The Study of Alternative Wooden House Construction base on People Ability

W Poomchalit[1], K Suzuki[2], A Suzuki[3]

[1] Graduate school of Science and Technology, Kyoto Institute of Technology, Kyoto, Japan. e-mai: walanrak_p@rmutt.ac.th

[2] Graduate school of Science and Technology, Kyoto Institute of Technology, Kyoto, Japan

[3] Graduate School Of Science, Kyoto University

Abstract. For communities in Thailand that carries day-time dwellers of aging people, women and children especially old communities that is mostly contained of wooden houses, strength of building structure has been depended upon the ability of maintenance of people. Even wooden houses are generally seen but craftsman carpenters are not enough available and more expensive. Thought, they are easily built with basic tools and skill as cutting and hammering but, their strength is varied because they are also related to personal vitality and ability in construction and budget. Under the study framework, the relationship of personal construction ability and load carrying of structure are the main consideration to explore an appropriated method of wooden house reconstruction that is strongly enough for live load, easy for everyone to build and reduce the cost. It must promote sustainable conservation and development while it is contributing sufficiency living. So, actual load carrying has been investigated by measuring of house and furniture before calculating. An ability has been tested by target groups' workshops. The data has been classified by types of material; reused woods and general construction woods, basic tools as hammer and nails and 2 methods of construction; cutting and joining. Two data has been compared and matched together to find the decent alternative. It seems that, the alternative material probably suitable for people's ability but it needs more design to strengthen and makes it easy to construct. *Keywords. Timber structure; Wooden house; Alternative construction; Sustainable; People ability.*

1. Introduction

Nowadays, in general, houses and residences in Thailand are always made of permanent materials such as reinforce concrete. But, there are some groups of houses that have been made of wood. They are old houses in original settlement age around 100 years and low-income people's houses that have been made by dwellers themselves or local carpenters. So, mostly of those houses are in an unattractive character by the reason of construction skill and ability of maintenance.

Normally, wooden houses in Thailand are always constructed with hardwood. Their density of dry wood approximately around 720 kg/m3 up to more than 1000 kg/m3
[2] because Thailand is located in the tropical zone, humidity and insects are important factors that destroy building structure. So, hard wood is suitable to use for building live-time extension. But it requires the craftsmanship carpenter to construct. While number of craftsman carpenters are decreasing but hire cost is increasing, it is difficult to maintain those wooden houses as well by the reason of household economic and income.

In the previous study, old communities and low-income communities are contained of the similarly main group of aging people, women and children. Therefore, ability of house maintenance depends upon the condition of people vitality, living behavior, and construction cost that has been resulted to construction technique [8]. This means, construction technique is related to ability of construction tools usage, live-load carrying of houses, material selecting, joinery and the limitation of payment or investment for reparation or reconstruction. However, there are many additional conditions that must be considered but in this research only focuses attention on wooden houses reconstruction by the dwellers themselves. Load carrying of building and ability of people to make the strengthen joinery based on several materials are the main consideration factors.

2. Research Objective and Framework

2.1Reaearch objective

According to the introduction, this research is focused to explore an alternative construction or maintaining method for wooden houses that matched together with the vitality of dwellers, common tools, available materials and cost reducing.

2.2 Research hypothesis

According to construction wood types that have been used in Japan Architecture from the past to present are included of Japanese Cedar, Japanese Cypress, Japanese Walnut, Japanese Larch, Umbrella Pine, Evergreen Oak, Hemlock Spruce, Chinquapin and Chestnut [5]. Comparing with construction wood in Thailand, these woods are contained of lower density than Thai construction timbers. Follow the standard 1002-16 of the Engineering Institute of Thailand [2], those density ranges are classified as medium-softwood to softwood or very softwood because of the density values are approximately around 300-650 kg/m3. as follows ;

Table 1. Density Of Construction Timbers In Japan

Wood type [5]	Density (kg/m3) [3]
Japanese Walnut	650-700
Japanese Cedar	300-420
Japanese Cypress	510
Japanese Larch	500
Umbrella Pine	350-510
Evergreen Oak	600-900
Hemlock Spruce	400-700
Chinquapin	515
Chestnut	560

However, when considering on the area of the building, especially the residence, it has been found that the structure of ancient Japanese architecture and residence are post and beam structure [9]. For the residence, the bay of posts is in various ranges of 3-12 feet or 0.90- 3.60 m. (Fig. 1.) [4].

