EPFL ENAC IIC laboratory for timber construction IBOIS

Origami - folded plate structures

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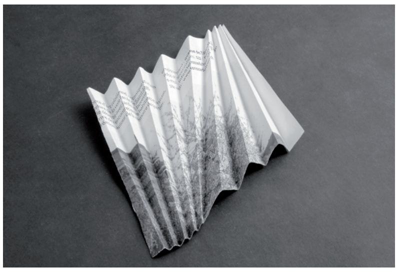

fig.1 Simply-corrugated surface

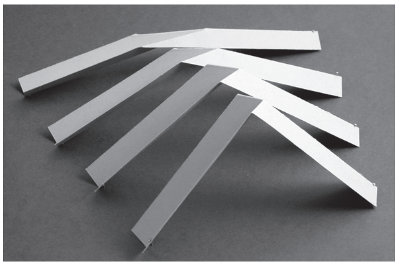

fig.2 Reverse fold

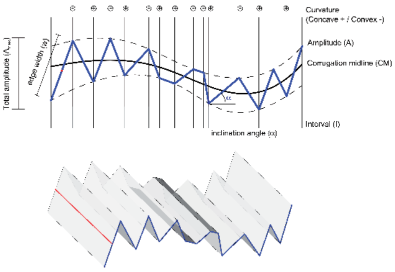

fig.3 Corrugation profile

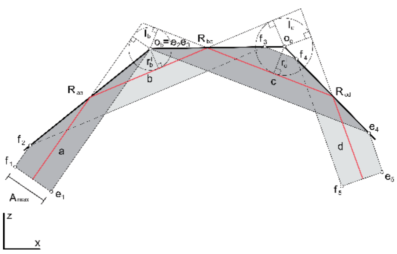

fig.4 Cross section profile

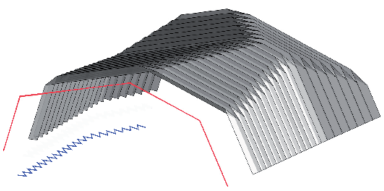

fig.5 Doubly-corrugated surface

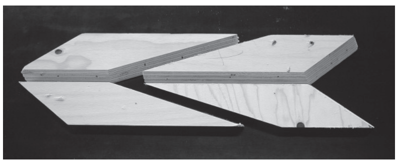

fig.6 Offset

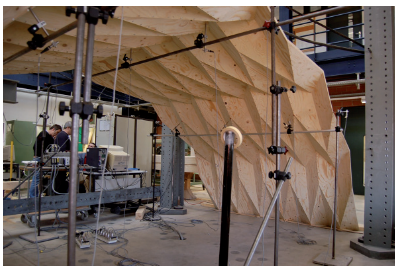

fig.7 Plywood prototype

This research investigates new methods of designing folded plate structures that can be built with cross-laminated timber panels.

Folded plate structures are attractive to both architects and engineers for their structural, spatial, and plastic qualities. Thin surfaces can be stiffened by a series of folds, and thus not only cover space, but also act as load bearing elements. The variation of light and shadow along the folded faces emphasizes the plasticity of space and envelope. Folds not only create structural depth, but also perceptual deepness. Folds give rhythm to space, and variations can be used to express a spatial sequence as well as to modify the structural strength. Because of this we are convinced that a design method which rapidly generates and modifies folded plate structures is of great interest, and can form the basis of a productive collaboration between architects and engineers.

In the last fifteen years the timber industry has developed new, large size, timber panels. Composition and dimensions of these panels and the possibility of milling them with Computer Numerical Controlled machines shows great potential for folded plate structures.

An interdisciplinary team investigates architectural, structural and mathematical aspects of folded plate structures.

The main focus of the architectural portion is the form-finding process which is inspired by Origami, the Japanese art of paper folding. Based on a simple technique, Origami gives birth to an astonishing formal richness and variability. Complex geometries are generated in an economic way and this research aims at transferring these principles to construction with timber panels. In an intuitive approach, we investigate different folding patterns with paper folding. The geometry of selected patterns is analyzed with the aim to generate them in 3D modeling software.

We develop a method that generates doubly-corrugated surfaces by two polygonal lines: the corrugation profile and the cross section profile (see fig. 5).

The corrugation profile (see fig. 3) defines the characteristics of simply-corrugated surfaces, composed of straight main folds (see fig.1). Simply-corrugated surfaces can be bent by reverse folds (see fig. 2). A series of investigations outlines the parameters which influence the geometry of reverse folds.

The cross section profile (see fig. 4) introduces a secondary corrugation. It outlines the general shape of the folded plate geometry and defines the bending angles of the reverse folds.

The pattern of folded plate geometries is qualified by the configuration of the two profiles. We establish the conditions which allow control of the pattern type and design of folded plate geometries which respect a given corrugation amplitude. This allows rapid repersentation of complex folded plate structures in space as well as unfolded. A great variety of forms can be generated. This variability is attractive because it allows the engineer as well as the architect to react on project specific conditions by modifying different parameters of the folded plate structure without distorting its expressive character.

Further on the possibilities of offseting the generated surface are investigated (see fig. 6). The influence of different parameters on the offset geometry is shown.

Finally a series of prototypes investigates the feasibility of folded plate structures generated with the proposed design method (see fig. 7).

Keywords: Origami, folded plate structures, cross-laminated timber panels, reverse fold, doubly-corrugated surfaces, corrugation profile, cross section profile