

THE SUSTAINABLE TRADITIONAL STRUCTURAL SYSTEM OF 'TONGKONAN' IN CELEBES, INDONESIA

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Summary

The interesting of the word sustainable is, when we see the planet as one organism, in a sense of the interconnectedness of everything in the dimension of both space and time. It recognizes and reveres the relationship that exists between different elements in natural world harmoniously.

Although many traditional structural systems have been largely replaced by the high technology as a result of industrialization, but still espoused by most of traditional cultures in developing countries, like in Celebes, Indonesia. The term sustainable is recognized as way of life that both practical and a deep spiritual and social obligation. It is no surprise that in traditional architecture is still dominant where people still live close to the earth. In this society, people understand where the things they consume come from and accurately aware of the amount of energy required transforming raw materials into building. An intimate social contact with the cycles of nature further ensures that people are aware of how fragile survival is, and the extent to which it depends upon a harmonious relationship with nature.

Therefore, this paper discusses two keys that can be coined in 'tongkonan' traditional structure, are flexible and incremental structural system. Understanding the structural characteristics is like getting to know someone in person, not just from a reflection in a mirror.

1. Introduction

Toraja land is located in the Northern part of the South Sulawesi Province, situated between Latimojong Mountain range and Mount Reute Kambola. Toraja communities consist of three groups, the Eastern around Lake Poso, Western Toraja around the Palu River and Kalawi in Center Sulawesi. The Specific architecture of Toraja house has its own architectural form. They are shaped like a boat and the two ends are shaped like a bow. Toraja legends claim that they arrived from north by sea. Caught in a violent storm, their boats were so damaged as to be unseaworthy, so instead they used them as roofs for their new homes, the 'tongkonan' with their boat shaped roofs, always face towards north. Toraja house is usually a compound buildings consist of traditional houses ('tongkonan') and rice barns ('alang').

The buildings are carved with ornaments of various shapes. The ornament is painted with traditional color dominated with black and red color. All of them create the aesthetic value of the Toraja houses. The gables and the wooden wall panels are formed with geometric, spiraling designs and motifs such as buffalo heads and cockerels painted in red, white, yellow and black, the colors that represent the various festivals of Aluk To Dolo ('the Way of the Ancestors'), the indigenous Toraja religion. Black symbolizes death and darkness; yellow, God's blessing and power; white, the color of flesh and bone, means purity; and red, the color of blood, symbolizes human life. The pigments used were of readily available materials, soot for black, lime for white and colored earth for red and yellow; tuak (palm wine) was used to strengthen the colors. Many of the designs are associated with water, which in itself symbolizes life, fertility and prolific rice fields. Tadpoles and waterweeds, both of which breed rapidly, represent hopes for many children.

Village layout varies according to size. As a general rule, in the larger settlements of Toraja land the houses are arranged in a row, side by side, with their front gables facing north. Each house stands opposite its own rice barn, and together these form a complementary row parallel to the houses. Roofs are aligned on a

north-south axis. The major agricultural ceremonies of the Toraja year are celebrated in the area between the houses and the barns.



Figure 1 The agricultural activities in front of 'tongkonan' (left) and the ornament of tongkonan's wall (right).

'Tongkonan' structure was built on wooden piles, traditionally, the roof was constructed with layered of bamboo, and the wooden construction of the house assembled in tongue and groove system without nails. This honored material, in combination with rattan, coconut leaf and variety of woods such as teak and ironwood, produce similar 'tongkonan' construction throughout the region. This paper examines the influence of society philosophy on the structural systems, detailing and materials found in 'tongkonan' house, because the spectacular of 'tongkonan' has been proved throughout centuries.

The intention of this paper is to record and present the sustainability of materials and construction methods and to recommend 'tongkonan' structure as flexible and incremental structure to be maintained and reused for sustainability.



Figure 2 The open platform of a rice barn opposite two traditionally 'tongkonan' is frequently used as a meeting and recreation area.

2. Materials and Construction of 'Tongkonan'

Traditional Toraja architecture can be divided into five categories on the basis of function: house (banua) which is known as 'tongkonan', rice barn ('alang'), rice guard-houses, livestock stall, and funeral architecture. This paper will discuss specifically about 'tongkonan' as the most important structure of Toraja architecture.

