VERNACULAR HOUSES TYPOLOGY AND ITS RESPOND TO THE EARTHQUAKE
Case Study: Duku Ulu Village, Bengkulu, Indonesia

Sugeng Triyadi [1)], Iwan Sudradjat [2)], Andi Harapan [3)]
[1)] SAPPK ITB, E-mail: sugeng_triyadi@yahoo.com
[2)] SAPPK ITB, E-mail: dekan@sappk.itb.ac.id
[3)] SAPPK ITB, E-mail: andiharapan@yahoo.com

Architecture Department
School of Architecture, Palnning, and Policy Development
Bandung Institute of Technology
Indonesia

Abstract
Desa Duku Ulu, one of the oldest village in Rejang Lebong Region, Bengkulu Province, Indonesia, is the earthquake area. Some of earthquakes made several damages especially for buildings. Interestingly, many of vernacular houses are survived and got only light damages while there are many modern building got great damages. Unfortunately, the potential of vernacular houses are not optimized by the local people. As time pass by, many house has been constructed with different ways. This paper will elaborate 5 vernacular houses typologies and their respond to the earthquake . The study methods used are field study, semi-structured interview and forum group discussion with local community and documentation by field measuring and building redrawing. Field study and semi-structured interview focus on two aspects of observations, which are: 1) traditional building and 2) skill & local resource use. Observations to vernacular building include 4 aspects: 1) house form & design, 2) structural system, 3) material used, 4) joinery & other details (construction system). Observation to skills and local resource include: 1) building skill, and 2) culture (such as solidarity).

Keywords: Vernacular house, vernacular building construction, vernacular houses typologies, houses form, earthquake, Duku Ulu Village, Rejang Lebong, Bengkulu

I. INTRODUCTION

Province of Bengkulu lies in the southwest of Sumatra Island (2° – 5° SL and 101° – 104° EL). Like many other parts of Indonesia, its place where earthquake strikes frequently. The notable earthquakes in recent history happened in 1833, 1914, 1952, 1979, 1991, 1997, 2000, 2007 and 2009.

In 2007, the 7,8 SR earthquake has made damages for 15.000 houses with various conditions. From this amount, many houses construction which had heavy damages (and collapsed) were made from brick. On the contrary, the vernacular houses which are constructed in woods by amateur people didn't have many damages (just few of them) [13]. Although the construction is not *right* in modern construction's view (i.e. the truss that hasn't *right* in modern theory of force distribution). The study methods used are field study, semi-structured interview and forum group discussion with local community and documentation by field measuring and building redrawing.

II. VERNACULAR BUILDING AND EARTHQUAKE

Vernacular house is house that is made and habited by most of people. Commonly, those houses are made based on the traditional house's form and space programming, but with different construction [1]. Moreover, vernacular house is smaller than ordinary traditional house and doesn't adopt the traditional house's symbolisms and decorative. This kind of vernacular building is called as *people house* [7, 9, 10, 11, 12].

Vernacular building uniqueness is the construction method that has been a tradition from ancient history (trial and error) in order to appropriate the condition of nature [6, 7] . Rapoport on his research said that vernacular building characteristic

are: 1) not made based on principles and theory of modern building, 2) fit the environment, 3) fit the community's ability (of economy and technology), 4) represent the culture of community, 5) fit to the local resources and open to changes (trial and error) in order to survive. Based on the aspect of vernacular building forming, Rapoport also said that forming process based on model and variation [9]. Variation is achieved by enrichment of model.

Jigyasu said that the community that lived in the earthquake is will always has a solution to survive in that area. It can be seen from the houses that always respond to the earthquake [8].

In earthquake are as said by Triyadi & Harapan [13, 15, 16], vernacular building has made an appropriation or respond to the earthquake. As a result, the houses remain survive several earthquake, such as vernacular houses in Liwa, Lampung Barat [16]. The same condition can be seen in Desa Duku Ulu in Rejang Lebong Region, Bengkulu Province, Indonesia.

Besides survived earthquake, the vernacular building also fulfills the modern principles of building: symmetric, has wall structure system, uses light material (esp. for roof), and interconnected columns [4, 5].