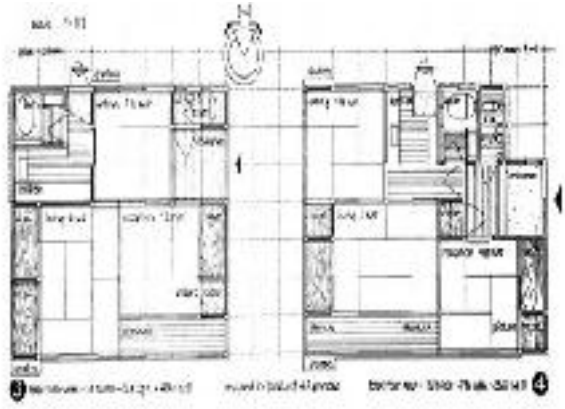
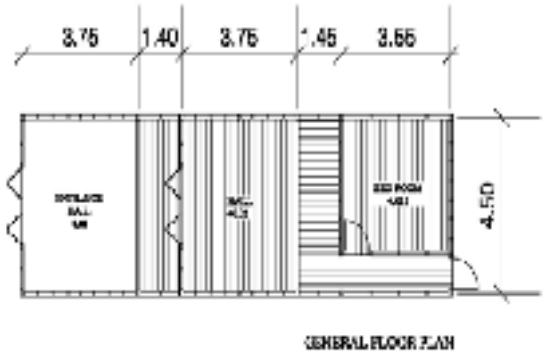


Figure 1. Example of Dimension of Japanese House Planning [4].



Source: Surver

Figure 2 Character of houses; dimension and proportion in study area

Compared to wooden houses in the study area, the range of bay between columns is between 1.00-3.75 m. It is similar together with Japanese houses. So, the question of the research is, if the resident especially daytime dwellers that consisted of old people, women and children unable to build a structure of hardwood that strong enough to support the living live load so, is it possible to use another type of lower density wood for reconstruction? Because, by their vitality of aging and women who are

the main residents in community [8], maintaining ability may be able to be improved if they choose matching material for their construction skills.

2.3 Research framework.

Follow the standard 1002-16 of the Engineering Institute of Thailand [2] has classified construction wood into 5 types such as ;

1) Very soft wood; The density is approximately around 450-630 kg./m.
2) Soft wood: The density is approximately around 550-700 kg/m3.
3) Medium soft wood: the density is approximately around 700-900 kg/m3.
4) Hard wood: The density is approximately around 850-1000 kg/m3.
5) Very hard wood: the density is more than 900 kg/m3.

General wood that has been used for building is the type of hardwood that very heavy and requires skillful of construction. That means, standard strengthen must be built with standard skill and type of wood. So, if the skill or type of wood is changed, it has been resulted to structure strengthen also. Therefore, the framework of this research was set based on density of construction wood which included of hardwood and softwood. It is because of the hypothesis, if the construction wood changes from hardwood to softwood, the people need other construction method to make that structure still be on the standard strength. It is the appropriated technology.

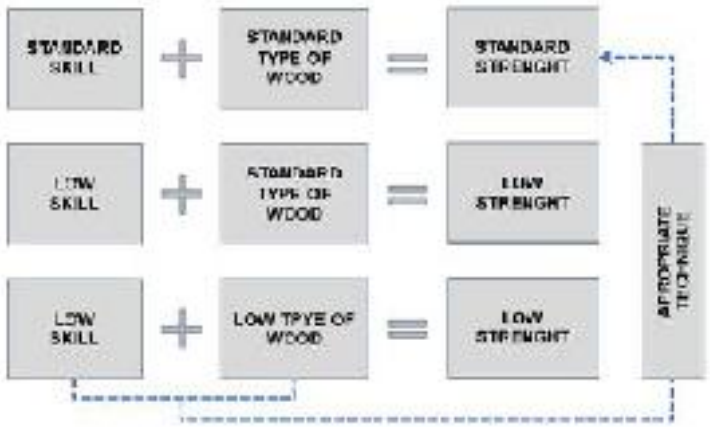


Figure 3. Research framework.

From the framework, standard type and low type of soft wood were tested to explore the efficiency of construction skill. If the skill of people gives low strengthen and efficiency, it will require an appropriate technique or method to resolve and increase more strengthen of structure.

3. Proces Of Research Results

Follow research hypothesis and framework, the concept of methodology in this research has been determined on the basis of 3 dimensions of the focusing criteria of house, people and material.

1) Strengthen means to the appearance in a stable or unstable of “Houses”. To improve and conserve the livable value of those houses, gerneral character of them was serveyed and measured to identify pattern of structure, joinery and dimension of materials. The classification of dimension and material must be used to create testing model.
2) Skill means to ability or vitality of “People” to construct or build a structure or part of house. So, in the process of understanding people were motivated to create individual structure with the join that they can produce by themselves with the determinated wood type.
3) Type of wood is related to the type of “Materials”. Several type of interested groups of wood were tested in a scale of testing model. The change of material has been set on the basis of the relationship of hardness and vitality of poeople to explore construction efficiency.

