G-FEET STICKY HOUSE: THE STRONG AND QUAKE-RESISTANT HOUSING FOR POST EARTH QUAKE SOLUTION

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ABSTRACT

Earthquake is a natural phenomenon occurs in Indonesia. Naturally, earthquake does not kill people, but buildings do. People were killed by the fallen debris of building parts when earthquake occurred. The key to create an entire building lies on the joint system which is why most of building failures occurred on the joint system. Prawiro et all (2010) stated that G-Feet Structural Joint System is the future alternative reversible structural joint system designed based on gecko's feet concept. The research by Andari et all (2011) found that the joint system was optimum in shear stresses which were mostly created by lateral forces of earthquake. The idea was more lateral forces would lead the joint system to become stickier. Sticky brushes refer to the ability of joint system to easily stick and become strong enough receiving 10 tons/m² load. This can be happened due to the geometry of sticky brushes which are becoming the locking system of the joint system. Therefore, G-Feet Sticky house is supposed to be a new concept of post earthquake houses for the victims. Material selection and 3D computer modelling were used for the final design of G-Feet Sticky Houses to be safely and easily to install. The design is supposed to be useful and helpful especially for the victims as temporary houses which can be modified as the permanent one. The big wall panels are designed for faster construction process while the joint system combines the ability of sticky brushes and the geometry of wall panel edge detail.

Keywords: *earthquake resistant, G-Feet sticky house, G-Feet structural joint system, portable*

ABSTRAK

Gempa bumi merupakan fenomena alam yang sering terjadi di Indonesia. Secara natural, gempa bumi bukanlah yang membunuh manusia akan tetapi bangunan yang melakukannya. Orang-orang terbunuh oleh reruntuhan bangunan yang jatuh ketika gempa bumi terjadi. Kunci dari keseluruhan bangunan terletak pada system sambungannya yang hampir secara umum kegagalan suatu bangunan disebabkan oleh bagian sistem sambungannya.

Prawiro et all (2010) menyatakan bahwa sistem sambungan G-Feet adalah sistem sambungan masa depan yang dirancang berdasarkan prinsip kerja kaki tokek. Penelitian Andari et all (2011) menyebutkan bahwa sistem sambungan tersebut bekerja maksimal terhadap gaya geser yang akan sangat bagus sekali merespons gaya gempa yang berupa gaya lateral. Semakin gaya lateral yang terjadi semakin menempel sistem sambungannya. Bulu-bulu lengket mengacu kepada kemampuan sistem sambungan yang dapat mudah melengket dan cukup kuat untuk menerima beban 10 ton/m^2. Hal ini terjadi karena geometri yang menjadi sistem pengunci pada sambungan. Rumah temple G-Feet diharapkan menjadi rumah portable yang akan menjadi konsep baru bagi perumahan pasca gempa bumi. Pemilihan material dan pemodelan 3D digunakan untuk memperoleh desain final yang aman dan mudah dipasang. Desain diharapkan dapat berguna dan dapat membantu para korban sebagai rumah sementara yang dapat dimodifikasi menjadi rumah permanen. Panel dinding besar didesain untuk proses konstruksi yang lebih cepat sementara sistem sambungan mengombinasi antara kemampuan bulu-bulu tempel dan geometri dari detail ujung panel dinding.

Kata kunci: *tahan gempa, rumah temple G-Feet, sistem sambungan G-Feet, portabel*

INTRODUCTION

Earthquake is a natural phenomenon that often occurs in Indonesia. The summary of the study results by Indonesian earthquake revision team (2010) shows that high earthquake activity in Indonesia revealed by the record in the span of time between the years 1897 to 2009, where more than 14,000 seismic events with a magnitude of more than 5.0 richter scale.