More explanation of Gutierrez [7] and Jigyasu [8] mentioned the requirement of vernacular building: 1) the plan has to be simple and symmetrical, 2) the material has to be light, 3) the joint system has to rigid and flexible, 4) unified construction and structure system, especially in roof, wall and foundation system. Based on the previous explanation, objects of study are: 1) plan and form of building, 2) building construction and structural system, 3) building material, and 4) joint system of building component.

III. RESEARCH METHODOLOGY

The research methods used are field study, semi-structured interview and forum group discussion with local community and documentation by field measuring and building redrawing to find indigenous knowledge related to against the earthquake (Fig. 1). Field study and semi-structured interview focus on two aspects of observation, which are: 1) vernacular building and 2) skill & local resource. Observations to vernacular building include 4 aspects: 1) house form & design, 2) structural system, 3) material used, 4) joinery & other details (construction system). Observation to skills and local resource include: 1) building skill and 2) culture (such as solidarity). Building skill and culture are important things to identify the capacity of the vernacular building. 5 typologies of vernacular building were found in Desa Duku Ulu, which will be elaborated based on observation aspects.

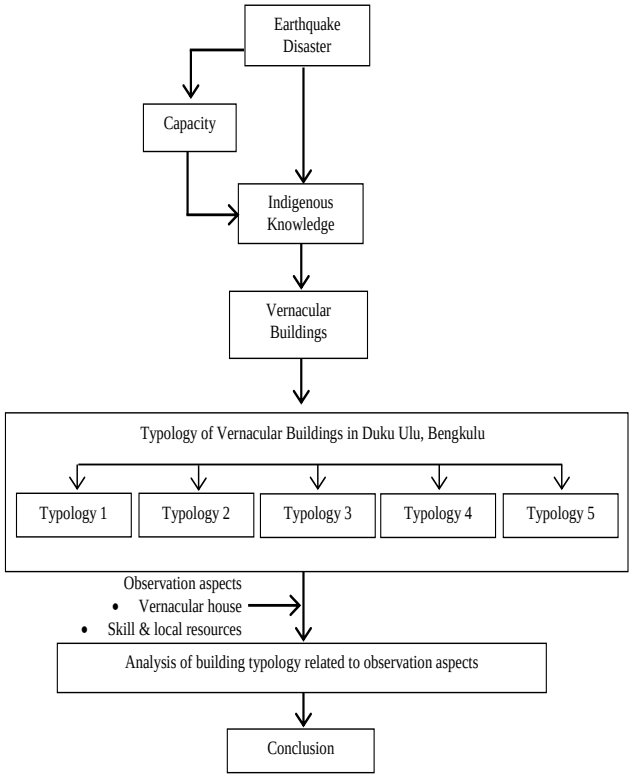


Fig. 1. Research methodology

IV. DESA DUKU ULU and ITS VERNACULAR BUILDING

In Bengkulu, there are two kinds of vernacular houses: Rejang vernacular

house and Melayu vernacular house. Rejang vernacular house is adopted from Rejang traditional house (Umeak Potong Jang/ Umeakan) and influenced by Meranjat traditional house's form.

Fig. 2. Condition of Duku Ulu Village

As one of the oldest village in Rejang Lebong, Desa Duku Ulu has many Rejang vernacular building (Fig. 2). There are five main typologies of vernacular building in this kampong, categorized by the shape and ages of the building. Typology 1 is the first typology that constructed at 1800s. The form of building is same with Rejang traditional house. The dimension is square (7.2 x 8.4 m^2) and has a knock-down construction. In 1833 earthquake, the survived building lost its *ijuk* (the trunk of the sugar palm) roof. From that year, the use of *ijuk* is replaced.

Typology 2 is the developed kind of typology one. Its differences are roof material and longer plan (7.15 x 10.58 m^2). These houses are constructed at 1900s. When 1914 earthquake happened, many houses of this typology have foundation great damage. So people replaced the conventional foundation with colonial prefabricated concrete foundation (Dutch concrete). These new houses are called typology 3.