2.1 The Materials of 'Tongkonan'

'Tongkonan' was built with natural materials like bamboo, timber, rattan, and wooden tree. The frames, posts, and beams usually were made of timber, wooden piles or bamboo piles. The floor consists of wooden boards laid over thin hardwood joists, between the floorboard and the hardwood joists a layer of split bamboo is laid to give extra rigidity to the floor. Its wall and partition were built from wooden board, wooden upright, or plaited bamboo. All of these components were prefabricated before in a shed called 'pondok' and would be assembled with fitted wood joints, without the use of nails.

'Tongkonan' roof traditionally was covered with bamboo layers and thatch. The bamboo layers constructed in panels; which were prefabricated before and tied to the roof structure with rattan string. The framework, the ridgepole, and the cross rafters were made of bamboo or timber.



Figure 3 The traditional 'tongkonan' used bamboo and thatch for roof covering.

The Toraja people usually gained these materials from the forest and the nature surrounds them. They also used simple and traditional carpenter tools and the wood carver to build the house and even though in traditional condition, they have already used bamboo scaffolding for finishing their jobs.

There is no specific characteristic of the materials. The natural materials were used only because of the practical and economical reason. They tended to use material that was easy to get as long as it's strong enough and the size was suitable. In the development there is no prohibition to use other materials as long as the philosophical value of 'tongkonan' can be maintained.

2.2 The Lay-out Plan of 'Tongkonan'

The orientation of 'tongkonan' is always facing north, because Toraja people believe that north is symbolized life. This is why in Toraja villages the houses stand in a row side by side from East to West. The rice barns stand facing 'tongkonan' with their front gable towards South. Parampa is the yard that lies between 'tongkonan' and 'alang'. Here the crop is left to dry; it's also a place for children to play, women to work, and men to arrange cock fights.



Figure 4 The 'tongkonan' (right) and the rice barns (left) in lowland settlement, Tikala district.

There are at least three rooms inside 'tongkonan':

- Tangdo

This room is located in the north. In this first room placed a staircase that provides access to the central room. Tangdo is the sleeping quarter of unmarried girls.

- Sali

It is the family's main living area. In this room the hearth is situated on the eastern side. The hearth consists of a large rectangular wooden box which is used to cook (called a 'dapo') and also can be functioned as a fireplace because Toraja land has a cold weather. The hearth is located on the eastern side because food and rice is firmly associated with life and the eastern ritual sphere. Sali is also the sleeping area for unmarried young men of the family and for the servants.

- Sumbung

This third room is located in the South. It is where the master of the house and his wife sleep. Here are stored valuable things in large baskets / trunks called 'batutu'.

The space below Longa (the overhanging section of the roof, always present in a 'tongkonan' of any status) is used for tasks as spinning or weaving. And the space below the house, called 'bala-bala' is used to stable animal, like chickens, cows, pigs and buffaloes.

The plan of the house is rectangular and it has flexibility to be divided by the partition. The room division above is only based on practical reason, so it can be change according to the needs.

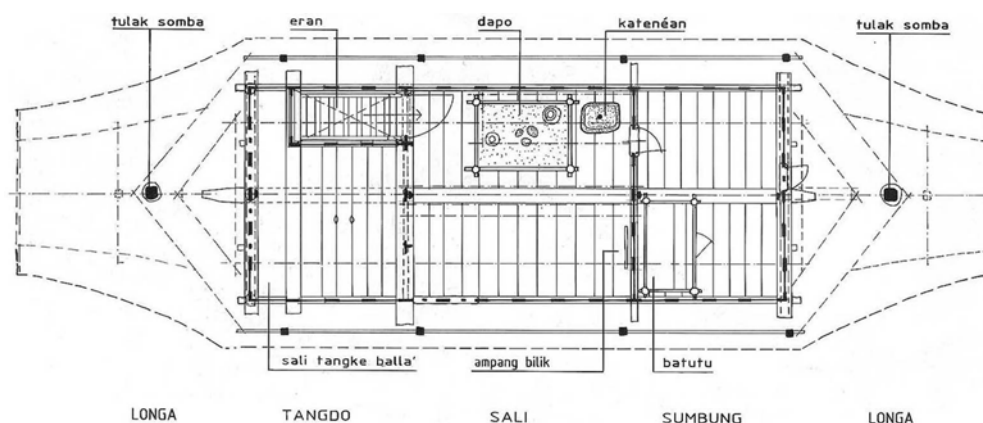


Figure 5 The Lay-out plan of 'tongkonan'.

