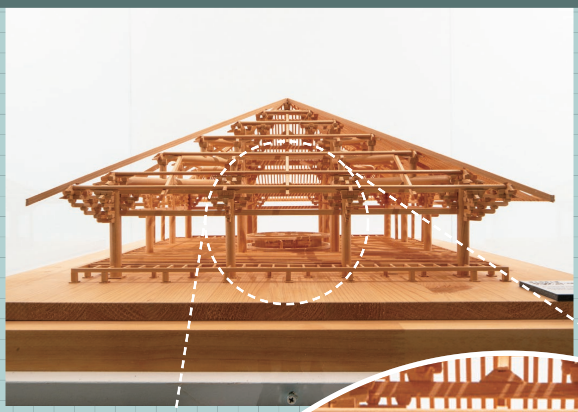
Highlights of the Structural Models

Various forces act on architecture. Because gravity acts on the earth, architecture is subject to loads of people, furniture, snow, wind, earthquakes, water, soil pressure, and its own weight. These forces act in the direction of gravity (vertical) and the lateral (horizontal) direction due to earthquakes, typhoons, and other events. What measures are taken to withstand these forces and maintain structural stability? Let's take a look at the flow of forces using structural models!

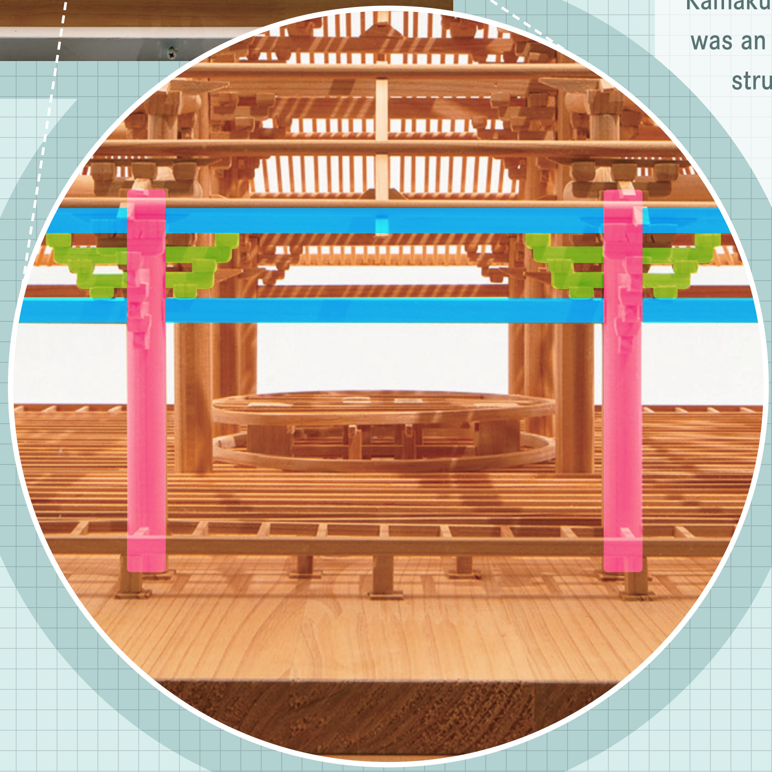
Jodoji Temple



[Rigid Frame Structure]

Flexibly passing on seismic forces

Nuki (penetrating beams) penetrate through the columns (vertical timbers), and both are fastened firmly. Integrating the columns and penetrating beams increases the stability of the building against lateral forces such as earthquakes and winds and allows the building to pass on the forces flexibly. Chogen used this type of "nuki structure" in the Kamakura period (1185-1333) to create a solid structure without using hardware, which was an ingenious structural idea. Streamlining the structure yielded the beauty of the structural members and an open space, making it tenacious and strong.