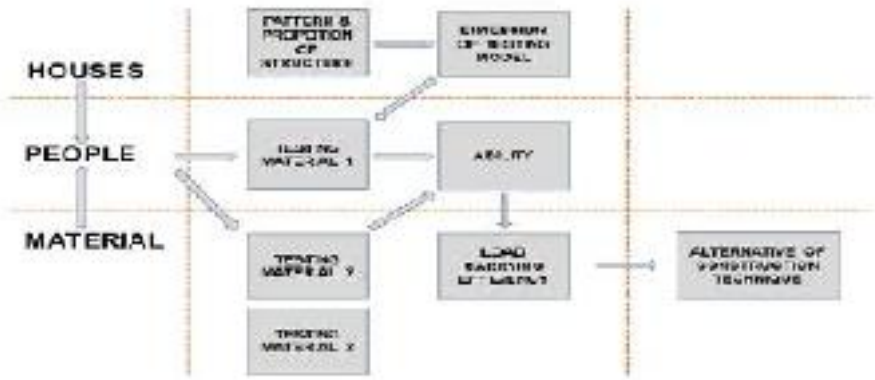


Figure 4. Concept of process determination.

Research procedure were divided connected to each subject. Several tools that are suitable for each step of those topic were used. Results of each part were compared together. However, it has been possible that result of one part will be connected to results of others.

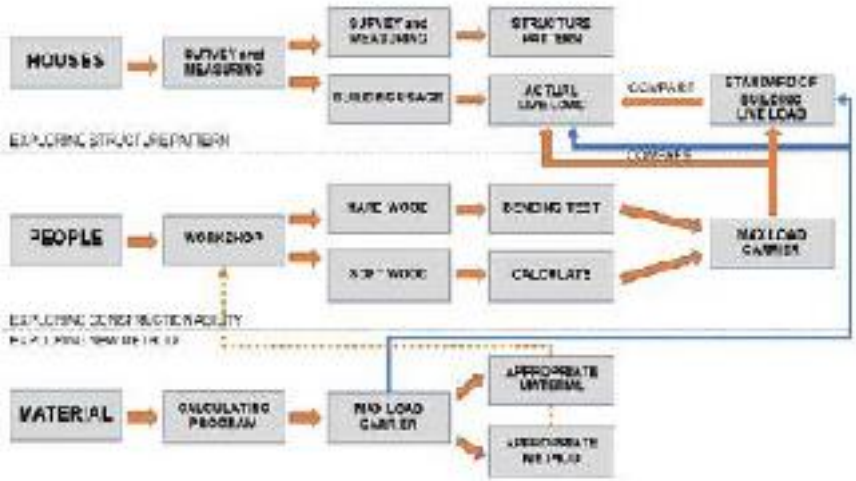


Figure 5. Research procedure flow chart.

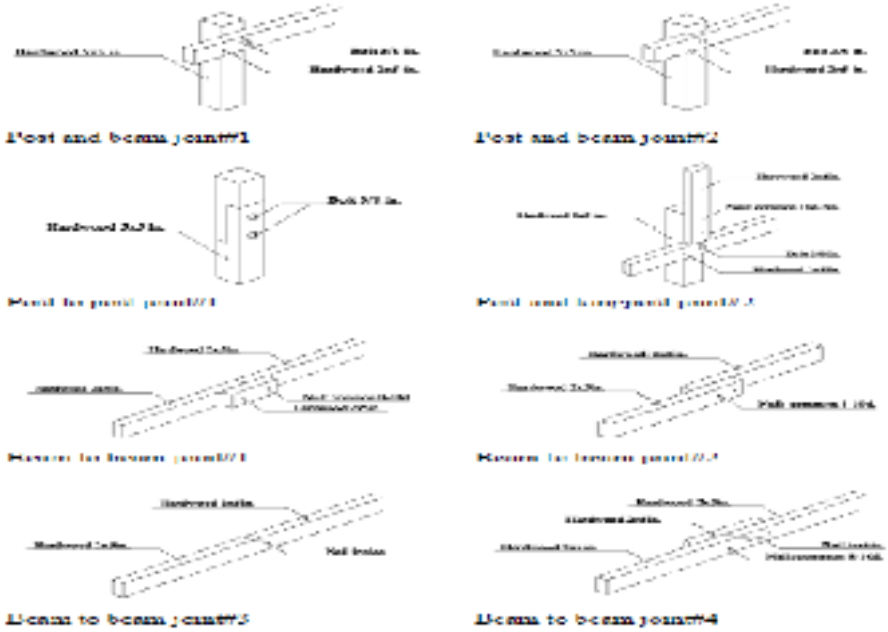
Follow Fig.5., to describe the relationships between construction ability of people that produce a result of strength and efficiency of load carrying of structure, research procedure has divided into 6 sub-sections :

