Tectonics of Vernacular: The Design Techniques of the Tongkonan House, South Sulawesi, Indonesia

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Abstract

Tongkonan house is a vernacular house of the Toraja tribe in the South Sulawesi Province, Indonesia. It has a structural system different from the other stilt houses. Its unique building construction creates an attractive form for a traditional house.

The aim of this research is to present the design techniques employed in the material production of Tongkonan vernacular houses through the examination of the tectonics of the structure that has produced the structural systems. Tectonics is the idea that an engineering structural form would create beauty in architecture and produce the building aesthetics known also as the art of construction.

The research applied descriptive analytical methods, explaining the material techniques in the construction of the building. Data was collected by taking direct measurements of the Tongkonan house. Each upper, middle and lower frame is measured using a laser meter and redrawn using software to make it easier to identify each component, connection system, and dimensions in the structural pattern. The results will be further analyzed to produce a development process and visualization of the design techniques of the Tongkonan house. Technique and material combination method create a rigid construction character and interconnection between each construction elements. Piles positioned with similar length and size creates a pattern character with horizontal and vertical lines and the grid, presents harmony and a well-ordered impression.

Keywords: Tectonic Structure; Building Aesthetics; Material Combination; Building Expression; Vernacular House.

Introduction

Structure has an important role in architecture design. According to Juniwati & Widigdo (2003), the relationship between the structure and architecture has two differences. First, a structure applied to realize a building to stand is the structural element whose function is to transmit the load of the building. Alternatively, the structure could integrates with the function and the building form, and thus the structural elements could also function as an architectural element that presents an architectural value (Juniwati & Widigdo, 2003). A structure that presents the architectural forms in the second relationships type would be called the tectonics or the art of architecture.

Tectonics in architecture is a creation that seeks the structure and construction of buildings not only for the robustness of the building, but more than that how to express the aesthetics contained therein. In addition, the aesthetics of structural art (tectonics) produced in the building's structural system is in line with the load distribution mechanism so it can be said that the function of tectonics is to provide an articulation in the load distribution mechanism of

the structural elements (Frampton, 1995). Innovative forms create potency of expressions in architectural forms and enable artistic expressions from the details and the construction joints. The forms result in artistic forms with aesthetic values and meanings, not only as an abstract form or a figurative form, but also expressing symbolic meanings or the building philosophy. Therefore, tectonics will create an architecture work to become highly creative and enrich its meanings.

Some have defined tectonics in architecture. Porphyrios (2000) in an essay entitled "From Techne to Tectonics", explain tectonics as a method and building material processing technique that requires an expertise and skill to realize an expressive and impressive form (Ballantyne, 2002). According to Ekhlassi & Rafati (2015), the adaptation of decorations to structural-constructional requirements of buildings, called tectonics. Architectural tectonics is the result of interactions between architecture and nature and architecture with humans that produce aesthetics. The technological elements in architectural tectonics are structure and construction, details and connections as well as ornamentation (Ibnu *et al*, 2021).

Tectonic architecture in several studies shows that there is a relationship between design and adaptation. Ekhlassi & Rafati (2015) study entitled *Facade Tectonics in Traditional Houses of Shiraz, Iran, Case Study: Zinat-al-Molk House*, shows that the elements of traditional facades of Shiraz were basically shaped according to unavoidable structural necessities, while the designer has used distinctive ontological and representational methods to adorn these elements, and created a surface which mediates between the solid structural volumes and human cultural and artistic needs. In addition, Ibnu *et al* (2021) study entitled *Technological Elements in Traditional Architectural Tectonic Case Study: Ghumah Baghi in Basemah Highland,* found that the identification of the architectural technology elements of Ghumah Baghi shows that the ghumah baghi structural system is a knock-down structure and has a high level of adaptation to earthquakes.

In line with the tectonic architecture in Indonesia, the Indonesian archipelago architecture or Arsitektur Nusantara is decorated with various tectonics, because architecture prefers simple forms and no significant variations. The application of tectonics in Indonesian architecture could expose an aesthetic because its natural and valid to expressing the structure (Johnson, 1994; Mahatmanto, 1999). Expression is a quality to show something. An expression does not only define the product quality, but also the state of the character of the creator; indeed, an expression would define a character of a culture (Wasilah & Hildayanti, 2017).