On may 2006, Yogyakarta has experienced the most dangerous earthquake which killed thousands of people. Media Center Gempa DIY (2006) has recorded that almost 5.743 people were killed, 38.423 were injured, 126.932 families lost their houses, 183.399 families got major damage for their houses and 259.816 families got minor damage. The data shows that there are large number of families lost their houses caused by earthquake and many of them were killed. Naturally, earthquake doesn't kill people, but buildings do. That means, the people were killed by the falling of building parts when earthquake occured. A large number of casualties was caused by the parts of building collaption which originated from the weakest structural damage of the building. That the weakest structural damage of the building was known as the structural joint system. Earthquakes dominated by lateral loads cause the building shifts sideways and damages its joint system. Prawiro et all (2010), stated that G-Feet Structural Joint System is the future alternative reversible structural joint system designed based on gecko's feet concept. The research of Andari et all (2011) showed that it works optimally to the shear stresses, which is mostly created by lateral forces of earthquake and will become stickier. Sticky brushes refers to the ability of joint system in which can easy to stick and become strong enough while receive 10 tons/m^2 load. This can be happened due to the geometry of sticky brushes which are becoming the locking system of the joint system.

Based on these problems, then obtained an idea to apply these findings in the design of earthquake resistant houses that use sticky brushes based joint system (G-feet joint system) as a solution of the strong and quake-resistant portable house design.

Earthquake

An earthquake is a vibration or shock that occurs on the surface of the earth. Earthquakes usually caused by the movement of the earth's crust / tectonic plates (http://id.wikipedia.org/wiki/gempa_bumi, 2009).

Indonesia has high opportunities for experiencing an earthquake, it can be happened because Indonesia had been traversed by active mountains path and geologically to be the meeting of tectonic plates that cause earthquakes (Figure 1).

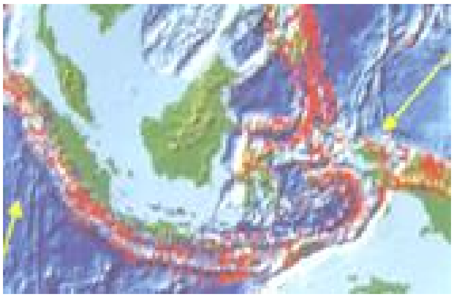

Figure 1. Indonesia Earthquake Map
Source: ReIndo dan BMG, 2009

Buildings that affected by the earthquake, there are specific symptoms that is interesting to observe, almost all of the buildings that collapsed, the main damage lies at the confluence of the structure, rather than on the structure holders. Then, it is concluded that the connection system plays a key role in anti-earthquake building beside the main structure itself (Figure 2).

Figure 2. Buildings after Earthquake
Source: http://www.scribd.com/document _downloads/7201221?extension =pdf

In Figure 2, picture (a) shows the column structure still intact but the joints between columns with beams have broken. In figure (b), flat roof beams remain intact and collapsed to the side because of disruption of connections between columns and beams. In the picture (c) shows the connection that damaged by the earthquake. In figure (d) shows that there are cracks arising at the junction between the beams and floor above.

Earthquake Resistant Structure

In order to withstand the loads from any direction, the building must be able to withstand the load of two orthogonal angles. Building designer will typically consider the factor x and y separately. Earthquake loads from any direction can be used as components of x and y that can be retained by the building (Figure 3 to 6) when the load comes from two directions. Charges can be held by the following pressure:

a. Horizontal pressure should be channeled to the ground (seismic Load Line)

