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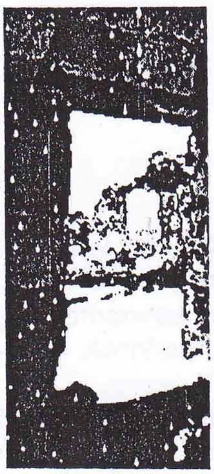
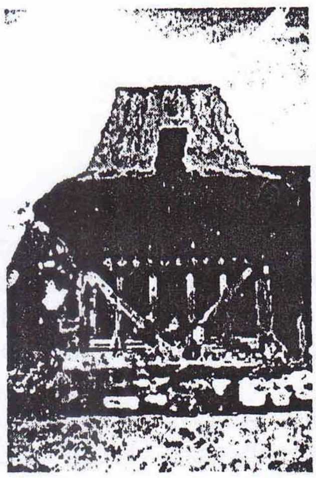
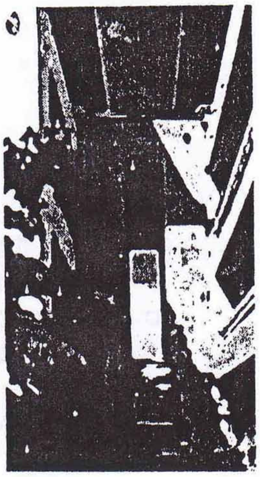

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Subthemes II : Using and Experiencing Place

BUILDING CONSTRUCTION'S RESPONSE TO THE EARTHQUAKE
Case study: Lamban Tuha and Bidai House

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Abstract

Earthquake is one of nature phenomenon that must be considered in making proper building structure. Geographic characters in certain place have been inspiring people to decide a suitable structure system for their dwellings. They had a basic understanding on construction which lead them to make a responsive construction for earthquake.

This paper discuss two kinds of structure system which were belong to *Lamban Tuha* in West Ogan Komering Ulu, South Sumatera and *Rumah Bidai* in Rejang Lebong, Bengkulu. They were chosen because of their uniqueness structures, *Kalindang* and *Ari* for *Lamban Tuha* and *Bidai Wall* for *Rumah Bidai*. The resistancy of these building will be observed by using the analysis of earthquake resistant building structure, according to earthquake resistant building general theory.

***Keywords**: earthquake resistant building, structure*

I. Introduction

In responding the nature, people had created responsive structure which could be judged as an adaptive (or responsive) structure on the spesifix nature character. This paper discussed two example of earthquake resistant solution. Firstly, it will discuss the Lamban Tuha, located at West Ogan Komering Ulu Regency, South Sumatera Province, which had *Ari* and *Kalindang* system on its structure. This building had erected for more than 200 years and had been proven resistant to earthquake that happened nearby the location frequently. When the most hazardous earthquake happened in Liwa (1933), all the buildings in this village were damaged except Lamban Tuha House. This earthquake intensity was 6.7 in Richter scale. (Siswanto, 1997)

Table 1. Hystory of Big earthquake in South Sumatera Region (Bengkulu, Lampung and South Sumatera Provices) for the last 200 years

Year	Frequent of Earthquake	Damage Intensity	Location
1893	1 times	High	South Sumatera
1908	1 times	High	South Sumatera
1909	2 times	Very high High	South Sumatera
1933	1 times	Very high (6.7 in richter scale)	Lahat, South Sumatera
1963	1 times	High (4.7 in richter scale)	Kotabumi, Lampung
1994	1 times	High	Liwa, Lampung

Source: Siswanto, 1997

The second one is *Bidai* House, located at Rejang Lebong Regency, Bengkulu Province. This building had *bidai* structure. Even though this technology relatively younger compare to *Ari* and *Kalindang*'s, it was also proven as an earthquake resistant building sturcuture, when the recent earthquake happened in Bengkulu in 2000 (in 5.7 Richter scale).