The study of tectonics of Indonesian architecture requires an examination of the important parts of the building as the research object. Prijotomo (1998) states that the parts of a building that should be documented and examined in the tectonics of Indonesian traditional architecture are joints, corners, the periphery/line, and the tip. For the example, in a study entitled Tectonic Method for Traditional Longhouse the Core Form of So Langkepatamuan Architecture, it was argued that tectonic views are oriented to the mechanic form of the longhouse. The traditional so langkepatamuan longhouse as mechanic form is a critical value of the ancient Dayak Taman craftsmanship. The tectonic method could show the aspects of the mechanical structures of the Dayak Taman house. Those aspects of the mechanical structure of the core form consist of the method of construction, the logic of structure, and the art of joints. The method of construction so langketamuan is an iron wood frame system with salaman joint system that works against local foundation settlement. In another hand, the art of joint shows there are three interconnected pairs of joint that work together as a two-dimensional wooden frame. Those tree aspects could redefine the previous meanings of so langkepatamuan architecture as visual evidence. By exploring the core form of so langketamuan longhouse, scientists could perceive the evidence of the art of thinking and making of Dayak Taman architecture. Finally, the tectonic method could have the capability to broaden the perception about longhouse architecture (Wuysang *et al*, 2017).

In other words, Indonesian traditional architecture has interesting parts for research from a tectonics perspective, such as the building of Batak Toba, Minangkabau, and Toraja. These three traditional houses have a similarity; their curved roof is upward.

These houses have many similarities in terms of the form, the structural systems, and the details of construction systems (Wasilah, 2019). Nurdiah (2011) explains the differences of these three traditional houses in "Studi Struktur dan Konstruksi Rumah Tradisional Suku Batak Toba, Minangkabau, dan Toraja" or the structure study and traditional house construction in Batak Toba, Minangkabau, and Toraja Tribes. Many research shows the differences in roof construction. A curved roof part with a leading role in traditional house of Batak Toba and Minangkabau are ridge and triangle panel and in Toraja traditional house is ridge element, longa (slanted beams), and busu-busu (a plank shaped like a dagger).

The Toraja traditional house is known as Tongkonan house. There are many types of Tongkonan houses in accordance with the functions. Tongkonan Layuk is a Tongkonan house and function as a center of custom authority to publish custom rules (Oktawati & Wasilah, 2016). Tongkonan Layuk has some elements such as equipment, such as ornament and decoration with a great quantity than other types of Tongkonan (Zaid, 2004).

Architecture development of these is along with the advance of technology in materials and building structures. In fact, the material technology and structure become important in the design process to create a modern design. Architectural tectonic research on vernacular houses has been carried out by several researchers because the structure of the building created is not only capable of producing aesthetic value but also the robustness of the building in supporting the activities that take place inside it. Tongkonan Layuk house is a house with modern woodworking tools but consistently practice a traditional method, initiated with material selection to the construction system application. The material is a local material, *uru* wood types (Elmerelia spp) and bamboo. The aim of this research is to study the material characteristic and building construction systems in the tectonic assembly of Tongkonan House, South Sulawesi, Indonesia.

Research Methods

This research method is a qualitative method with an exploratory approach to identify technological element in architectural tectonics Tongkonan house. Each step of research applied descriptive analytical methods, explaining the material techniques in the construction of the building. This research was conducted in Tana Toraja Regency, the South Sulawesi Province. The research object is the Tongkonan Toraja building form. It employed observation by authors in one of Tongkonan house in Kole Sawangan Village is located in the Malimbong Balepe District, Tana Toraja Regency in November 2022, as a data collection method calculating the dimensions of the building structure.

Data was collected by taking direct measurements of the Tongkonan house. Each upper, middle and lower frame is measured using a laser meter and redrawn using the AutoCad software to make it easier to identify each component, connection system, and dimensions in the structural pattern. The data was analyzed interpretatively based on tectonics of literature study. Tectonics of the Tongkonan house is examined through the structural parts of the Tongkonan house.