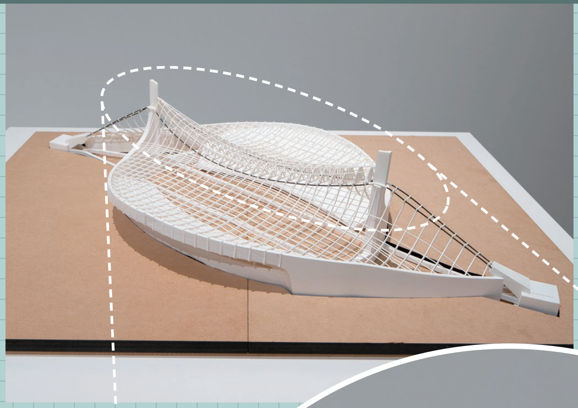


- ······ Columns (vertical timbers)
- ······ Nuki (penetrating beams)
- ······ Hijiki (inserted bracket arms)

The hijiki (inserted bracket arms) strengthen the joints and support the overhanging eaves. They provide structural reinforcement and characterize the design of Jodoji Temple.

Possession: The University Museum, The University of Tokyo   Model maker making: Takahiro Hirayama

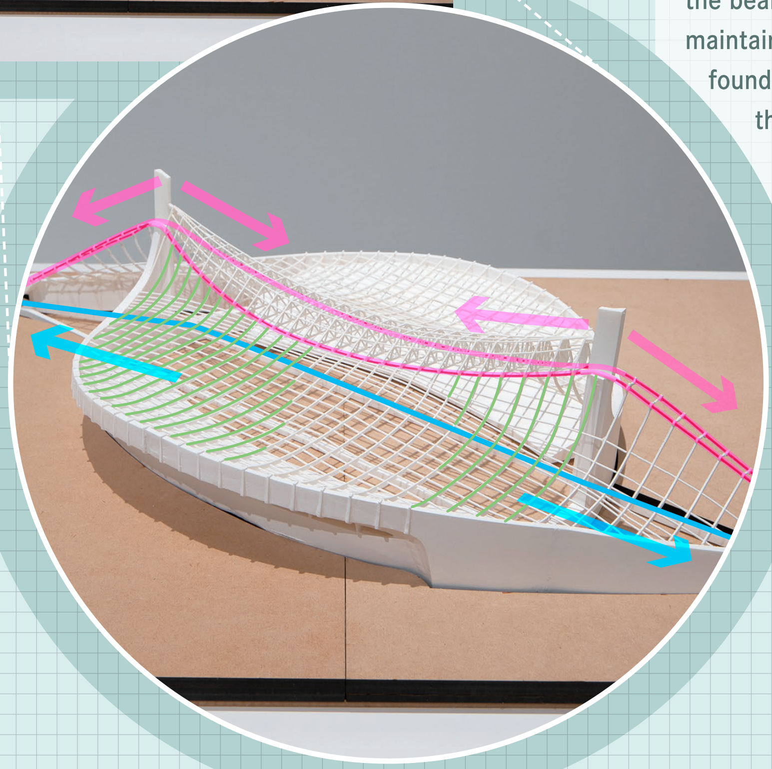
Yoyogi National Stadium



[Cable Structure]

Supported by tensile forces

Vines and ropes are not capable of bearing compressive or bending forces. However, they can support a load only by tensile forces when stretched between two supporting points, in the same way they have been used for suspension bridges for a long time. They are suitable for large spans because this method can maximize the bearing capacity of cables. The Yoyogi National Stadium uses this principle to maintain its shape by suspending the roof with main cables and connecting it to the foundation, which are connected so that they thrust against each other to prevent them from closing inward, via two supporting columns.



- ······ Cables suspending the roof
- ······ Main cables suspend the roof firmly
- ······ Holding on tight to support the cables

The characteristic shape of the roof is not a pure suspended shape from a mechanical viewpoint but a curve that architect Kenzo Tange drew. The curved surface was adjusted using steel frames with adequate stiffness to achieve this natural roof surface.

A Gassho style House in Shirakawa-go

Leaning against each other for stability

Connecting bar-shaped members to form trusses (triangular frameworks) provides a highly stable structure. They allow for configuring a system that does not generate forces in the bending direction, a weakness for bar members. The structure consists of gassho-bari (two inclined beams leaning against each other) and rikubari (horizontal members) that restrain their feet from opening.

