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Designing A Camouflaged Pavilion in A Bird Park with Metaphor Technique through Section Plan

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Abstract. Metaphor technique adapting organic shape from nature requires advanced technology for its development. Metaphor with regular irregularity concepts provides better camouflage and harmony within context. Irregularity on bird's nest metaphor is shown better in section plan. Conceptual thinking by section integrating various parameters requires dominant understanding toward structural context. Design context is a pavilion at Nansha Bird Park, Guangzhou, China. The presence of the pavilion should not interfere bird's habitat. Design purpose is making a pavilion that camouflage with minimum interruption toward site. Design approach applies metaphor technique. Metaphor utilizes natural shape (biomimicry) of bird's nest as nest for humans and birds. By cutting the pavilion into half, the structural complexity of bamboo construction can be shown clearly. Form finding process is done by digital technology and parametric design to achieve optimal form from desired metaphor. Site contextuality is responded specifically by the utilization of bamboo material and construction. Structural system utilizes interwoven bamboo layers to shape monocoque structure with vector-active system. Exploration is done by Rhino 5 and Grasshopper application. Form exploration focuses on bamboo layers as pavilion's structure. Patterns by Grasshopper's scripts are applied to each layer. The pavilion's shape is derived from basic spherical shapes as a metaphor of bird's nest. The resulting shape is stretched to create more space and split in half to expose its structure. Pavilion design responds to site and climate by considering the relationship of function, material, and bamboo construction parameters. Limitation on parametric concepts makes optimization simulation problems have to be adjusted with constructability.

Keywords: bamboo construction, metaphor, parametric design, regular irregularity, section

1. Introduction

Site is located at Nansha Bird Park, Nansha District, Guangzhou, Guangdong Province, China. The site is a man-made wetland park with 141 known species of migrant birds visiting each year. In Guangzhou, the wet season tends to be hot and overcast and the dry season tends to be comfortable and mostly clear. Throughout the year, the temperature varies from 51°F to 91°F and is rarely below 42°F or above 96°F.

Users of this design object are Nansha Bird Park's visitors who need to sit and rest while watching birds around the park. Those activities are responded by a shelter design related to birds. The object's response is a half pavilion that blends in with nature, shelters the user, and accommodates views of the bird park. Design approach uses metaphor of bird's nest that become the nest for human and birds. The metaphor is represented at pavilion's form.

The design's objective is to make the pavilion as a part of nature. Design provides a hidden and calm space that does not interfere with bird's habitat. The layered bamboo nest blends in with the surrounding landscape as camouflage for not interfering with the bird's environment.

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Metaphor brings verbal and non-verbal knowledge about physical and metaphysical phenomenon from one place to another (Sariberberoğlu, 2018). Meaning in metaphor is permanent and rooted, not temporary. In the relationship between architecture and metaphor, Koolhas emphasizes that today's architects need to focus on producing architectural metaphors that can shape society rather than simply completing the technical details of buildings (Sariberberoğlu, 2018).

The use of metaphors in architectural design is an approach to "think outside the box". Concepts formulation that prioritizes metaphor before building needs has become a thinking methodology. The use of metaphors in interpreting contemporary architecture influences the aesthetic enjoyment of building users. Reading architecture separately from the architect's concept neglects the architect's intention. Therefore, today's architects tend to incorporate metaphorical discussions into their conceptual discourse and deepen the concept as a whole (Sariberberoğlu, 2018).

Metaphor techniques can be inspired by nature through biomimicry. Biomimicry is an approach to design materials, structures, and systems modeled from biological entities and processes. Biomimicry simulates or co-opts natural processes (Sariberberoğlu, 2018). On the other hand, there is the biomorphic method. Instead of imitating shapes in nature directly, architects with this method investigate nature in a more abstract form, such as Gaudi, Guimard, and Horta (Butt & Dimitrijević, 2022).