Table 2. Description of Earthquake nearby Bengkulu Year 2004-2005

Year	**Frequent of EQ**	**Intensity**	**Location**
2004	11 times	4.6 - 7.3 Richter scale	Bengkulu
2005	9 times	3,8 - 5,6 Richter scale	Bengkulu
	3 times	5,5 - 6,6 Richter scale	Lampung

Source: Earthquake News, National Earthquake Center, BMG

The tracing these two uniquenesses on earthquake resistancy would be investigated by using the literature study of earthquake resistance building general theory. The observation scope was limited on general building structure system.

II. Earthquake Theory on Building Structure (Schodek, 1980)

According to Schodek, earthquakes are vibratory phenomena associated with shaking loading on the earth crust. There are several basic types of hazard associated with earthquake. These include surface fault raptures, ground shaking, ground failure and tsunami. The waves cusse the earth's surface and any building resting on its to vibration.

As the building is vibrated, forces are developed in the structure of the building because of the tendency of the mass of the building to resist the motion. The forces developed are consequently inertial in character. The magnitude of these forces depens on many factors. The mass of the building is clearly important, since the forces involved are inertial. Other factor include the way the mass is distribute the stiffness of the structure, the stiffness of the soil, the type of foundation, the presence of damping mechanisms in the builing, and, of course, the nature are magnitude of the vibratory motions themselves.

In designing structural systems, the way lateral stability is achieved is an issue of fundamental importance. The issue is important in buildings of any height but absolutely crucial in high-rise constrction. The way a structure resists lateral forces not only influences the design of vertical elements but, as will be seen, the horizontal spanning elements as well.

Schodek state that there were common methods of resisting lateral forces: implications on connection type. It is known as the four methods of achieving lateral stability as follows:

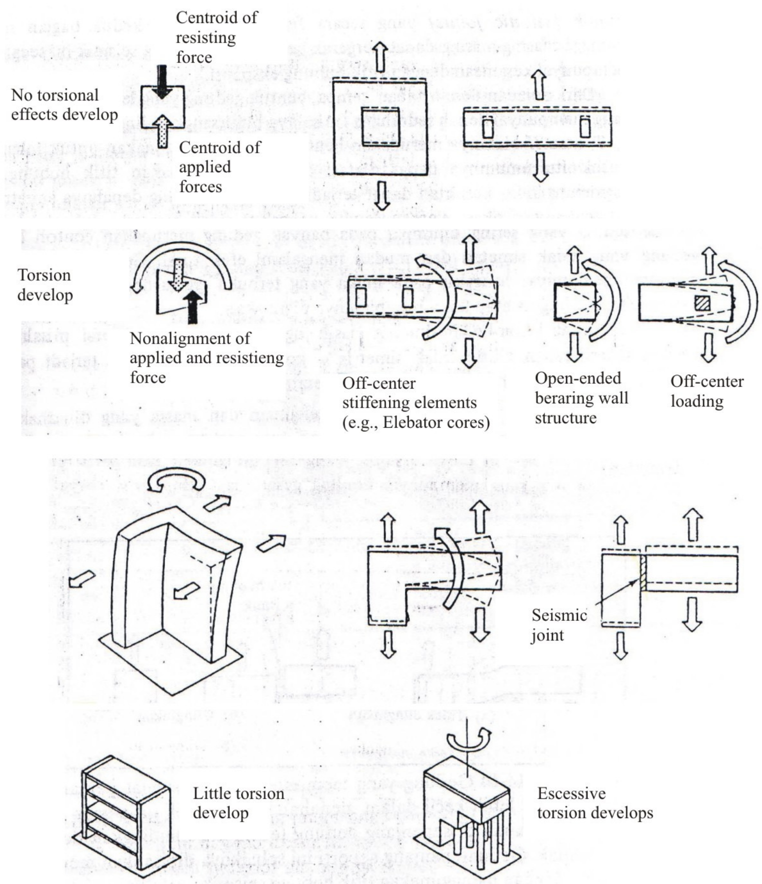
- Diagonal bracing (joins can be pin-connected)
- Frame action (joints must be rigid)
- Shear wall (joints can be pin-connected)
- Brace frame (a redundant system)