[Truss Structure]

In the Shirakawago house, joints are fastened with ropes, and the beams are fixed with komajiri (pointed feet.) These simple joints provide sufficient strength to withstand heavy snowfalls. The second floor composed of trusses was used as a sericultural room that required an ample working space.

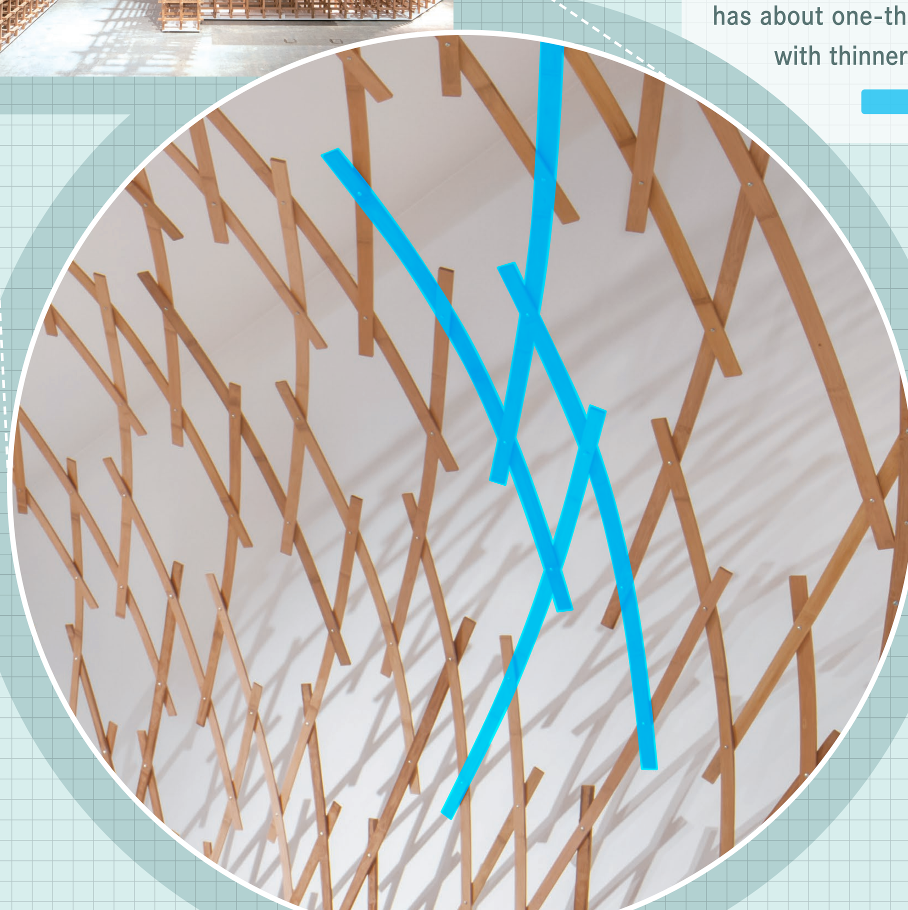
Possession: Shirakawa Village Educational Committee

Bamboo Structure

Supporting each other

In a reciprocal structure known as "aimochi kozo" in Japanese, short members support each other to bridge long spans. This reciprocal bamboo structure uses a series of collapsible reciprocal units to form the arches, suppressing the outward opening forces of the arch surfaces while leveraging bamboo's flexibility. Bamboo has about one-third the strength of steel, allowing for a more delicate structure with thinner members than wood.

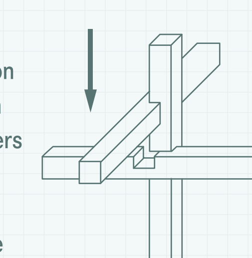
······ Reiterative unit

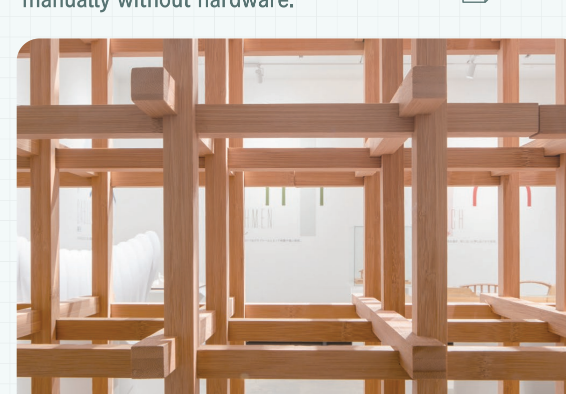


[Reciprocal Structure]

Mikata-koushi

Mikata-koushi is a construction method in which the joints on the laminated bamboo members are staggered by a half width and assembled in three directions, which can be done manually without hardware.