The method of construction for example is a relation between method, material and gravity. The gravity dictates the weight of the tongkonan materials; therefore, it needs some methods to construct the tongkonan construction. The method, material and gravity thought to create a method of construction to build the tongkonan structure. Then the art of the joint is created by the thought of wood material and gravity. The joints prevent the structural elements from being damaged. Furthermore, the logic of structure is created by the thought of material and method. Certain material creates some logical method to assemble it. (Table 1).

Table 1: Analysis output of the Architectural tectonic in Tongkonan House
Source: Author

Structure and Construction		Tectonics Criteria	Analysis
Structure and Top Construction	a.	Have an aesthetic value from construction art (art of construction)	The Tongkonan roof construction has an art of construction, as explore in the roof frame and roof envelope forms a

Structure and Construction	Tectonics Criteria	Analysis
	b. Exposing the structure clearly/truthful. c. Expressive and aesthetic structure form	ship-like or buffalo horn-like that becomes a characteristic feature of Toraja. The house has special pile to support the roof cantilever or call as *tulak somba*.
Structure Body Construction	a. Have an aesthetic value from construction art (art of construction) b. Exposing the structure clearly/truthful. c. Expressive and aesthetic structure form	The Tongkonan body construction has no significant construction art, because the body mostly dominated by wall ornament decoration. Consequently, the construction is not fully exposed/ highlighted. Therefore, this part is not completely unique for tectonics characteristic feature of Toraja.
Structure Pedestal Construction	a. Have an aesthetic value from construction art (art of construction) b. Exposing the structure clearly/truthful. c. Expressive and aesthetic structure form	Tongkonan pedestal construction is also has construction art. There is interconnected piles and beam configuration that forms a spatial structure. The pedestal structure part is clearly observed/exposed.

This research is limited only to the tectonics of the roof and the pedestal part of the structure of Tongkonan, because these two parts show significantly the uniqueness of Toraja tectonics found only in this traditional house. In other words, the research focuses on the sub and top parts of the structure of Tongkonan.

Findings

Tectonics of the Tongkonan Top Roof

The findings of this study are from on-site observations, in-depth interviews with residents of Tongkonan houses and Torajan people in general, and analysis conducted by the author, found that the part of roof structure includes roof frame, roof cover, and *tulak somba* pillar (Fig. 1). The roof frame is from wood material and roof cover is from bamboo. The roof component has a heavy load component to suppress the bottom part of the construction to retain it from the blowing wind and any other lateral forces. However, the roof is directly connected with the ground through *tolak somba* columns.

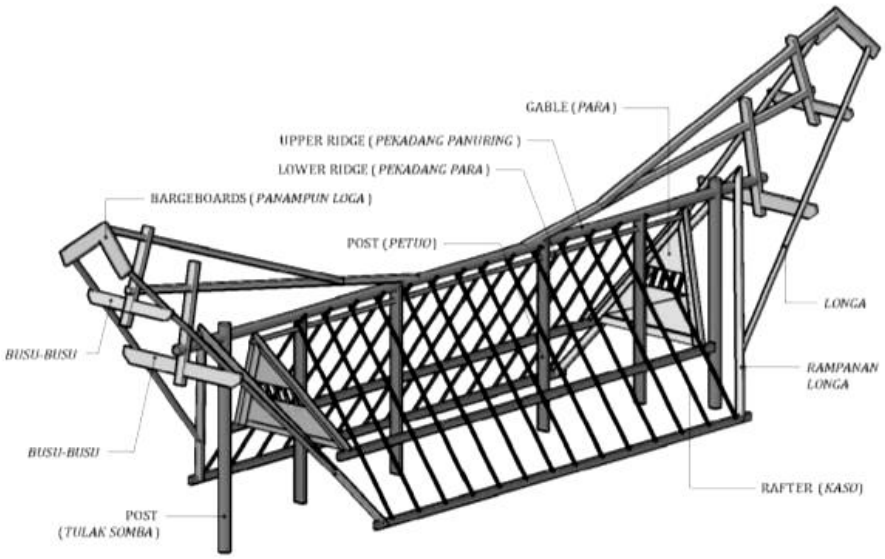
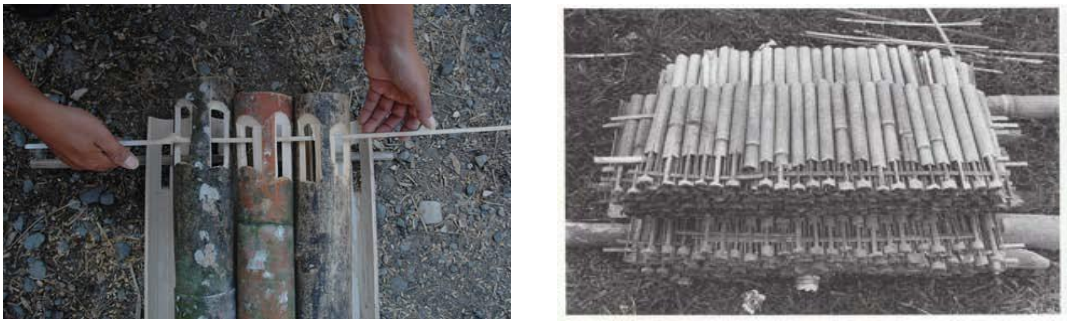