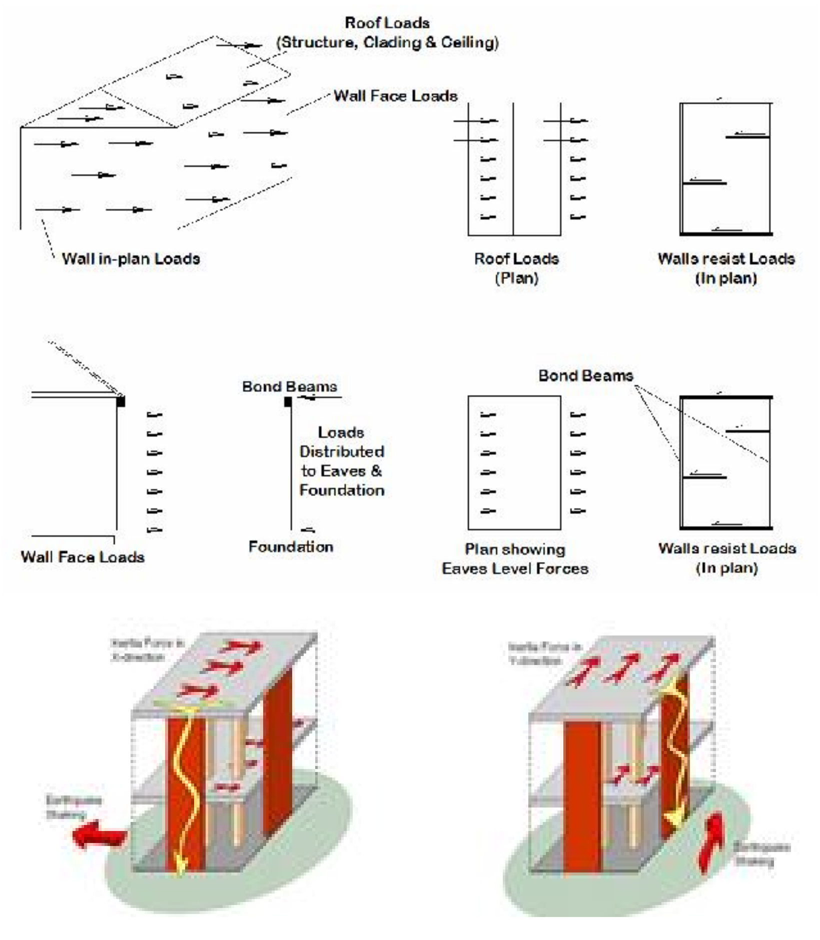

Figure 3. Chronology of Horizontal Force on Building
Source: Szakats, Gregory A.J, 2006

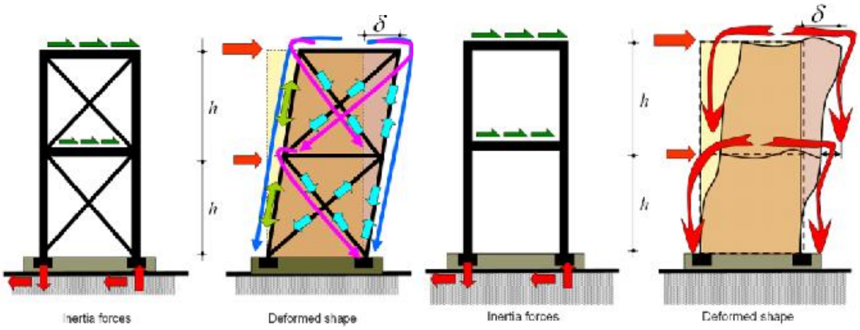

Figure 4. Bracing to Retain a Building.
Source: Szakats, Gregory A.J, 2006

b. Framework as Tension Retaining
Retaining special voltages are often used in low-rise buildings (up to two storeys):
- Framework as tension retaining using steel holder efficiently, using tensile strength.
- If attacked lateral loads, only tension retaining that carry the load; retaining pressure is not carrying the load. (Szakats, Gregory A.J, 2006)