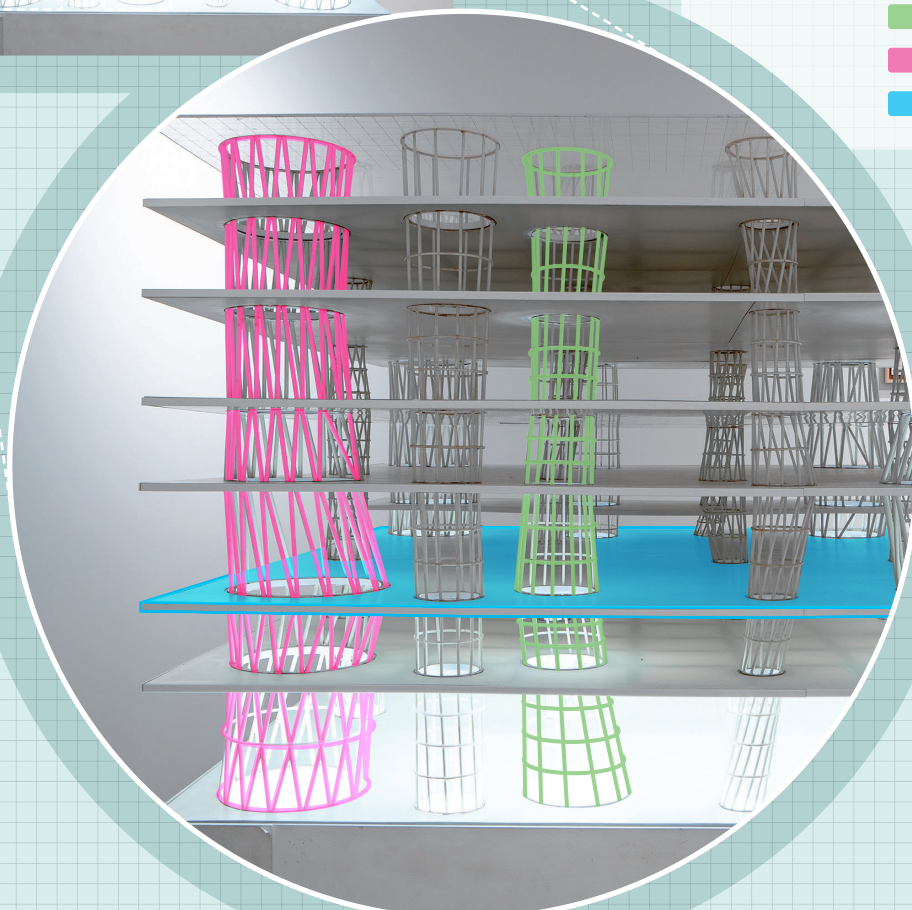
Possession: Hirokazu Toki Laboratory, The University of Shiga Prefecture

Sendai Mediatheque

Supporting with tubes and plates

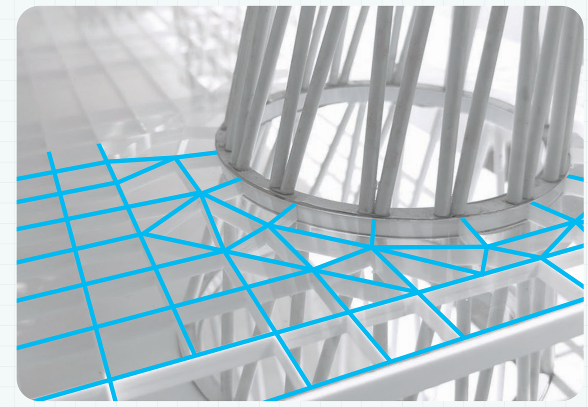
The structure of the Sendai Mediatheque consists of tubes receiving gravity, tubes receiving seismic forces and gravity, and ultra-thin floors supported by these tubes. The tubes receiving seismic forces are twisted to form HP shells, whose shapes effectively increase the buckling resistance.

