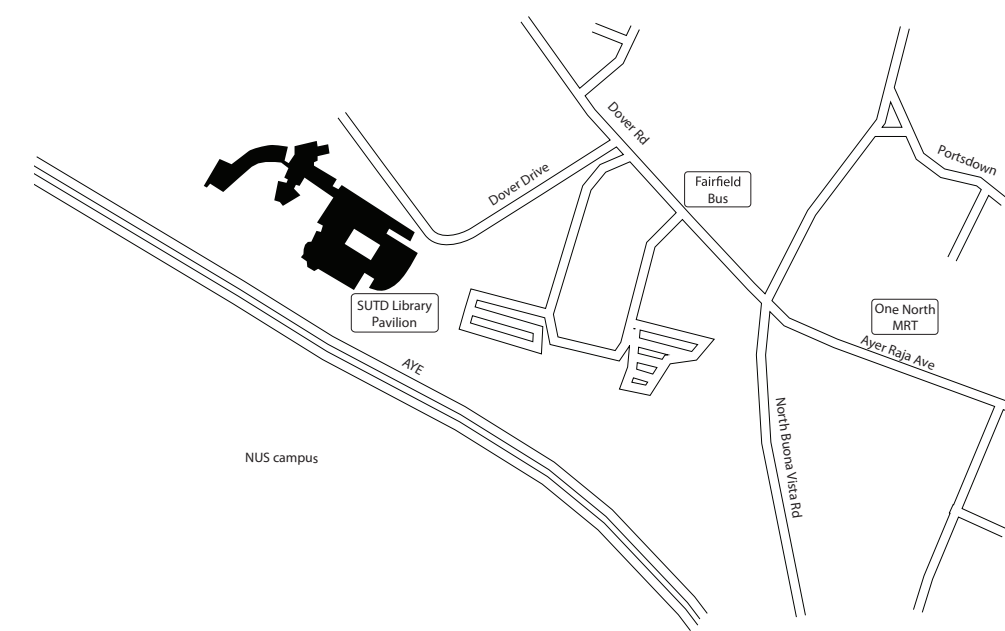


SUTD GRIDSHELL



SITE

The SUTD Library Pavilion is located on the temporary SUTD Dover Campus, 20 Dover Drive in Singapore. The pavilion stands on a sloping lawn behind the library. The curved site is on a plinth with three mature trees, facing the library in the north and the AYE expressway in the south.

The nearest MRT station, One North, is within a 10min walk. The nearest bus stop is at Fairfield Methodist Pre-School. Geographic location coordinates: 1.299607, 103.781152