Humans generally seek regularity to respond the nature. In fact, nature works a lot in irregularity. Optimal solutions in nature sometimes involve erratic processes. Irregularity often works more efficiently (Buchanan, 2011). The simplifications that humans make to seek regularity run the risk of ignoring the unique and non-repeating details in nature. In fact, these details contain essential information to understand nature. Instead of simplification to look for patterns that are too general, an idiographic view is needed to understand these unique and non-repeating (idiosyncratic) detailed patterns (Fattorini, 2017)

Christopher Alexander solved design problem by understanding its context and finding its order (Peters & Peters, 2018). His pattern language method is gathering recurring solutions from similar context, then recreated the pattern to provide logical answer. Pattern languages derived from nature were developed from biomimicry techniques (Hoeller et al., 2007). Biomimicry learns the best ideas from nature, then imitates designs and processes from nature to solve problems (Butt & Dimitrijević, 2022).

Alexander's pattern language shapes the system for parametric design that could address complex constraints, parameters, performance requirements, and compositional options of design (Peters & Peters, 2018). Parametric design is able to control geometry and components dynamically for designer to evaluate those alternatives effectively (Nasir & Arif, 2023). It accommodates integration of new materials and structures in various design environments (Gaha, 2023).

Parametric design procedures use parameters, such as basic forms, variables, operations, numbers, and relations, as input. Then, those parameters are calculated through mathematical processes to explore solutions interactively for solving design problems. Its initial forms, parametric values, and operations can be modified to gain the most optimum solution. It overcomes the problems of limited geometric and topological transformations (Abdullah & Kamara, 2013).

Digital technology allows architects to create innovative and complex architectural designs according to the concepts of form, building function, structural systems, materials, and the

surrounding environment (Andadari et al., 2021). Digitalization of architecture supports architect's freedom of creativity as a tools for generating and visualizing ideas (Sediadi & Semlali, 2022). Digital architects, such as Gehry, Hadid, Libeskind, and Mayne, have the same thoughts that emphasize the importance of freedom from specific realities (uncertainty) that relates to bisociative thinking as their nature of creativity (Junaidy et al., 2019). Digital technology helps architects to analyze, simulate, and visualize their design idea to optimize its performance (Peters & Peters, 2018).

Metaphor techniques bring phenomenon from one place to another (Sariberberoğlu, 2018). The phenomenon can be taken from natural forms. Natural forms usually come in organic irregular shapes. In architectural design, modeling of organic shapes requires more advanced technology than modeling of geometric shapes. Parametric design can address that issue.

Design context is a pavilion at Nansha Bird Park. The presence of the pavilion should not interfere bird's habitat. The pavilion should blend and have minimum interruption toward site. Therefore, design object requires camouflage and harmony with its surrounding environment. Metaphor techniques in design can be explored through regular irregularity concept to provide better camouflage and harmony toward context. Natural form and pattern is commonly irregular. Bird nests have organic form and irregular interwoven pattern. The metaphor of bird nest's form and pattern can unite and blend within its surrounding environment.

The irregularity of bird nest form metaphor can be well presented through section. Section becomes design context that must integrate various parameters. Thinking conceptually in section requires dominant understanding of structural context. The section presents the complicated layers of interwoven bamboo laths that shape the pavilion's structure.

2. Methods

Design strategy focuses on formal language. The design approach uses metaphor technique. This technique is used to generate form concepts. The method is carried out at the stages of formulating design objectives, developing ideas, selecting decisions, and evaluating (Boeijen, et al., 2014). Design objectives are obtained by defining design problems, namely a pavilion that camouflage with minimum interruption toward site. The strategy for finding big ideas is done by brainstorming method. Brainstorming is carried out within the context of the Nansha Bird Park site and building function as a pavilion. The big idea is a metaphor of the cut shape of a bird's nest with the concept of regular irregularity for camouflage. The big idea is developed into more detailed ideas using the mind mapping method. Ideas detailing are carried out to suit the context of the site, climate response, user activity, structure, and materials.

The bird's nest metaphor is taken to respond to design problems. The pavilion should not interfere bird's habitat. The design object has criteria to camouflage with the surrounding environment. So, the metaphor is done by taking a form from nature (biomimicry), namely a bird's nest. In this design, the bird's nest is also a nest for humans and birds. This metaphor leads to the concept of pavilion's form. The half-nest concept embraces the duality between cover and exposure of a shelter that blends with nature. The section of half nest exposes the complexity of interwoven bamboo structure that represents the irregularity in nature.

