

( 続紙 1 )

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論文題目	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)		
<p>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.</p> <p>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.</p> <p>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.</p> <p>The order of seven main chapters corresponds to the progress of work on this thesis:</p> <p>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.</p> <p>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</p>			

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.

注) 論文内容の要旨と論文審査の結果の要旨は1頁を38字×36行で作成し、合わせて、3,000字を標準とすること。

論文内容の要旨を英語で記入する場合は、400～1,100 wordsで作成し  
審査結果の要旨は日本語500～2,000字程度で作成すること。

(続紙 2)

(論文審査の結果の要旨)

伝統的な工法で建てられた木造住宅は、現在の日本の耐震基準を満たすために補強を要することが多々ある。また、新築であっても耐震基準を満足するためには開放的な空間とはできず、壁が多く入ったものとならざるを得ない。すべての建築物は、現代的な評価手法により耐震性能を確保する必要に迫られるが、伝統木造に限っては抵抗機構に未解明の部分が多い。そこで、本研究では、未解明の部分のうち、一般建築物でも使われる差し鴨居を持つ垂れ壁付き独立柱について水平性能評価を実施したものである。文化的な価値を継続しつつ、地震に対して安全な建築物を建設していくうえで有用な研究である。

特に特筆すべき点は以下のとおりである。

- 1) はりせいの大きな差し鴨居は変形によって幾何学的に材軸にわたって圧縮力が生じ、圧縮力の両端支持点の高さの違いからそれがモーメント抵抗となり、さらには水平抵抗力へ転じる。その抵抗力を実験で明らかにし、さらに、柱の曲げ、柱の接合などを変数として、数式化した点。
- 2) 上記の抵抗力のもととなる圧縮力は接合部の回転剛性に対する抵抗と相互作用があることを実験的に明らかにし、かつその定式化を図った点。
- 3) 差し鴨居を持つ垂れ壁付き独立柱は、柱の曲げ抵抗が水平抵抗能力の維持に大きく貢献しているが、計算上柱が折れることが多い。しかし、実験をすると柱が折れないこともある。その原因が基準強度の誘導と柱の切り欠きによる低減率の評価にあることを指摘し、その新たな評価方法を誘導した点。
- 4) 垂れ壁の高さを考慮し、かつ1)～3)の影響まですべてを解析モデルに取り入れ、実験により解析モデルの妥当性を明らかにするとともに、設計に使える解析モデルを提案した点。

以上のように、伝統的木造住宅の地震時抵抗要素のひとつである差し鴨居を持つ垂れ壁付き独立柱の水平抵抗力を精緻に示したことは、文化的な価値を損なうことなく補強を進め、未来に残す建築物の安全性を高めるうえで、極めて有益であり、木質構造学、建築構造学、防災学、文化財保存学の発展に寄与するところが多い。

よって、本論文は博士(農学)の学位論文として価値あるものと認める。

なお、令和4年2月15日、論文並びにそれに関連した分野にわたり試問した結果、博士(農学)の学位を授与される学力が十分あるものと認めた。

また、本論文は、京都大学学位規程第14条第2項に該当するものと判断し、公表に際しては、当該論文の全文に代えてその内容を要約したものとすることを認める。

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ただし、特許申請、雑誌掲載等の関係により、要旨を学位授与後即日公表することに支障がある場合は、以下に公表可能とする日付を記入すること。

要旨公開可能日： 年 月 日以降 (学位授与日から3ヶ月以内)