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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 2 実験結果と考察
Title(English)	Study on the Seismic Performance Evaluation of RC Frame with CLT Panels Part 2 Experimental results and discussions 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 2 Experimental results and discussions 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

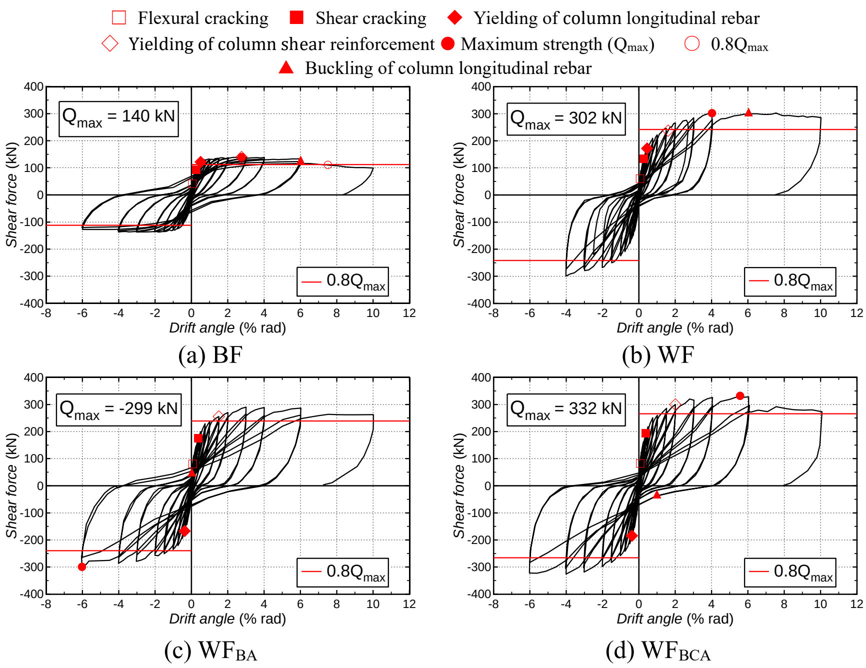
Details of four specimens and the experimental program to investigate the seismic performance of RC frame with CLT infills were described in **Part 1**. This part explains the experimental results.

2. Experimental Results

The shear force vs. drift angle relationship of each specimen is shown in **Fig. 1**, whereas **Fig. 2** compares the backbone curve of each specimen**. Fig. 3** shows the visually observed rocking behavior of CLT panels during the drift cycle of R = +6.0% rad. In addition, **Fig. 4** shows damage to all specimens after the testing. The response of each specimen and their comparisons are summarized below.

2.1 Experimental behavior

Flexural cracks appeared at the top of the tensile column (south side column) during the first loading cycle of R = +0.06% rad for all the specimens with CLT infills. In contrast, it appeared at the top of the tensile column during the drift cycle to $R = \pm 0.16$% rad for specimen BF without CLT infill. For all the specimens with CLT infills, vertical cracks appeared in the CLT panels during the cycle of R = +0.06% rad. Shear cracks occurred and developed at the bottom of both columns under the cycle of R = +0.38% rad for all the specimens with CLT infills, while it initially appeared at the bottom of the compression column (north side column) during the drift cycle to R = +0.32% rad for specimen BF. For specimens BF and WF, the column longitudinal rebar yielding was observed during the drift cycle to R = +0.5% rad, while it appeared during the drift cycle to R = -0.38% rad for specimens WF_{BA} and WF_{BCA}. During the loading cycle to R = +0.75% rad, the rocking behavior of the CLT walls was visually observed for all the specimens with CLT infills, as shown in **Fig. 3**. For specimen WF_{BA}, during the loading cycle to R = -1.5% rad, the top corner of the north CLT wall started to protrude in the out-of-plane direction; however, such out-of-plane protrusion was limited even up to the final drift of R = 10% rad. The maximum strength (Q_{max}) of 140 kN was recorded during the drift cycle of R = +3.0% rad for the BF, while that was recorded 302 kN during the drift cycle to R = +4.0% rad, -299 kN and 332 kN during the drift cycle to R = -6.0% rad for specimens WF, WF_{BA} and WF_{BCA}, respectively. The buckling of column longitudinal rebar was visually observed during the drift cycle to $R = \pm 6.0$% rad for all specimens. That caused the drop of strength to lower than 80% of the maximum strength (Q_{max}) at the drift of R = +7.5% rad for specimen BF, as shown in **Fig. 1(a)**. However, the lateral strength remained almost stable up to the drift of R = +10.0% rad for specimen WF, as shown in **Fig. 1(b)**. The lateral strength was