Because of buildings longer plan, many parts of building didn't survive in the 1979 earthquake. When people wanted to fix the damages, they made new kind of foundation because they cannot made foundation like the Dutch made. In the same time, there are many craftsmen came from Meranjat, Palembang brought their knowledge of construction methods. As the result, new buildings in Desa Duku Ulu was typical with buildings in Meranjat. These new houses are called typology 4.

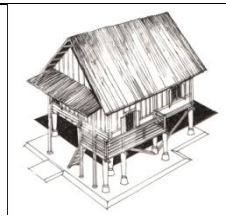
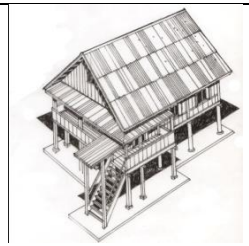
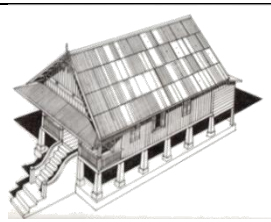
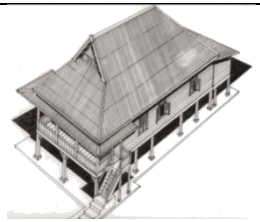
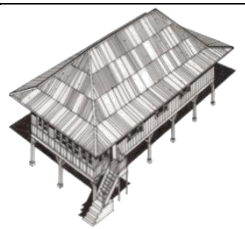
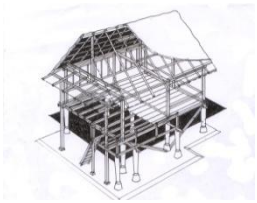
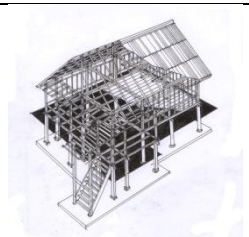
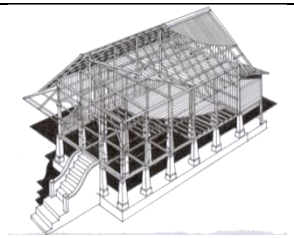
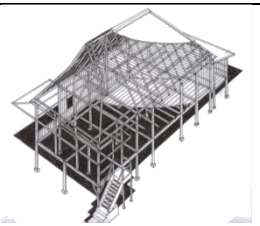
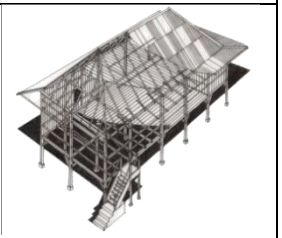
Lately, when 1991 and 1997 earthquake happened, many buildings got damages. With insufficient knowledge, the craftsmen's that time cannot made previous kind of roof, so they made new kind of roof that made typology 5, the typology remains until today.

V. VERNACULAR HOUSE TYPOLOGY IN DESA DUKU ULU RESPONSES TO EARTHQUAKE

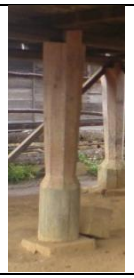
There are four aspects that be standard of earthquake survival of the vernacular building in Desa Duku Ulu: 1) building form, 2) structure system, 3) material, and 4) construction system. The building form shows less response to earthquake nowadays because of its unsymmetrical plan. The structure system of building consists of three main parts: 1) upper structure system (roof and ceiling), 2) middle structure system (wall), 3) substructure system (floor and foundation). Main materials that used for structural system are wood and bamboo. Unfortunately, the structural system becomes more separated.

The materials used in all typologies of building are light materials, except typology 3 (use concrete for foundation). From the view of material, typology 1 is the lightest typology and most safe from the earthquake. The construction system that intended in this paper are construction details, like joints, *coakan* (connection system), etc. In typology 1 and typology 2 the knock-down system of joint used entirely in building. On the contrary, in typology 3, typology 4 and typology 5 the use of nails are getting high.