Form finding process uses parametric design. Bird's nest shapes are more complex organic shapes than geometric shapes. Thus, more advanced technologies, such as digital technology and parametric design, are needed to explore these organic shapes. Parametric design allows the designer to perform simulations and modify various existing parameters to

find the expected shape. Software used in this process is Rhinoceros 5 (Rhino 5). Rhinoceros is a 3D modelling CAD software whose geometry is based on mathematical NURBS model (Fink & Koenig, 2019). It has Grasshopper plug-in to define algorithms for its visual programming environment (Apellániz & Vierlinger, 2022).

3. Discussion

3.1. Responses to Site Context

Metaphor design method to respond to site context specifically uses bamboo material and construction. The shape of bird's nest is obtained from its interwoven material. Bird nest in nature is shaped from grass stalks, twigs, and leaves woven into a single unit. These materials have long, flat, and flexible characteristics. Those characteristics can be found in bamboo laths and strips.

Contextually, bamboo is a local material that commonly used in China for building structure and construction. Bamboo forests in China have a total area of 6.73 ha and cover one third of world's bamboo forests. The design site is in Guangdong province which has 446,200 ha of bamboo forest. Moso bamboo (*Phyllostachys*) covers 60% of the total area of bamboo forests in China and grows mostly in southern China (Dlamini et al., 2021). Moso bamboo (*Phyllostachys pubescens*) material can be protected from fungi that cause weathering and discoloration by applying a wood preservative (Möller & Mild, 2019).

3.2. Structural and Material Concepts

The monocoque structure is a system in which the structure and the envelope work together. The load transfer system is fully integrated into the building envelope. This system is commonly found in the automotive, ship, and aircraft industries. Since the 20th century. This system began to be widely explored in the field of architecture. Commonly used materials are concrete in Algeciras Market Hall (1933) and Restaurante Los Manantiales (1958), polyurethane and wood in the Raybould House (2003), polymer in the Beast (2010), steel sheets in the Porsche Pavilion (2012), as well as ETFE and carbon fiber in the ICD/ITKE Pavilion (2015) (Elmas & Saltik, 2017). In monocoque system of this pavilion design, its structural strength relies on its nest form.

Based on the load distribution, structures can be classified into bulk-active, vector-active, surface-active, and form-active. Structures with an active vector system transmit external loads through the composition of the rod elements that transmit the tensile and compressive forces (Ching et al., 2014). This vector system can be found in truss structures, space frames, and geodesic domes. In this pavilion design, the structure works in a vector system that distributes the load in all directions through each bamboo segments.

Bamboo is a more sustainable material than steel, concrete and wood. Bamboo construction is generally energy efficient and environmentally friendly. Steel construction consumes more energy than bamboo. Steel production produces CO2, while bamboo instead absorbs CO2 and produces O2 (Yadav & Mathur, 2021). Bamboo is endemic to most developing countries and has fast growth rate and high strength-to-weight ratio (Lorenzo et al., 2020). Bamboo has 3,06 times higher flexural ductility and better strength properties than wood (Chen et al., 2020). Bamboo culm with larger diameter and thicker wall could receive more load (Chaowana et al., 2021). Bamboo culms can reach their full height of up to 20 m in 3 months. However, these rods require a maturation period of between 3-6 years to achieve optimal strength for structural applications (Adier et al., 2023). Above ground bamboo structures exposed to weather have a durability of 5-15 years if given boron protection (Kaminski et al., 2022).

In this pavilion design, the foundation that connects the bamboo structure to the ground uses an anchor system. This system was adapted from the precedent Pavilion in Vergiate, Italy,

which was developed by Christoph Tonges (Minke, 2012). This system is capable of withstanding large compressive loads. The base of the bamboo sticks is filled with cement mixture and a metal covering is attached to prevent the bamboo from breaking. Threaded steel rods are placed along the shaft filled with cement in bamboo sticks, metal covering, to the concrete foundation that sinks into the ground. These threaded steel rods and concrete foundations simultaneously provide space between bamboo base and ground preventing rotting due to moisture.

3.3. Form Finding through Parametric Design

Form finding process uses parametric design to achieve optimal form that fits desired metaphor concept. The Rhino 5 software is used to create the basic shape of the bird's nest metaphor. This software allows simulation and modification of 3D models to achieve the required shape and space volume. The Grasshopper software is used to form the details of the interwoven bamboo laths as a structural material for the bird's nest shape. The parameters can be modified to find the optimal diameter and density of bamboo laths.