In his book, Schodek also stated there are some general considerations in designing dan planning the earthquake resistant building structure as follows:

a. Symmetrical structures do not experience exceptionally high torsional forces and are hence preferred to nonsymmetrical structures

b. Structures that are nonsymmetrical because of either their basic configuration of nonsymmetrical placement of lateral-load-resisting elements typically experiences high torsional forces which are very destructive. Nonsymmetrically-placed masses can also lead to similar torsional effects.
c. Nonsymmetrical configurations with reentrant corner (e.g., L- or H-shaped buildings) are particularly susceptible to destructive torsional effects. Primary damage often occurs at the reentrant corners. Allowing separate building masses to vibrate independently by using seismic separator joints that allow free movement to occure generally improves structural performance.
d. Building that are nonsymmetrical in the vertical direction also experience destructive torsional effects. Discontinuous shear wall are particularly problematical.

Figure 1 General Consideration in Earthquake Resistant Building Planning



Source: Shodek (1980), p. 494

General Characteristics of Earthquake-Resistant Structures

Structures that are continuous in nature and more or less uniformly distributed through out building generally perform well when subjected to earthquakes. Pin-connected structures, such as traditional post and beam assemblies, are far less capable of absorbingenergy than are comparable continuous structures (e.g., frames with monolithic joints). Another general characteristic of viable earthquake-resistant structures is that column-and-beam elements are generally coaxial. Offsets or nonaligned members often present extremely difficult design problems.

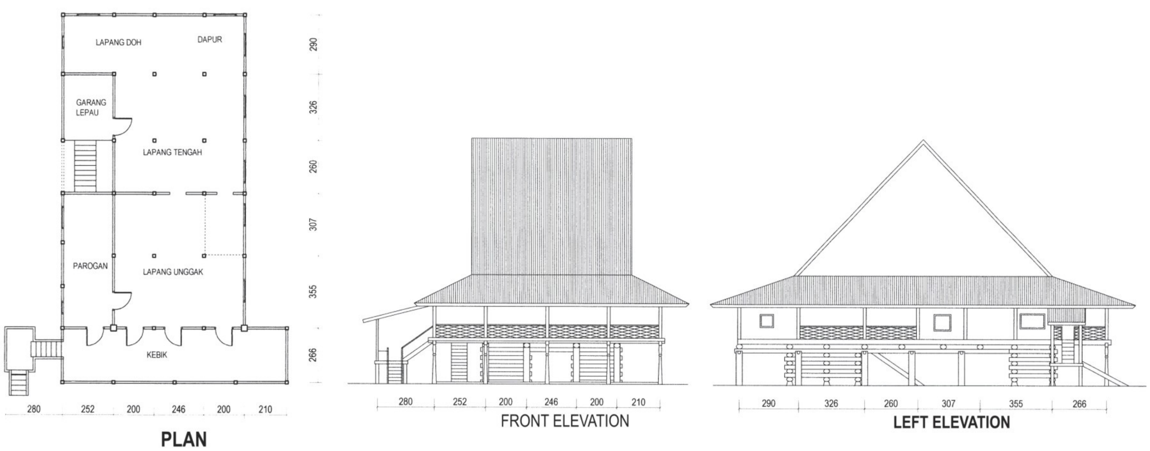
Materials

Timber can be an extremely good material for use in earthquake region. It is light in weight and capable of absorbing large amounts of energy when deformed and before collaps. Low-rise wood-framed structures are highly earthquake-resistant and perform well in earthquake regions.

III. *Lamban Tuha* Building (Siswanto et.al, 1997)

Lamban Tuha building is an old tradisional house owned by Ranau ethnic which lived near by Ranau Lake, the border area between Lampung Province and South Sumatera Province. Research did by Siswanto et.al (1997) observed *Lamban Tuha* in Banding Agung District, Ogan Komering Ulu Regency, South Sumatera Province. Its building support system was able to anticipate the earthquake effect. When the earthquake happened, the flexible *kalindang* structure would be shaking without making any damage caused by earthquake.