Table 1. Comparison of Bengkulu vernacular houses in Duku Ulu Village based on observation aspects (building shape, structure, material and construction methods)

No.	Observation Aspects		Typology 1	Typology 2	Typology 3	Typology 4	Typology 5
1	**Building**						
	• Building Plan		Square (7,20 x 8,24) m^2	Square (7,15 x 10,58) m^2	Square (6,74 x 13,58) m^2	Square (6,70 x 15,08) m^2	Square (5,23 x 16,42) m^2
2	**Structure**						
	Upper Structure	Roof	Wood frame structure and bamboo.	Wood frame structure and bamboo.	Wood frame structure and bamboo.	Wood frame structure and bamboo.	Wood frame structure and bamboo.
		Ceiling	Wood frame structure and bamboo.	Wood frame structure.	Wood frame structure.	Wood frame structure.	Wood frame structure.
	Middle Structure	Wall	Wall frame made from solid woods structure frame, consisted of column (main structure) and wood beam (horizontal and vertical).	Wall frame made from solid woods structure frame, consisted of column (main structure) and wood beam (horizontal and vertical).	Wall frame made from solid woods structure frame, consisted of column (main structure) and wood beam (horizontal and vertical).	Wall frame made from solid woods structure frame, consisted of column (main structure) and wood beam (horizontal and vertical).	Wall frame made from solid woods structure frame, consisted of column (main structure) and wood beam (horizontal and vertical).
	Sub Structure	Floor	Floor structure made from solid woods structure consisted of main beam, supporting beam and wood board as floor covering.	Floor structure made from solid woods structure consisted of main beam, supporting beam and wood board as floor covering.	Floor structure made from solid woods structure consisted of main beam, supporting beam and wood board as floor covering.	Floor structure made from solid woods structure consisted of main beam, supporting beam and wood board as floor covering.	Floor structure made from solid woods structure consisted of main beam, supporting beam and wood board as floor covering.

		Foundation	Foundation system is *umpak* (stone based foundation). This kind of foundation allows collumns to move during earthquake. With the solid structure, the whole building is simply move from its position without causing any damages. Stone-based foundation is the most suitable type of foundation for building in earthquake area.	Foundation system is *umpak* (stone based foundation). This kind of foundation allows collumns to move during earthquake. With the solid structure, the whole building is simply move from its position without causing any damages. Stone-based foundation is the most suitable type of foundation for building in earthquake area.	Foundation system is *umpak* system consisted of foundation foot (*kaki pondasi*) and flat foundation. Foundation foot and flat foundation are one solid thing because made from concrete. This technology is introduced by the Dutch in 1920s. Column and floor structure is supported by foundation foot in connection system as supporting place.	Foundation system is *umpak* system consisted of foot foundation and flat-surfaced stones. Foot foundation made in knock-down system and attached to columns and floor structure with peg.	Foundation system is *umpak* system consisted of foundation foot (kaki pondasi) and flat foundation (concrete). The foot foundation made from wood.
3	**Material**						
	Upper	Roof	Palm fibre (the trunk of the sugar palm)	Corrugated metal (zinc)	Corrugated metal (zinc)	Corrugated metal (zinc)	Corrugated metal (zinc)
		Roof structure	cylindrical wood	cylindrical wood	cubical wood (1/2 non solid/ ½ fabricated)	cubical wood (1/2 non solid/ ½ fabricated)	cubical wood (1/2 non solid/ ½ fabricated)
		Ceiling	bamboo matting	bamboo matting	Wood board	Wood board	Wood board
		Ceiling structure	Wood + Bamboo	Wood + Bamboo	Wood	Wood	Wood
	Middle	Wall	Wood + Bamboo	Wood	Wood	Wood	Wood
		Wall structure	Wood	Wood	Wood	Wood	Wood
		Column	cylindrical wood	cylindrical wood	Wood	Wood	Wood
	Sub	Floor	Wood + Bamboo	Wood	Wood	Wood	Wood
		Floor Structure	Wood + Bamboo	Wood + Bamboo	Wood	Wood	Wood
		Foundation	*Umpak*, consisted of foot foundation (wood) and flat-surfaced stones (square stone).	*Umpak*, consisted of foot foundation (wood) and flat-surfaced stones (square stone).	*Umpak*, foot foundation and flat foundation is one solid thing because made from concrete.	*Umpak*, consisted of foot foundation (wood) and flat-surfaced stones (circle stone).	*Umpak*, consisted of food foundation (wood) and flat foundation (concrete).

