Verification of construction efficiency for test houses by 2-story CLT panel construction and 6-story wood frame construction (1)

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1. Introduction

The following 2 themes with constructing the test house and verifying the performance were adopted as the leading projects for timber construction technology funded by Housing Bureau, MLIT in Fiscal Year 2014.

- Test house applying the properties of CLT panel → (Japan CLT Association)
- Project of building the full-sized 6-story wood frame construction → Japan 2x4 Home Builders Association

- The verifying the performance were conducted as collaborative research projects with BRI. Results obtained through the building procedure of 2 tests houses would be reported here.

Photo 1 CLT test house (Veranda with cantilever panel)

Photo 2 Open space with the continuous wall

2. Test house of CLT panel construction

1) Outline of the test house and the verifying issues

The outline of the test house is shown in Table 1. The verifying issues are as follows, but The only issues of i) and ii) would be reported here.

i) Design of the floor plan applying the properties of CLT panel and the trial of structural calculation
ii) Building the test house actually and the verification of construction efficiency
iii) The long term deformation properties of the cantilever panel
iv) Evaluation of the comfortability (thermal environment, sound insulation, and floor vibration by walking)
v) Moisture desorption behavior on the flat roof due to rainfall under construction

Table 1. Outline of the CLT test house

Structure	CLT panel construction
Stories	2
Building area	130 m^2
Floor area	166 m^2
Height	8.98 m
Work period	Oct, 2015- Mar, 2016
Volume of CLT	114 m^3

2) Floor plan applying the properties of CLT panel

The veranda with 3 m cantilever applying the length of panel (Photo 1) and the open space (Photo 2) with the continuous wall applying the 6 m height were constructed, as shown in the floor plan of Fig. 1.

3) Objective and method to verify the construction efficiency

Because the CLT panel construction has started at 2012, there are not the established construction methods and details. In order to improve the construction efficiency, the objective is to obtain the basic data about the construction time.

4) Measuring method

The working time was measured manually and the working was taken by 5 fixed cameras (Photo 3) and the camera set at the end of the crane.

5) Results of measurement

The distribution of working time to construct each portion was shown in Fig. 2. The time to set the wall and floor panel were half of the total time. Because the numbers of wall and floor panel were 107 and 27, respectively, the setting a floor panel spent the time 5 times as long as setting for wall panel. The relationships between the size of the panel and the time spending to set the panel were not clear.

Fig. 1. Floor plan of the CLT test house

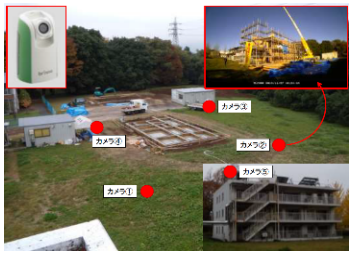

Photo 3. Position of cameras

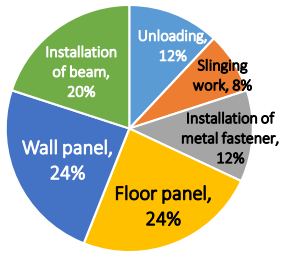

Fig. 2. Distribution of working time

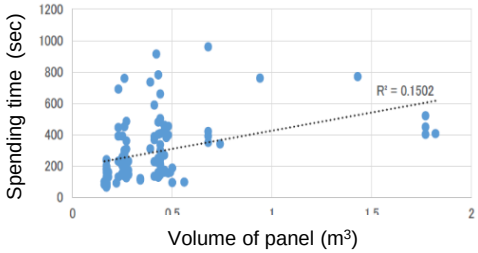

Fig. 3. Relationships between the size of the panel and the time spending to set the panel

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3. 6-story 2x4 construction

1) Objective

Applying the high capacity shear wall and 1 or 2-fire resisting structure which were already developed, the test house was completed (Photo 4 and Fig. 4) in order to verify the construction efficiency.