2.3 The Construction of 'Tongkonan'

The Toraja people usually divide the construction of 'tongkonan' into three parts: sub structure which is symbolized the underworld, the world of cattle; middle structure which is symbolized the middle world, the world of human being; and upper structure which is symbolized the upper world, the world of the gods.

2.3.1 The Sub Structure

The space under the house is used at night for stabling animals. Its height is about 2.35 meters according to the height that can be reached by the buffaloes.

The sub structure of housing construction has two types:

- The log-house construction

The log-house stands on a foundation of four cornerstones. In this construction round beams are placed on each others, their ends interlocking at right angles by means of slots cut on both sides. The cornerstone is a mountain stone which is used as the foundation to avoid termite and decaying by ground water.

It is the older way of building and according to this view, the house originally had only one level and the modification of this level into a foundation for an upper living area did not take place until the 17th century.

- The pile-house construction

The pile-house constructs on four or many sided posts, bumpy-chop, are set on base stones, and connected by cross-beams which pass through holes chiseled in the posts. There are three cross-beams in longitudinal and transversal section that tie the posts vertically and create vertical and lateral stability. This technique is more economical because it used less wood.

At the ends of each post is across a transversal beam and a longitudinal beam. These beams which are called 'tangdan' transferred the loads from the upper structure to the sub structure. Below each partition on the ground floor, stands sided posts in transversal order. One of the posts is called 'ariri posi' (navel post) which is located in the central of the house, as the main post in philosophical meaning.



Figure 6 The base stone (left), the log-house construction (middle) and the pile-house construction (right).

2.3.2 The Middle Structure

The height of this part is about two meters. The floors consist of thick transverse boards and are frequently at different levels. Different levels of floor are supported by different height of horizontal beams.

The walls consist of framework of flat, rectangular uprights which passing through the horizontal beam. The uprights stand on the beams of the floor frames and in the upper ends support the top beam (called 'samborinding') of the longitudinal walls which serve as purlins. The construction of partition walls, which standing on the central joist of the floors, is the same as the side walls.

Thin boards, usually over 40 centimeters wide, fill the rectangular openings in the framework, inserted into grooves cut in the uprights.

2.3.3 The Upper Structure

The distinctive structure of the 'tongkonan' house is a curved roof. The concave curvature is achieved by pinning to the front and rear ends of the straight, jutting ridgepole one or two additional beams. The ridgepole lies over cross rafters and is supported by the ridge-purlin. The outer ends of the ridge-purlin are supported by the pediment and the center, within the house, rests in the grooved ends of the posts standing at each transverse wall. The pediment is supported by the top beam/purlin.

In the case of highly curved roof, the section of the ridgepole projecting beyond the ridge-purlin at the front and back of the house are afforded additional support by a free standing pole rising from the ground (called 'tulak somba').

The ends of the ridgepole run through the center of short, vertical hanging spars grooved in their upper ends to carry the first of the upwards-angle beams at the front and rear of the house. Transverse ties pass through both the free-standing poles and the lower ends of the hanging spars. Each vertical, hanging spar has two functions: at its top it supports the pinned extra ridgepole in its upwards slant; its lower end, through the transverse tie, carries the rafters of the projecting roof as they branch off outward at an angle from the gable rafters, thus preventing the roof from collapsing.

The rafters lie on the ridge-purlin, the 'samborinding', and the longitudinal beam on the transverse partition wall. The bottom ends of the rafters are also supported by additional longitudinal beams which are supported by additional sided posts.

2.4 The Development of 'Tongkonan'

Through ages, it can be seen that there is a development of 'tongkonan' in structural system and model. Two differences in form are immediately apparent: the curvature of the roof and the relative overall height.