Table 2. Description And Tool Of Sub Section Study

Building/ houses	Study of building	Part I	Pattern, function, area, dimension and proportion, structure system and joinery.	Survey check list Measuring
People/ dwellers	Study of Behavior of use	Part II	Building used from dweller's behavior.	Measuring of furniture Calculating
	Study of Constructio n abilit y	Part III	Type of tool, structure pattern, craftsmanship, connection and joinery	Workshop
Material	Study of strengthen	Part IV	Finding of maximum load of structure.	Testing with

				Universal Tsing Machine (UTM)
Relationship between people and material	Efficiency of constructed	Part V	Comparing maximum load from workshop and calculated to find efficiency of the people to construct.	Calculated Program; AWT and Cornell University model.
		Part VI	Calculating load carrying in the scale of real structure and design.	Next study

Part I is a study of houses and buildings. Dimension and proportion of the building, usage, building function, structural materials, methods of joint and so forth were survey and measured. The checklist sheet and data collecting form were used as tools in this part. From surveying and measuring, structural components of houses in this community have been similar together. They were constructed with Post and Beam system. For this study area, size of the pole is approximately around 5x5 inches. The beam is approximately around 2-2.50 inches of thickness and 4-5 inches wide depending on their position on house structure. The widest bay is 3.75 m. and narrowest is only 1.00 meter. The original houses were 1-story-house covered with high slope of gable roof. The ratio of the distance between floor to crossbeams and crossbeam to ridge pole is near 1: 1 in dimensions. Most joints are fixed with nails. But, there are only some areas such as connecting between the pole and floor beams are fixed with bolts. However, for some buildings, the nails are used to joining all entire structures.



Source: Surveying.

Figure 6. Character of joint on vertical and horizental componants

Part II is a behavior study of building or house usage. So, this section focuses on living activities that generate live load on the main structures. Mostly in older buildings, there is usually a lot of unnecessary belongings. So, in this step, only specific furniture used in everyday life is collected. By collecting data, it was classified information into 6 categories; 1) wardrobe, 2) beds, 3) shelves, 4)

cabinets or cupboards, 5) chairs and tables and 6) other such as electrical appliances. All dimension of furniture and sub-elements were measured and calculated the weight of each one. Then, average weight per area will be calculated and compared with the standard value under the Building Control Act 1979; 6th addition 2017 [7] that has controlled of live load carrying of residential building which is set at 150 kg/m3. Based on the results, it was found that 15 buildings from 19 occupied buildings had a live loacarrying between 10-80 kg/m3 (table III).

Table 3. Actual load carrer of building in study area

Bld. Code	Area (m2.)	House member (Person)	Total weight	Actual Load Carrying	Total Load carrying	Avg. (kg/m2.)
*009	60.00	5	300	1,416.42	1,716.42	28.607
*395	70.18	3	180	1,575.34	1,755.34	25.011
*399	36.00	2	120	924.47	1,044.47	29.013
*403	77.40	10	600	3,716.45	4,316.45	55.768
*405	57.75	5	300	4,263.89	4,563.89	79.028
*407	151.14	8	480	2,076.61	2,556.61	16.916
*409	36.00	1	60	896.81	956.81	26.578
*413	94.90	4	240	1,041.35	1,281.35	13.502
*415	62.55	2	120	557.76	677.76	10.835
*419	96.03	9	540	2,390.64	2,930.64	30.518
*421	74.12	6	360	1,307.27	1,667.27	22.494
*423	103.20	5	300	2,864.77	3,164.77	30.666
*427	70.18	5	300	1,604.72	1,904.72	27.139
*431	35.30	2	120	2,132.70	2,252.70	63.816
*433	50.00	5	300	1,940.85	2,240.85	44.817
AVG.	69.42	4.63	277.50	17.87	1,914.00	31.75

Source: Surveying.

Part III is a part of construction testing. In this part, structures through the workshop based on the information from Part 1 to determine the size of the model were tested. By the size and proportion of the beam that is focused, structure model was create in the size of 1.5x3 inches or approximately 3.75 cm. of thickness, 7.50 cm. wide and 1-meter long. Wood materials were divided into two groups of construction wood. Group 1 is the wood that was contained of hard wood which ages and types have corresponded to building ages. Group 2 is the most common construction timber with the cheapest price. It is because of controlled factors and consideration conditions for building conservation according to the previous study that consisted of construction budget, ability of residents and materials used [8]. Therefore, common tools that easiest available were set as workshop tools as Fig. 7.