2) Verifying issues

This test house was subjected to verify 8 issues as followings. The verifying issue of iii) would be presented here.

i) Trial design of 6-story 2x4
ii) Structural calculation
iii) Construction design
iv) Performance to vertical load
v) Performance to lateral load
vi) Performance of openings
vii) Sound insulation
viii) Durability

Photo 4 the 6-story 2x4 construction

3) Outline of building and amount of wood used

The outline of the building is shown in Table 2. Amount of timber and each wood-based material used in the building is shown in Table 3. Total volume of wood used in it was 0.37 m3/m2 and much larger than 0.173 m3/m2 which is the volume1) used in ordinary 2x4 detached house. Thus, it is clarified that the mid-rise 2x4 construction contributes to promote the wood utilization. Amount of wood used in each part of building, ratio of domestic material and kinds of material are shown in Fig.5.

Table3 Amount of materials used in the 6-story 2x4 test house

	Member	Material		Volume (m^3)	
Wall	Frame	lumber	SPF: 1F-5F	26.7	
			Japanese Cedar: 6F	2.0	(2.0)
			Douglas Fir: High performance shear wall	2.4	
		GLT: High performance shear wall		3.1	
	Lintel	LVL		0.2	
	Board	Structural plywood		11.5	(5.7)
		OSB in Midply wall system of 3F and 4F		0.6	
		Structural particleboard (6F)		0.2	(0.2)
		Structural MDF (6F)		0.1	(0.1)
	Subtotal			46.8	(8.0)
Floor	Floor materials	LVL (1F, 4F)		6.9	
		CLT (2F)		8.0	(8.0)
		Stressed skin panel of LVL (3F)		3.4	(3.4)
		I-joist (OSB in web: 5F)		0.1	
		I-joist (LVL in flange,:5F)		0.2	(0.2)
		SPF on warren truss of 6F		2.7	
	Board	Structural plywood of all story		3.5	(2.9)
	Subtotal			24.8	(14.6)
	Flooring & others (each floor)			3.9	(2.8)
	Exterior wood siding (6F)			0.2	(0.2)
	Subtotal			4.1	(2.9)
Total amount				75.7	(25.5)

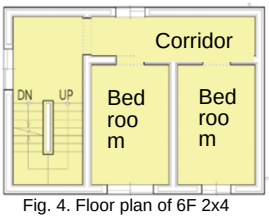

Fig. 4. Floor plan of 6F 2x4

Table 2. Outline of the test house

Structure	2x4 construction
Story	6
Building area	38.95 m^2
Floor area	206.09 m^2
Height	17.309 m
Work period	Oct., 2015-Mar., 2016

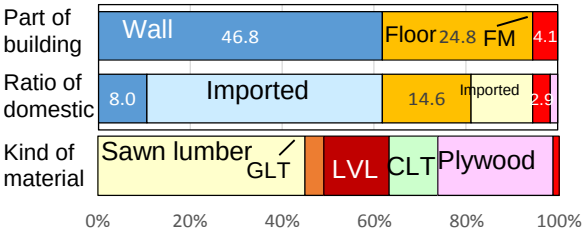

Fig. 5. Amount of material used in the 6-story 2x4 test house (m^3)

4) Man power to build

The distribution of working time for each procedure of the 2x4 construction which has been assembled with the prefabricated panel was shown in Fig. 6. The 28 man hour and day framing procedure corresponds to the 0.14 man hour per floor area and approximately the same as that of low-rise detached house. However, 0.07 man hour is needed to secure the accuracy of construction. As a result, the test house was constructed only with the error of 1.0-1.5/1000 in the horizontal and vertical.

Because the mid-rise timber construction was required to be fire resistant structure, the huge amount of gypsum board was installed. It is important to make the installation of gypsum boards efficient.

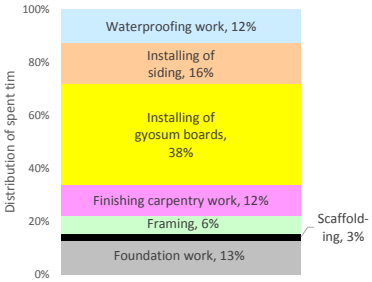

Fig. 6. Distribution of working time to construct the test house

4. Conclusion

As a result, the verification of construction sufficiency on CLT and 6-story 2x4 test houses made us find the properties, problems and improvable issues for each construction.

Reference 1) Q&A related to wood, http://www.zenmoku.jp/moku_pr/QandA/ask2-11.html, Japan Federation of Wood-Industry Association.