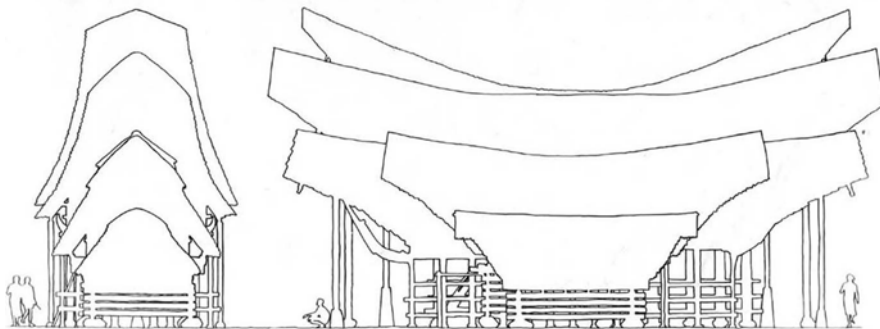


Figure 7 The development model of 'tongkonan'.

The developments are:

- The curvature of the roof is increase.
- The building as a whole moves towards more and more emphasis on the vertical dimension.
- The body of the building is shorter and narrower, the inside section seems to shrink under the mighty roof.
- The construction becomes more delicately jointed: the weight-bearing parts, the posts and beams are less massive but more numerous.
- The construction is more elegant, but also a more unstable impression, the total effect is much more spectacular.

Until 19th century the development of 'tongkonan' showed the highest spectacular of the traditional structure in Celebes. The popularity of 'tongkonan' has been becoming a symbol for the traditional architecture of Celebes and has appeared as a 'tongkonan' house model souvenir for tourism purposes. Unfortunately, after the 20th century when modernization entering the land of Toraja, the development of 'tongkonan' structure has suffered from degradation of structural system as well as material construction techniques. The spectacular curved roof returns to the efficient structure of flat gable roof with modern steel construction technique.

In the next section, it discusses about how sustainable is 'tongkonan' structure based on variable flexible and incremental system from both engineering and social sustainability.

3. The Sustainable of Traditional Structural System of 'Tongkonan'

The uniqueness of 'tongkonan' traditional structure has been interesting many scholars, Taisei Corporation in Japan and the world culture heritage of UNESCO, to give fund for preservation. The spectacular of 'tongkonan' structure is dominated by the roof. It was covered with thatch and steeply pitched and shaped in the form of a saddle back, symbolizing the form of fisher boat. The wooden construction used to assemble the house with tongue and groove techniques without nails. The houses were constructed by large wooden pillars that rested on flat stones. The stone beds protected the wood from rising damp. The sub structure was strengthened by mortise system of beams into the piles, and the created space was used as night time for cattle. All the components of the house were prefabricated, and the final assembly took place at site.

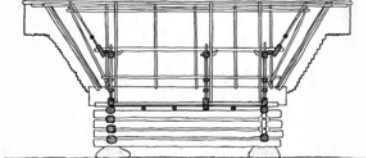
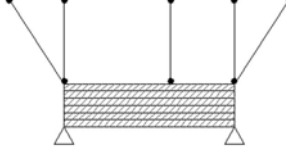
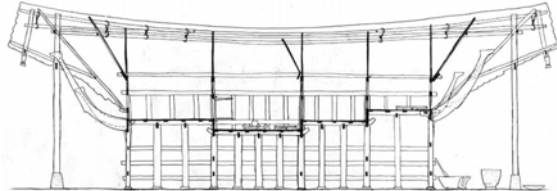
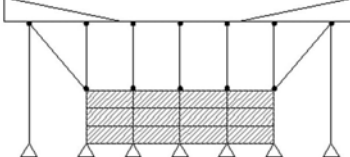
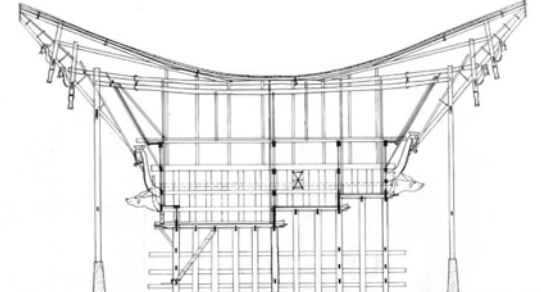
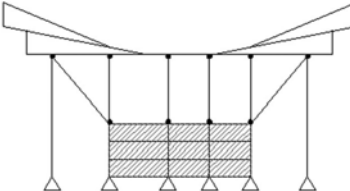
The philosophy of 'tongkonan' dwelling that the three dimensional space of the house not only places borders round a part of the universe, but also serves as an expression of the universe in its entire. Vertical conception of the structure expresses relationship between heaven, earth and underworld. The horizontal lay-out was according to the fundamental points or according to location between mountains and sea. These are echoed in the symbolic meanings attributes to different parts of structure.

