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Bamboo Architecture: Structure, Construction and Space: Part 2

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Abstract In Part 1, Design of bamboo structures was primarily presented. In Part 2, spatial quality resulted from bamboo structures is highlighted. Furthermore, VTN Architects' design process for bamboo architecture is discussed.

Keywords Spatial quality of bamboo structures, Bamboo joints, Bamboo craft

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1. Spatial Quality Resulted from Vtn Architects' Bamboo Structures

The spatial implication of our bamboo structures comes from the unique qualities of the material, from the fixing methods of the joints, and from how we use our units to create complex and interesting structural forms.

1.1. Closed yet seemingly vast space:

First, our bamboo units are flexible enough to create two main types of spaces: closed space and open space. A closed space that utilises our bamboo structure is *Dai*

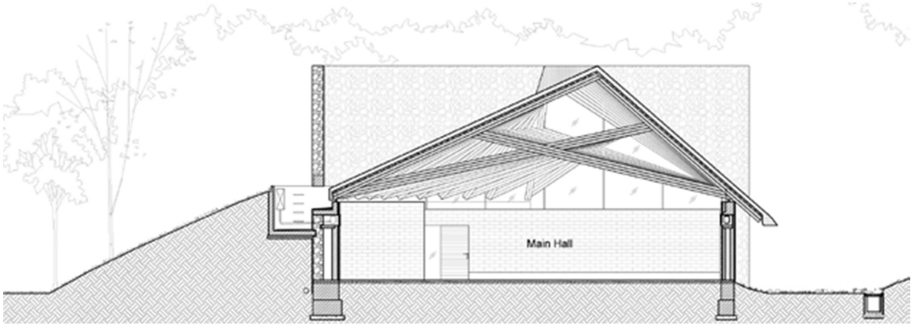


Figure 1. Section of Dai Lai Conference Hall, showing the roof bamboo units.



Figure 2. Dai Lai Conference Hall.

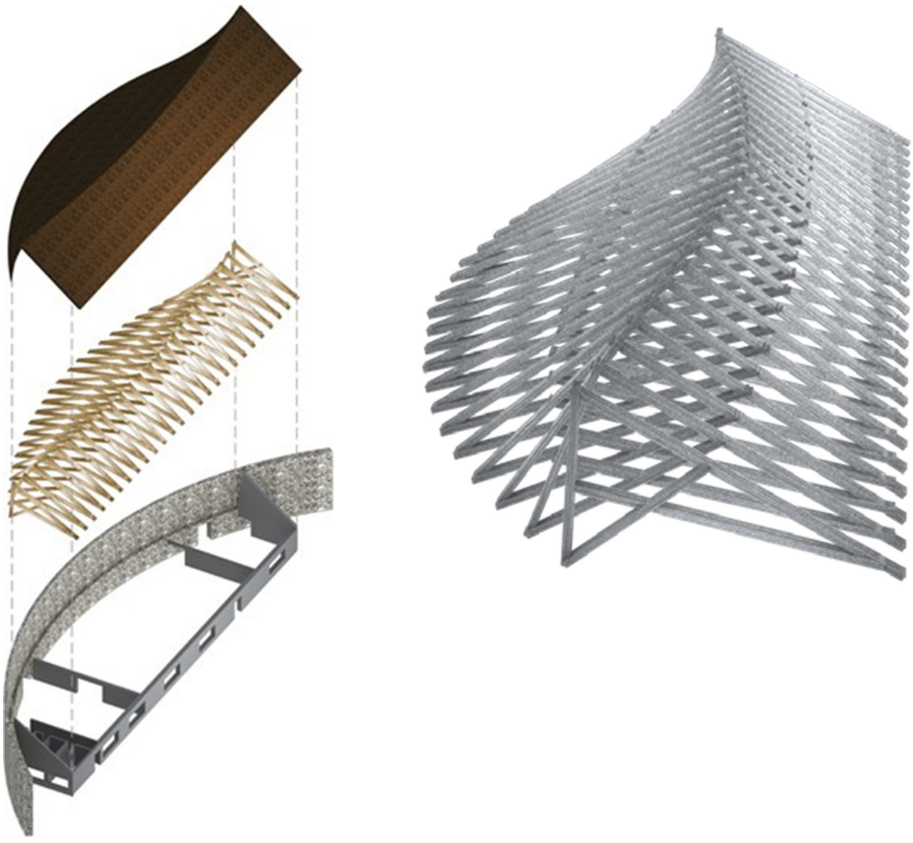


Figure 3. Section of Dai Lai Conference Hall, showing the roof bamboo units.



Figure 4. Exterior of Dai Lai Conference Hall.

Lai Conference Hall. A series of bamboo truss units that span 13.6 m raise the roof and free the interior space of structural columns. The joints position at each frame is adjusted to make a curved roof. The hall is enclosed. However, the roof structure allows the space to be felt as wider and more open. This quality comes from the exposed elements, from the fixing method to provide large span capacity and from the natural texture of the culms.



Figure 5. The openness of Bamboo Wing.



Figure 6. The openness of Bamboo Wing.

1.2. Semi open space by bamboo units:

On the other hand, we see *Bamboo Wing* using unique bamboo units and tensile cables to allow the entire space to be free of columns, leaving the building open to nature. The openness allows the space to be flexible. It can house wedding parties, live music concerts, or ceremonies. It also allows fresh air in, minimising the need for air conditioning. The deep eaves and water let people enjoy nature directly.