Form exploration focuses on the layers of bamboo structures that make up the pavilion. For each layer, a pattern is then applied using the Grasshopper's script. The shape of the pavilion was derived from the basic spherical shape. Several spherical shapes were then shaped as a metaphor for a bird's nest. The resulting shape was then stretched to create more space within it. The pavilion was then split in half to expose its structure.

3.4. Integration of Concept in Design

Half pavilion shows both functionality and aesthetics through its exposed structure, as can be seen in building's section. By cutting the pavilion into half, the structural complexity of bamboo construction can be shown clearly.

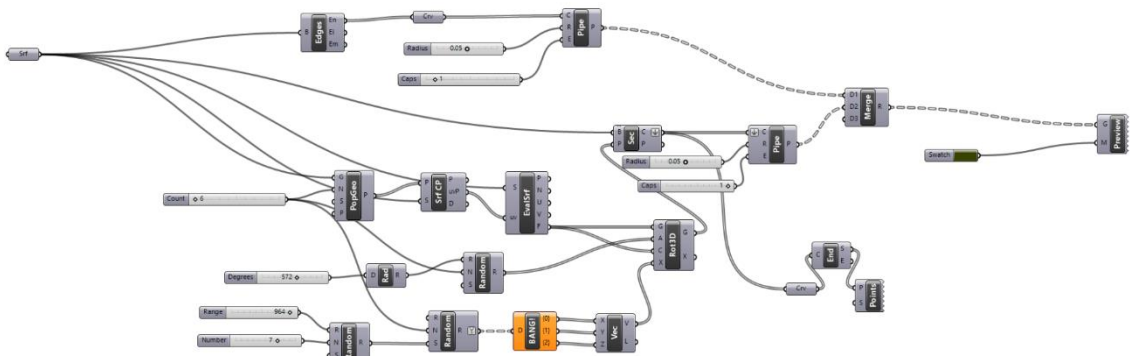

Figure 3.1. Bamboo Randomness Pattern on Grasshopper (Author, 2022)

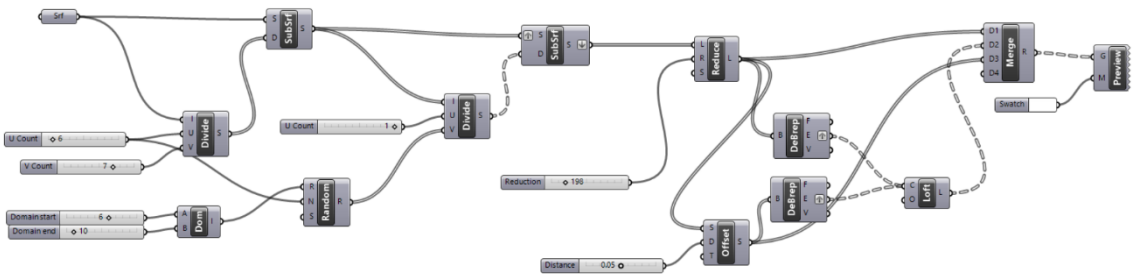

Figure 3.2. White Woven Bamboo Strips Pattern on Grasshopper (Author, 2022)

Exploration is done by Rhino 5 and Grasshopper software, as shown in Figure 3.1. and Figure 3.2. Form exploration focuses on the layers of bamboo structures that make up the pavilion. For each layer, a pattern is then applied using the Grasshopper's script.

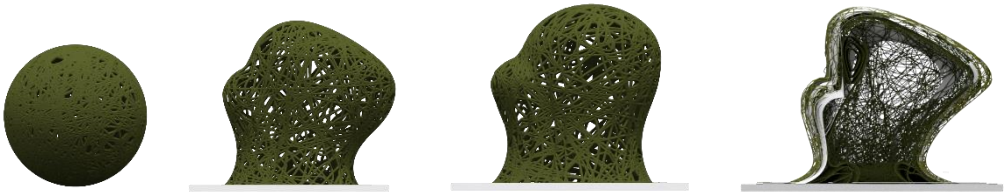

Figure 3.3. Form-making Process (Author, 2022)

In form-making process, there are 4 steps, as shown in Figure 3.3. First, the shape of the pavilion was derived from the basic spherical shape. Second, several spherical shapes were then shaped as a metaphor for a bird's nest. Third, the resulting shape was then stretched to create more space within it. Fourth, the pavilion was then split in half to expose its structure.