The Toraja ancestors might constructed their building by trial and error, but they learn from nature, they believe that someone holy (called 'Puang Matua') creates all natures in the world in balance for living harmoniously. All the 'tongkonan' structure did not pile to the ground, but they just put their building on stones foundation ('umpak'). Although some scholars may said that traditional structure was resulted from lack of construction tools, but now after the UN agenda 21 declared, and when the slogan of sustainable has been rising, most of the traditional structures had shown their sustainability whether environmentally, and socially. This 'old structure' is now being replaced by nails and modern materials, like corrugated metals and plastics as a result of the industrialization and economic crises.

According to the UN Agenda 21, to increasing the sustainability can be measured by the four 'Rs', reduce, refurbish, reuse, and recycle. First, in term of reduction, the 'tongkonan' structure may not reflect the using less material because it used a lot of wooden trees and bamboos. But the length of building duration has sustained that 'tongkonan' structure reduce environmental impact as well as cost energy, because most of them have been built more than one century. Second, both of the 'tongkonan' structure and the room lay-out are still can be utilized as the family ceremonies and furthermore, some of the Christian church has imitated the 'tongkonan' structure with new materials and, indeed, it reflects the ritual ceremonies as in the old time. Third, the 'tongkonan' structure demonstrates the potentiality to be dismantled and resemble again in another place. Yet, the roof structure can be shaped incrementally from plain gable to concave curvature gable by jutting the cantilever on both sides of the ridgepole. Fourth, nonetheless the 'tongkonan' structure can be recycled to be many other architectural products like furniture or other related wooden construction because most of the materials of the main structure were fresh materials without any factory processing. Thus, the 'tongkonan' structure demonstrates their prospective as sustainable structural system environmentally, socially as well as from engineering point of view.

From the table below we can learn the structural behavior system of 'tongkonan'. The pile foundations are stitched up by continuous horizontal beams all over the piles performing as the box foundation of the upper structure. And a heavy roof gives benefit to the stability of the structure, especially towards lateral forces, like wind and earthquake. Moreover, the behavior of this structure relies on a disorganized combination of materials being stressed in tension, compression, shear, and bending all at once. If the lateral forces were to become focused on one element in this interlocking puzzle, that element would be firmed. This 'tongkonan' structure does not have much lateral strength, but still stay up over centuries. This can be happened because this structure has sufficient lateral capacity by allowing incremental low-level damage in the form of the mortise joint behavior of the unequal assembly of interlocking elements. And yet, the individual timber remains elastic, so the system behaves as if it were ductile.

Table 1 The Involution of 'Tongkonan' Structure

The Original Structure	The Structural Model	Structural Behavior
<p>The log-house construction</p> 		<p>The Triangle shape frames stabilize pinned roof system.</p> <p>The interlocking slots cut connections of log-house construction behave as dismantled rigid joints.</p>
<p>The archaic type of polygonal piles</p> 		<p>The main roof structure is similar, but the curvature is created with additional triangle pinned frame supported by additional standing pole.</p> <p>The solidness of piles stitched by beams constructed a rigid box foundation.</p> <p>The pile-house system reduces materials and cost energy.</p>
<p>The modern type of square piles</p> 		<p>The longer roof overhangs act as incremental cantilevers which able to reduce structural loads and enhance structural capacity.</p> <p>The heavier roof gives benefit to structural stability as a whole.</p> <p>The construction with square piles and beams becomes more delicately jointed.</p>
<p>Sustainability</p> <p>The structural flexibility can be detected through the loose connections which were constructed in all tie and mortise joints and performs as a solidness space frame structure both in roof and foundation construction.</p> <p>The potentiality as an incremental structure can be discovered from the architectural form, especially on the roof cantilever involution.</p>		

People no longer feel proud to build their traditional houses. The mortise construction is time consuming and tedious. In addition, the changing value on building materials was caused by the money system, people are forbidden gather the indigenous materials from the forests or fields and they had to purchased materials sold at the local stores. As a result people used corrugated metal as their roof replacing bamboo and coconut leaf. Unfortunately, the problem resulting from this new material is not anticipated. Besides of the uninviting corrosion problem, the metal roofs are noisy, provide poor insulation and are not permeable.

