Structural Behavior of Chuandou Timber Frames with Masonry Infill Subjected to In-Plane Cyclic Loading

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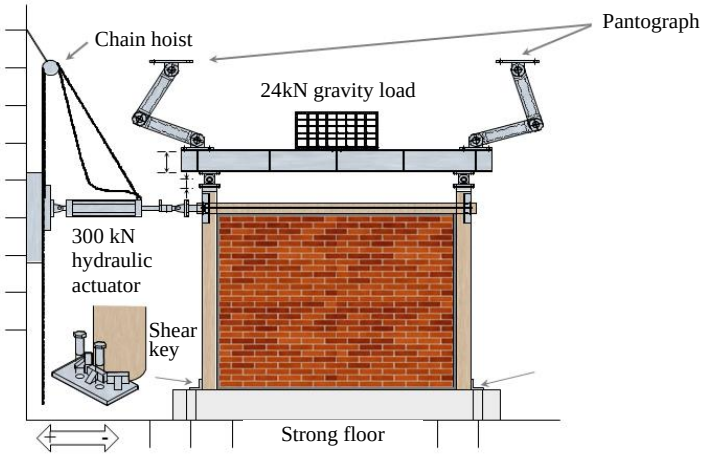
The Chuandou timber frame is a traditional timber structural system widely used for nonengineered residential houses in South China; this system is featured by beam-to-column joints with direct penetration tenons and free-standing column bases. With the proper infills, Chuandou timber frames have exhibited advantageous seismic performance over other nonengineered structural systems in past earthquakes in terms of collapse prevention, although the mortise-tenon connections, masonry infills, timber beams and columns may have sustained various extents of damage. To investigate the seismic behavior of the structural system, six full-scale Chuandou timber frame subassemblies were subjected to in-plane quasi-static loading, four of which were infilled with masonry walls. The test results show that the masonry infills provided the most lateral resistance of the system, whereas the timber frames could sustain a large lateral drift without losing their vertical stability. The typical failure modes were identified from different specimens. The lateral strengths of the specimens in the current test were evaluated using the existing code equations. The results suggest the necessity of considering the aspect ratio in calculating the shear strength of masonry walls.

I. Introduction

The Chuandou timber frame system is still used nowadays in south China with masonry infill (Figure 1(a))[1]. The Chuandou frame is one of the two major timber structural systems in China and has a history of approximately 500 years. Compared with other traditional timber systems, it is distinguished by the following features: (1) the timber beams and columns are joined by penetration tenons, in which the full section of a beam goes through the mortise on the columns; (2) it uses no timber braces, and meanwhile, is always infilled with masonry or wood panels as partitions; (3) there are neither sill beams nor mechanical anchors at the column bases (Qu Z. et al. 2015). To this end, six full-scale single story one-bay Chuandou timber frame subassemblies were subjected to in-plane quasi-static loading in an experimental test program in China in term of observe the fundamental seismic behavior of Chuandou timber frame with masonry infill, including the commonly seen seismic damage such as pull-out of beam tenons, cracking, collapse of masonry infills. This paper summarizes the details of the specimens, the test method and some important seismic properties of the systems such as *Q*max, initial stiffness, equivalent damping ratio are compared with those of other timber systems in the literature.

Each of the single-span timber frame is consisted of two circular sectioned timber columns and a rectangular sectioned timber beam. The specimens were categorized into two groups by their height-to-span ratios of 0.8 and 1.5. In each group, there was a bare frame specimen and two masonry infilled specimens which difference was their infill thickness. In the test, the columns rested on top of a concrete grade beam without mechanical anchorage while additional shear keys were provided for infilled specimens to avoid excessive slip at the column base (Figure 1(b)).

(a) Chuandou timber frame after Lushan earthquake. (Qu et al., 2015)



(b) Setup.

Figure 1. Chuandou timber frame with masonry infill.

II. Experiment Study

Figure 2 shows the hysteresis curves obtained by the static cyclic loading tests. For the specimens of wide span, the lateral strength and stiffness of the bare frame W0 is much lower than the two masonry infilled specimens (W50 and W110). However, the timber frame can sustain a large displacement without losing its vertical load-bearing capacity. For specimen W50, the masonry infill started to crack in the middle from +0.25% drift ratio. It collapsed at -3% drift ratio. For specimen W110, rigid body rotation was observed, and the cracks of the masonry infill concentrated at the bottom. the loading was terminated at 4% drift ratio because a timber column was pulled out of the shear keys and could not fit back during unloading.

Similar phenomena were observed in the short span specimens. However, the lateral strength of specimen S0 is higher than that of specimen W0. Rigid body rotation occurred in both masonry infilled specimens (S50 and S110). The masonry infill collapsed at +4% drift ratio in specimen S50, whereas little damage to the wall panel was observed in specimen S110.