							
4	**Construction System**		Knock Down	Knock Down	Knock Down	Semi Knock Down	Semi Knock Down
	Upper	Roof	*Ijuk* bonded to roof-batten used rattan ribbon	Corrugated metal (zinc) nailed to roof-batten	Corrugated metal (zinc) nailed to roof-batten	Corrugated metal (zinc) nailed to roof-batten	Corrugated metal (zinc) nailed to roof-batten
		Roof structure	Peg system	Peg system	Peg system and nail	Nail	Nail
		Ceiling	Bamboo as ceiling bonded used rattan ribbon.	Bamboo as ceiling bonded used rattan ribbon.	Wood board as ceiling bonded with nail	Wood board as ceiling bonded with nail	Wood board as ceiling bonded with nail
		Ceiling structure	Connected by peg and rattan ribbon as strengthener	Connected by peg and rattan ribbon as strengthener	Connected by nail	Connected by nail	Connected by nail
	Middle	Wall	Numbered wood board arranged vertically and connected in peg system	Numbered wood board arranged vertically and connected in peg system	Wood board arranged vertically and connected by nail	Wood board arranged horizontally and connected by nail	Wood board arranged horizontally and connected by nail
		Wall structure	Wall structure connected by knock-down system and pegged	Wall structure connected by knock-down system and pegged	Wall structure connected by knock-down system and nailed	Wall structure connected by knock-down system and nailed.	Wall structure connected by knock-down system and nailed.
	Sub	Floor	Wood board and bamboo	Wood board	Wood board	Wood board	Wood board
		Floor Structure	Floor structure connected by knock-down system and pegged	Floor structure connected by knock-down system and pegged	Floor structure connected by knock-down system and nailed	Floor structure connected by knock-down system and nailed	Floor structure connected by knock-down system and nailed
		Foundation	Foot foundation connected to column and floor structure by knock-down system and pegged. Foot foundation located up the flat stone (square stone).	Foot foundation connected to column and floor structure by knock-down system and pegged. Foot foundation located up the flat stone (circular stone)	Foot foundation and flat foundation is one solid thing because made from concrete that connected as based for column and floor system	Foot foundation connected to column and floor system by knock-down system and pegged. Foot foundation located up the flat stone (circular stone)	Foot foundation connected to column and floor structure by knock-down system and pegged. Foot foundation located up the flat foundation (concrete)

VI. CONCLUSION

Based on the study methods, there are five typologies of vernacular houses in Duku Ulu village. Typology 1 is old vernacular house of Rejang people. It was constructed at 1800s and made by wood. Typology 2 is developed and simplified form of Typology 1. Typology 3 is Colonial Typology, because it was made with a help form Dutch in 1920s. Typology 4 is made by craftsmen from Meranjat, Palembang at 1980s, and Typology 5 is house that had been developed by people in 1990s.

All of the Vernacular building typologies nowadays in Desa Duku Ulu are not responding to the earthquake; although this region is have high vulnerability to earthquake. It can be seen from the houses form that become longer and unsymmetrical, structural system that become un-rigid, and joint system that less responds to earthquake and can be seen in using of nail. Although they still use heavy material for the houses.

The changes of houses typology show the degradation responses to earthquake. The trial and error process of learning from earthquake is not happened. No wonder, when earthquakes come in 1979, 1997, and 2000 many vernacular houses got heavy damages. It is because of three factors: 1) lack of craftsmen, 2) lack of wood, 3) instant culture in constructing houses.

People of Bengkulu, especially in Desa Duku Ulu should be explained about indigenous knowledge of its building tradition and its unique respond to the earthquake. So they can use their local construction method instead of concrete and brick (without right principles) in order to survive against earthquake.

