# NœudAL Pavilion: Ultralight folded nodes for bespoke geometries

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1 General view of the NœudAL pavilion built in September 2022 (Andrei Nejur © 2022).

This research project, conducted at the University of Montreal School of Architecture, presents an innovative approach to the construction of reticulated structures, focusing on the development and application of a novel, ultralight aluminum node. The node, constructed from a folded, laser-cut, 1-mm aluminum sheet, is designed to accommodate wooden linear members with varied rectangular sections, making it adaptable to bespoke geometries and low valence nodes. This innovative design offers a solution to the long-standing challenge in the construction industry of balancing cost, customization, and weight for reticulated structures through novel node designs (Abdelwahab and Tsavdaridis 2019; Dyvik et al. 2023; Chilton 2007; Rochas 2014; Hassani et al. 2020).

The present project showcases the node design in a large-scale structural prototype, a pavilion built in an academic setting in the fall of 2022 (Figure 1). The pavilion serves as a practical demonstration of the use of the nodes to incorporate reclaimed construction timber into complex reticulated structures, showcasing the potential of this innovative approach in real-world applications. The research behind this project involved two main concurrent thrusts: network optimization and node construction.

### The Reticulated Network

Network optimization involved the creation and optimization of the topology and geometry of the reticulated structure. This process began with the development of a base shape designed to reduce the amounts of bending and/or torsion in the nodes. The shape was

PRODUCTION NOTES

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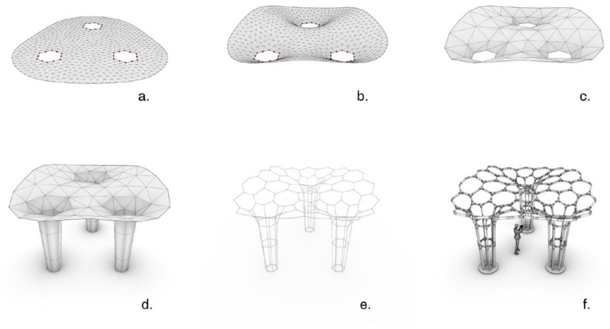
|---|---|
| Client: | University of Montreal |
| Status: | Built |
| Location: | Montreal, QC, Canada |
| Date: | 2022 |



2 Form-finding steps for the reticulated network.

3 General view of the 148 nodes (Kevin Larouche-Wilson © 2022).

4 Evolution of the node design from curved strips to the augmented shell.

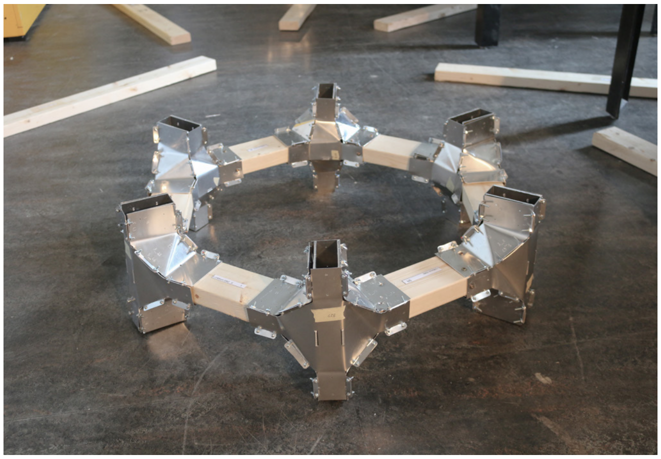
developed to predominantly transmit axial efforts, achieved by relaxing a surface mesh under an inverse gravitational force using the Grasshopper physical simulation engine, Kangaroo (Piker 2013). The resulting shape rested on three legs, forming a funicular structure. The network optimization process also involved a re-meshing to resize the parts of the network to the average size of the timber kit and a dual-making process to reduce node valence. The form-finding process was split in two, with the upper part of the structure (the canopy) relying on the re-meshing/dual process, and the lower part of the pavilion (the legs) constructed using a parametric approach. The resulting network contained two and three-valence nodes for the canopy and four-valence nodes for the legs. Figure 2 shows the steps of the network development: 2.a) flat mesh with red vertices selected as anchors; 2.b) base mesh relaxed under inverse gravitational pull; 2.c) remeshed base mesh to timber kit scale; 2.d) base mesh with extended legs; 2.e) final reticulated network as the dual of the base mesh, with edge lengths optimized to the timber kit; 2.f) 3d model of the final pavilion. Figure 3 shows the the evolution of the node design and Figures 4 through 9. denote the process of implementation of the design in the full-scale prototype.