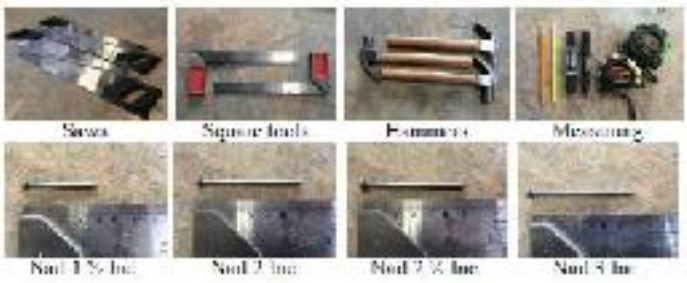


Figure 7. Common tools that were used in workshop.

To test their ability, activities of workshop were divided in 2 parts; part of cutting and joining as Fig.8 and Fig. 9.

Figure 8. Workshop activities.

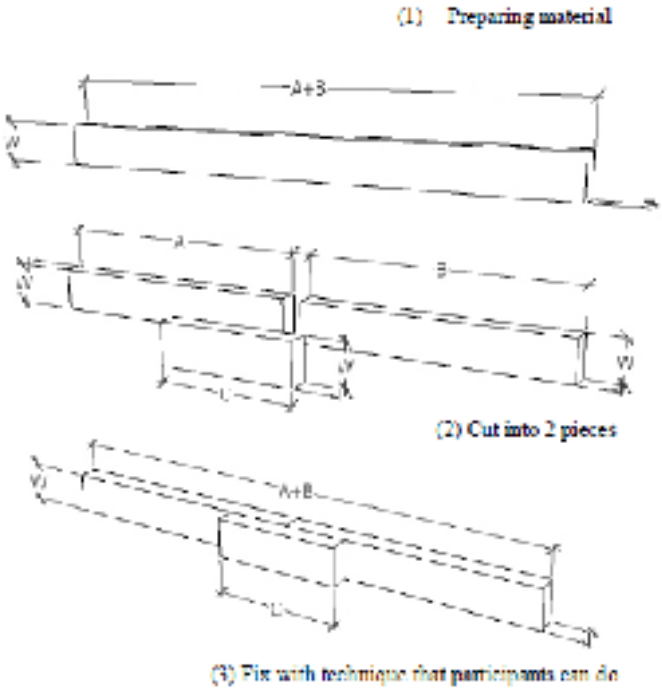


Figure 9. Proces of making the testing model

In this part, from the total of 19 households, eight households attended to the workshop. Represented 88.89 percent of the participants are women. The youngest participant is 12 years old and the oldest is 70 years old. The results were as table IV.

Table 4. Qualitative Result Of Workshop.

Model	Old used wood		Cheapest price wood	
Code*	Nail size	Description	Nail size	Description
MD70	8d 2.5 in.	There are a few cracks along the grain around nailing. The joint is still tight but, can move while rocking.	8d 2.5 in.	Nailing distance is quite fitful, tight and does not move while rocking
MD65	8d 2.5 in.	The joint is tight and does not move while rocking.	8d 2.5 in.	Nailing distances are not fitful. But, the joint is still tight and does not

				move while rocking.
MD57	10d 3.0 in.	There are lightly cracks on the area of joining. But, the joint is still tight.	8d 2.5 in.	More nailing than other and very tight.
MD44	8d 2.5 in.	There are lightly cracks on the area of joining. There is a part of some nails were left out of wood parts.	8d 2.5 in.	Nailing distance is quite fitful, tight and does not move while rocking
MD40	8d 2.5 in.	There are serious cracks on side member. The join always moves.	8d 2.5 in.	Nailing distance is quite fitful, tight and does not move while rocking
MD29	10d 3.0 in.	There are a few cracks along the grain and the joint is not tight.	8d 2.5 in.	Nailing distance is quite fitful, tight and does not move while rocking
MD16	8d 2.5 in.	There are a few cracks along the grain and nails length exceeds total connection thickness.	8d 2.5 in.	Nailing distance is quite fitful, tight and does not move while rocking
MD12	10d 3.0 in.	There are lightly cracks on the area of joining. But, the joint is still tight.	8d 2.5 in.	More nailing than other and very tight.
* MD = Model Number = Age of participants				

By the result of workshop has shown the qualitative characters of structure creating by dwellers themselves. For the old wood that caught the same range of age and density of the really remaining houses, the created structures are not in the concrete character. They do not fix as well. The joints have been flexible. Some of them were cracked and did not stable enough to call strong structure. The people have told about working through the hardwood that they are very hard, heavy and difficult to cut or hammering with nails. However, For the cheapest price of construction wood, the appearance of structures from workshop looked better than the structures from first group. They are the general type of construction wood but not suitable for the building. They are contained of several kinds of wood and their density are 460-630 kg/m3. Their soft and light weight made them easy to cut and hammering and they have been given a little different pattern of joints.