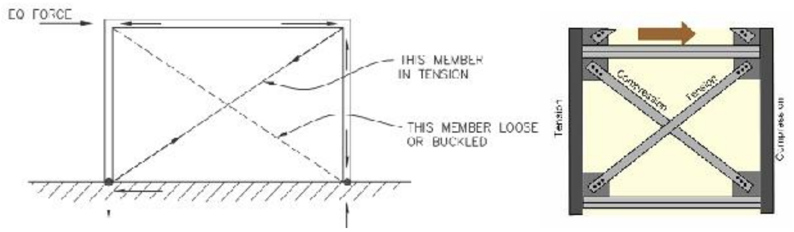

Figure 5. Framework as Tension Retaining
Source: Szakats, Gregory A.J, 2006

c. Floor Diaphragm

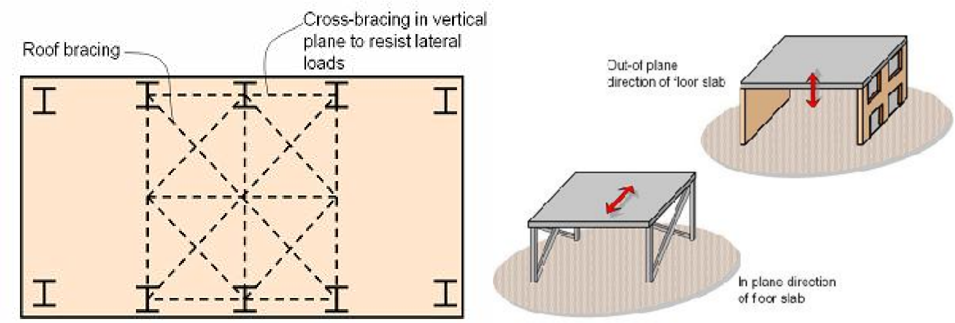

Figure 6. Floor Diaphragm
Source: Szakats, Gregory A.J, 2006

G-Feet (Gecko Feet) Joint System

Prawiro *et all* (2010) say that the variety of the joint system assessed based on the context faced by the designers of the joint system. G-feet (Gecko Feet) is a future and eco friendly alternative joint system which is designed based on the working principle of gecko's feet that have the ability to: (a) easy to stick, (b) locking system, (c) long-time usage and (d) re-usable (Figure 7 and 8).

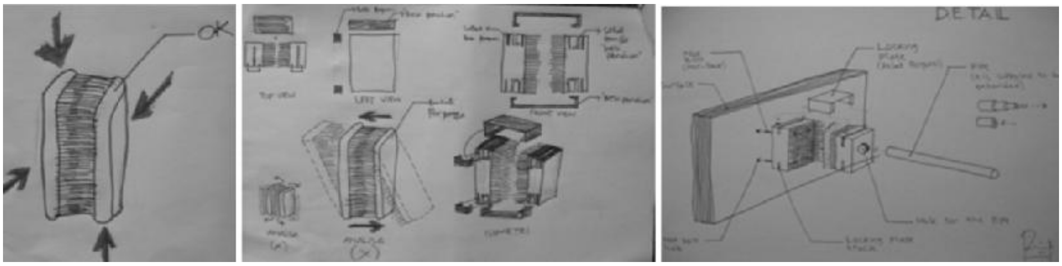

Figure 7. One Level hierarchy of G-feet Joint System
Source: Prawiro et all., 2010

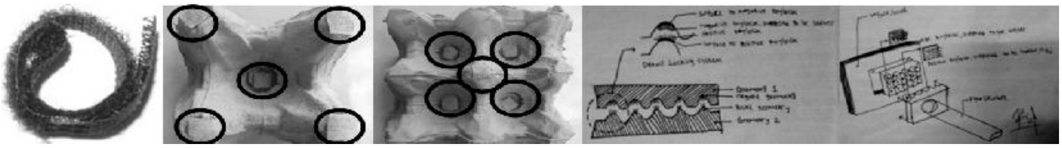

Figure 8. Two Level hierarchy of G-feet Joint System
Source: Prawiro et all., 2010

"Sticky Brushes" is a main part of G-Feet (Gecko Feet) joint system because of its strong adhesive as a joint system. This is appropriate with the principle of gecko's feet, that are easy to stick on a surface due to a vander walls force occurs between spatula and tip of a spatula on a surface of object (Nyssa, 2009). These are the following sticky brushes research data that can be used as a reference in designing the sticky houses (Table 1).