1.3. Semi open space by dome structures:

The openness also comes from our play of scale, illustrated in the massive spaces inside our dome structures. By restricting the structural height to a single



Figure 7. The massive space inside our dome structure at wNw Bar.

storey space, we maintain the pure and expressive language of our ribbed units with no intrusion from interior load-bearing structures. As a consequence, our bamboo units become perimeters with diverse spatial planning. The open spaces become flexible for multiple uses and for changing needs that include future expansion of the clients. The openness is possible due to the span capacity of our bamboo units, which allows our structures to span widely and our roofs to go up high. Inspired by traditional Asian architecture with three stepping roofs and lighting strips in between allow indirect light to enter the space inside.

The semi outdoor space in our bamboo structures is also utilised by the corridor created by the wings of our frame units. At *Vedana Restaurant*, we create an en- gawa space through our outer corridor, linking the internal environment to the outside.



Figure 8. The massive space inside our dome structure at Vedana Restaurant.



Figure 9. Castaway Island Resort, located on an island.



Figure 10. Vedana Restaurant in the middle of a lake, a blossoming forest, and mountains.

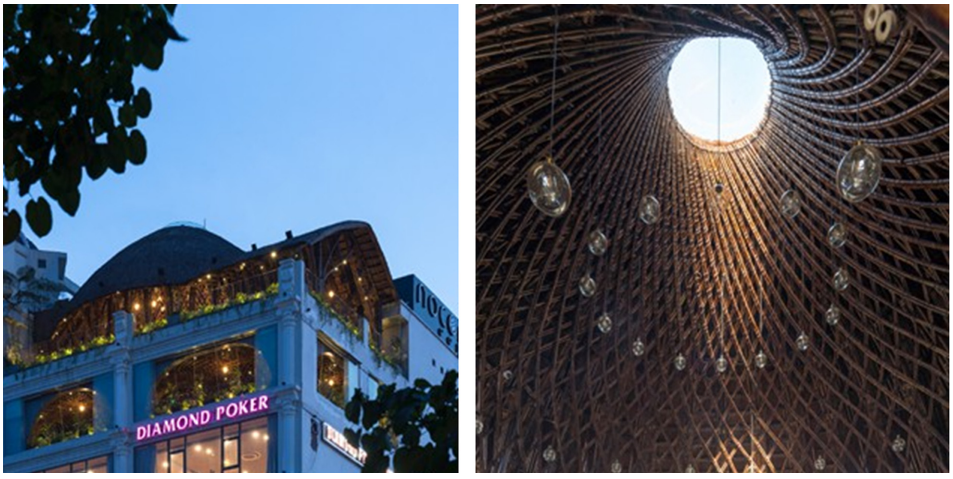


Figure 11. Nonenco Cafe, a unique space in the middle of the city.



Figure 12. Nonenco Cafe cave-like space.



Figure 13. Bamboo column of Kontum Indo- chine Cafe.

This also becomes an environmental strategy, with pond surrounding our struc- ture bringing cool air to the inside.



Figure 15. A joint of hp shell structure.

1.4. Sympathising with Natural Landscape Through Colours, Screen Aes- tHetic and Semi-outdoor Space:

The openness also comes from the fact that most of our projects are within mas- sive landscapes. The ideal locations bring a unique spatial quality that blurs the relationship between inside and outside. *Vedana Restaurant* is in the middle of a blossoming forest, mountains, and a lake. The indoor space transitions towards the landscape via a semi-outdoor space. Because of the massive open space below the dome structure, the inhabitants can inhabit both the inside and the outside at the same time. Another example is *Castaway Island Resort*, which is on a beautiful island in *Cat Ba Archipelago*. The HP shell structure forms a semi-outdoor space for social interaction. The triangular openings created by the shell modules frame our views towards the ocean and the surrounding islands. The inside-outside rela- tionship is blurred beautifully.



Figure 14. An aesthetic of screen/ filter & the brown colour of bamboo.



Figure 16. Unique surface quality of *Castaway Island Resort*.



Figure 17. Interior of Bossco Cafe.



Figure 18. Dong Na Clubhouse.

This further connects people to nature.

Even when employed in the middle of the city, our bamboo units create unique spaces that open up to the cityscape. For instance, *Nonenco Cafe* at Vinh city is a renovation project that uses bamboo over an existing concrete structure. 10 bamboo columns hide the existing concrete structures and divide the open space into smaller private areas. They create a unique cave-like space that can never be experienced in its totality. The structure frames each area a snippet of the beautiful cityscape.

These create semi-outdoor spaces, even in urban area that symphathise with the landscape. This sense of openess is achieved purely by our structural forms, etc.. The colour of our bamboo also blends quite beautifully with natural landscape.

Our bamboo construction method also allows for a unique aesthetic of screen/ filter from the mesh-like texture. The aesthetic comes from the structural depth, the bundled bamboo culms and the blurred relationship between inside and outside.

The structural depth is evoked by the use of multilayer frames. Each frame unit is exposed with a clear structural hierarchy of arches, columns, and then bracing. They overlay each other, progressively build up the depth of the structural units.

The fixing method of layering bamboos culms into a dense sand-which system also plays an important part. Our units filter out the harsh sun while still letting natural light in, casting shadows across space. The transparency of the structure wel- comes fresh air to flow through. These qualities further blur the inside-outside relationship, allowing the inhabitants to be at one with nature.