- ······ Tubes receiving gravity
- ······ Tubes receiving seismic forces and gravity
- ······ Steel plates fabricated according to the force flow



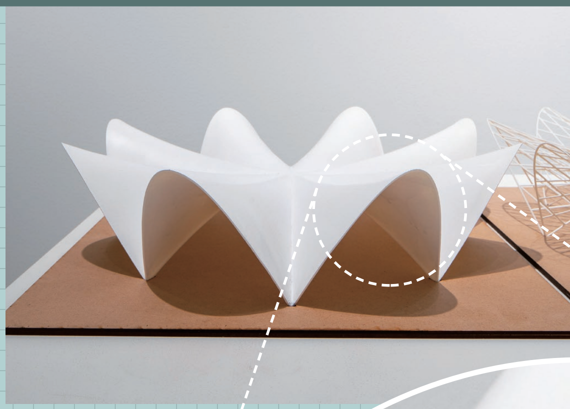
[Tubes and Sandwich Slabs]

The floor assembly is made of vertical plates called ribs, sandwiched between upper and lower steel plates, arranged to follow the force flow, and radially aligned near the columns.
Since the steel plates of the floor structure were extremely difficult to construct, shipbuilding engineers who excelled in steel plate fabrication made them.



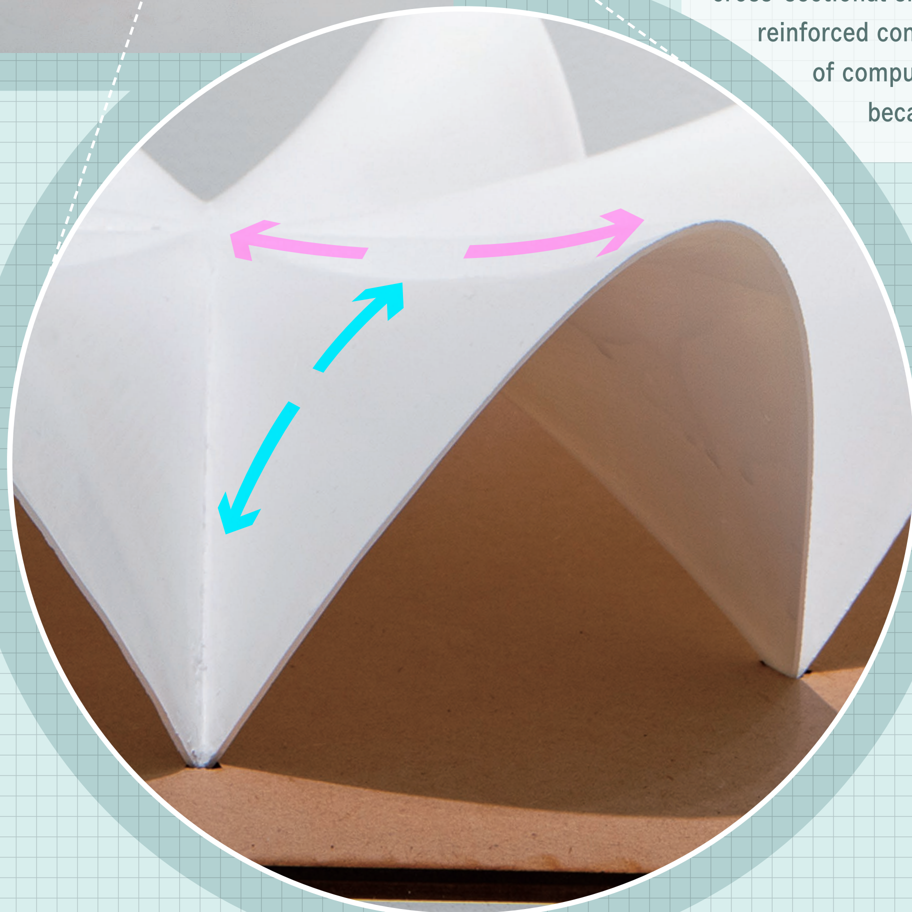
Possession: Mutsuro Sasaki

Restaurant in Xochimilco



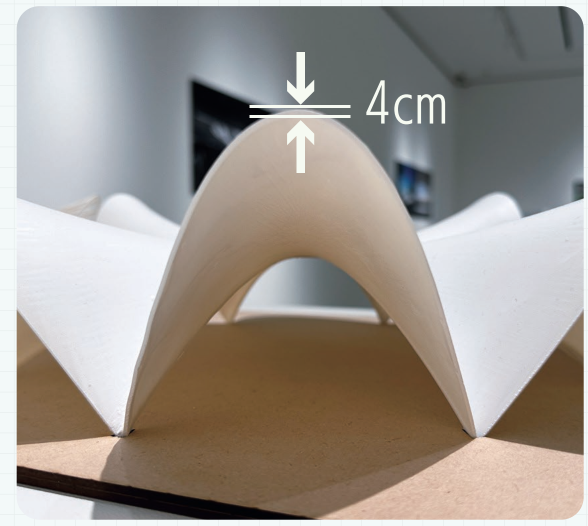
Thin and light