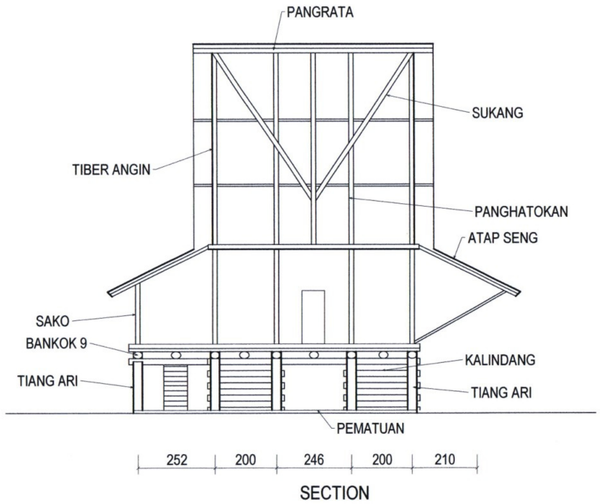
Figure 2. *Lamban Tuha* House



Source: Redrawed from Siswanto et.al (1997)

Its structure consists of timber frame, with the building core (main room) as main structure. Additional room was an extension of terrace function which changed the open room became a close one. Roof structure was consists of arranged timber balk without any joint (local term: *penugungan atap*). The top of ther roof was erected by single continuous balk called nok. For its rigidity, the frame was supported by three columns which worked together with *sukang (skoor)* as support frame for timbering of a roof. Horizontally, the roof structure was fixed by two homogeneus horizontal balk, called *penugungan*, and a vertical balk, called *tetayan tikus*. Rafter of this building was a round balk, and the roof was covered by *tiber angin* (or *daun nipah*, certain named of local leaves use by local people as roof material). These leaves were ordered line in simple way. These *tiber angin* could be replaced by *sesar cecah*, a certain horizontal ordered boards. Roof frame carried on a big wood balk as a part of roof structure system.

Figure 3. Section of *Lamban Tuha*

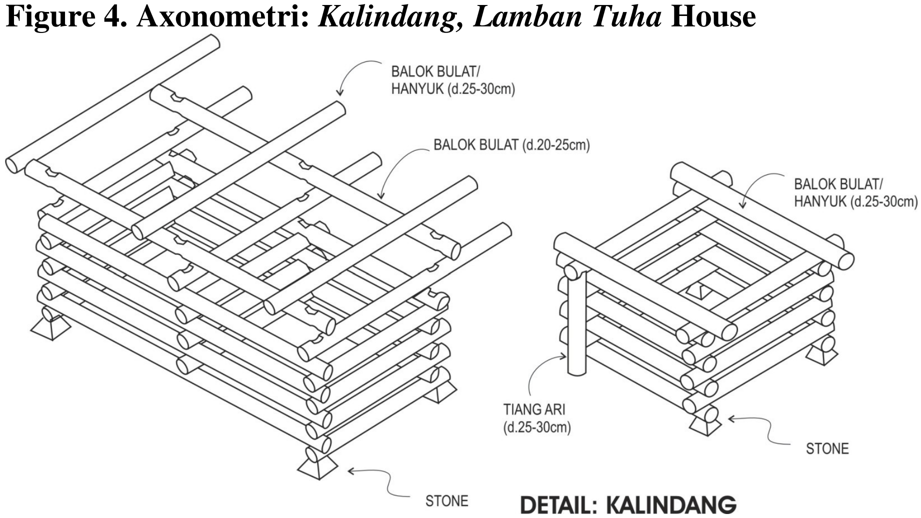


Source: Redrawed from Siswanto et.al (1997)

The body of building was consisting of a column structure (named *Sako*) and building cover. The floor construction was consist of some boards, were supported the floor by using some balks. These balks were carried by a bigger round balk.