Fig. 1: Roof construction
Source: author

The roof cover of the Tongkonan house is from bamboo. It has a layered structure and form an impression of a thick cover. First, the bamboo is divided into two parts and assembled with bamboo sticks into one module. Every one module contains 10-12 bamboos. Then, the module for the roof cover is tied with rattan and rafters. Furthermore, the bamboo module stacks again on the top of each module to create a layered cover, avoiding a leakage. The top part is covered by a layer called as *bubung*. In other words, the material combination method for the envelope is from bamboo, a combination of tenon and a binding method (Fig. 2). The joint in truss and roof frame apply a binding system with rattan and clamp system (Fig. 3).



(**a**) (**b**)

Fig. 2: Module joint technique in roof cover: (**a**) Bamboo stacking assembly process; (**b**) The final result of the bamboo assembly which consists of several layers
Source: author

(**a**) (**b**)

Fig. 3: Clamp and binding joint technique in roof part: (a) Clamp technique in roof part; (b) Binding joint technique in roof part
Source: author

Tectonics of the Tongkonan Pedestal Part

The pedestal Tongkonan structure generates a spatial system created by a connection between piles with horizontal beam or *roroan* (Fig, 4). The Tongkonan piles is from wood, and most piles are long and foursquare supported by a natural stone foundation. The application of natural stone shows the effort of the community to protect the wood piles from the groundwater and prevent the building subsidence because of a groundwater leak.