Part IV is a strengthen testing of model structures that were made by workshop in part III. To find out of maximum load carrying, those structures were used to perform the Bending test using the Universal Testing Machine (UTM). This experiment utilized a 4-point load-bearing approach at 0.75

m. length of span (Fig. 10.) in which testing results were obtained maximum live load appears as Fig. 11.

Figure 10. Testing machine and preparing.

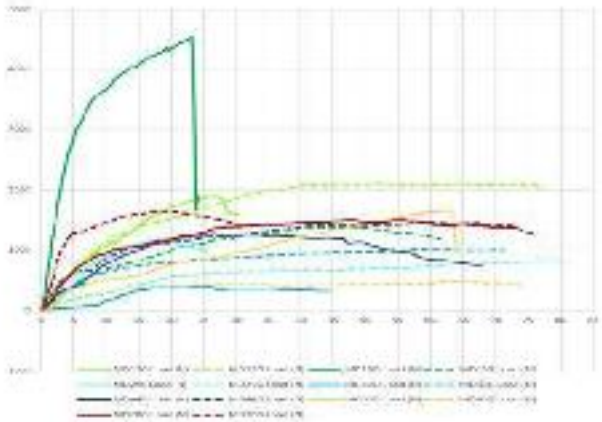


Figure 11. Maximum load result of model

From Fig. 11, it seems that by the dwellers who are aging, women and children, their vitality resulted to load carrying given by different types of material. The range of maximum load given from 2 types of material are similar together.

Part V is the calculation of maximum load carrying of model structures. By using the online programs; Wood Fastener Capacity Calculator of Cornell University [6] and Connection Calculator of American Wood Council (AWC) [1]. The calculated results will be compared with the results from part IV to find out the efficiency of loading capacity derived from construction skill of residents. In this part, the density of material was checked again by calculating with weight and dimensions of model. By any result, there is a model caught some error and cannot classify to any group. So, in this part, there are only 7 models to compare.

Table 5. Calculated Density Of Each Group.

Model Code	Old used wood (kg/m3)	Cheapest price wood (kg/m3)
MD70	769.83	623.13
MD65	826.41	576.58
MD44	719.97	594.67
MD29	854.63	577.88
MD40	811.22	498.10

MD12	840.34	466.45
MD16	850.80	588.83

Table 6. Calculated Max. Laod Capacity Of Uesd Wood

		Connection Calculator [6]		Wood Fastener Capacity Calculator (Calculate with White Oak) [1]			
Model Code	**Testing Max. Load (kg.)**	**Total (kg.)**	**ability (%)**	**Total (kg.) type IV**	**ability (%)**	**Total (kg.) type IIIs**	**ability (%)**
MD70	153.48	237.68	64.57	248.57	61.74	449.97	34.11
MD65	168.53	234.05	72.00	248.57	67.80	428.19	39.36
MD44	131.14	342.92	38.24	372.85	35.17	683.11	19.20
MD29	122.01	306.63	39.79	301.19	40.51	489.88	24.91
MD40	41.43	248.57	16.67	248.57	16.67	460.85	8.99
MD12	193.52	408.23	47.40	372.86	51.90	642.29	30.13
MD16	463.51	288.48	xx	301.19	xx	513.47	90.27

From table VI. by using the calculated program, the critical load was classified. However, the critical is classified by minimum load type of single shear connection. So, by the yield modes of common nailed wood-connection, the other types matched to corrupted behavior of nails of testing model were calculated and compared to their maximum tested loads. For these types, the efficiency of constructed ability of the people were given approximately between 35-70% by yield mode type IV and 8-40% by yield mode type IIIs [10]. However, by the size of fastener and method of construction, it probably gives higher percentage up to 90%.

