Experimental and analytical investigation of the Spin-Valence kirigami space frame

Julien SAHUC*, Gordana HERNING*, Emily BAKER[a]

*MIT, 77 Massachusetts Avenue, Cambridge, MA, 02139, USA
jsahuc@mit.edu
gherning@mit.edu
[a] University of Arkansas, Fay Jones School of Architecture + Design, Fayetteville, AR, USA

Abstract

Spin-Valence is a pattern-logic that transforms a flat sheet of material into a structural space frame. Through cut patterns, spin-folds and encoded connections, a single layer effectively becomes two layers connected via triangulated legs. Unlike most space frame systems, this method is not a series of connected members, but one single sheet, cut and folded (kirigami), and reconnected to itself [1]. Spin-Valence was initially developed and assessed through a heuristic and iterative approach to design.

Cut patterns influence cross-sectional properties, joint behavior, ease of unit deployment, and connectivity between units. Original design iterations proceeded in search of performative efficiency of a flat spatial structure in which diagonal elements were folded out to span the interstitial space between the upper and lower chords of the frame. Diagonals included plates with uniform depth, plates with distinct entasis, and latticed plate elements forming angle-shaped cross-sections. As this deployable frame is further analyzed for potential use in flat spanning systems (e.g., as a wall or a roof), curved vaults, and gable frames, understanding the relationship between geometry, force paths, element capacities, and global and local behaviors is needed to characterize its structural performance.

Experimental tests are conducted on the units of the frame and on the multi-unit assembly to evaluate their behavior and capacity when subjected to uniformly distributed load. Test results are compared with analytical predictions that form a performance-oriented design framework relating geometric variables of the diagonal element to the stiffness and strength of potential frame configurations. In the multi-unit frame, strength and stiffness gains due to structural triangulation are investigated, and the overall behavior is analyzed to identify optimal solutions for strengthening the form through geometry. Analytical predictions and test results are compared with findings from numerical analyses conducted concurrently in a related study, allowing a more extensive structural characterization of the frame [2].

Figure 1: Single unit undergoing compressive test

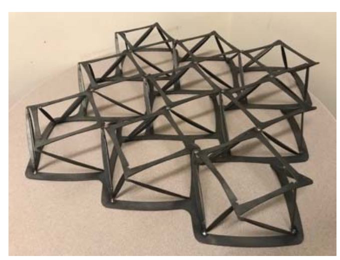

Figure 2: Multi-unit frame

References

[1] E. Baker, "Spin-Valence: Kirigami Space Frame", in *Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium*, Cambridge, MA, 2018.

[2] N. Sherrow-Groves, E. Baker, "Structural Finite-element Analysis of Steel Kirigami to Characterize Global Behavior", paper abstract to be submitted for consideration as part of the *Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium*, Barcelona, Spain, 2019.