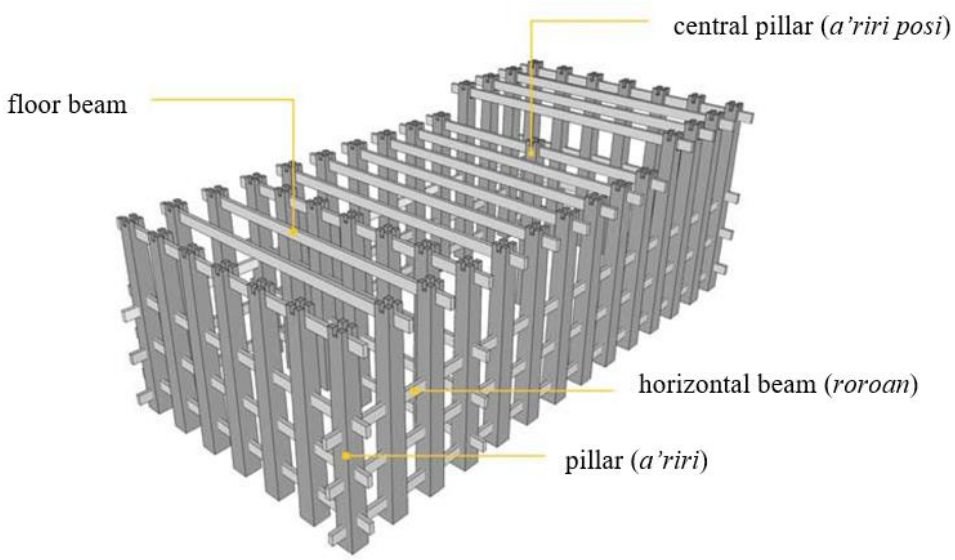


Fig. 4: Tongkonan pedestal construction
Source: Author

The piles follow the floor differences in the Tongkonan ground plan. The Tongkonan Layuk room is divided into three zones: *tangdo, sali,* and *sumbung*. The interior zone partition is indicated by a difference in floor elevation and the partition wall. Consequently, the pile is positioned exactly under the partition wall to support the floor beam. There is a center spot in the middle of the house or *a'riri posi* with a mythological meaning. The pile height is not continued to the wall and roof, but stops at the floor beam. Then, the pile tip is combined with the floor beam to create a square.

Pile and beam arrangement that creates a room-like a box. The distance between each pile is 40 cm or 15.7-inches. The distance between the horizontal beam or *roroan ba'ba* is 60 cm or 23.6 inch (Fig. 5). Piles positioned with similar length and size creates a grid pattern character with horizontal and vertical lines, and present a harmony and an impression of well-ordered structure.

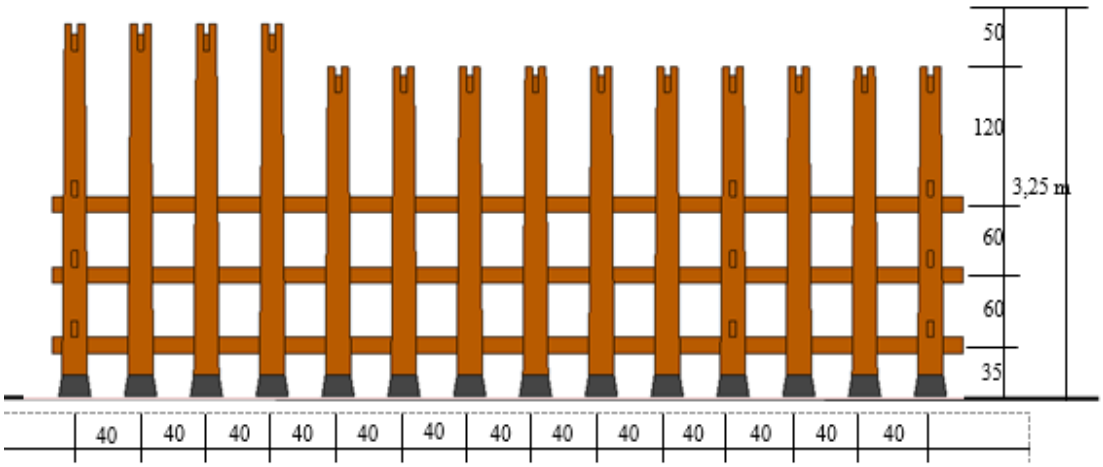


Fig. 5: Distance between the pile and the beam
Source: Author

Foursquare pile form presents a rigid character but follows with the pile size. The bottom pile decrease to the top. Therefore, the pile and beam series create a pattern in a

trapezoid form, although in plan view, the form is a square/box. The technique in tenon and mortise joint system presents a character that is a unity between each of the construction elements. As consequence to the joint technique, there is a showing off in the pile element and there is a longer beam that is intentionally longer to prevent a loosen of the tie (Fig. 6).

An arrangement of Tongkonan house pile is applied to the horizontal beam surrounding the four house sides and also the pillar inside the house. The horizontal beam tie could provide a support for the horizontal forces, such as the wind load and the earthquake (Fig. 6). Additionally, the Tongkonan house pile position is not perpendicular to each other and the pile dimension from the bottom to the top becomes smaller. This condition could lock in the pile and beam that reduces a pile shift that causes any horizontal force. The vertical force is distributed to all the piles through the intersection beam between the floor and the pile. Overall, wood construction in Tongkonan house pile significantly exposes a strong character of pullung to the force to act.

