Cut Fold Span Connect

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This poster presents the "Cut Fold Span Connect" studio, a fourth-year architecture fabrication course supported by a $2400 material donation from the American Institute of Steel Construction (AISC). The studio explores innovative structural systems through the manipulation of sheet steel using CNC plasma cutting and folding techniques. Emphasizing a low waste/no waste approach, the project prioritizes material efficiency, retaining all elements of the cut pieces except for necessary bends.

The semester began with an introduction to both analog and digital metal fabrication methods. Students developed half-scale prototypes, progressing from intuitive paper folding experiments to full-scale applications in steel. This iterative process enabled students to investigate the interplay between form, strength, and structural integrity in load-bearing architectural elements.

In the second half of the semester, a collective project applied knowledge gained from prior work. The collection of individual proposals led to a larger collaborative final structure, designed and fabricated within the fabrication lab and briefly installed on-site off campus. Structural analysis simulations effectively predicted performance characteristics observed post-assembly, showcasing the practical application of theoretical learning. Students learned to navigate the complexities of design as a material process, adjusting their designs to accommodate the inherent qualities of steel. This experience not only deepened their understanding of fabrication processes but also highlighted the critical feedback loop between design and construction, akin to professional practice.

Ultimately, this studio fostered an appreciation for the malleability and strengths of materials, reinforcing the importance of embedding structural, form, and assembly information directly within the cut patterns, challenging students to innovate within the parameters of a specific material.

Keywords: Steel, Digital Fabrication, CNC Plasma Cutting, Material Exploration

Cut Fold Span Connect

ARCH 606 ADS 6 Fall 2023 — Kansas State University
Instructor: Brian K. Lee
Structural Analysis: Reese Greenlee
Students: 7
Duration: 7 weeks

Cut Fold Span Connect: A fourth-year architecture fabrication studio course supported by a $2400 material donation from the American Institute of Steel Construction (AISC). The studio explores innovative structural systems by manipulating sheet steel using CNC plasma cutting and folding techniques. Emphasizing a low-waste/no-waste approach, the project prioritizes material efficiency, retaining all elements of the cut pieces except for necessary bends. The semester began with an introduction to both analog and digital metal fabrication methods. Students developed half-scale prototypes, progressing from intuitive paper folding experiments to full-scale applications in steel. This iterative process enabled students to investigate the interplay between form, strength, and structural integrity in load-bearing architectural elements. In the second half of the semester, a collective project applied knowledge gained from prior work. The collection of individual proposals led to a larger collaborative final structure, designed and fabricated within the fabrication lab and briefly installed off-campus on-site. Structural analysis simulations effectively reflected the performance characteristics observed post-assembly, showcasing the practical application of theoretical learning. Students learned to navigate the complexities of design as a material process, adjusting their designs to accommodate the inherent qualities of steel. This experience not only deepened their understanding of fabrication processes but also highlighted the critical feedback loop between design and construction, akin to professional practice. Ultimately, this studio fostered an appreciation for the malleability and strengths of materials, reinforcing the importance of embedding structural, form, and assembly information directly within the cut patterns, challenging students to innovate within the parameters of a specific material.

Design Goals:

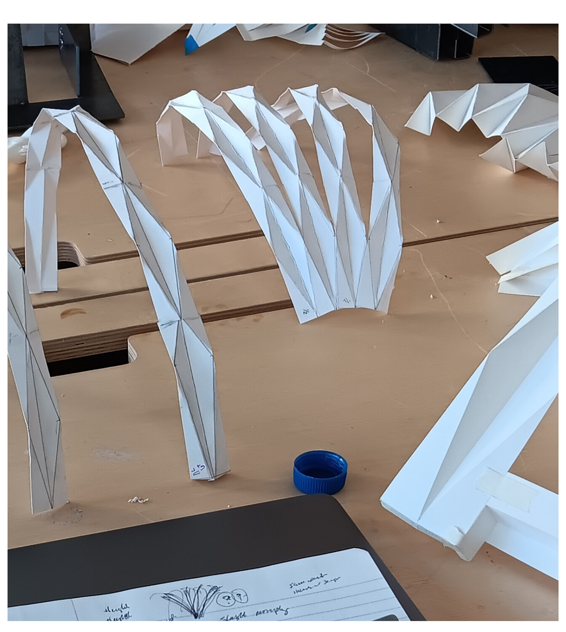
Folding: create structural strength using folding methods