### The Node Design

Node construction focused on the production of a metal node capable of accommodating the available timber members in the proposed configuration. The node design evolved through several iterations, Figure 3 shows several milestones of the node evolution over the course of several months. The final design of the three-valence node shown in Figure 10 (a through c) consists of five laser-cut, 1-mm aluminum plates that are pre-bent and assembled into a shell for the node. During assembly, a custom, cut 3-mm planar aluminum plate is introduced inside the node shell, inhibiting the rotation of the studs in the plane of the node. The three-valence node weights an average of 350 grams.

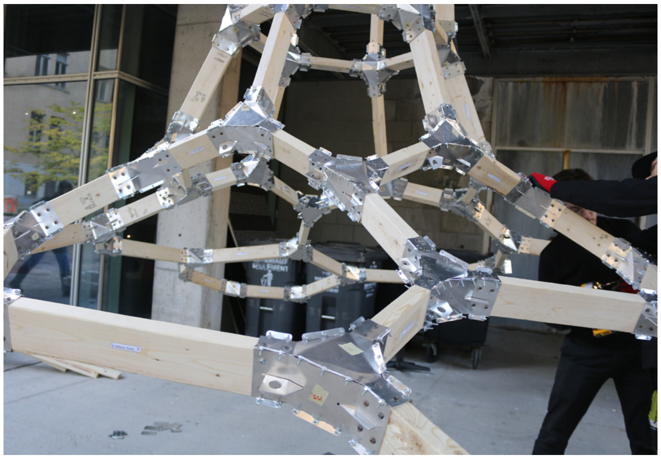
The four-valence node, while more complex, was developed using a similar strategy. The topology of the node shell had to cater to four studs with divergent directions that could not be assimilated to a set of in-plane connections. As a

5 Applying the finishing touches on one of the structural legs (Kevin Larouche-Wilson, © 2022).



6 Structural leg ring with 6 nodes (Kevin Larouche Wilson © 2022) .

7 Pre-assembled canopy cells (Kevin Larouche Wilson © 2022).



8 Upside down leg assembly (Kevin Larouche Wilson © 2022).

9 Final assembly on site (Kevin Larouche Wilson © 2022).

result, the geometry of the shell was created by producing all the pairwise relationships between the network edges (studs) meeting in a node, and then creating the six folded plates that were defined by those connections. To stiffen the node, three 3-mm interlocked planar plates were used. The details of the four-valence node are shown in Figure 10 (d. throughf.). To unfold the node geometry with the special cutouts for the rigid plates the bolts and the screws, Ivy for Grasshopper (Nejur and Steinfeld 2016; 2017) was used with a custom workflow.

### An Early Conclusion

The research project yielded promising results as demonstrated by the construction of the pavilion, but also identified several areas for further development. These include the need for more precise bending aids, strategies for large-piece assembly, and more in-depth, finite element analysis (FEA) and testing. The project demonstrates the potential of integrating low-thickness aluminum sheet in structural applications in combination with construction timber. It also shows the potential of combining computational design with affordable digital fabrication and manual assembly for a viable alternative to the existing construction paradigm for reticulated architectural structures.