Table 7. Calculated max load capacity of cheapest price wood

Model Code	Testing Max. Load (kg.)	Connection Calculator [6]		Wood Fastener Capacity Calculator [1]			
		Total (kg.)	ability (%)	Total (kg.) type IV	ability (%)	Total (kg.) type IIIs	ability (%)
MD70	168.52	172.17	97.77	188.24	89.52	395.80	42.46
MD65	91.84	128.82	39.47	150.50	34.76	372.07	16.29
MD44	149.00	182.34	81.71	225.89	65.96	481.72	30.95
MD29	85.29	157.85	54.03	150.50	56.63	292.11	29.20
MD40	103.81	206.84	50.19	193.95 *	53.98	332.03 *	31.26
MD12	214.93	254.01	84.62	246.75 **	87.11	491.90 **	54.83
MD16	142.85	153.88	xx	150.59	94.86	408.44	46.61

*was calculated with density of Douglas Fir-larch was calculated with density of Hemlock. Others were calculated with density of Red Maple. These types of construction wood were calculated with the types of American woods that give nearest value of density of the models. By the result that was given, both of calculation method mostly gave higher efficiency of construction skill.

4. Discussion

Even the hardwood is generally stronger than soft wood though, the method of construction and skill of the people were effective to their strength. By comparing the type of wood and the maximum load carrying of each model has shown that the type of material that matched to people's skill of construction and their vitality will give the similar results.

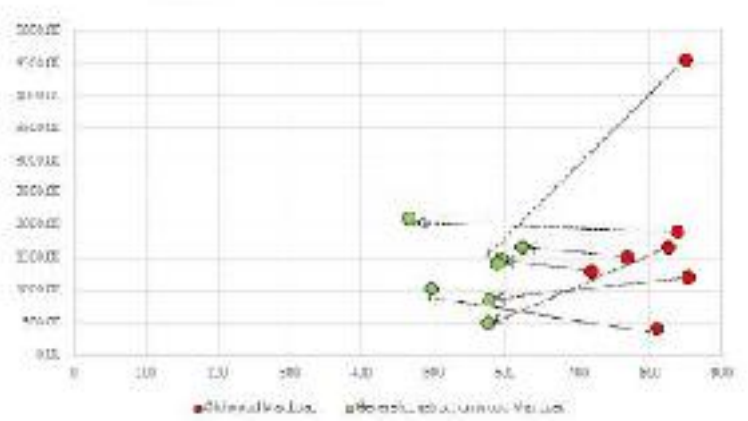


Figure 12. groups of max. load gave by hardwood and soft wood.

From fig.12., the group of red bullets are maximum load given by hardwood models and the group of green are maximum load given by softer wood. By consideration, even some of maximum loads were shifted down but, they are in the same range of maximum loads that were given by hardwood structures. It is because of characters of loading (fig.13).