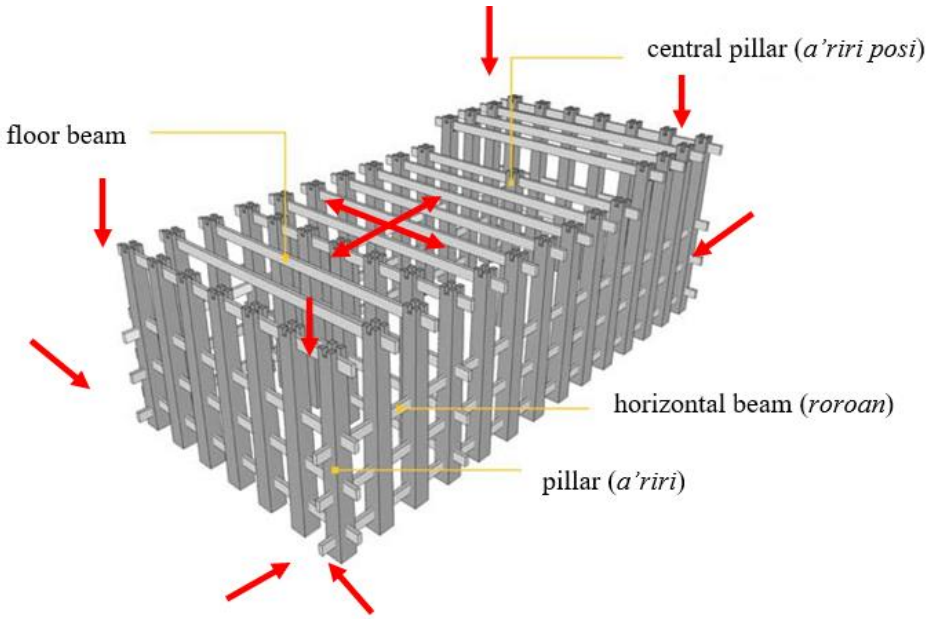


Fig. 6: Force application in Tongkonan pile structure
Source: author

The structure finishing on the force creates a spatial construction that consists of a pile and the horizontal beam with a large dimension. The construction presents a strong construction to support the top load of the Tongkonan. As a result, the Tongkonan also explains a rigid construction character.

Discussion

Tongkonan house has no ceiling. Thus, the roof construction is clearly seen or is exposed in terms of the materials and the types of joints. Bamboo, wood, and rattan impart a visual aesthetic value to the of Tongkonan roof structure. The bamboo assembling with the multi-layer structure as a roof cover shows a rhythmical, heave, and rough texture impression. This texture is clearly seen in all part of the roof periphery (Fig. 7).