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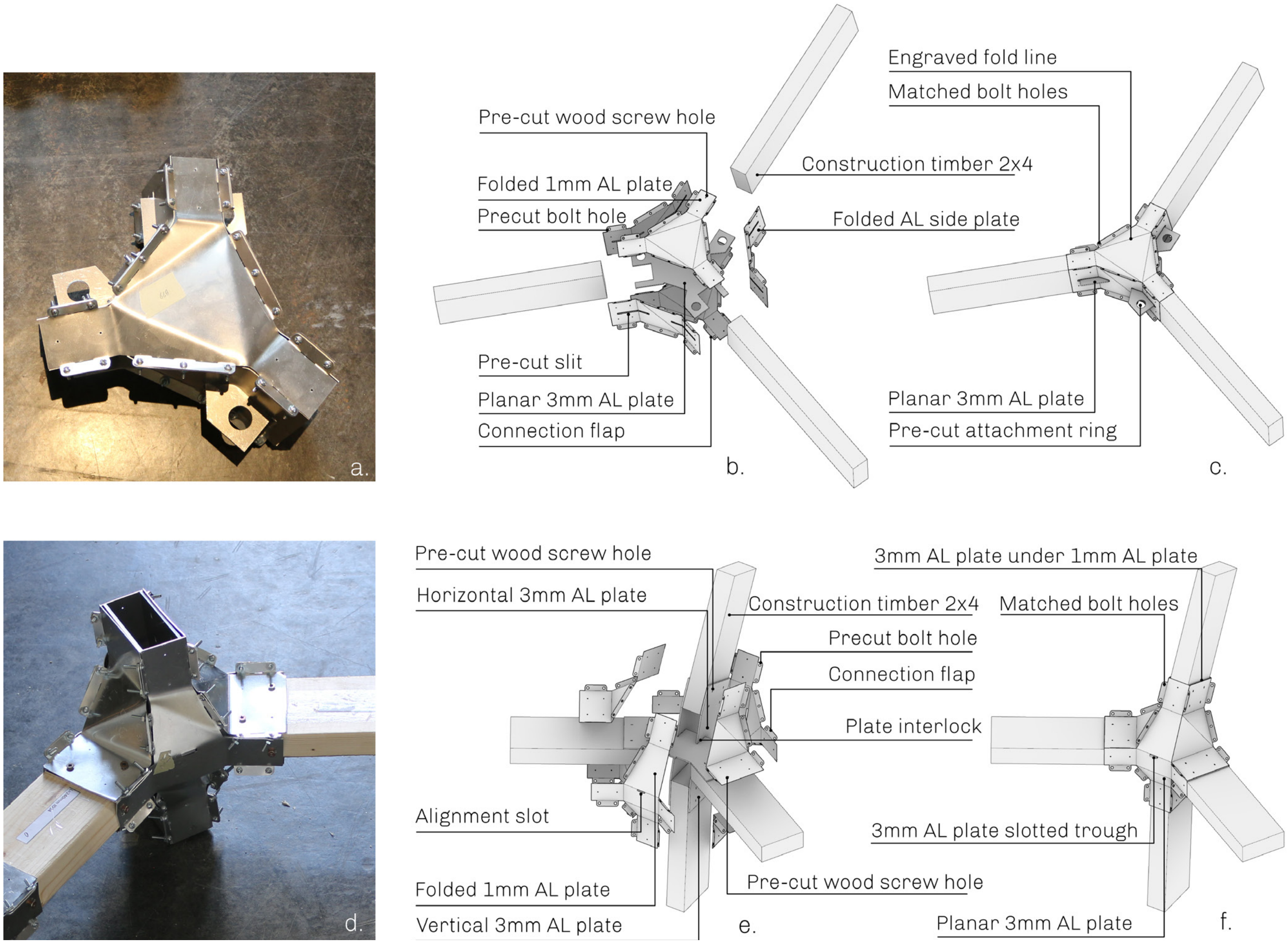

**10** Diagrams of assembly for the three-valence (top) and four -valence (bottom) node types.

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**11** Assembled pavilion leg detail (Kevin Larouche Wilson © 2022).

**12** Aerial view of the finished pavilion (Andrei Nejur © 2022).

## IMAGE CREDITS

Figure 3,5,6,7,8,9, and 11 : © Kevin Larouche-Wilson 2022.

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