論文要約

# LATERAL PERFORMANCE OF A FRAME WITH DEEP BEAMS AND HANGING MUD WALLS IN TRADITIONAL JAPANESE RESIDENTIAL HOUSES

(木造伝統構法住宅の差鴨居と垂れ壁付き構面の水平耐力)

LI ZHERUI

The residential houses built with traditional construction techniques often face the demand of reinforcement to reach the specifications of the current seismic standard in Japan. The existing resistance of the original structure should be accurately evaluated to minimize the cost of reinforcement. According to construction notification No.1100, the resistance of hanging mud walls and corresponding bending performance of the columns are the two factors mainly considered in the seismic assessment. Since the resistance of moment-resisting joints and the deep beams are not included, the actual resistance of the frame is likely to be underestimated. Simultaneously, the bending capacity of the columns should be reassessed as the limiting factor of shear resistance in the frame.

This study aimed to investigate the resistance of the frame with deep beams and hanging mud walls, clarify the working mechanisms and contributions of different load-bearing elements in the frame, and explore an analytical model of the entire frame that can accurately reflect the shear capacity and interaction among the load-bearing elements.

A series of comparative experiments of the frames with and without hanging mud walls were conducted in the first step, as well as frames with hanging mud walls of different height aspect ratios. The contributions of main load-bearing elements, including mortise-tenon joints, deep beams, and hanging mud walls, were identified. Secondly, the performances of the load-bearing elements were investigated respectively. Afterwards, the diagonal effect of the deep beam and its interaction with beam-column joints were discussed. The parameter analysis of the height aspect ratios of squat mud walls was performed. Additionally, the bending performance of columns was further explored with the consideration of different interior notches, the coefficient in bending strength calculation of the columns was obtained through statistical analysis. In this study, an analytical model of the frame with deep beams was proposed. Besides, a 2D simplified analysis model of the frame with deep beams and hanging mud walls was established and was basically in accord with the experimental result.

The order of seven main chapters corresponds to the progress of work on this thesis:

Chapter 1 presents a general introduction of the background, motivation, objective, and methodology of the research. In Chapter 2, a literature review is performed on the studies closely related to the traditional timber frames with deep beams and hanging mud walls.

In Chapter 3, a static loading test of the two groups' comparative specimens, including the frame with and without hanging mud walls, and the frame with hanging mud walls of different height aspect ratios, were conducted. The contribution of main load-bearing elements, such as the mortise-tenon joints, deep beams, and hanging mud walls, were extracted from the frame. Besides, their effects on the shear distribution in the frame, the deformation of the columns, and the failure modes of the whole frame were analyzed. Further experimental investigation of each load-bearing element is illustrated in Chapter 4. Static loading tests were performed on three types of moment-resisting joints, the single-span frames with deep beams, and squat mud walls with different height aspect ratios. The interaction between the deep beam and the beam-end joints was clarified by comparing the frame and elemental test results. The correlation between the resistance of the squat mud wall and the height aspect ratio was furtherly discussed.

Chapter 5 concentrates on the load-bearing capacity of the columns regarding the influence of interior notches open for the mortise-tenon joints. Furthermore, the flexural properties of columns without notches under three-point and four-point load configurations and columns with three different notch combinations in multiple directions were analyzed experimentally and statistically. The results indicated that the mean bending strength of columns with three different notch types was consistent with those without notches, the continuous timber on both sides of the notch had a beneficial effect on maintaining a higher strength and reducing the stress intensity around the notch. The fracture position and the standard deviation of the bending strength were affected not only by the notch depth, but also by the notch width on the tensile side of the column.

In Chapter 6, the analytical model of reflecting the diagonal effect of the deep beam and its interaction with beam-column joints in the frame was established by analogy with the existing models. The result indicated that the resistance of the deep beam is affected by both the magnitude of the moment of the beam-column joints and the difference between the joint moments on the left and right sides of the beam. Meanwhile, the axial force on the deep beam is conducive to delaying the occurrence of ultimate failure of the beam-column joints. Then, the simplified 2D analysis model of the frame with deep beams and hanging mud walls was proposed and confirmed through experimental results.

In Chapter 7, all the key findings from this thesis are summarized, and further potential works are proposed.