Material Efficiency: design with dimensional and material constraints

Volume: Maximize volume with the given material quantity

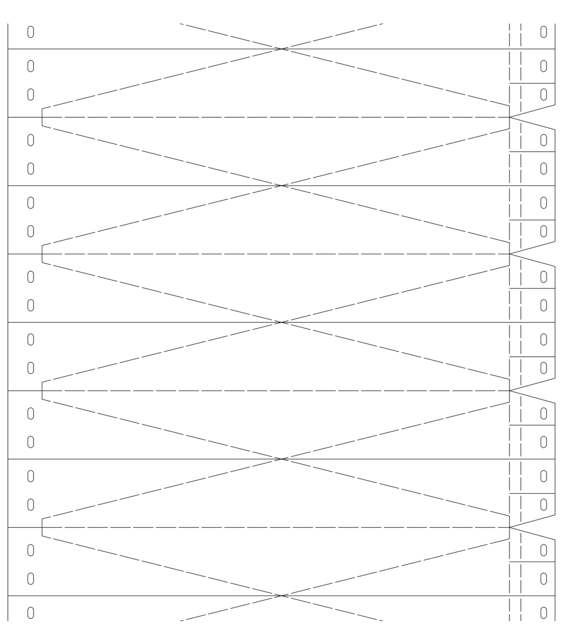
Fabrication: create a structure that is modular and demoiuntable

Process



Paper Study Models

Detail Prototyping



Cut File Patterns

CNC Plasma Cutting

Folding

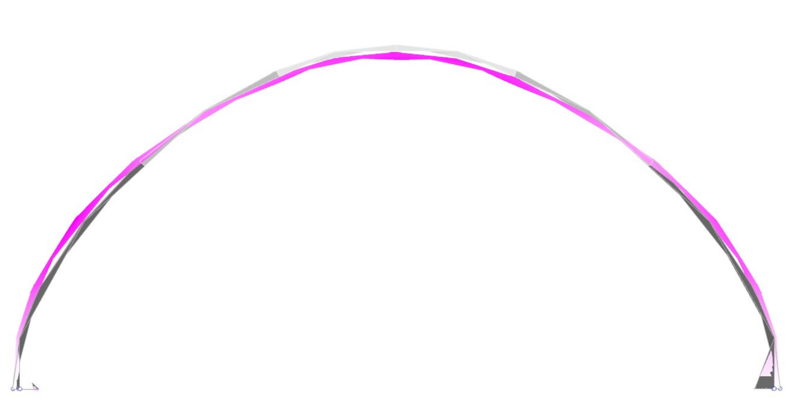
Assembly + Installation

Structural Analysis

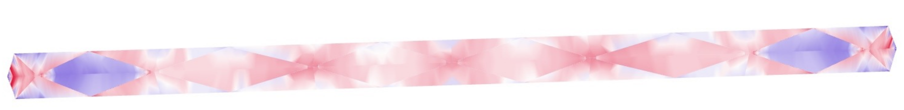
Preliminary information and results for one module of pavilion. ASTM A1011 Grade 36, typ.

The structural analysis of the pavilion structure was developed through an iterative modeling process, beginning with a simplified representation and progressively introducing additional complexity. The initial model assumed fully continuous, rigid (fixed) connections to evaluate the global behavior of the structural system, verify primary load paths, and confirm overall stability under design loads. This baseline model provided a conservative framework to assess the structural performance without the influence of localized connection flexibility.
Following validation of the simplified system behavior, the model was refined to incorporate more realistic boundary conditions and member characteristics. Pinned connections were introduced where appropriate to reflect actual connection detailing, along with adjustments to account for variable member stiffness and secondary effects. This phased approach ensured that the simplifying assumptions in the preliminary model were sufficient to capture the essential structural behavior, while the subsequent complexity allowed for a more accurate assessment of localized demands, deformation patterns, and connection behavior consistent with the intended construction methodology.

Fully welded, no bolts, no tabs.



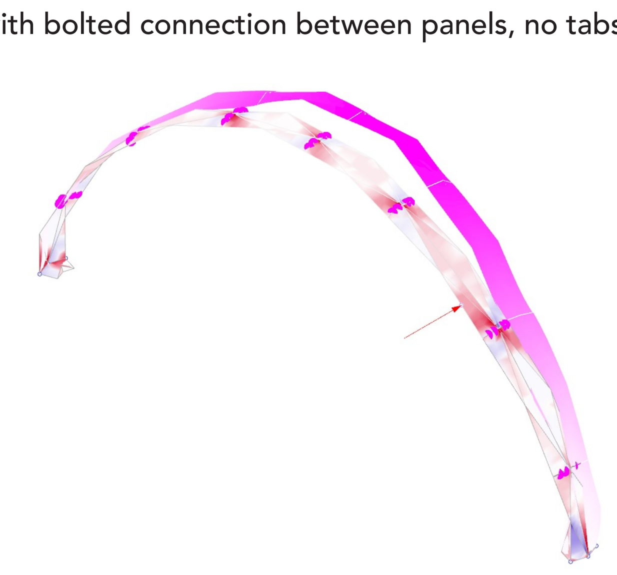
Dead Load Deflection: 0.02”