1.5. The Spatial Beauty of The HP Joint:

In HP shell structures, corner joints are difficult because of the need to con- nect multiple bamboo frames in different angles together at one point. Steel elements are

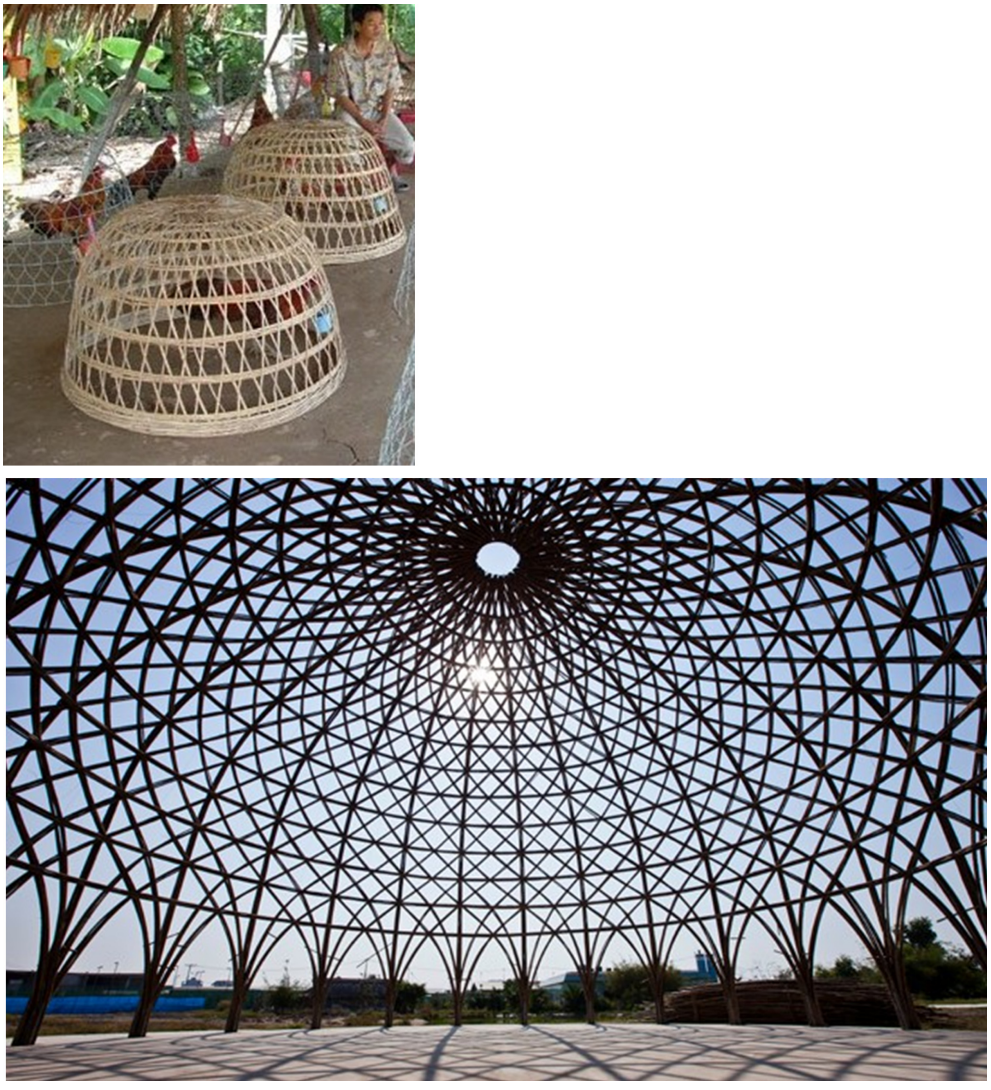


Figure 19. *Diamond Island Community Center* inspired by a hen-house.



Figure 20. *Kontum Indochine* Cafe, inspired by fish basket.

added along bamboo joints to ensure adequate support. The com- plexity transforms our bamboo structures into an aesthetic of depth and tex- ture for a unique architectural surface that enhances the spatial quality.

First, it allows for variations of structural depth. This varied depth cre- ates a unique wavy ceiling and roof surface as it relieves the plainness of an architectural surface and creates opportunities for natural and artifi- cial light to interact with each other. This quality stimulates a space through fluctuation between bright and shadowed areas over the shell surface.

The spacing, the position and the density of our bamboo culms over a solid ceiling surface also create a rhythmic pattern that is both intriguing and pleasing to the eyes.

This unique quality is repeated and progressed in many of our projects such as

Bossco Cafe or *Dong Na Clubhouse*.

1.6. Traditional And Local Bamboo Craft and Modern Structural Forms:

Our bamboo structures are also good examples that combine traditional local bamboo craft and modern structural forms and methods. We often take inspiration of very simple traditional and local tools and structures and then we literally scale them up into impressive bamboo structures.

For instance, our large dome structure at *Diamond Island Community Center* is inspired by traditional bamboo hen-house in Vietnam. By simply scaling the humble hen house up, we achieve a good structural form. Evidently, the scale shift presents many translation problems and we have to invent new elements to make sure the structure works in the bigger scale and structural requirement. Problems.