The shear strength of infilled specimens are evaluated by *FEMA-273*(FEMA)[2] and *Chinese design code for masonry structure*(GB)[3], the results are denoted by dotted lines and solid lines in Figure 2, respectively. The results show that FEMA fit to the maximum stress of wide span specimens, and GB fit to the short one. However, FEMA and GB could not fit to the maximum stress of all four specimens, because both of them evaluate the masonry panel without considering aspect ratio of the panel.

III. Conclusion

This paper reported an experimental test on a traditional Chinese timber structure system, namely Chuandou frames with masonry infills, which is widely used for non-engineered residential houses in South China. Six full-scale Chuandou timber frame sub-assemblage specimens of various aspect ratios and masonry infill thicknesses were subjected to lateral cyclic loading. The results show that the deformation of the infilled frames with thick walls tended to be dominated by rigid body rocking, while the wall shearing is more significant in thin wall specimens. It is also shown that the masonry infills provided most of the lateral resistance in the system.

Acknowledgment

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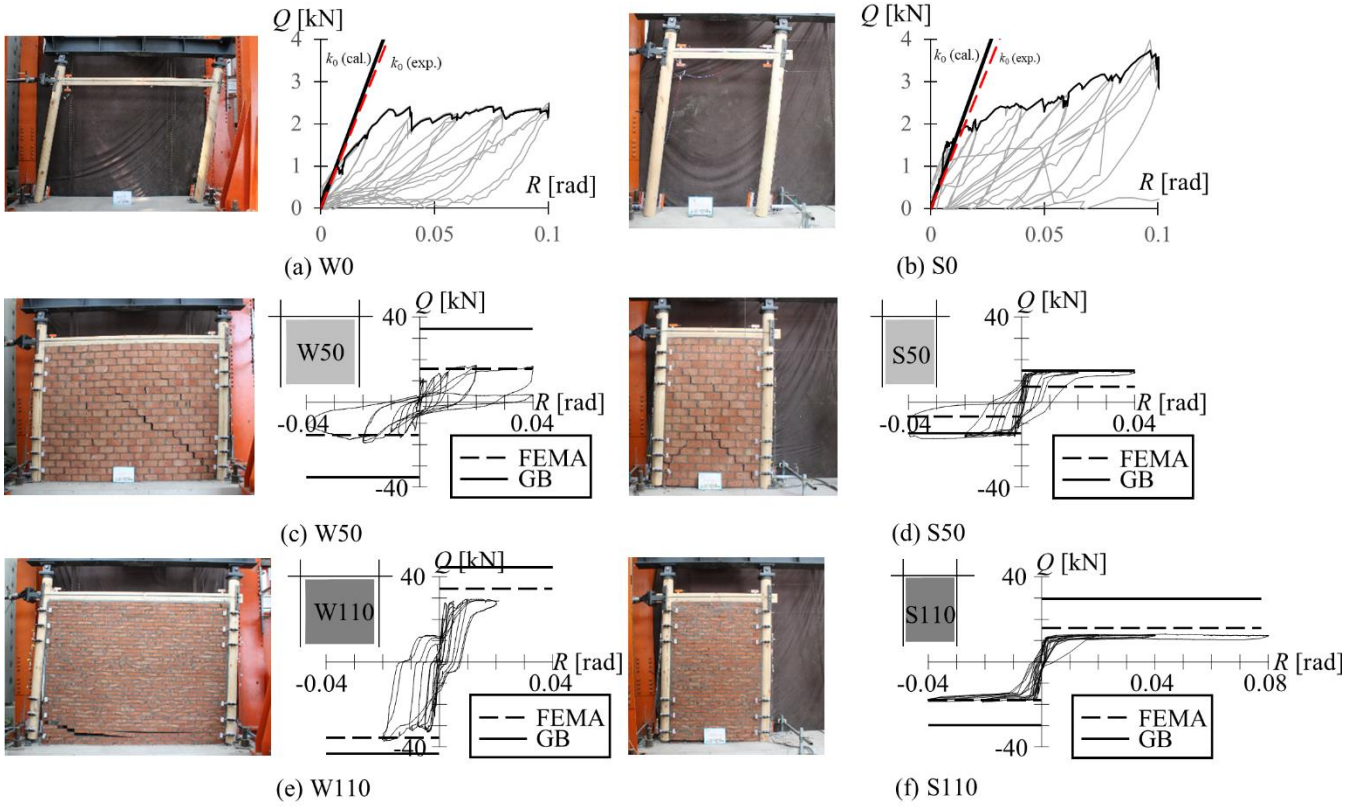

Figure 2. Hysteresis curves of Chuandou timber frame.