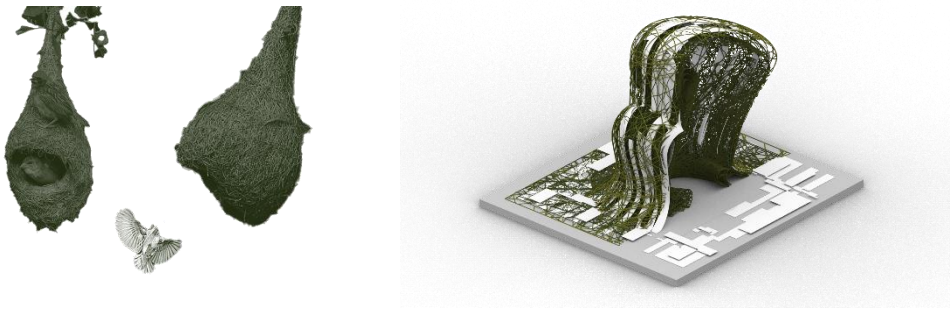

Figure 3.4. Metaphorical Form of Bird's Nest (Author, 2022)

The pavilion design provides a shelter with minimum interruption toward site. The layered bamboo nest blends in with the surrounding landscape as a camouflage for not interfering the bird's environment. Its half nest embraces the duality between cover and exposure of a shelter that blends with nature.

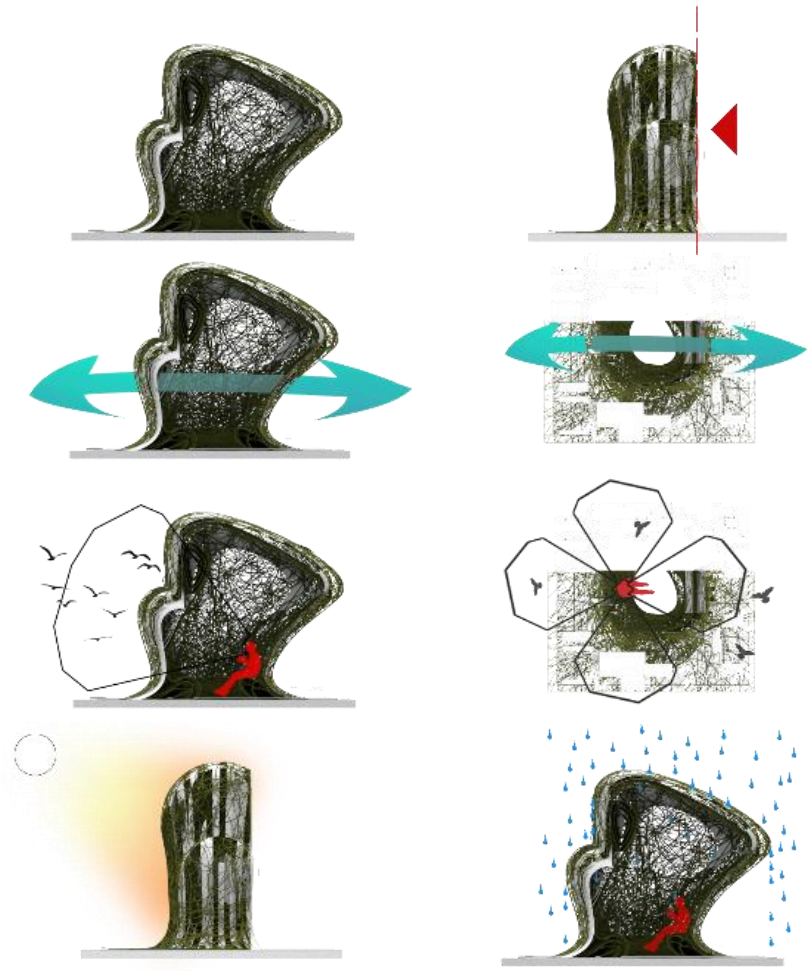

Figure 3.5. Site Context and Climatic Responses (Author, 2022)

The pavilion design responds to site context and climate, as shown in Figure 3.5. Cut form exposes structural random complexity and provide entrance. Random gaps between bamboo laths minimize wind load and maximize air circulation. Semi-circular shape and random openings provide view and interaction to all directions. Half nest provides shelter for shading and rain protection. The nest concept with porous pavilion's envelope allows a little sunlight and rain to still penetrate so that people inside can still feel the sensation of being part of nature.