For inverse conical structural form at projects such as

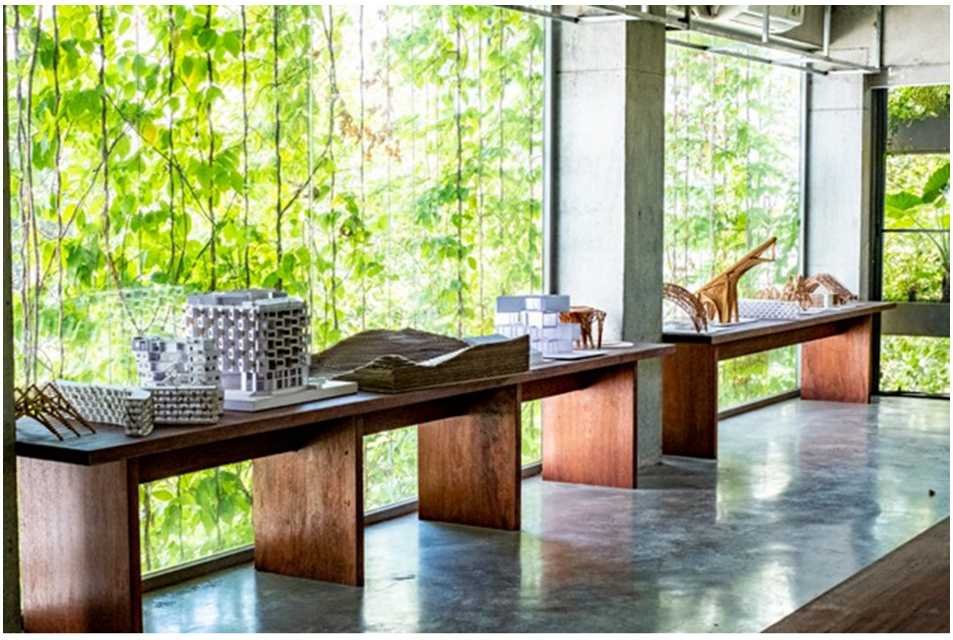


Figure 21. Our office is packed with physical models.



Figure 22. Our joint system.

Kontum Indochine Cafe, which has structural columns that are narrow at the base and open widely towards the roof to form the strong visual of inverse cones. This is a direct reference from Vietnamese basket for fishing. By simply replicating the simple form of a simple mundane tool, we turns something humble to a complex structural system in *Kontum Indochine Cafe* that is made from steel tensile ring and bamboo elements.



Figure 23. Bundling joints on site.

2. Our Design Process

2.1. Our Design Process:

In our office, **we utilize many architectural tools to explore our ideas**. They include physical modelling and digital tools (that involves scientific research, making diagrams, and graphic representation). This helps our designs to embrace early experimentation and also fully realized

before they become a reality on construction sites.

Physical modelling is our favourite tool when it comes to the design process. We have a dedicated floor in our office for our staff to make physical models. There is a corner on level 4 full of materials, several big tables with cutting mats and a foam cutting machine. The staff enjoy laying everything on a massive table or lying on the floor to cut and assemble paper, bamboo sticks, timber, or foams into many scales. Bamboo models are our treasures since they are unique to our office. As part of our office's culture, our interns and architects enjoy making models as an experimental tool and a way to learn about structure and architecture. We use them in almost every design meetings to discuss ideas and approaches as well as how to move forwards. We write and mark on our models because we believe them to be iterative and experimental tools.

Our design process is a process of trial and error and gradual updates from the scales of smaller physical models of a joint to a full mock-up frame on-site and the outcomes. We experiment with our physical model just like how we deal with our actual bamboo frames: from making a joint to making a bundle to making a modular frame into making structural forms.

2.2. A VTN Bamboo Joint:

The idea of the joint is important in our design thinking. The key to using bamboo as a primary structure in architecture comes from the junction between bamboo



Figure 24. Our modular bamboo frames.

elements that bears tension and stress. The stiffness, strength, and stability of the joints dictate the ability of bamboo to be used safely and effectively as the main load-bearing components in a building. **The role of structural joints is to strengthen the bamboo culms** to allow safe and adequate transmittance of loads between elements and finally into the ground. Of course, the idea of the joints also influences **the tectonic of our architecture**: the way we join smaller culms to create a bundle and to create frames, and the way we join many frames to create a form.

There are many ways to deal with the joints between bamboo culms in construction, such as bundled node, column and tie node, screw style node, or using steel members along with steel plates (Mengting Yuan, 2015). Each creates variables in terms of costs, difficulty in assembling, and structural strength. At *VTN Architects,* we use **a very low-cost fixing method of ropes and nails** to establish our fundamental joints. To ensure its structural qualities, we create 1:1 models of the joint with ropes and pins to test the rigidity and the aesthetics of the joints. The unique method of making bamboo joints generate unique qualities to our bamboo structures in terms of structural forms, construction methods, and spatial qualities.

The joint is collected into a bundle using a fixing logic that is unique to *VTN Architects:* a comb-like connection with thick ropes and bamboo bolts which involves the act of sandwiching elements to each others and stacking them to thicken the joints into bundles.

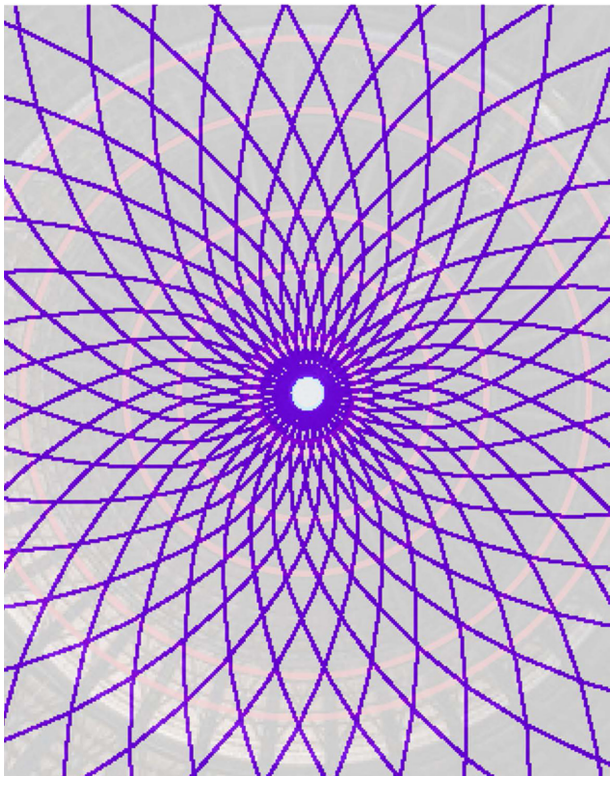


Figure 25. Our physical modular bamboo frames.