Table 1. The Recapitulation Physical Test on Hook and Loop System

Type of sample	Pull test		Moment test		Sliding test	
	Hook's tension (kg/cm^2)	**Loop's tension (kg/cm^2)**	**Hook's tension (max) (kg/cm^2)**	**Loop's tension (max) (kg/cm^2)**	**Hook's tension (kg/cm^2)**	**Loop's tension (kg/cm^2)**
A	0,494	0,343	0,344	0,600	1,000	0,887
B	0,470	0,199	0,264	0,157	0,761	0,489
C	0,234	0,144	0,098	0,123	0,596	0,482
D	0,239	0,097	0,126	0,186	0,664	0,394
average	0,359	0,196	0,208	0,267	0,755	0,563

Source: Andari et all, 2011

Portable Houses

The case studies that can be integrated with G-feet joint system design in designing portable house are the compact house and log home. Log home is a design principle of a joint system using wood blocks arranged into a form fields. The compact house is a simple functional building which is formed by the material unity intact. This several advantages can be applied to G-feet sticky house with a more modest home design in one piece of material that used g-feet joint system, so it does not need to take a very long production time (Figure 9).

Figure 9. From left to right a) compact house, b) log home
Source: Stewart, 2012

RIA ITS in Aceh

During post-disaster period (2005) after tsunami hit Aceh ,member of The Laboratory for Housing and Human Settlement at ITS (Institut Teknologi Sepuluh Nopember) designed a non-conventional approach to post-disaster housing construction with limited local support and readied it sooner than the end of emergency period. The house called RIA, which stands for "Rumah ITS untuk Aceh" or "ITS House for Aceh" (Setyawan, 2010). For more details see Figure 10.

Figure 10. From Top to Bottom a) Built Process, b) Result
Source: Setyawan, 2010

The basic components of RIA were as follows :

1. Made from simple materials and with simple tools.
2. Easy to be built in any kind of place; did not depend on special site situation
3. Earthquake resistant
4. Flexible enough to be modified for functions other than housing, such as office, market, school, clinic, prayer house, etc.
5. Easy to be further developed by the victims for post-occupation needs

Methods

Earlier methods of research used a concept of input-process-output (Figure 11). For input data there are literature study on earthquake resistant connection systems, a variety of portable house design and earthquake resistant buildings, then the data are processed by selecting the appropriate material and then use method of trial and error on 3d modeling and continued with the making of a mock-up to get G Feet Sticky House ideal form.

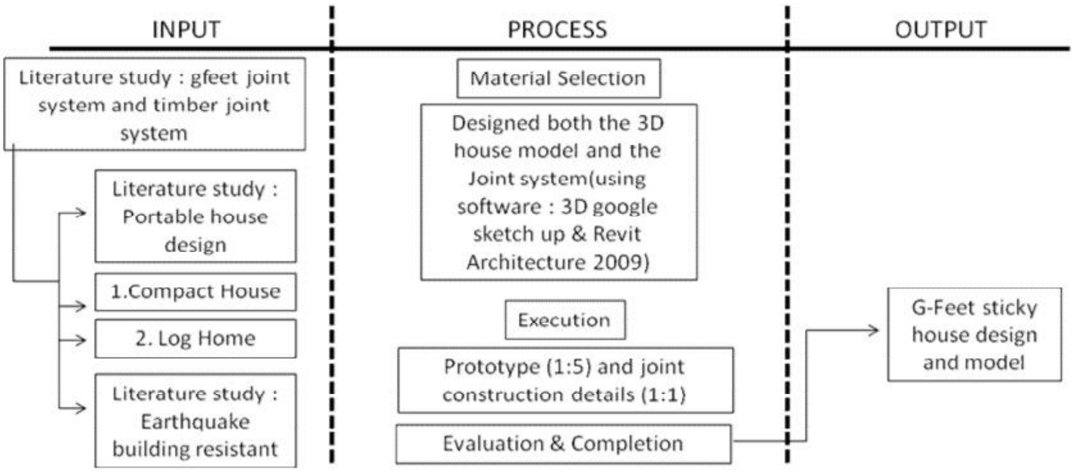

Figure 11. Methods
Source: author documentation

RESULTS AND DISCUSSION

Here are the results according to the above methods (Figure 12 to 16):