Buildings are generally made of columns and beams, but this "shell structure" comprises thin, smooth, curved surfaces like seashells. This geometrically defined curved surface shape allows forces to flow efficiently and, therefore, can be used to cover large spaces with a light structure using members with minimal cross-sectional size. Shell structures, made possible by the widespread use of reinforced concrete to construct smooth curved surfaces and the development of computational theories to design them, evolved after World War II and became a driving force in the structural design world.

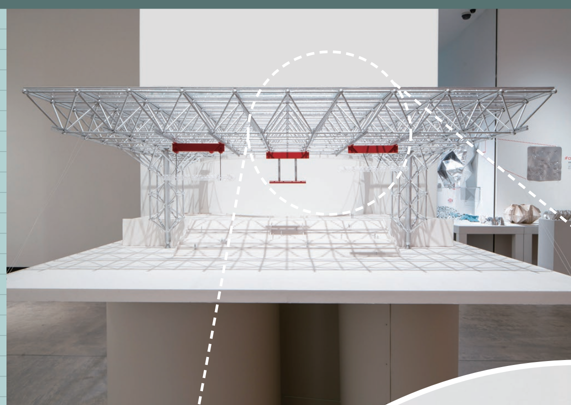


[Shell Structure]

The restaurant in Xochimilco consists of an HP shell (hyperbolic paraboloidal shell), which covers an interior space of 30m x 30m square with an ultimate thinness of 4cm at the general section.