MATERIALS

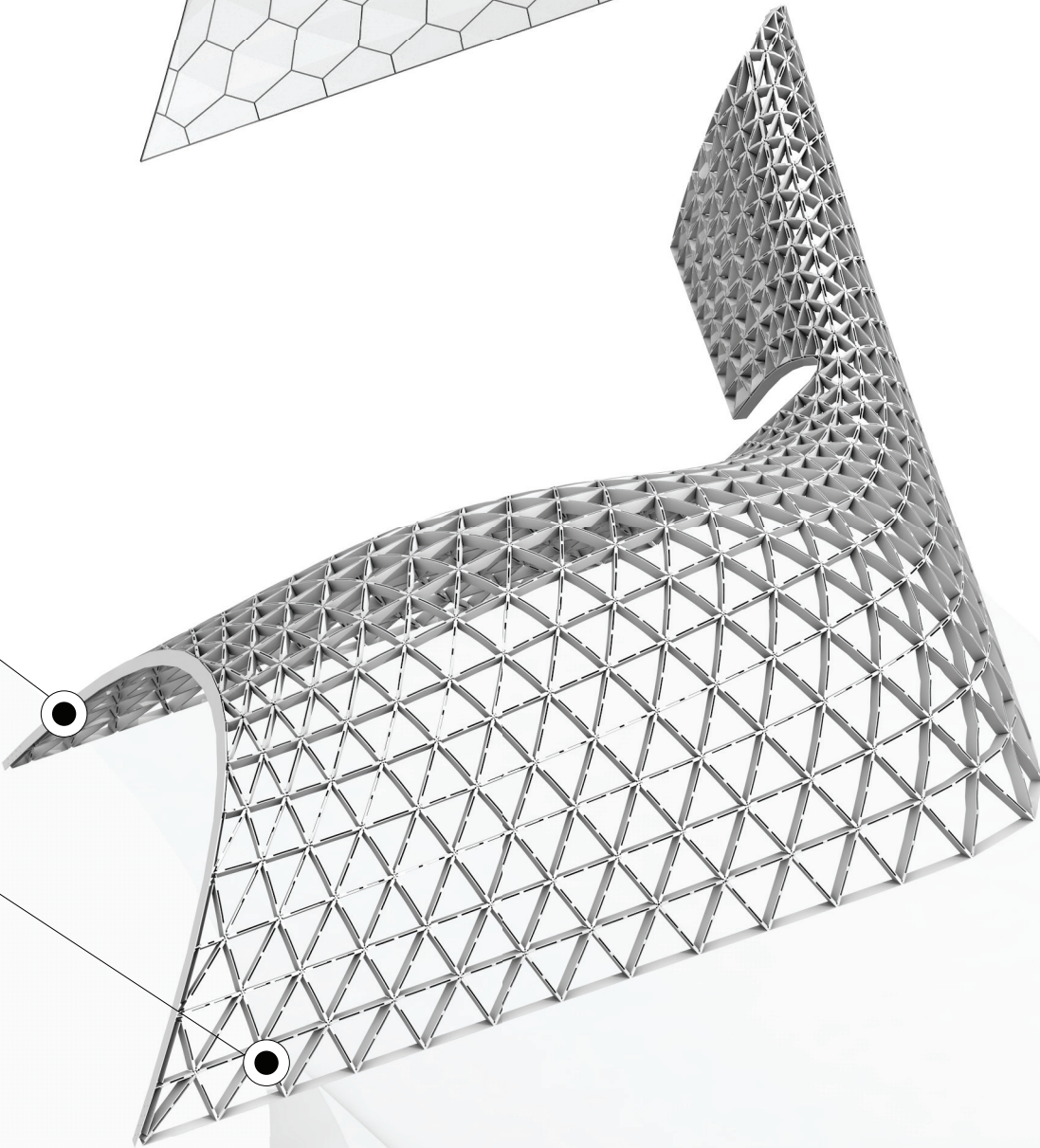
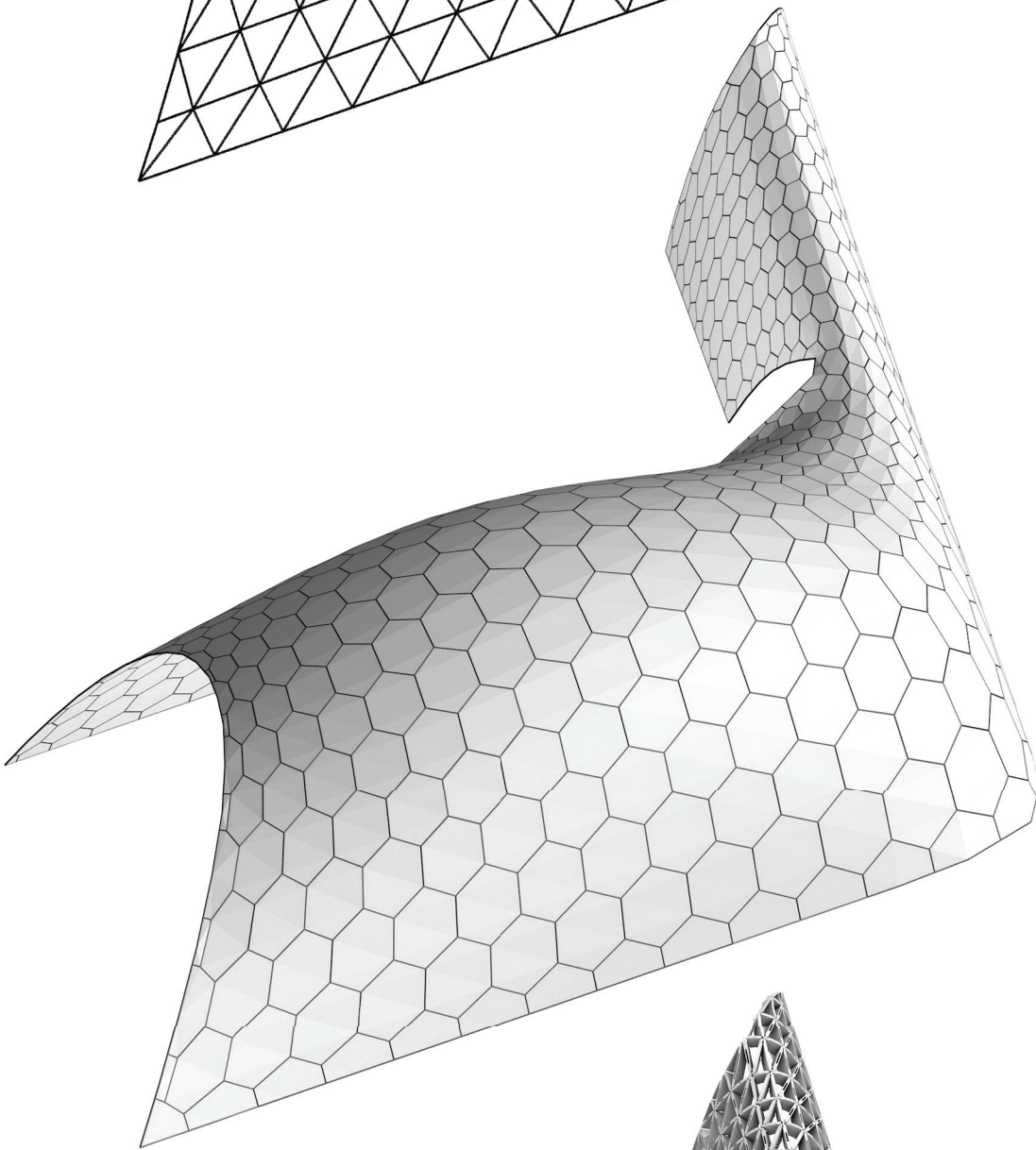
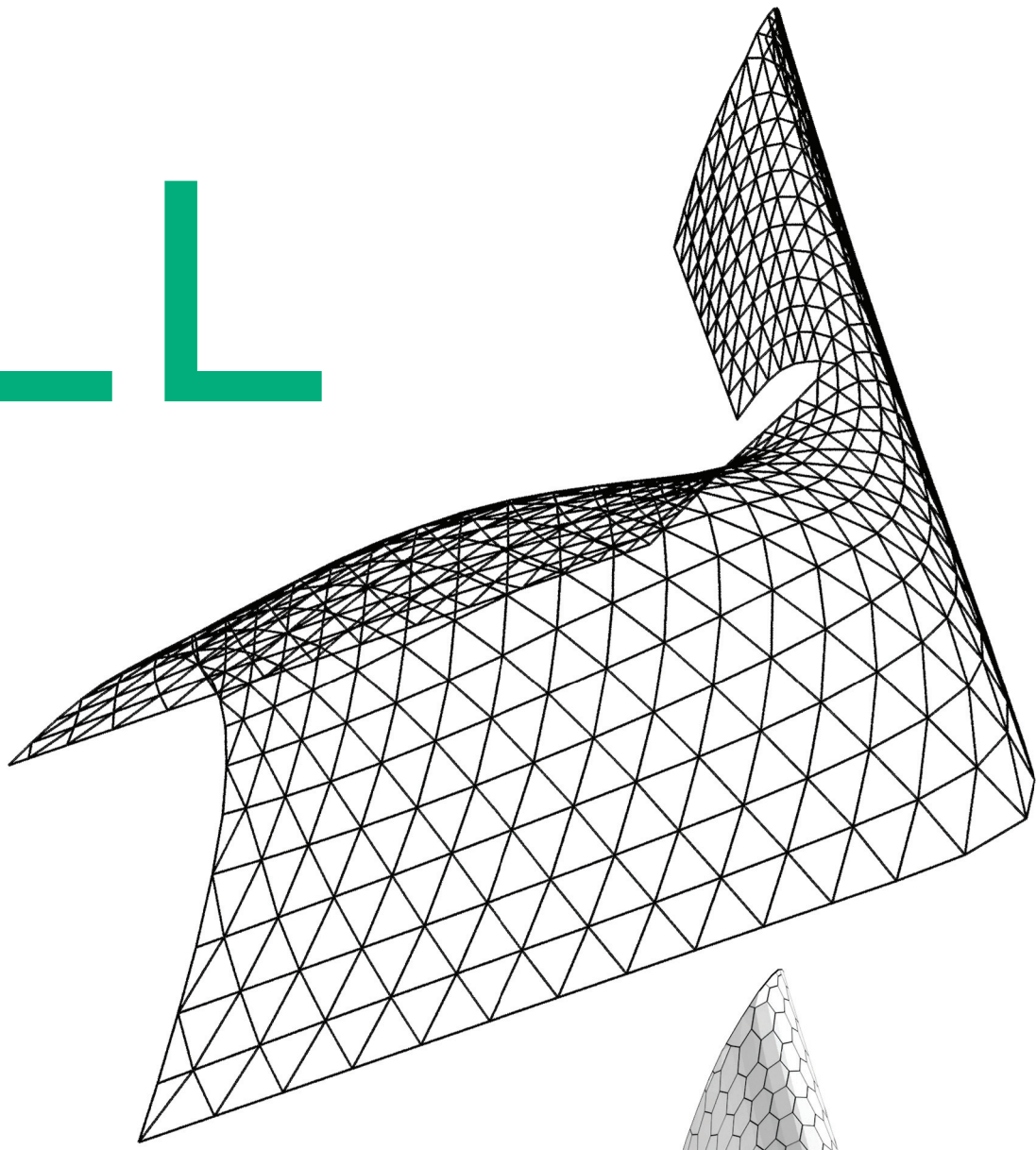
The gridshell structure is made of 12mm marine plywood (7 ply) with film on both sides. Spacer blocks between two parallel plywood panels are made of 25mm marine plywood. The outer cladding uses 2mm galvanized rolled steel tiles and the inner reinforcement straps at each node use 2mm mild rolled steel. All bolts and screws use stainless steel for weather protection.

