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論題(和文)	CLT 壁を有する RC 架構の耐震性能評価に関する研究：その 1 柱降伏型充填壁架構の実験計画
Title(English)	Study on the Seismic Performance Evaluation of RC Frame with CLT Panels Part 1 Experimental program on infilled frames with a column-sway mechanism
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Study on the Seismic Performance Evaluation of RC Frame with CLT Panels
Part 1 Experimental program on infilled frames with a column-sway mechanism

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Moment-resisting frame
Rocking mechanism Structural test
Reinforced concrete Wooden walls

1. Introduction

The construction industry is one of the largest producers of solid waste and CO_2, often using non-renewable resources. Cross-laminated timber (CLT) is a renewable resource that stores CO_2 throughout the building life cycle. Moreover, the CLT panels make the construction process easier, faster, and more sustainable. Since reinforced concrete (RC) frame buildings are used worldwide, using CLT panels in such structures would be an outstanding contribution to a sustainable society. However, most of the structural studies focused on structures entirely made of CLT or CLT with steel frames [1, 2], and only a few studies focused on the RC frame with CLT infills. Thus, the seismic performance of RC frames with CLT as infill walls is still not clear, lacking of an appropriate analytical model of its behavior. Hence, this study was performed to experimentally investigate the in-plane performance and propose an analytical model to estimate the seismic performance of the RC frame with CLT infills. Moreover, the applicability of the proposed analytical model was verified by comparing the experimental and the analytical results.

2. Experimental Program

2.1 Specimens and material properties

Four 40% scale specimens were designed considering the experimental parameters as presence/absence of CLT infill wall and connection methods of the CLT wall with surrounding RC frame, as shown in **Fig. 1**. The details of the column yielding type RC frame (BF specimen) which is the same for all specimens are shown in **Fig. 2** and **Table 1**. The other three specimens are RC frames infilled with two CLT panels (each of dimensions: 1200×600×86 mm in height×length×thickness), interconnected by anchors (6 mm diameter, 42 mm embedded length, and 60 mm pitch), as shown in **Fig. 1**. The connection method of CLT walls with the surrounding RC frame is likely to affect the relative deformation and the force transfer mechanism between RC members and CLT infills, thereby the overall performance of the RC frame. Hence, three specimens with different connection details between CLT and RC frame were designed, namely: WF, without any anchor connection between the CLT panels and the frame, WF_{BA} with anchor connection between CLT panels and beam only, and WF_{BCA} with anchor connection between CLT panels and both beam and column of surrounding RC frame, as shown in **Fig. 1**. The CLT infills were fixed such that the fiber direction on the surface (strongest direction) was parallel to the column height. The mechanical properties of the materials are summarized in **Table 2** and **Table 3**.

Table1 Specifications of RC frame and CLT wall

	Prototype		Specimen	
	Column	Beam	Column	Beam
B × D (mm)	550×600	400×800	220×240	190×320
Long. rebar	10-D22	6-D25	4-D13	4-D19+4-D16
p_t	0.47	0.47	0.48	1.60
Shear rein.	D13@100	D13@200	D6@60	D10@60
p_w	0.46	0.317	0.48	1.25
CLT (L×H×t)	3605mm×2896mm ×180mm		1200mm×1200mm ×86mm	

p_t: Tensile reinforcement ratio
p_w: Shear reinforcement ratio

Table 2 Material properties of reinforcement

Type	Elastic modulus	Yield stress	Yield strain
	N/mm^2	N/mm^2	μ
D10 - SD345	215×10^3	420	1.95×10^3
D10 - SD785R	218×10^3	851	3.91×10^3
D13 - SD345	212×10^3	401	1.90×10^3
D16 - SD345	199×10^3	380	1.92×10^3
D19 - SD345	191×10^3	388	2.03×10^3
D6 - SD295	190×10^3	430	4.25×10^3
Φ6 - SR295	164×10^3	337	4.06×10^3

Table3 Material properties of concrete and CLT

Specimen	Elastic modulus	Compressive strength
	N/mm^2	N/mm^2
BF	25×10^3	30.5
WF	24×10^3	28.6
WF_{BA}	26×10^3	31.8
WF_{BCA}	25×10^3	30.6
CLT (parallel to fiber)	52×10^2	22.0
CLT (perpendicular to fiber)	25×10^2	9.14

2.2 Loading method

Static cyclic horizontal loads were applied to the specimens using the loading system at Osaka University. Loading was controlled by drift ($R=\delta/h$), where δ is the horizontal displacement at the center of the beam, and h (=1360 mm) is the height from the top of the stub to the center of the beam, as illustrated in **Fig. 3**.

Each specimen was subjected to a constant axial load equal to 15% of the design compressive strength of the column (= 190.1 kN) through the vertical jacks. Then, the static horizontal loads were applied, as shown in **Fig. 4,** keeping the loading beam horizontal while maintaining the total axial load. The bottom part of all the specimens was fixed on the loading system using PC bars. The first experiment was conducted for specimen WF.

