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Topic

The research topic 'Active-bending' emerged from the interest in new design approaches and construction methods for complex double curved structural and architectural design. The essence of this topic lies in the ability to create something single- and double curved from initially flat elements. The simplicity of transforming of-the-shelf building components into something structurally and aesthetically far more complex could potentially lead to a new approach of small to medium sized structural systems. This topic relates to several studios in the Building Technology Master program, namely, material science, structural design and design informatics. The performance of an active-bending structure depends on material properties, structural strategies and computational parametric design. These three disciplines are integrated throughout the research process.

Process

The process started with a literature review on current and previous research in active-bending structures. The vast majority of prior research focussed on the creation of single curved structural elements which were then used to compose small-scale designs. Previous work can be separated into research in active-bending static structures and active-bending kinetic structures. The static structures emerged from elastic deformation of beams and thin plates. Active-bending kinetic structures base their strength on slender curved rods combined with fabric membranes. Considering the given time, this research will focus on active-bending plate structures. First, because elastic deformation of plates behaves differently from elastic deformation of beams, which could lead to new insights. Secondly, because current and previous research barely focusses on deformation of plates only, disallowing the development of their potentials and feasibility.

The period after the formulation of the research questions and methods is called the phase of research by design. Existing mathematical approaches to simulate double curvature (Calladine, Gauss) have been the guiding theory in this phase. A bottom-up method was used to start with single geometrical components. The arrangement in a particular order or topology was the base of a double curved structure. Individual components were only bent in one direction with single local curvature, leading to a global double curved structure. The insights gathered from this approach have been used for the continuation of the design process. However, the double curvature has been further researched in a more nuanced matter with a focus on the deformation of single elements, not just aiming for a double curved final design.

The Gaussian curvature measure has been used in this entire research so far. A broader understanding of this measure shows it cannot be applied to the curvature measure of actual material. Material properties such as the Poisson's ratio disrupt this mathematical approach. Rewriting the formula of Gaussian curvature including material properties shows that deformation of plates from flat to curved leads to an overall double curved plate. In the entire process, this has been an unplanned theoretical addition, ending up as the research's' guiding theme. The double curvature, found in the nuance of deforming flat plates is now a structural stiffener rather than an architectural aesthetic result.

The use of relatively simple geometry allows for an in-depth understanding of the effects of bending and torsion of flat plates. The optimised stiffening of individual plates can be a building component. These components can be used as design elements with their given parameters such as length, height, amount of curvature, torsion and material properties.

The process has changed from what was initially planned. It intended to focus on design variables which could be used for active-bending architecture. Looking back at this initial process, it would have lacked a theoretical basis. The used theoretical framework leads to a deeper understanding of what happens in the deformation process of plates, rather than focussing on a double curved result only. The entire process has a more structural focus from which architectural parameters can be derived. The building methodology shows the feasibility of application of this new structural system.

Society

Today's advanced software technology allows designers and engineers to create form and analyse structures based on the elastically erection process. Previous examples of such structures are mainly understood practically, based on empirical analyses. The integration of a combined approach, both theoretic and practical, lead to a comprehensive understanding of active-bending structures, which is fundamental for the developments of this building approach.

Advantages such as low material use, natural erection process and the use of standard flat materials make this method economically highly interesting. Because it is a relatively new method, the application mainly emerges in small-scale designs such as cantilevers, pavilions and shelters. It offers a wide range of possibility for mobile structures where building time is limited, for example in war zones or disaster areas. Aesthetically, active-bending structures provide a new language for double curved building components or entire structures, leaving architects and engineers with new design parameters.