The complex framing system of wood or bamboo tied by rattan is being replaced by wood rafters and nails, which required less layers of structure. This rigid detailing allows for less movement, giving the structure a disadvantage over its predecessor, which was developed over centuries to resist high winds, heavy rains and moderate earthquakes (Central Celebes is in the 3rd earthquakes region). In addition, the natural roofing material allowed sufficient drainage of water and balanced natural venting system in homes. The many layers of bamboo provided insulation from heat as well as noise. Industrialization has driven people to be

efficient, to be prestige, and to abandon their tradition of construction at the expense of losing what traditional culture remains.

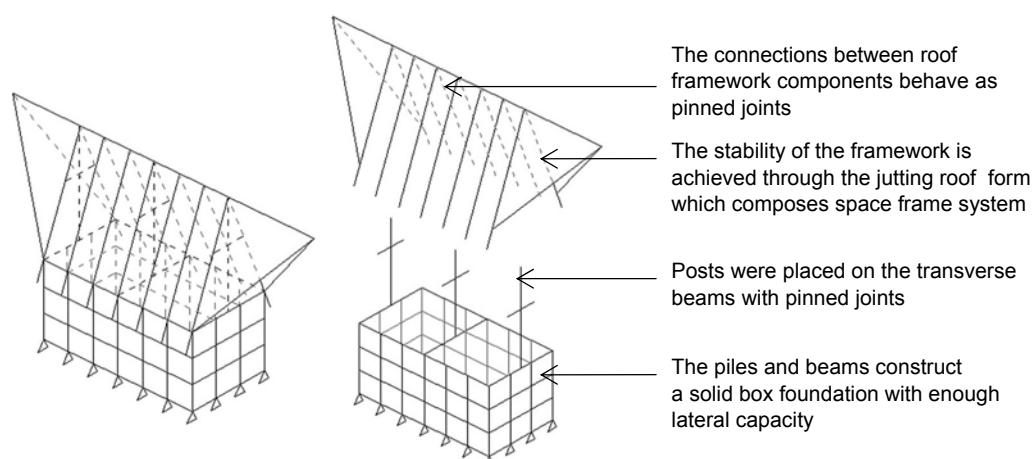


Figure 8 The axonometric of 'tongkonan' structural system.

4. Discussion

This paper does not intend that we should return to an age that has ended. The changes that have occurred in traditional structure and construction are thoughtful, but reversing them wholesale is neither a possible, nor a worthwhile objective. There are however, some useful lessons of flexible and incremental system of 'tongkonan' traditional structure can bring:

- First, contemporary construction can benefit from an understanding of the 'tongkonan' traditional structural system. The principle lesson is that strength and rigidity are less effective. The additional principle is flexibility, ductile and solidness behavior.
- Second, respect to the work of our ancestors is an essential factor to full understanding on the contribution that this work can continue to make the future. So much of the world's pursuit of modernization has been fueled by a belief that we alive today know more and do things better than those our ancestors before us. Nonetheless, 'tongkonan' structure has withstood over the hard rainy season and wind throughout centuries.
- Third, considering the extreme difference between the old and new style of construction, there are a number of specific ideas from 'nail-less' timber construction. The tongue and groove detail tied with rattan introduces incremental potentiality in structural building system. Understanding the structural characteristics is like getting to know someone in person, not just from a reflection in a mirror.
- Fourth, the efforts to maintain the 'tongkonan' sustainable traditional structural system is: empowering local people to create 'tongkonan' for one community, advocating education about sustainable building practices to create live dignity without destroying their natural habitat, detailing particular technological advances in sustainable construction that can have wide application or inspiration.

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