1. Design principle of gfeet sticky house joints for each modul
   a. Joints between the straight plane (x-x, y-y, z-z)
   b. Joints between the angled plane (x-y, x-z, y-z)
2. Mock-up of Gfeet sticky house joint system (scale 1:1)
3. Gfeet sticky house model (scale 1:5)
4. Gfeet sticky house manual book to ease of the assembly

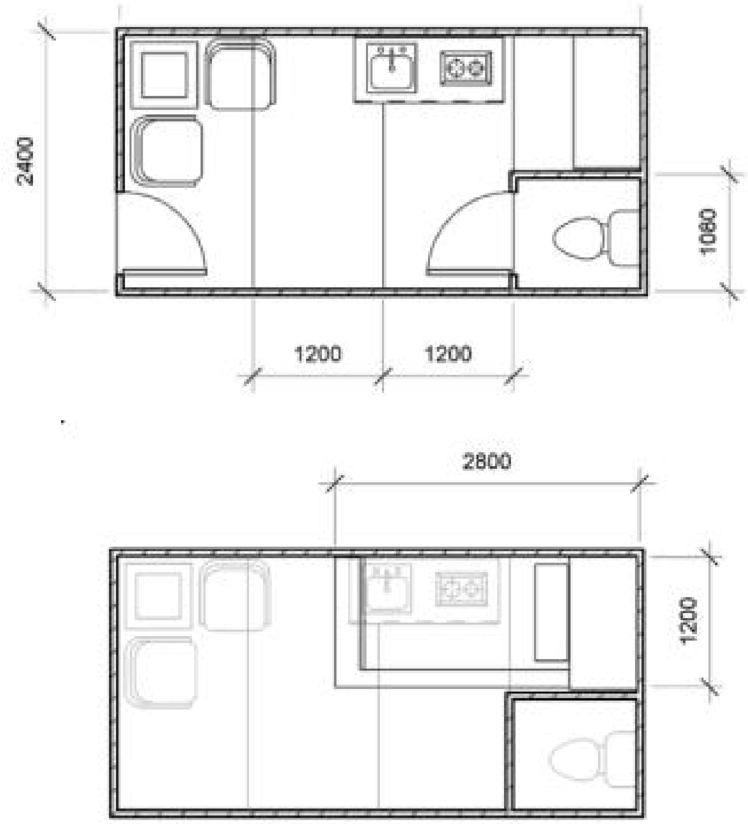

Figure 12. Plans
Source: author's documentation