Figure 3.6. Free-form Shape and Random Pattern of Pavilion's Envelope (Author, 2022)

Its freeform and curvy shape provide some comfortable space for various positions of bird watching activity, as shown in Figure 3.6. Visitors can stand, sit, or lay to relax and rest while

interacting with the bird. The gaps between bamboo strips provide random openings for visual, auditory, and physical interaction between human, bird, and other natural elements.

The section of half nest exposes the complexity of interwoven bamboo structure that represents the work of bird nests in nature. The randomness of bamboo structure represents the irregularity of nature. Multiple layers of woven bamboo laths and strips enhance the rigidity of the structure. It also provides protection against rain, sun, and wind.

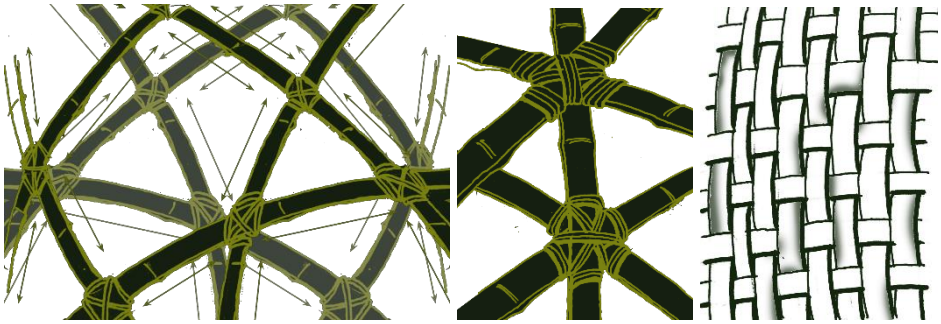

Figure 3.7. Structural Details (Author, 2022)

Interwoven bamboo laths work as structural elements. The structure works in a vector system that distributes the load in all directions through the segments. Loads distributed in each segment. The nest also uses a monocoque system so its strength relies on its shape. Each joint of bamboo laths and strips is fixed traditionally by “lianas” or bindings of natural fibers or of dampened leather that tighten as they dry. Binding of natural fibers ensures a flexible but stable joinery. The covering layers use woven bamboo strips. Structural details can be seen at Figure 3.7.

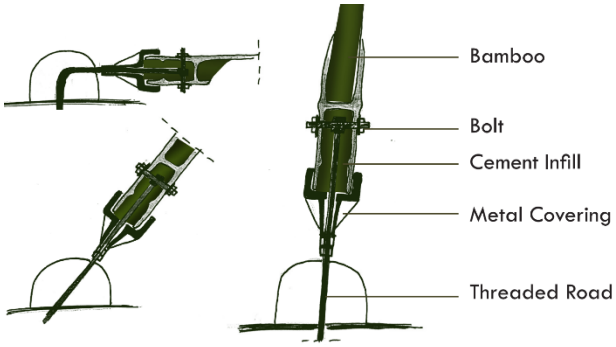

Figure 3.8. Anchor Details (Author, 2022)

A metal covering is installed to prevent the lath from splitting and protect the base from moisture. The metal coverings work as an anchor between pavilion base and ground. The metal coverings are anchored to the ground to keep the curvy shapes of bamboo. The anchors are located in some critical points to ensure the rigidity of the nest's form. Anchor detail can be seen at Figure 3.8.

The pavilion is built of bamboo material that can be easily found in China, such as *Dendrocalamus* or *Phyllostachys*. Bamboo is split into bamboo laths. The bigger diameter of the bamboo is, the wider width and longer length of bamboo laths could be. If the diameter is small, the width should be narrow to reduce the curvature in its x-axis, so that the lath could be easily bent in its y-axis. Later, the thickness of bamboo lath is thinned out so the bamboo lath could be easily bent.

