process is part of a long-standing discussion (Dermody et al. [3]), which seeks to activate the design competences of the architect within the structural realm. Physical models have offered for long a medium for a qualitative or quantitative understanding of structural performance, employing a learning-by-doing pedagogy, while digital modelling has grown to discuss generative practices via trans-typological strategies (Mueller and Ochsendorf [4]) or white-box tools (Block et al. [5]).

The present proposition seeks to be a part of this discourse, by offering a paradigm that discusses structural concepts by means of material constructs within an inclusive design perspective. The strategy was developed by the Chair of Structural Design of the Department of Architecture of the ETH-Zurich, within the framework of the second-year undergraduate course in Structural Design. Reminiscent of a design studio, the semester-long design exercise “Constructing Equilibrium” aims to guide the student from initial abstract concepts to a concrete architectural project. Founded on the core position of the Chair - of an inclusive understanding of structural design as the interplay of force, form and material - the assignment introduces the structural concept as the primary design driver, stressing, however, the interrelationship between statics, architectural concept and material properties.
2. Step 1: Exploring structural concepts

Informed by the works of the Swiss artists P. Fischli & D. Weiss, this playful, yet structured, introductory activity, asks for the construction of three spatial compositions in static equilibrium, conveying respectively one of the following three generic conditions: spanning, cantilevering or hanging. Relying only on contact forces, each physical artefact is to be assembled from 4-6 items selected from a given catalog of common household objects - however, with explicit material, formal and structural properties.

The task is performed by intuitive manipulation of the material construct, yielding immediate feedback regarding the performance of both the individual object and the overall configuration. The interplay between the local action and the global equilibrium allows to discuss the inherent structural organization of the material composition, triggering a shift from formal to relational considerations.

The designs bring evidence of a broad variety of, eventually unforeseen, configurations (Fig. 1), serving as a proof-of-concept for an approach apt to explore genuinely spatial structural arrangements, operating beyond typological boundaries and fostering a qualitative understanding of structural performance.

Figure 1: Exploring structural concepts by means of material compositions of objects in equilibrium. Material compositions (photographed by R. Dubois) and respective strut-and-tie diagrams (developed retrospectively by L. Enrique and P. D’Acunto) bring proof of the variety of the generated structural concepts.
3. Step 2: Translating structural concepts

This endeavor involves the integration of structural and architectural concept into a resourceful scheme that responds to contextual constraints - such as program, site and scale - and incorporates design intents regarding architectural space - in terms of articulation, sequence, qualities, … The particular feature of this approach is the intention to accommodate several objectives beyond mere structural optimization in discussing the evolution of the structural concept.

The task aspires for a translation of the structural concept to a meaningful architectural idea by means of a broad range of media common in the design culture; all sorts of references - including nature, art, architecture or technology - are employed to convey the perceptual, syntactic or semantic features of the material construct - articulation of volumes, organizational principles, networks of relationships, spatial sensations, … Conceptual design competences discussing the relationship between the structural and the spatial organization are nurtured across a constant oscillation between abstract and concrete constructs.

As the richness of the design process and outcomes attest (Fig. 2), the strategy allows to discuss an extended understanding of the structural concept, encompassing notions of an underlying hierarchy, a recurring pattern or a powerful metaphor next to that of structural performance.

Figure 2: Translating the constructed structural-concept-in-abstractum to an architectural-idea-in-context.
4. Review

The present paradigm tackles common issues in structural education; an analytic perspective, mostly constrained within typological boundaries, employing a precedent-based modality, often associated with a two-dimensional interpretation of structural performance; eventually limiting the design vocabulary.

Inscribing in the projective track, the strategy shifts the focus to the global scope, the conceptual aspect and the synthetic component of structural design. Echoing Allen’s long-standing belief about the potential of a studio pedagogy for technical matters (Allen [6]), the approach dissolves the boundaries between structural and architectural concept, challenging the prevailing linear model of the design process. The fundamental notion of structure - possibly with an extended interpretation - is brought into play in the early stages of the design process, while contextual constraints are eventually introduced to underline the fundamental relationship between structure and space. The proposition seeks to constrain the scope and the means at first, only to ultimately expand the solution space, by progressively incorporating a range of design objectives. In the same way, the precedent-based approach is excluded as a starting point, while references are welcome as a way to support, refine, evolve or translate the design concept.

From an educational standpoint, this strategy seeks to activate the mode of inquiry of the architectural design culture (visual, conceptual, modelling competences) to the structural realm [Wetzel [7]), while extending the active-learning pedagogy towards a generative modality. A playful, yet structured, methodology, relying emphatically on material constructs, is suggested to foster intuitive spatial explorations and nurture qualitative structural awareness. The role of the physical model in structural education is extended from experimental to exploratory practices, while material constructs are reintroduced as mediators of diagrammatic nature serving to discuss both formal (composition) or relational (disposition) interpretations of the structural concept. From a research perspective, the proposition triggers a reflection on the nature of the structural design concept, process and related mode of inquiry; eventually promoting an exploratory praxis to best accommodate the open-ended nature of structural design.

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