Figure 13. Perspectif View
Source: author's documentation

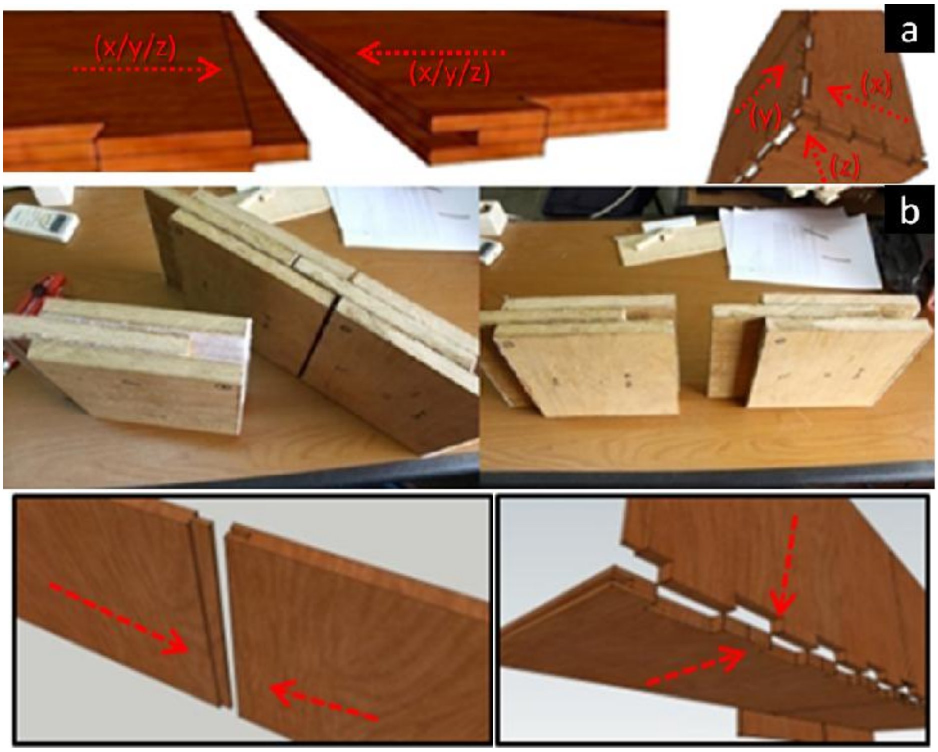

Figure 14. G-Feet Sticky House Details:
a) Joints between the Straight Plane and the Angled Plane,
b) G-feet's Joints Mock-up (scale 1:1)
Source: author's documentation

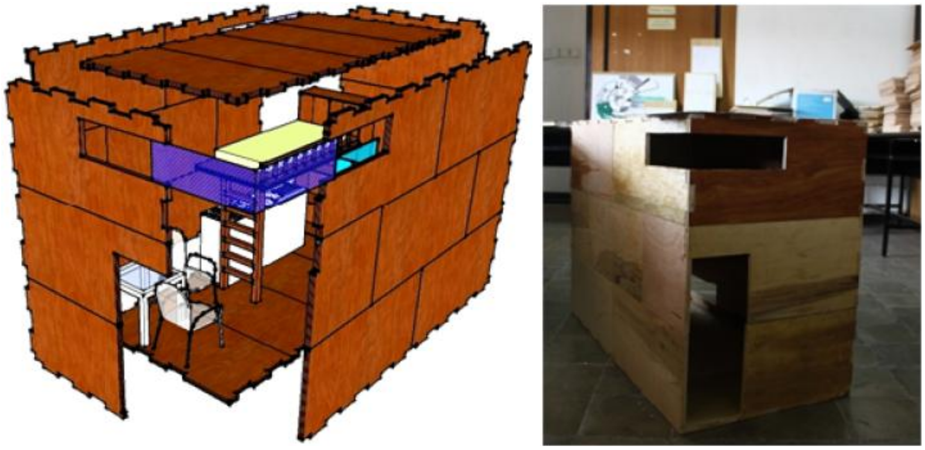

Figure 15. G-feet Sticky House Design and 1:5 Model
Source: author's documentation