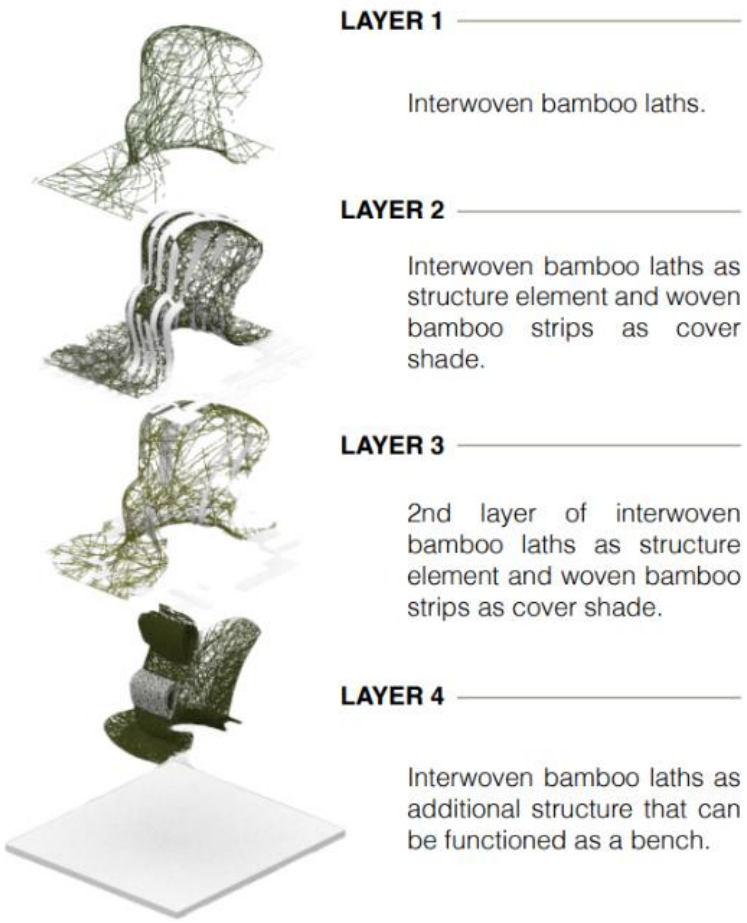

Figure 3.9. Pavilion's Axonometry Diagram (Author, 2022)

In this axonometric diagram in Figure 3.9., there are 4 main layers. Layer 1 as the outermost layer is made of interwoven bamboo laths. Layer 2 consists of interwoven bamboo laths as structure element and woven bamboo strips as cover shade. Layer 3 is the second layer of interwoven bamboo laths as structure element and woven bamboo strips as cover shade. Layer 4 as the innermost layer is made of interwoven bamboo laths as additional structure that can be functioned as a bench.

The pavilion design responds to site context and climate, by keep concerning on relationship of functional, material, and bamboo construction parameters. Limitation occurs on parametric concept that makes optimization simulation of bamboo construction must be adjusted with constructability aspects. There is a problem on volumetric shape in which the final form could not be controlled to fulfil the needs of building loads logic. The recommendation for the following design is to do form finding with optimization of the joints to find a more logical shape without having to make manual adjustments.

4. Conclusion

The bird nest metaphor is one form of integration in design which emphasizes harmony with nature. Metaphor techniques in design can be explored through regular irregularity concept to provide better camouflage and harmony within context. Section becomes a design context that must integrate various parameters. Conceptual thinking by section integrating various parameters requires dominant understanding toward structural context. The development

and exploration of complex organic shape requires advanced technologies, such as digital technology and parametric design.

Site is located at Nansha Bird Park, Guangzhou, China. The needs for a shelter that camouflage and does not interfere bird's habitat is responded by pavilion design with bird nest metaphor. Design objective is to make the pavilion as a part of nature. Half-cut best shape exposes structural complexity and irregularity of its material. Bamboo material and construction respond to site contextuality. Structure incorporates multiple layers of interwoven bamboo laths that works as monocoque with vector-active system.

Form finding process utilizes parametric design to achieve optimum shape according to desired metaphor. Exploration by Rhino 5 and Grasshopper software focuses on structural bamboo layers that shape the pavilion. Rhino 5 is used to explore optimal basic spherical shapes and volumes. The shapes are cut to expose the structure. Grasshopper script applies structural bamboo pattern for each layer. Half pavilion exposes functionality and aesthetic sectionally. By cutting the form into half, the structural complexity of regular irregularity concept can be seen clearly.

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