This creates a unique aesthetic of our bamboo structures, with thick and densely layered bamboo culms.

2.3. A modular frame:

From the joints, we make mock-up modular structural units to test aesthetic and structural properties: the length of each bamboo culms, the joints between them, the location and fixing solutions, the curves and bending radius. Each structural requirement is tested to ensure structural quality when the actual frames are to be erected on site.

Making the mock-up frames becomes a very specific method of our office:

_First, we print out (on paper) sectional cuts of our pre-designed bamboo frame modules. The cuts are usually generated from Revit or Rhino and the drawings usually contain grid-lines for references.

_Second, we put the drawings on flat white cardboards as a guiding background. We put a layer of transparent tape over the drawings so that we can work over the layer.

_Then, we will make mock-up frames, following the guides. We bend bamboo pieces one by one and we use glue and pins to hold the pieces into the guides and to connect them.

This process is identical to the erection process of bamboo modular units on- site (of course, with proper methods of fixing and fastening from ropes and nails instead of using glues). The mock-up process in the office is useful to us because

we consider in the mock-up models the same details we would consider in the real bamboo frames on site. Ideas such as joints, material length, or the shapes and geometry of the frames are considered.

With the physical modelling process, we test the length, the structural capacity including if they can stand still with vertical force and horizontal force. Every piece is to scale with the actual length of bamboo culms on site.

The erection process of bamboo frames on-site follows the same logic as our in house office modelling process.

First, we show our workers the sectional drawings of our modular frames. There could be one or many modules that are different or slightly different to each other so we have to prepare drawings of every single module needed in the project. We use grid lines very carefully in the drawings so that our workers understand the bending angles, dimensions and connections of each module and how they are fit within an overall form.

We make each module by recreating the drawings on steel plates on the ground first, just like how we do with the scaled physical models. Our workers redraw the grids into the plates. Then, they bend bamboo based on the drawings effectively on the ground. Precision is very important in our working process. Ropes, bolts and steel wires are installed into the joints on the ground.

2.4. From modules to forms:

When we finish making all the individual modules, we



Figure 26. Our full bamboo frames, created from multiple modules.

then assemble them to create full-frame models that embrace different structural forms and different structural systems. The bracing elements are added to ensure structural integrity.

Similarly, the erection of an overall structural form on site is done modules by modules with the help of cranes and scaffoldings.

The erection can be fairly low-cost with scaffoldings and cranes. The cranes are used to lift the entire frames pieces by pieces into their positions. The scaffoldings are used for our workers to climb up and deal with the joints.



Figure 27. Bending bamboo frames on site according to predetermined grids.

2.5. Digital tools:

We use digital software to design our bamboo structures. We normally use Re- vit to be more precise with our bamboo structures. We model every bam- boo elements to calculate the number of bamboo culms needed for each frame, to investigate the comb structural joints, on how to put the individual bam- boo elements together to create a structurally sounded frame as a whole.

This is a practice of patience and detailing that ironically, turns thinking about the frame back into thinking about the joints, the bundles and the individual culms. Then we use the information to estimate cost and send it to the clients.

As we can't observe the spatial quality of our interior spaces with only physical structural models, we use digital software to tease out the atmosphere in our bamboo structures that is created by light, materials, and physical spaces. We use 3dsMax to test out different scenarios and spatial qualities for our bamboo projects.

The selection of furniture, material and lighting fixtures are all tested with 3dsMax renders in a trial and error



Figure 28. Making a module on the ground.



Figure 29. Making a module on the ground.



Figure 30. Many of our experiments in physical models.



Figure 31. Many of our experiments in physical models.

manner. We also use renders to check design iterations and how different bamboo configurations affect a space.

2.6. Regarding Hiroshi Naito

Our bamboo practice is by the architectural practice of my mentor at University of Tokyo, Hiroshi Naito. Hiroshi Naito focuses on **how to make architecture simple, honest with materials and structures.** With him, **engineering is pushed into architecture.** Structures, structural joints and their spatial implications are important in creating good architecture (Naito, 2013). Many ideas are executed greatly in his architecture.

He appreciates the beauty of structural simplicity and the harmony between architecture and nature. He doesn't view forms as something extravagant but as a meaningful contribution to functions, nature and human comfort. His architecture has a simple beauty, **becoming one with surrounding nature**. His view that through times, **architecture should belong to the scenery** around it is seen clearly at *Makino Museum of Plants and People* when he said:

"I hope the buildings will have no elevations; so only trees can be seen. I want the building exists only as interior space. It is wonderful. As the surroundings mature, the architecture becomes more resistant to typhoons. ***It is ideal for architecture to stand with the environment.*** *Modern architecture stands alone. I don't think modern architecture gets power from the earth. It is hard to see architecture standing alone. For architecture, it is better to exist with its surroundings. I think architects are starting to think about this issue."* (Kanai, 2002).