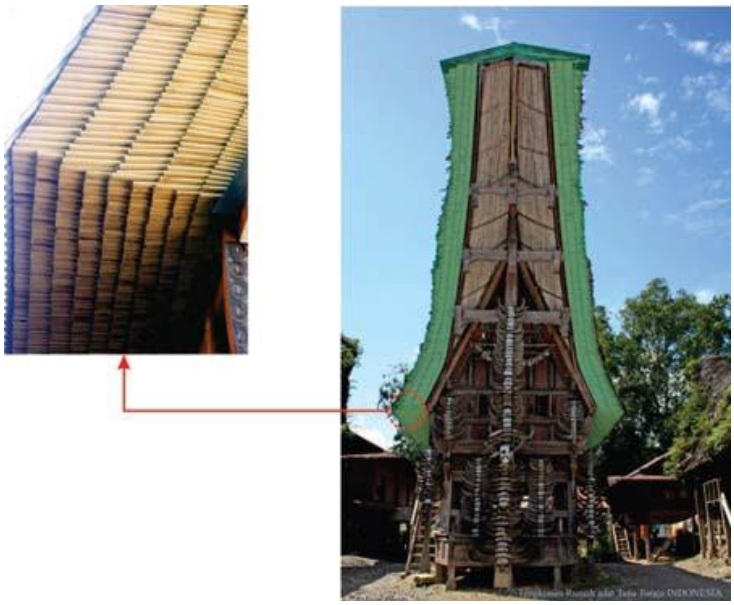


Fig. 7: Visual construction form in roof envelope
Source: Author

The impression created by the clamps and the binding joints in the Tongkonan frame roof is formed by the connections between wood that create a rigid construction. The construction is earthquake-resistant, because during an earthquake, the Tongkonan roof frame is elastic against any shock wave. A curved Tongkonan roof form in the roof ridge creates an influence to the incoming force (Fig. 1). The force principle applied in the Tongkonan roof is both of roof tip pulled by the beam towards the sideways position and pulled by the ridge beam that creates a curvy cantilever. There are tulak somba pillars on both of cantilever tips, which function as support. The *tulak somba* pillars become the characteristic feature of the Tongkonan house. Indeed, this pillar becomes interesting with an addition of the buffalo horn decoration, with a symbolic function.

The roof load is distributed to the roof cantilever pillar and to the Tongkonan wall beam and then continued to the foundation pile. In addition, the roof cantilever load is directly distributed to the ground through the *tulak somba* pile. A selection for roof cover component is the heavy load, in order to suppress the pedestal construction that create a complete wind resistant and another lateral force. The structure finishing for application force produce an upward curved roof. The roof with the upward curve presents a flexible, dynamic impression, and highly mounted.

Furthermore, Tongkonan pedestal part practice spatial structure that consist of some piles and beam (Fig. 8). The pile in Tongkonan Layuk is from wood in a foursquare form. Each number of front and back piles is an odd number that is seven piles with symmetric arrangement and the center pile is the axis. Additionally, a number of piles in the long side is according to the length of the house or has 14 piles. These piles tied with horizontal beam or *roroan ba'ba*. *Roroan ba'ba* ussualy has three beams. Beam tie in the long side is called the *roroan lambe'*. The total number of *roroan lambe'* is always three beams. Assembly method for horizontal beam or roroan involved boring each wood and beam pile first, and then pinned by beams to assemble the piles. The pile at the end of the house intentionally has more length, avoiding a loosening of a joint. The joint system for the pile and the beam at the bottom part of Tongkonan is usually a tenon and mortise joint system without a nail (Fig. 9).

Fig. 8: Tongkonan pile construction
Source: author

(**a**) (**b**)

Fig. 9: Detail for Tongkonan pile joint: (**a**) Using the pedestal foundation; (**b**) Post connection system
Source: author

Fig. 10: Tongkonan beam construction
Source: author

The floor is supported by a square, big, and heavy beam (Fig. 10). The beam is supported by the building piles. An intersection of pile and floor beam practice tenon and mortise joints. Joints finish is practiced by a groove system. The floor beams are arranged by an overlap system and the weight makes the piles stand.

Conclusions

The tectonic method in Tongkonan house consists of three categories of thinking; methods, materials, and gravity. The architectural tectonic resulting from the design techniques of the Tongkonan house is a form of building that can adapt to the environment with the influence of technology and local wisdom. In this building, technique and material combination method create a rigid construction character and interconnection between each construction

elements. Piles positioned with similar length and size creates a pattern character with horizontal and vertical lines and the grid, presents harmony and a well-ordered impression. The weighting concept in the Tongkonan roof part is the effect from the arrangement technique on bamboo with overlapping and multilayer becoming a roof cover. The bamboo layer exposed truthfully generates a rough texture on the roof periphery. Moreover, the art of construction or tectonics of the bottom part applies a balance/symmetrical pattern. Every Tongkonan house always appears in a symmetric form, either from the front or the side perspective view.

As an indigenous innovation, the shaking connection system is sufficient to keep the shape of the tongkonan house standing all this time, due to the completion of the layered post and connection system with loading which can suppress the building so that it is not easily blown away by strong winds. By doing that task, it can stabilize the roof structure.

The potential of tectonics is reflected in the honestly and simplicity of materials, connections and structural systems, which produce balanced, harmonious and hierarchical composition. Architectural tectonics is a representation of vernacular building forms that can adapt to the environment and are indirectly able to create aesthetics of the complexity of structures in buildings. So many researchers prove that traditional designers used to have an adaptable attitude towards tectonics, they seldom exposed the rough and simple structural volumes and used ornamental forms and textures to blur its presence or at least adorn its structural shape.

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