METAL ARCHES

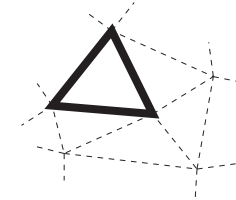
The two large openings of the gridshell are re-enforced with 8mm steel arches, which are connected to the nodes of the plywood grid. The metal arches help absorb large loads that terminate at the endpoints of gridshell lines on the arches and channel them directly down to the footing.

BOTTOM ROW STEEL TRIANGLES

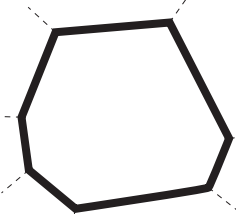
Bottom row triangles of the canopy are made of steel. Eight millimeter steel plates give the gridshell a solid footing where the highest land on the ground. These steel triangles, welded to a u-channel, are able to withstand water and thereby protect a critical part of the plywood structure from weakening over time.



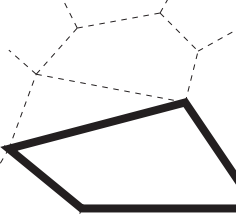
INPUT LINE NETWORK



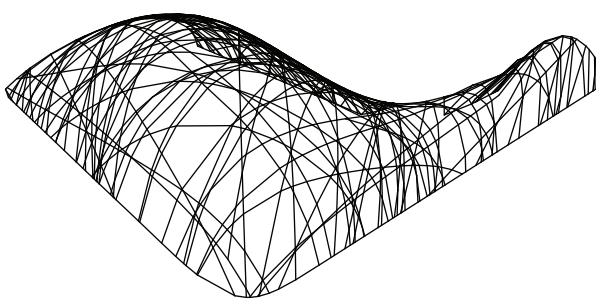
TRIANGULATED



N-GONES

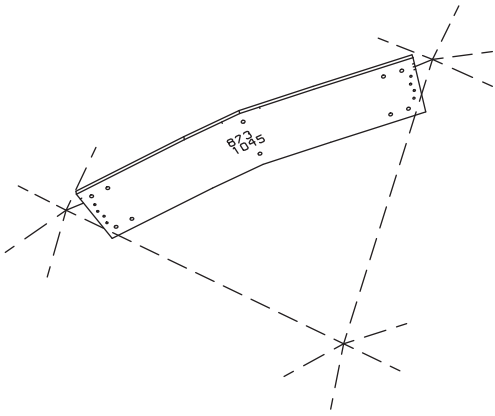


VARIABLE LOOP SIZE



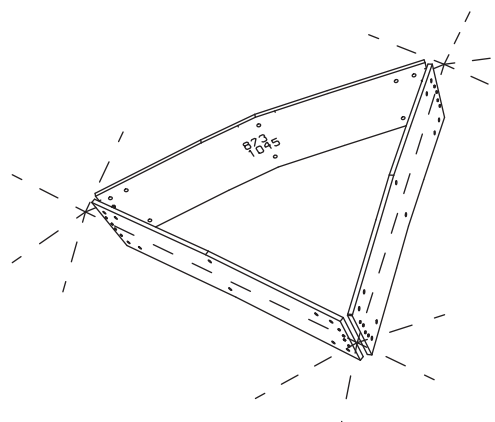
3D LINE NETWORK

The generation of the gridshell's geometric structure requires one user input – a curved line network. The line-network can follow almost any surface curvature with almost any line pattern. All vertices in the line network are used as structural joints in the gridshell. An algorithm turns the line network into a three-dimensional double walled structure, while keeping all components planar and all component outlines vertical, allowing them to be economically fabricated on 2D cutters.



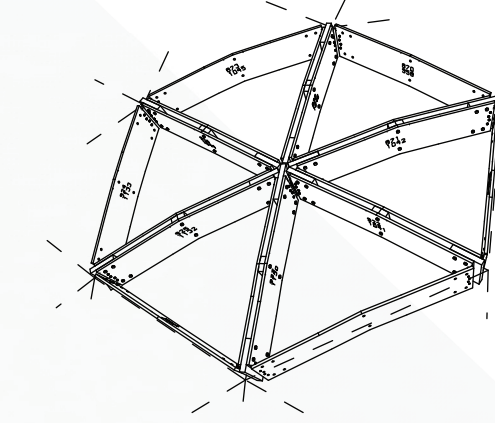
PANELS

The gridshell is made of 3012 plywood panels, each of which has a unique shape. All panels are fabricated using only vertical cuts, making fabrication affordable on standard 2d cutting machines. A slight curvature or angle in the outline gradually produces a curvature in the gridshell's structure. Each panel is engraved with two numbers. The top number specifies the "loop number", indicating which triangle the panel forms part of. The lower number specifies the "edge number". Two parallel edges of adjacent triangles share the same edge number. Each panel was additionally engraved with small stripe markings on the left and right side, which indicate the orientation of the neighboring panels. All necessary drill holes for corner hinges and spacer blocks bolts were marked on the panels and automatically cut on the CNC router.



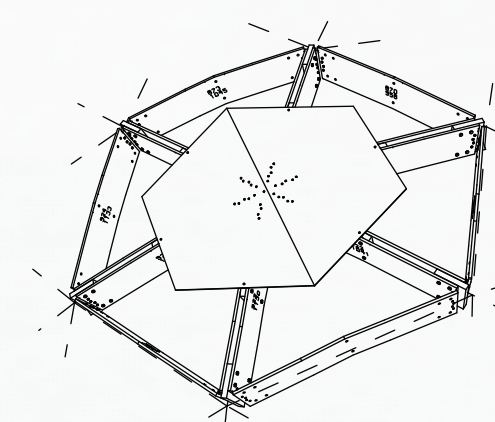
TRIANGLES

Three plywood panels form a triangles. The panels are joined with each other via standard 4-inch stainless steel door hinges to maintain position. The hinges are also used to handle the shear loads in the structure. Triangles were the first modules to be assembled off site.



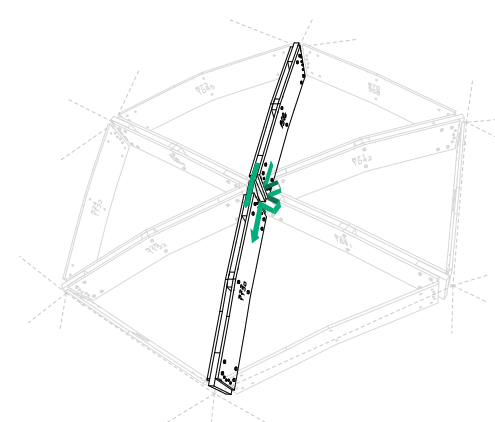
MODULES

Individual triangles were the first modules to be assembled. A set of triangles where later fastened together to form hexagonal modules. Individual triangles were assembled to each other with spacer blocks between parallel walls, fixed with four M8 bolts on each side of an edge. When six triangles are fastened to form a hexagon, a complete node is formed. The node can then be covered with a cladding tile on the top and a reinforcement strap on the bottom, both screwed into the spacer blocks.