One of his most famous building, *Sea-Folk Museum* sees Naito's client suggesting a space free of columns and therefore, allowing the spatial planning to be free. This led him to several sketches regarding a structure that frees up the interior spaces by **employing a series of columns + arch unit system**. The idea of open space presents in Naito's buildings since it evokes natural ventilation and blurs the inside and outside. The open internal space also demonstrates Naito's belief in **the relationship between architecture and nature**. He believes in an intimate relationship between inside and outside. He opposes the Modernist ethos that cuts off the interior with the outside world. By being cut off, the internal spaces of people are disconnected further from nature and from climate change. His buildings aim to destroy the natural environment as little as possible (Kanai, 2002).

This design ethos is **suitable to a tropical climate like in Vietnam**. Vietnamese spaces don't try to close off our internal spaces but we try to open them towards the outside, utilising natural ventilation. Naito also dislikes the uses of artificial

The honesty of material. By using or exploiting a



Figure 32. An erection of our bamboo modules on site.

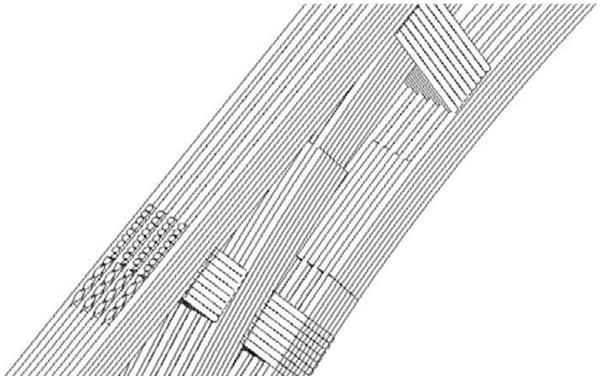


Figure 33. A zoom in of our Revit model of a modular frame, trying to investigate how to join bamboo culms.

material truthfully and not sacrificing the integrity of a material. In Naito's architecture, material is seen as having the need to be used in their pure intensity and materiality by not exchanging their intrinsic properties to any different kinds of materials. He prefers to use natural materials, as they lend a sense of intimacy and they provoke a sensory experience (Kanai, 2002).

Sea-Folk Museum sees **a wood joint system that connects smaller wood elements through a sandwiching/ stacking logic is used to join different wood elements** (that are different in length) into a singular frame that effectively spans 18.7m. He uses metal fittings in the joints to connect singular elements, similar to a conventional timber construction method (Naito, 2013). This interlocking characteristic let the structural elements extended out, overcoming

This idea of structural joints and systems that creates an overall architectural form is seen in many of Naito's project. This appreciation of architecture from micro-scale to macro-scale moves from joints to frame modules to structural forms to create architecture. In

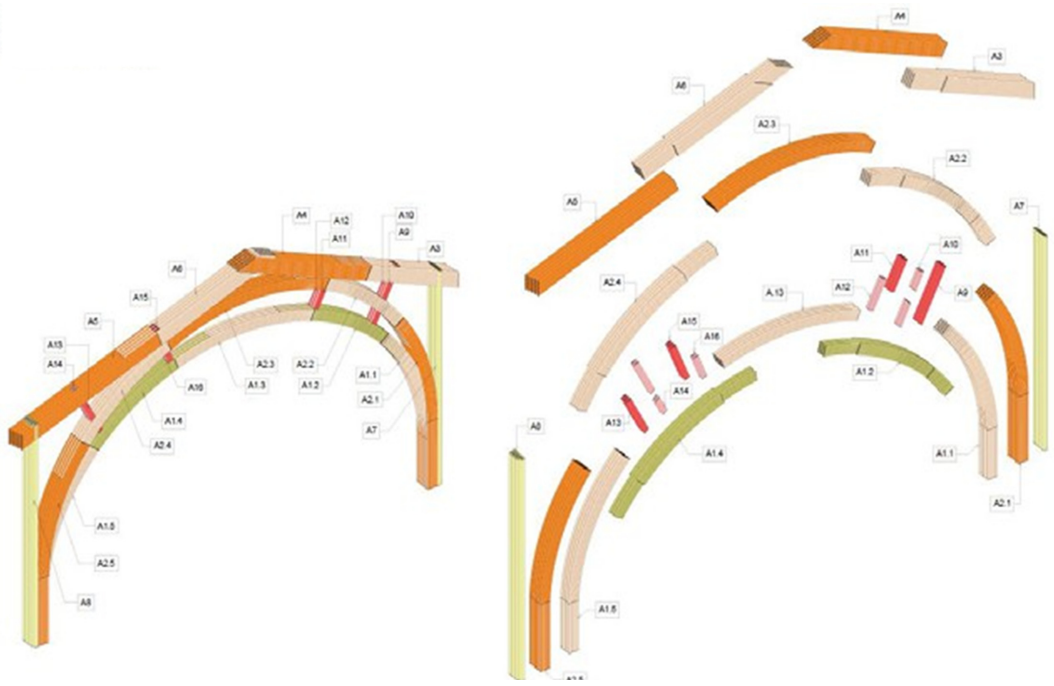


Figure 34. Using our Revit model to separate bamboo parts for fabrication and construction.