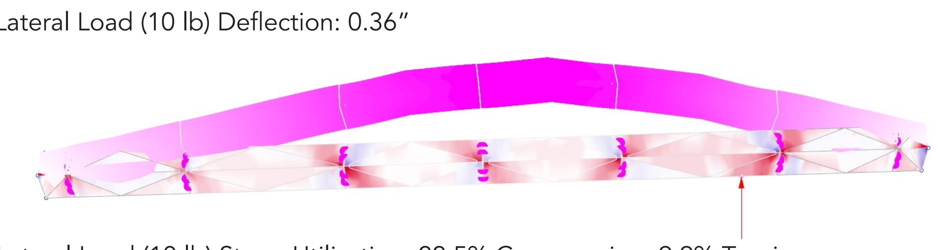
Dead Load Stress Utilization: 3.1% Compression, 2.5% Tension

With welded edges, the arch behaves as a continuous structure, and is minimally stressed under self weight (125 pounds). The shape of the arch is hemispherical (ish), and so it has an inflection point about a third of the way up where the compression and tension sides flip. The deflected shape below shows the bulging behavior that results. Note that a parabolic arch form would be all in compression, and not have this issue. Domes resolve this issue by hoop stress around the form (lateral bracing).

Welded edges with bolted connection between panels, no tabs



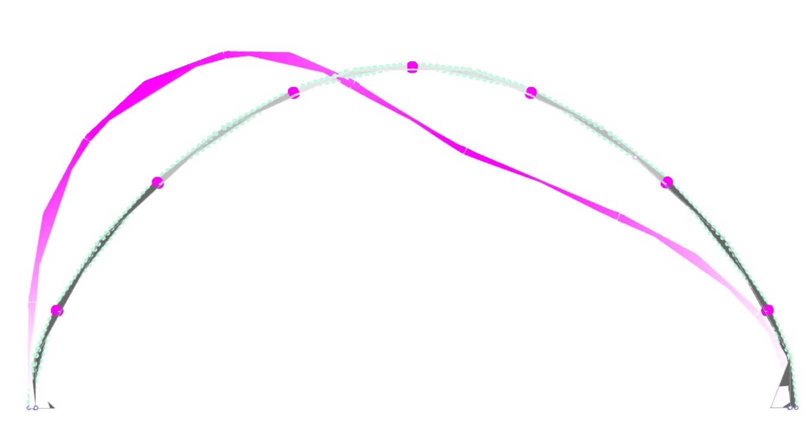
Lateral Load (10 lb) Deflection: 0.36”



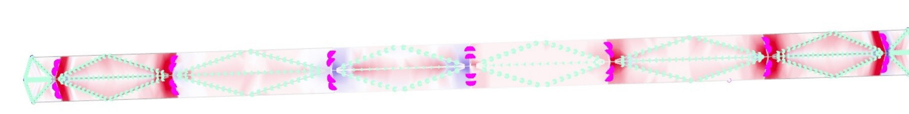
Lateral Load (10 lb) Stress Utilization: 22.5% Compression, 9.9% Tension

With welded edges, and bolted connections, the arch behaves as a continuous structure, and is minimally stressed under self weight (125 pounds). Note that this matches the first structure which is fully welded (see above). This makes sense as the connections between the panels are transferring axial loads primarily so the lack of rotational stiffness at the joint does not affect this load case. However, with a 10 lb point load applied laterally there is considerable deflection, and concentration of stress at the joints. Bolt stiffness was calculated according to ½” dia. x 1” bolt. Bolted connection assumes no rotational stiffness. The dead load deflection and behavior is the same as the fully welded structure (see above). With little rotational stiffness in the bolted connections however, and no lateral bracing, the structure deflects considerably under a 10 lb lateral point load.

As Built: Bolted connection between panels, and tabs along folded edges.



Dead Load Deflection: 2.23”



Dead Load Stress Utilization: 69.6% Compression, 18.2% Tension

With tabs at the folded edges, and bolted connections, the arch behaves as a continuous structure, but the panels are much more flexible and act more independently. The stress is concentrated at the joints, and the panel folds are deforming. Member stiffness was calculated for tabs. Rotational stiffness of the tabs needs further investigation. For this analysis it was assumed to be small, but not zero. The dead load deflection and behavior is much greater with this structure, and it is sensitive to the loading (and any geometrical deviations in the form). The deflected shape shown below is one mode of deflection that would change easily depending on the conditions. This type of in-plane lateral instability is indicative of its flexibility.
(Note that this structure would deflect 7.6” under a 10 lb out-of-plane lateral load.)