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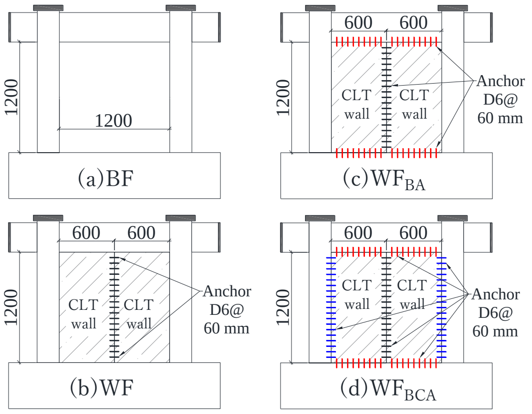
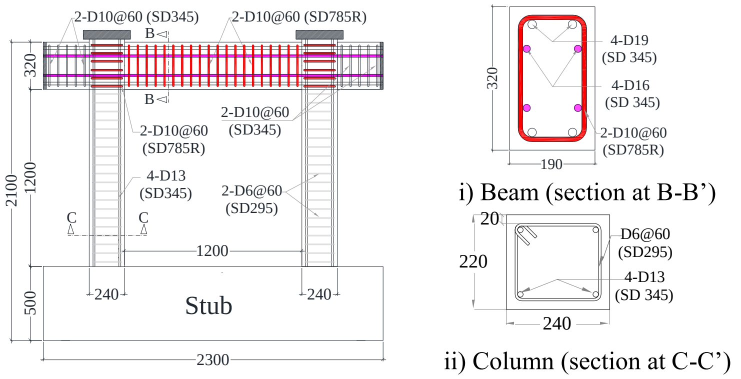
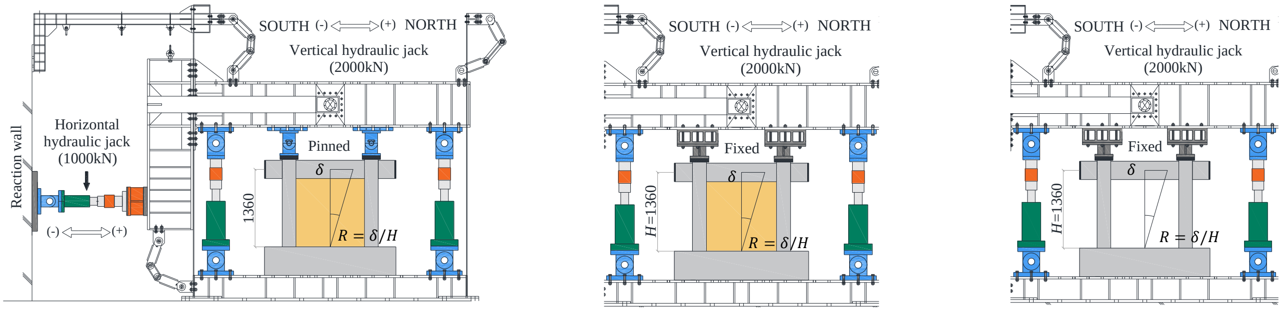


Fig. 1 Specimen types (Unit = mm)



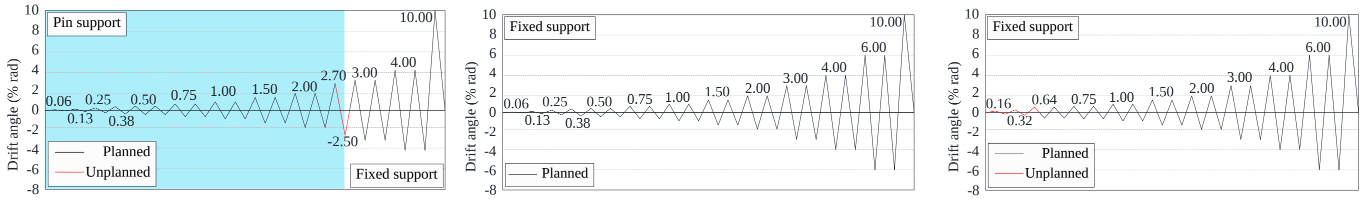
(a) Sectional elevation (b) Cross-section

Fig. 2 Details of RC frame (Unit = mm)



(a) WF (before R=2.0%rad) (b) WF (after R=2.0% rad), WF$_{BA}$, WF$_{BCA}$ (c) BF

Fig. 3 Test set-up (Unit = mm)



(a) WF (b) WF$_{BA}$, WF$_{BCA}$ (c) BF

Fig. 4 Lateral loading histories

Initially, pin supports were planned to connect the columns above the beam (second-floor column) with the loading beam, as shown in **Fig. 3(a)**. However, the CLT panels exhibited higher capacity than estimated during the loading cycle from R = +2.0% rad to +3.0% rad, causing severe damage to the columns above the beam; thus, the loading was performed for an unplanned drift of R = +2.7% rad and R = -2.5% rad (**Fig. 4(a)**). Then, the top supports were changed from pinned to fixed, as shown in **Fig. 3(b)**. To investigate the performance of the specimens in large deformation, pushover loading was applied up to drift R =+10.0% rad. The other specimens were tested with fixed supports at the column top, as shown in **Fig. 3(b)** and **(c)**. However, for specimen BF, the unplanned loading drifts (R = $\pm$0.16, R = $\pm$0.32 and R = $\pm$0.64% rad) shown in **Fig. 4(b)** were caused due to an error with the displacement measuring equipment (transducer) during the experiment. Moreover, after the drift R = ±4.0% rad, a decline in the strength during the pushover loading was observed; hence, additional loading was performed for drift R = ±6.0% rad. For specimens WF$_{BA}$ and WF$_{BCA,}$ the loading history shown in **Fig. 4(c)** was applied.

3. Remarks

Four 40% scale specimens were designed, and static loadings were planned to investigate the effects of CLT infill walls. Test results and the proposed analytical models are described in **Parts 2** and **3**, respectively.

[References]:

1) Giuseppe, D., Sascha, S., and Werner, S.: Effect of floor-to-wall interaction on the rocking stiffness of segmented CLT shear-walls, Eng. Structures, Vol.249, 2021.12

2) Ildiko, L., Anders B., and Roberto, T.: Strength and stiffness of cross-laminated timber (CLT) shear walls: State-of-the art of analytical approaches, Eng. Structures, Vol.178, pp.136-147, 2019.1

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