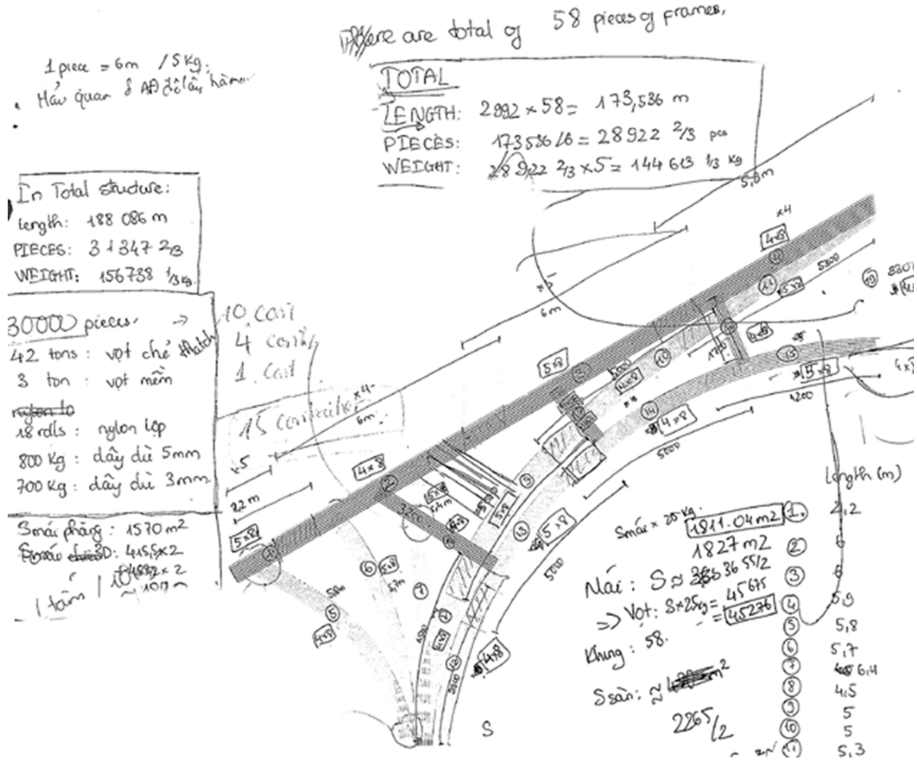


Figure 35. Using our Revit model to count bamboo culms.

Naito's buildings, the structural system determines the form of the architecture and not the opposite (Naito, 2013, Kanai, 2002). The role of an architect to him is to invent original structural systems and spaces to suit the unique context of each project. Then the architectural forms will be generated.

Similarity to Japanese traditional semi outdoor space

VTN bamboo architecture always plans semi- outdoor space to reflect Vietnamese climate and utilize it into spatial design. Our main structural form is designed to



Figure 36. Hiroshi Naito's *Makino Museum of Plants and People* blending with the landscape.

open up the interior to the natural environment and to utilize natural resources. This spatial composition provides views, natural light, wind into interior and realizes comfortable space while it's preventing from direct sun light. This space of VTN is similar as Japanese traditional semi outdoor space in old temples.

In Japanese temple, there are space named "Engawa" covered large roof which has buffer space for people to enjoy natural environment and connect outdoor space to interior space. Interior space become more rich to take natural elements. Such space can connect human to nature.

3. Conclusion

3.1. Our Unique Joint and Structural Systems Resulting in Unique Spatial Qualities:

VTN joint system is original, with one composed using Bundled, Pinned and Stacked method.This enables VTN