The supported column for the bottom of building called *Ar*i. *Ari* was located under the floor, and in certain case, *Ari*'s location was not coaxial with the *sako* (approximately 30 cm in distance). *Sako* worked for the body of building, while the *Ari* worked for the bottom one. If we look further as a whole building, *Sako's* locations used at additional room were not coaxial with the *Ari*. On the contrary, *Sako* used at a main room of building were co-axial with the *Ari*. The *Ari* carried on big stone on a hard land surface

Figure 4. Axonometri: *Kalindang, Lamban Tuha* House



Source: Redrawed from Siswanto et.al (1997)

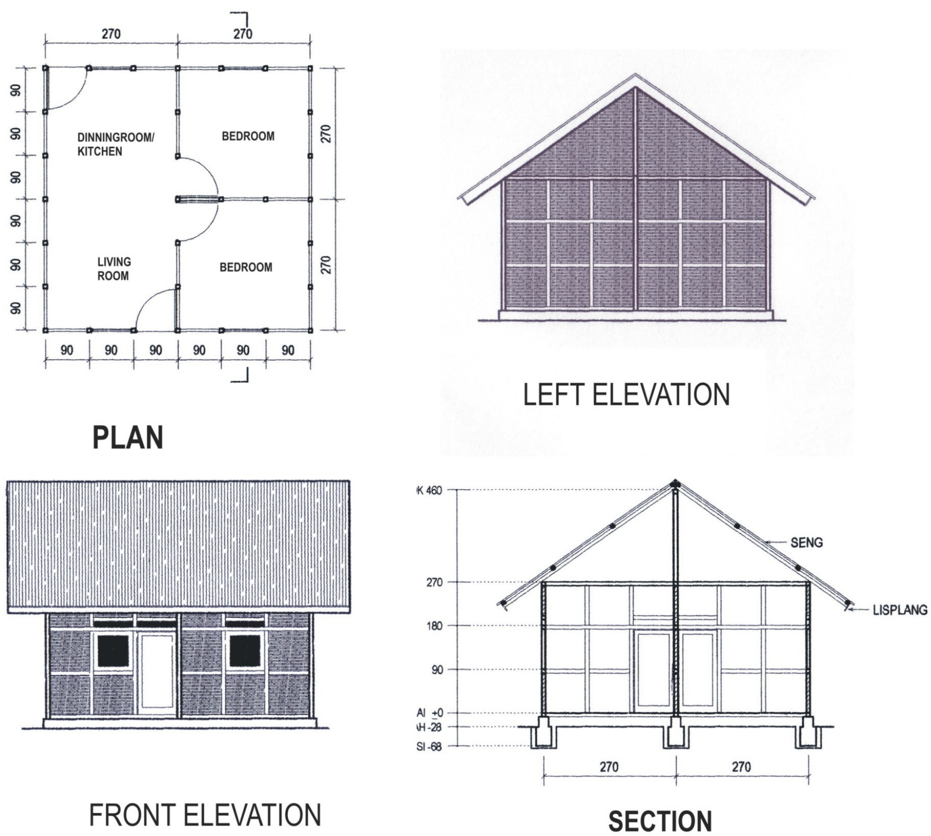
The bottom structure of *lamban tuha* was also supported by *Kalindang* System which was cooperated with *Ari*. *Kalindang* structure was consists of horizontal arranged balks, in crisscross order. Its arrangement formed a solid unity known as *pematuan*. The joint amongs the *kalindang*'s balks were categorized as tension, compression and fixed connection. Those joints were carried by the strength of the timber balks. There was no nail used in its joint system, but it was still able to netralized the force caused by earthquake.

The foundation of *lamban tuha* was *pematuan* (with one or several big stones) which combined with a base round timber balk. This system was placed on a hard surface. This system was considered as a good earthquake solution because it made the column would not be broken caused by the earthquake vibration.

IV. *Bidai* House (Fransiska, et.al, 2003)

Clearly, *bidai* house would see similar with other brick house. Generally, *bidai* house were erected on a stone foundation. Most of *bidai* house were not rise building, and it could be categorized as a semi-permanent building. The main structure was made by timber. The use of timber frame can be seen from the column made by timber (10/10 cm). Timber frame could be also use as frame for roof structure. The roofing frame use a simple form, saddle form, which carried by a column (10/10). The joint between ring balk and the roofing frame using full-lap joint.