CLADDING

Each node is covered by a 2mm sheet-metal cladding tile. The cladding tiles have a double function – they help transfer the structural loads between the plywood edges around each node and they form an overlapping fish-skin pattern to protect the interior of the gridshell from sun and rain. The cladding tiles are screwed with rubber washers directly into plywood spacer blocks between each edge, placing the screws in a zig-zag pattern so as to hit different ply layers for greater structural performance.



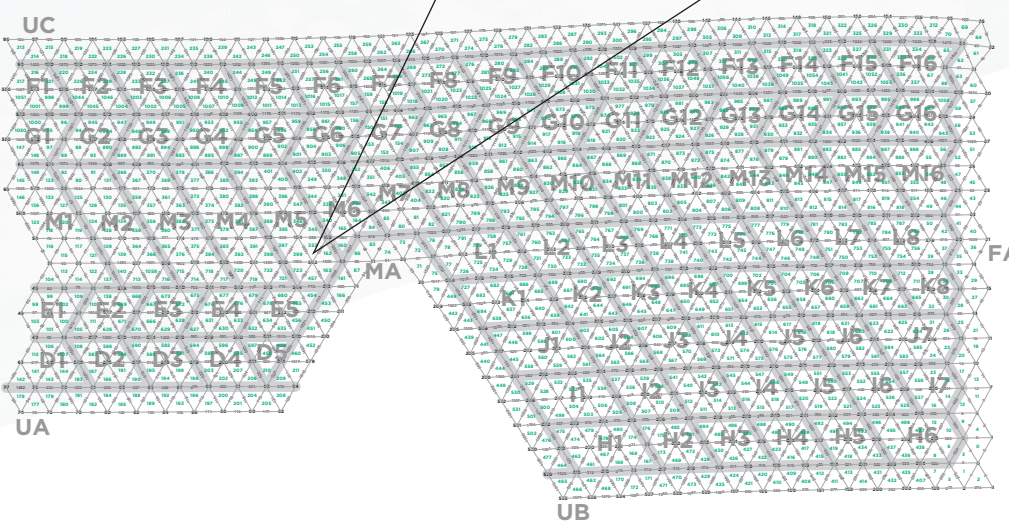
FORCES

Restricting all plywood manufacturing to only perpendicular cuts requires neighboring panels at the center of each node to stop at their intersection lines, producing an empty void at the center of each node. This poses a structural challenge because significant forces need to be transferred across each node of the gridshell. In order to achieve a direct load path, the steel cladding on the top and bottom of every node is also used to distribute forces between the plywood edges. Two load paths are established: one through sheet metal, allowing forces to travel directly through screws and spacer blocks around each node, the other through hinges and spacer blocks.

METAL CLADDING

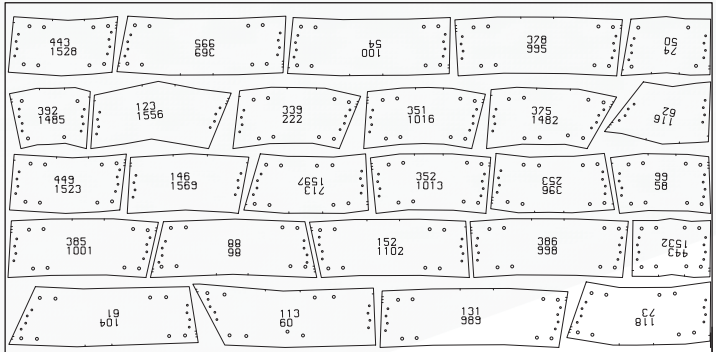
PLYWOOD STRUCTURE

TIMBER DECK



ASSEMBLY MAP

The map offers a numeric key to assembling all plywood and sheet metal elements of the gridshell together. The map indicates the node numbers and edge numbers of plywood panels, used to assemble panels to triangles, triangles to hexagonal modules, and modules to other modules on site. The map also illustrates the IDs and positions of all sheet metal cladding tiles and straps. The same numeric map is used to find all necessary spacer blocks between the module, whereas the thicker lines outline the extents of modules that can be assembled off-site and delivered to scaffoldings. This assembly map serves as the only construction drawing required to assemble the entire gridshell.



MATERIAL PACKING

With plywood panel hang a unique shape, it is important to reduce material wastage in fabricating the elements. A custom script is used to find the most efficient way of packing all 3012 panels onto standard 4x8 foot plywood sheets. The script takes each of the 3D plywood elements, lays it flat on a horizontal plane and sorts the shapes along a number of parameters in order to produce the fit with least waste.