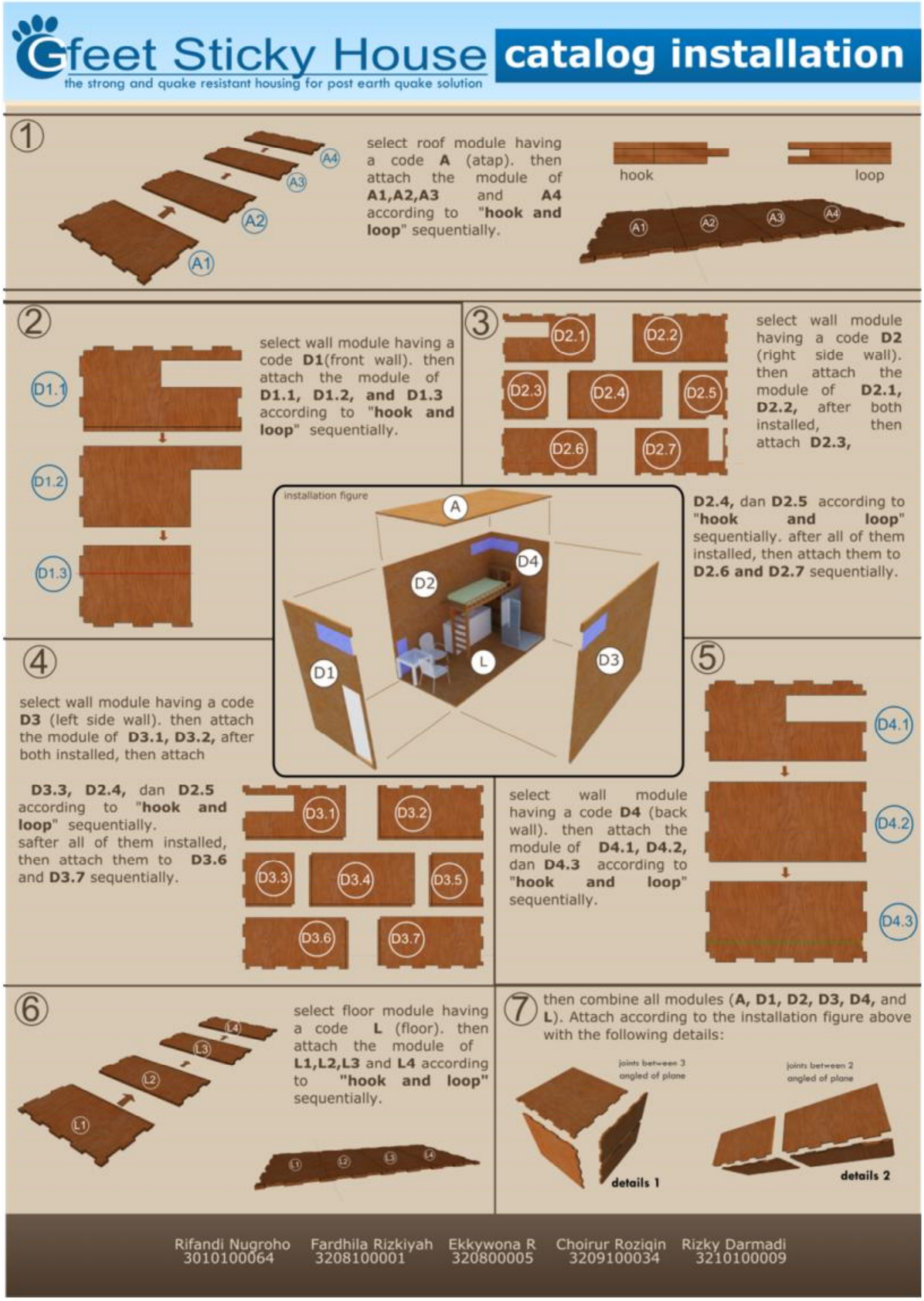

Figure 16. G-feet Sticky House Manual Book
Source: author's documentation

CONCLUSIONS

1. G-Feet sticky house is the model of portable house which was strong designed by using the easily stick materials. Thus, it safe from the quake.
2. G-feet sticky house joint system has a different design type following both the pattern of a straight plane (xx, yy, zz) and the pattern of an elbow plane (xy, xz, yz).
3. G-Feet Structural Joint System application on earthquake building resistant structure system has shown by the application of locking system on the edge of each module. This locking system makes each module connected each other. Thus, it become a strong unified (rigid) when exposed to lateral or axial force during the quake.
4. G-Feet Sticky House design, which applied G-Feet Structural Joint System on their structure system, produces the simple house design in a beam shaped. This simple beam shape was selected according to the efficiency of installing process.

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