(a) BF (b) WF

(c) WF_{BA} (d) WF_{BCA}

Fig. 1 Shear force vs. drift angle relationships

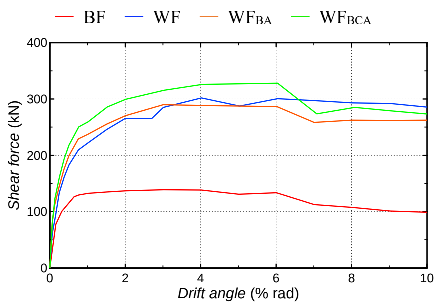


Fig. 2 Envelop curves of positive loading

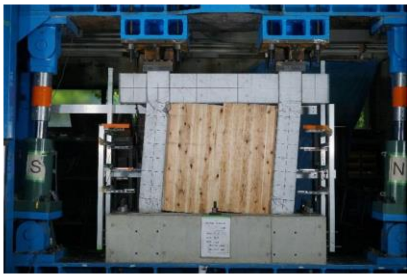


Fig. 3 Rocking behavior of BA

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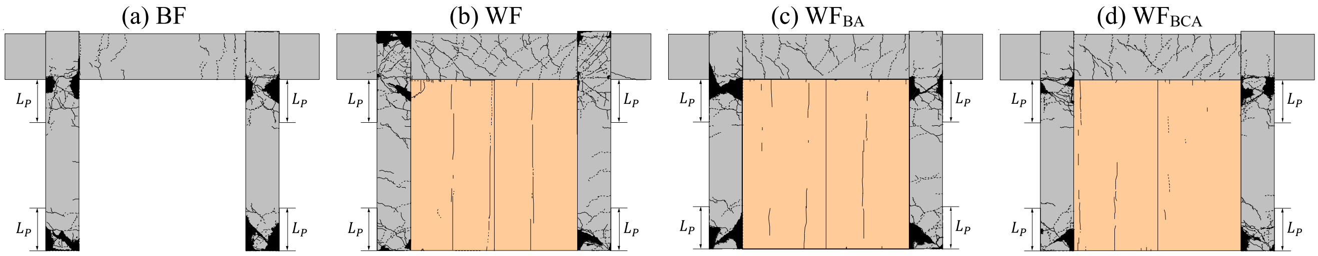

R = 10.0%rad (L_p : the plastic hinge length)

Fig. 4 Damage observed after the tests

dropped to approximately 87% and 82% of the maximum capacity for specimens WF_{BA} and WF_{BCA}, respectively. The support of axial loads acting on the specimens by the CLT walls is considered to be the main reason behind the phenomenon.

2.2 Comparison among the specimens

The initial stiffness and the maximum strength significantly increased for the specimens with CLT infills compared to the specimen BF, as shown in **Fig. 2,** i.e., the maximum strengths for specimens WF, WF_{BA}, WF_{BCA} were 2.2, 2.1, and 2.4 times higher than that of the specimen BF. As shown in **Fig. 1**, after the yielding of the column longitudinal rebar, the stiffness significantly decreased for specimen BF, whereas it was a little moderate for other specimens with CLT infills. Furthermore, the strength of the specimens with CLT infills did not drop by 80% of the maximum strength even during the large deformation showing a positive effect on the seismic performance of the structure. Regarding the connection methods between the RC frame and the CLT infills, the initial stiffness of specimen WF_{BA} was higher than that of specimen WF, as shown in **Fig. 2**. However, the lateral strength of the specimens was approximately the same. This resulted from the pulling out of the anchors between CLT and RC beam in the specimen WF_{BA} before the specimen exhibited the maximum strength. The specimen WF_{BCA} showed an increase in stiffness and strength by approximately 10% compared to the specimen WF. The reason behind such strength increment was likely to be mainly due to the anchors between CLT infills and the RC column since the anchors between the CLT and RC beam had already been pulled out before the specimen exhibited the maximum strength, as mentioned above. It was observed that the shear reinforcement bars of the column yielded during the smaller drift cycle (R = +2.0% rad) for the specimens with CLT infills compared to the specimen BF (R = +3.0% rad). Which might be due to the transfer of the punching forces from the CLT infills to the RC column after the formation of the shear crack of the columns. Focusing on the damage to the beams, several cracks were observed over the entire length of the beams in the specimens with CLT walls compared to the specimen BF, as shown in **Fig. 4**, which was also considered due to the punching effect of CLT infills on the RC beam. For specimen WF, many cracks appeared in the beam-column joints, which were caused due to the use of pin supports at the beginning of loading (up to R = +2.0% rad), while no additional cracks were observed after changing to the fixed support.

3. Conclusions

1) Experimental study showed that the presence of CLT infills increased the stiffness and the maximum strength of the RC frame.
2) The strength of the specimens with CLT infills did not drop by 80% of the maximum strength even during the large deformation showing the positive effect on the seismic performance of the structure.
3) Shear reinforcement bars in the column yielded early in the specimens with CLT walls due to punching forces acting from the CLT walls to the columns. In addition, damage to the beams was also more significantly observed by the presence of the CLT walls.

[References]

3) A. Murata, K. Sugimoto, Alejandro, V. M., Sujan, P., R. Yoon, Y. Sanada, H. Isoda, J. Sakuta, T. Ota, N. Kikuchi and S. Takabatake: Structural Test and Analysis of RC Frame with CLT Walls (Transactions of AIJ), 2022(in Japanese)
4) Hognestad, et al.: Concrete Stress Distribution in Ultimate Strength Design, ACI Journal, Vol.52, No.12, pp.455-480, 1955.12
5) AIJ: AIJ Standard for Lateral Load-carrying Capacity Calculation of Reinforced Concrete Structures, 2021(in Japanese)
6) AIJ: Design Guidelines for Earthquake Resistant Reinforced Concrete Buildings Based on Inelastic Displacement Concept, 1997(in Japanese)
7) S. Takahashi, K. Yoshida, T. Ichinose, Y. Sanada, K. Matsumoto, H. Fukuyama and H. Suwada: Flexural Deformation Capacity of RC Shear Walls without Column on Compressive Side (Transactions of AIJ), Vol.76, No.660, pp.371-377, 2011(in Japanese)
8) Meta, K., Boris, A.: Cyclic response of insulated steel angle brackets used for cross-laminated timber connections, European journal of wood and wood products, Vol.79, pp.691-705, 2021

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