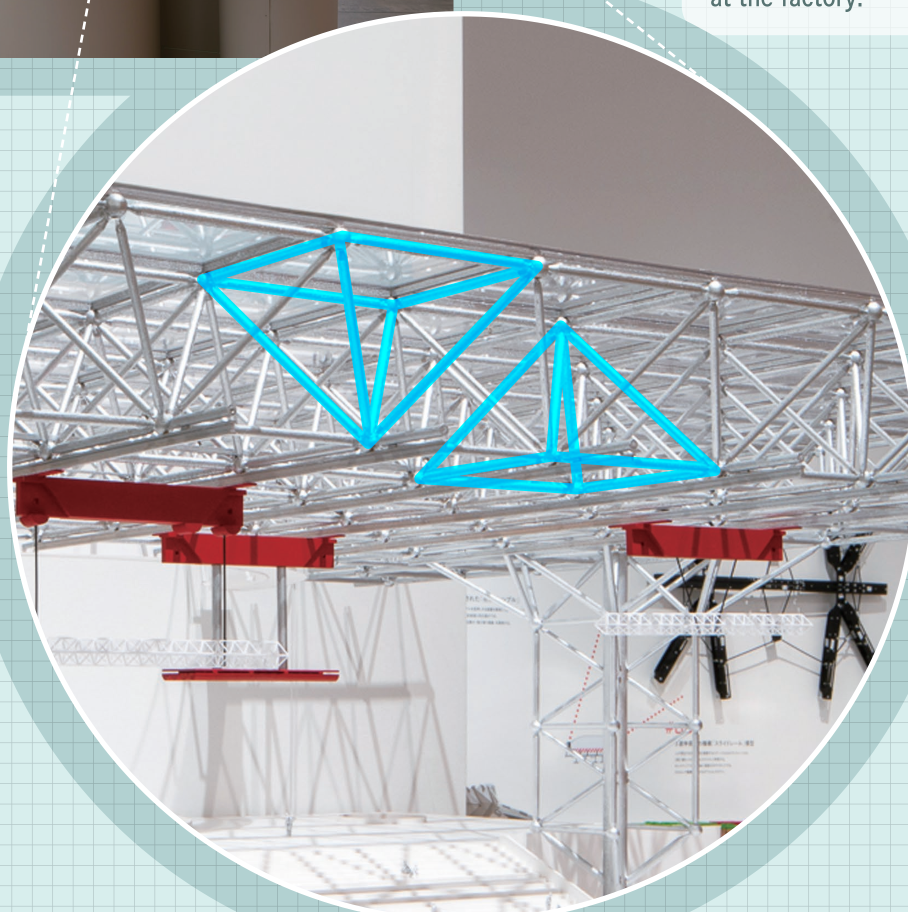


Expo'70 Space Frame for the Festival Plaza

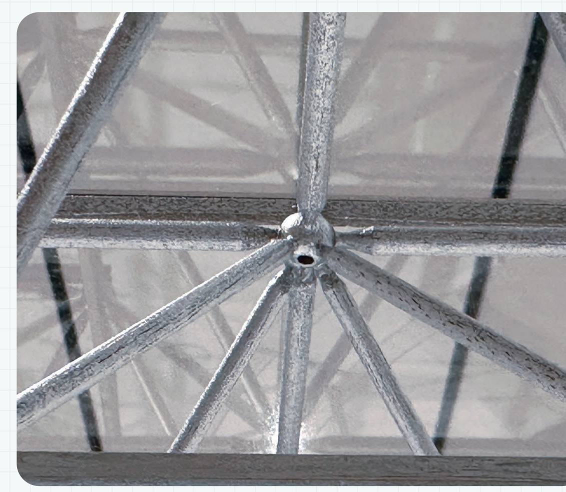


Three-dimensional force flow

The structure consists of bar-shaped members joined three-dimensionally, and the entire framework comprises a series of regular geometric units. It was conceived for easy assembly at the construction site and uses many bar-shaped members of approximately the same thickness to facilitate standardization and mass production at the factory.



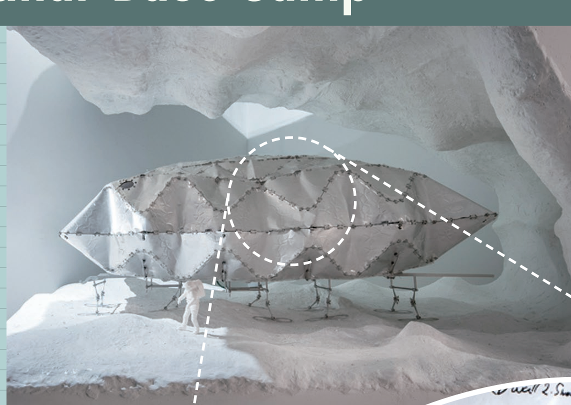
It uses mechanical joints made of cast steel and a mechanism that allows easy joining of members from multiple directions and absorbing errors between adjacent contact points when assembling. While there was no definite plan for the use of the "Osaka Expo Festival Plaza"(1970) after the Expo was over, this system allowed for flexible adaptation to permanent use and demolition a few years later.