Figure 5. *Bidai* House

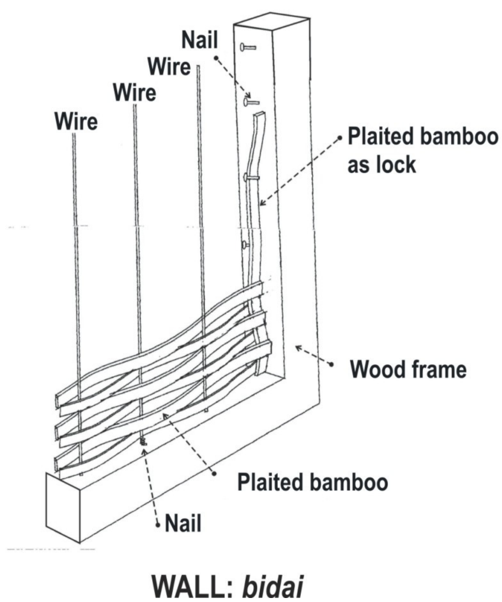


Source: Fransiska (2005)

This house use pebble or river stone for its foundation. There was nothing special founded in this structure. Eventhough the area where this building located is known as frequently earthquake happened, this stone foundation still used commonly. It is believed that the bidai structure in its wall structure made flexible structure beside the light building load.

The wall had a frame system which made from timber frame in modular arrangement. At the timber frame, there were two nails which tighted the wire line bottom and up of modul in 20 cm of distances. At the end of right and left of wiring arrangement, there were a series of nails as a place for tightening the key of plaited bamboo.

Figure 6. Wall: *Bidai*



Source: Fransiska (2003)

The wire which tigthned along up and bottom nail became the vertical bone (or bracing) for *bidai* wall structure. Bamboos were plaited on these vertical wires in crisscross order. It used bamboo *Telang*, a local name for local species of bamboo. The length of the space between bamboos's joint was approximately 70 – 100 cm. The modul of *bidai* wall was made based on this physic structure of bamboo; the average distance of bamboo joints. The plaited bamboo will be locked by a plaited bamboo, located at the end of wall fram (left and right of modul)

After the plaited bamboo had been formed, the wall was covered by mortar. This mortar consists of cement and sand with 1: 5 comparations in its composition. The way to covered the wall was started from the inside part of wall, then continued to outside, and it continued one after another.

For ordinary house, the attic wall can be worked as roofing frame, and can carry the load from the outrigger. On the contrary, attic wall of *bidai* house could not work as roofing frame. The timber balk still had to be placed at the top of bidai attic wall as roofing frame. This balk would carry the load from the outrigger.

V. Discussion

From the both description, there are some conclusions can be drawed. Both systems had some similarities and differences which are shown as follows.

Table 3. Comparation between *LambanTuha* structure and *Bidai* house

Categorization	***Lamban Tuha***	***Bidai House***
a. Structure system	*Kalindang* and *ari*	*Bidai* wall/ plaited bamboo
b. Mechanism of structure	Frame structure	Bracing frame
c. Configuration	Symmetric at the building core	Can be symmetric, or asymmetric
d. Main structure	Continuous in nature, using the arrangement of *Kalindang* system	Post-and-beam
e. Additional structure	*Kalindang* timber balks	Plaited bamboo wall covered by mortar
f. Material	Timber for main structure Timber for wall structure (in board form)	Timber for main structure Plaited and mortar covered bamboo for wall structure.

Source: Analysis

VI. Conclusion

- *Lamban Tuha* was a symmetry building. This symmetry form in its building core helped this building to overcome the unsteady situation caused by earthquake.
- The structure system of *Lamban Tuha* used a rigid combination between support point dan continuous in nature system. It made a flexible and simple system for its building structure. *Bidai* structure used a support point system with mortar covered plaited bamboo as wall bracing.
- Because of its long form, *kalindang* were placed at the shortest side of building. It is in line with the theory that for symmetry plan, the shortest wall should be strengthen to minimize the earthquake effect to overcome the effect of lateral forces caused by earthquake.
- Timber is still a good material for earth quake resistant building. Both building system use this positive timber character to overcome the earthquake effect.

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