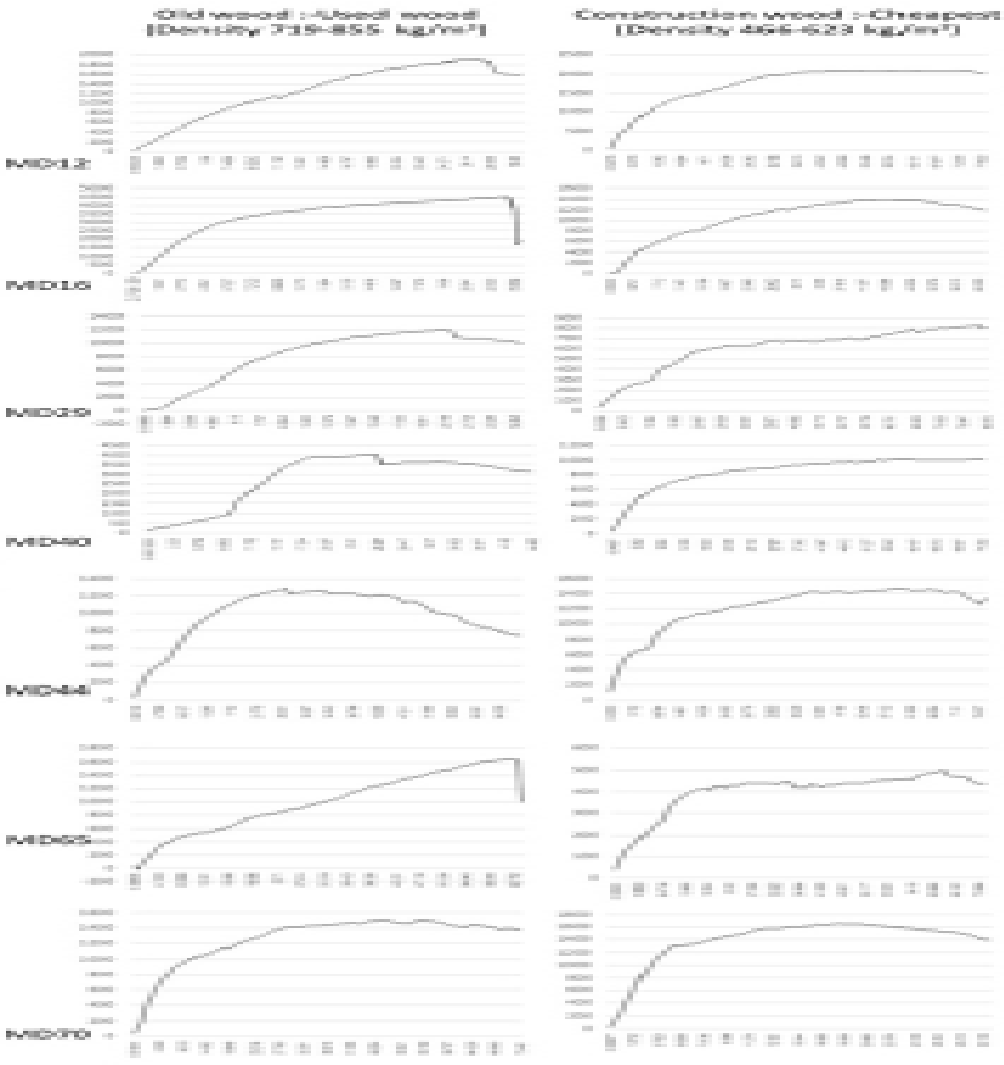


Figure 13. Loading characters of hardwood and soft wood.

There are several characters of hardwood model because the age of material and size of nails that the participants have chosen to create those structure model. They are resulted to the appearance characters and strength. The way of construction is an additional condition because of some positions of nailing, the people tried to fasten many times and it effected to the cracks that appeared on the model as part III's description. They are resulted to the graphs in fig.13.From the graphs and structural behavior while they were testing, load carrying of hardwood was related to the strength of the wood-type itself while load carrying given by softwood is relating to both of wood-type and size of fastener. They have been related to the construction skill and vitality of people also.

5. Conclussion

Changing of construction material matched to people ability needs other alternative method of construction. When the main material has been down grade, but it is suitable to people's ability, the structure can be strong enough to load carrying. However, there are many types of softwood in Thailand that can be developed for construction. So, it needs more design of fastener type, method of joining and other conditions to make the standard capacity.

6. Notification

Part VI is the next study because of the controlling of skill developed by replication. The time interval has been set. However, it is the process of calculation of maximum load carrying of real dimension of structures. Data collected in part I will be calculated with derived efficiency from part V and used for the design of alternative method before next workshop.

References

[1] American Wood Council (AWC). (n.d.). *Connection Calculator*. Retrieved August 29, 2017, from http://www.awc.org/codes-standards/calculators-software/connectioncalc

[2] Densities of Wood Species. (n.d.). Retrieved August 31, 2017, from http://www.engineeringtoolbox.com/wood-density-d_40.html

[3] Engineering Institute of Thailand (EIT). 2001. Standard 1002-16 Standard of Timber Building.

[4] Heino, E. (1985). *Mearure and Construction of the Japanese House* (1st ed., **Vol. 1985**). Singapore: Tuttle Publishing.

[5] Itoh, T. (2004). *Architectural Development of the Japanese House and Wood Species Used*. Retrieved from http://www.nara.accu.or.jp/elearning/2004/architectural.pdf

[6] Ochshorn,J. (2009). *Wood fastener capacity calculator.* Retrieved August 29, 2017, from https://courses.cit.cornell.edu/arch264/calculators/example9.1/

[7] Office of council of state. *Building Standard* Act 1979 5th edition 2017, Pub. L. No. Book 134, section 18A, The Government Gazette, 2017.

[8] Poomchalit, W, K. Suzuki, and A. Suzuki. (2017). "*The Relationship Between the Spatial Developments and the Change of Wooden-Houses in Original Settlements in the Expansion Suburban Area of Bangkok.*" presented at the 2017 Workshop on Urban Planning and Management, Sophia University, Tokyo, February 18.

[9] Schweitzer, R. (2004). *Traditional Japanese wood construction*. Presented at the Internationales Holzbau-Forum 2004.

[10] Tucker, B. J., Pollock, D., Fridley, K. J., & Peters, J. J. (2000). *Governing Yield Modes for Common Bolted and Nailed Wood Connections.* Department of Mechanical and Civil Engineering, George Fox University, United State.

[11] Yamato,S. (2006). *The Tradition of Wooden Architecture in Japan.* Retrieved from http://www.nara.accu.or.jp/elearning/2006/tradition.pdf