[Space Frame]

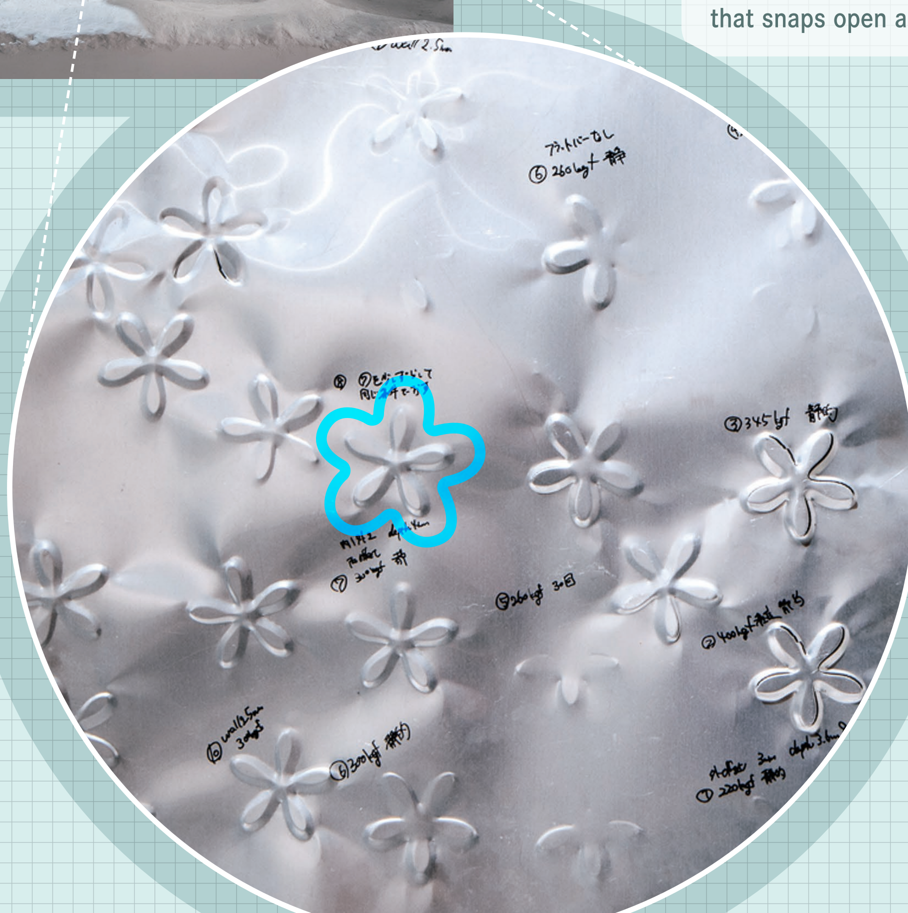
Possession：Park and Masudome Laboratory, Department of Architecture and Architectural Engineering, Kagoshima University

Lunar Base Camp



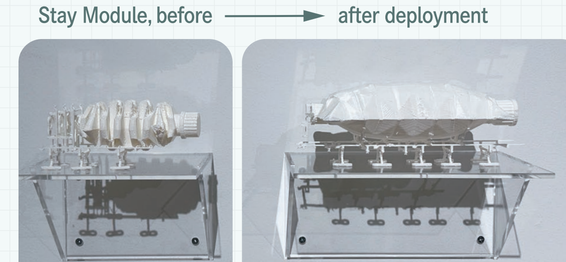
Collapse and deploy

The "floral dimples" on the surface of the stay module are a structural design to induce the "jump-shift" phenomenon, in which the collapsed outer skin expands outward when deployed. The "jump-shift" phenomenon refers to transforming from a state of equilibrium to another non-continuous stable state, like a hair clip that snaps open and close to form a reversed shape.



Since constructing structures in space is extremely difficult, determining the easiest construction method possible is critical. Also, lightweight construction is better from the viewpoint of transportation costs. Deployable structures, which use little force to open from a folded state to create a structure, are most reasonable in space.

Stay Module, before → after deployment



Space structures are designed leveraging geometry and mechanics, sometimes getting ideas or discovering new structural characteristics from insect wings while shuttling back and forth between knowledge of various fields.

[Deployable Structure]

Possession：Jun Sato Laboratory, Graduate School of Frontier Sciences, The University of Tokyo

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