VII. REFERENCES

[1] Triyadi, Sugeng, Harapan, Andi, Pribadi, Krishna S., Hidayat, B. *Indigenous Knowledge on House Building System in West Sumatra and Southern-West Java, Indonesia*. Text Book Indigenous Knowledge and Disaster Risk Reduction, From Policy to Practice, Editor: Rajib Shaw, Anshu Sharma, Yukiko Takeuchi. USA: NOVA Publisher, 2009.

[2] Ambrose, James & Vergum, Dimitry. *Design for Earthquakes*. New York: John Wiley & Sons, Inc., 1999.

[3] Brush, Stephen B. & Stabinsky, Doreen. *Valuing Local Knowledge: Indigenous People and Intellectual Property Rights*. USA: Island Press, 1996.

[4] Boen, Teddy. *Manual Bangunan Tahan Gempa (Rumah Tinggal)*. Jakarta: Teddy Boen & Rekan, 1978.

[5] Boen, Teddy et al. *Manual Perbaikan dan Perkuatan Bangunan yang Rusak Akibat Gempa Bumi*. Jakarta: Teddy Boen & Rekan, 1995.

[6] Ellen, Roy; Parkes, Peter; & Bicker, Alan. *Indigenous Environmental Knowledge and Its Transformations*. Amsterdam: Harwood Academic Publisher, 2005.

[7] Gutierrez, Jorge. "Notes on the Seismic Adequacy of Vernacular Buildings". *13th World Conference on Earthquake Engineering*. Vancouver. B.C. Canada August 1-6. 2004. Paper No. 5011.

[8] Jigyasu, Rohit. *Reducing Disaster Vulnerability through Local Knowledge and Capacity*,. Dissertation of Faculty of Architecture and Fine Art, Department of Town and Regional Planning, Norwegian University of Science and Technology, 2002.

[9] Rapoport, A. *House, Form and Culture*. London: Prentice-Hall International, Inc., 1969.

[10] Triyadi, Sugeng & Harapan, Andi. *Kajian Pengetahuan Lokal-Indigeneous Struktur dan Konstruksi Tahan Gempa pada Rumah Vernakular Sunda di Pangandaran*. Laporan Riset KK-Teknologi Bangunan, Institut Teknologi Bandung, 2007.

[11] Triyadi, Sugeng & Harapan, Andi. *Studi Sistemik Bangunan Vernakular Sunda*. Laporan Riset KK-Teknologi

Bangunan 2008, Institut Teknologi Bandung, 2008-a.

[12] Triyadi, Sugeng dan Harapan, Andi. "Kearifan Lokal Rumah Vernakular di Jawa Barat Bagian Selatan dalam Merespon Gempa". *Jurnal EMAS, Fak. Teknik UKI*, Jakarta, Vol. 18, No. 2, Mei 2008-a, ISSN: 0853-9723, Halaman 123-134.

[13] Triyadi, Sugeng & Harapan, Andi. "Kajian struktur & konstruksi bangunan rumah rakyat (vernakuler) dari konsep sustainabilitas". Prosiding Seminar Nasional Universitas Budi Luhur, Jakarta, hal. 2.1-2.15, 8 April 2008-b, ISBN 978-979-15842-1-0.

[14] Triyadi, Sugeng & Harapan, Andi. "Sustainable House Design in Vernacular Housing, Case Study: Dukuh Kampong, West Java". *International Proceeding " Green Architecture & Environment*", Hasanudin Universities, Makasar, 14 October 2008-c, Halaman 109-118, ISBN:878-979-15469-4-2.

[15] Triyadi, Sugeng "Penggunaan Bambu sebagai Material Bangunan pada Rumah Tradisional-Vernakular Sunda di Jawa Barat, Studi Kasus: Kampung Cikondang dan Kampung Dukuh". *Prosiding Seminar Nasional Rekayasa Bambu sebagai Bahan Bangunan Ramah Lingkungan*, Yogyakarta, 2009-a.

[16] Triyadi, Sugeng & Harapan, Andi, 2009-b, Potensi-Potensi Lokal untuk Mereduksi Resiko Gempa pada Bangunan Rumah Vernakular Lampung Barat (Liwa, Belalau dan Sekitarnya), Prosiding Seminar Nasional Universitas Teknologi Yogyakarta.