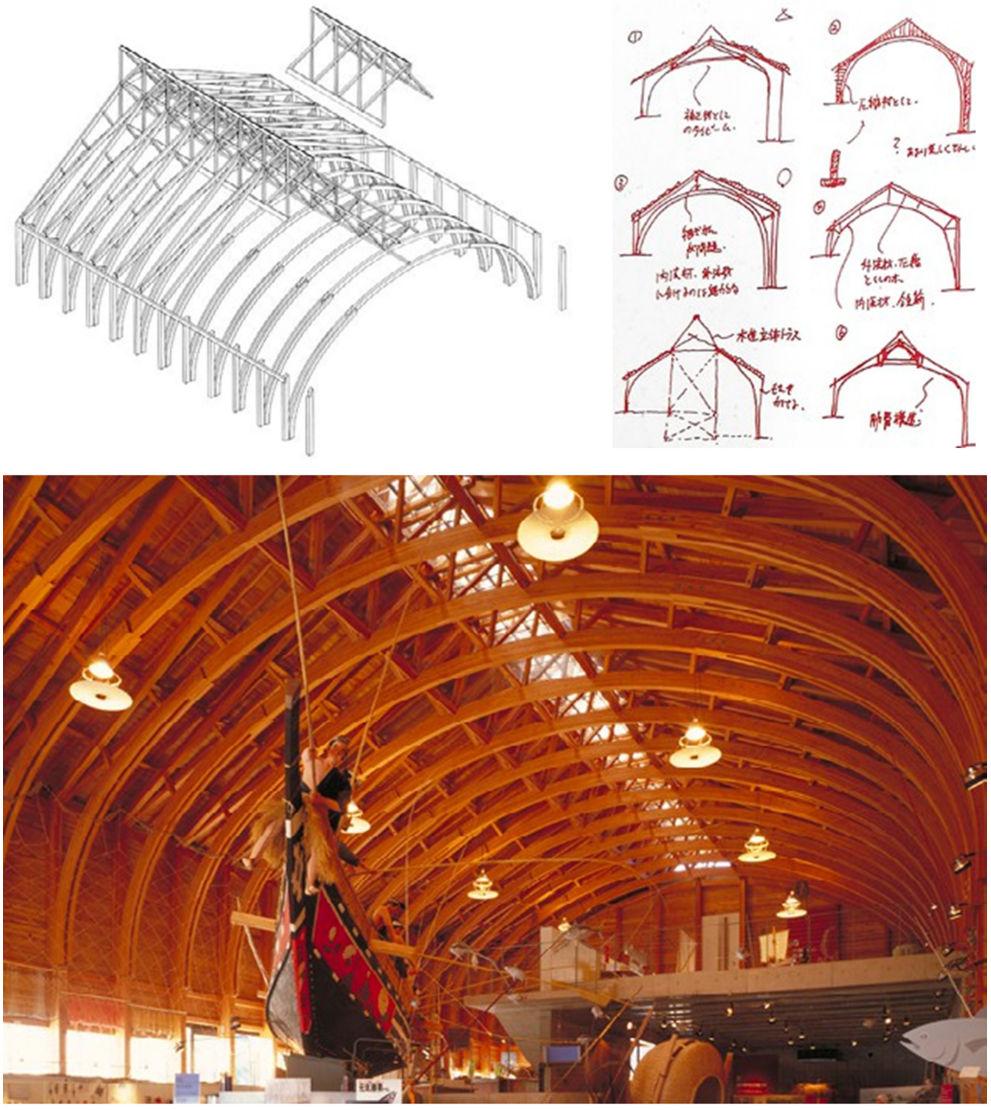


Figure 37. Hiroshi Naito's Sea-Folk Museum, with frame units repeated to create form.



Figure 38. Joints are used to extend the timber members outwards, increasing span capacity.

bamboo frames to have long span capacity even if each bamboo pieces has limit of maximumn length. These updated joints are used in prefabricated modular frame to make large structural forms. Joints enable VTN to do systematic process from one piece of bamboo to one frame unit and from multiple frame units assembled to structural form.

This joint system of VTN Architects is beneficial in many ways:

_It expands the span capacity of a bamboo frame so that it effectively helps to use bamboo in large scale structures.

_It absords the uneveness of the material so that the weakness of the bamboo can be eliminated, making the material suitable for building construction.

_Bundling bamboo culms also reduces the stress of loads put onto the bamboo as a whole, making the bamboo structural system more suitable.

_Natural fixing method with ropes and pins also reduces costs and expresses the material more honestly as it shows bamboo strength and beauty as a material without the exposed steel joints, usually employed by other bamboo architects.

_It helps to create a systematic unit system that can further exploit the material in construction.

Many bamboo projects by other architects see joints resembling steel or timber structures and didn't express all the beauty of bamboo as a building material. VTN joint system expresses bamboo beauty and strength in an honest way. Previous joints can also be costly especially by the use of steel joints. The VTN's fixing method doesn't need steel elements so it can reduce costs. And it sympathizes with the natural beauty of bamboo material itself.

Through these two unique qualities (joint system + structural systems) of our bamboo architecture, we managed to create unique spatial quality.

Our bamboo spaces are mostly open towards the outside, sympathizing with the natural landscape. Spaces at projects such as Vedana Restaurant or Castaway Island Resort are literally situated in the middle of the natural landscape, creating a varied quality of inside - outside - semi outside spaces that bring the fresh air and sunlight into the buildings. This contributes to our decision to utilise natural ventilation rather than air conditioning. Even with completely indoor spaces like Dai Lai Conference Hall, our large span frame units manage to create spaces that feel wider and more spatious. This is due to the impressive span capacity of bamboo frame units, thanks to the unique joint system that allow our bamboo frame units to create spaces that are large, open and expressive. The construction methods of the bamboo joints and frames also influence the spatial quality of our bamboo structures, with expose ropes and pins that are similar to the colour of bamboo culms In HP shell structures, corner joints are difficult because of the need to connect multiple bamboo frames in different angles together at one point. The complexity transforms our bamboo structures into an aesthetic of depth and texture for a unique architectural surface that enhances the spatial quality.

3.2. Education Of Staffs:

Our high quality bamboo architecture comes from the education of VTN workers about practicing meditation and keeping the five precepts. In VTN, keeping "the five precepts" is the most important aspect. VTN believe that keeping "the five precepts" will make us happy and will continue to spread this happiness to both us and clients. By keeping "the five precepts", people can get the trust of society and work on projects more calmly. And in the cycle of "arising and passing away", VTN believe that keeping "the five precepts" and conducting sincere efforts will lead to all happiness. So VTN can control project quality better because workers have better life through these own practicing.

It is said that 95% of human thoughts are of thinking unnecessary matters. Recently it seems that the flood of information has shifted the focus of human consciousness away from nature and toward settling into the world of the Internet.



Figrue 39. A system of units similar to our bamboo structural systems, freeing the space inside and creating a form.

The reason why VTN meditate one hour per day during working hours with all the staff is that staffs can observe themselves and organize their thoughts through meditation.

Through this observation,we nourish the skills for observing ourselves objectively, keeping us calm minded and reducing our unnecessary desires and stress. As a result, it contributes to enhancing concentration and creativity, and also improves the awareness and sensitiveness which are necessary to create an architectural space as a medium connecting human beings and nature.

We will continue to work on architectural design that incorporates nature into human life through daily practice. Quality of VTN bamboo architecture come from such staff's education in daily life. Not only technical education, but it's an education to support understanding others and precious environment. This truly understanding of human and nature is the core origin of high quality of VTN bamboo architecture.



Figure 40. Semi outdoor space in VTN bamboo architecture.



Figure 41. Japanese traditional semi outdoor space named "Engawa" in temple.

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