Analysis of Mechanical Characteristics of Walls of Masonry Structure House under Dynamic Load

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Abstract. Research and analysis on the walls of masonry structure houses in a certain area of north of Guangxi. The house walls are divided into three types: pure walls, walls with windows and walls with doors, and use ABAQUS to design the corresponding wall models. Adopt the horizontal periodic reciprocating load of different magnitudes to calculate the mechanical performance of the wall, and study the stress change characteristics and crack development law of the wall. The results show that: (a) Under load, the stress concentration of the wall is greatly affected by the hole. The larger the hole, the more obvious the stress concentration. (b) Under the load, the cracks change with the holes in the wall, and the cracks in the non-porous wall show a straight shape. As the wall openings appear and become larger, the cracks gradually change from a straight shape to an X shape, and then it becomes the law of V-shaped and inverted V-shaped.

1. Introduction
Masonry structure houses are widespread in the process of urban infrastructure construction, especially in urban and rural areas. With its low cost and simple construction method, the masonry structure house attracts a large number of urban residents to continue to build, and also attracts a lot of scientific research personnel to conduct research. In recent years, research on masonry structure houses has been extensive. For example, in terms of seismic reinforcement, according to the characteristics of the old masonry structure, He D D [1] adopted a prefabricated structure with a jacket to reinforce it, which verified the good reinforcement effect of this method; Liu H [2] has studied the traditional reinforcement methods of existing masonry structure houses in villages and towns, and proposed a post-length prestress reinforcement method; Li W F [3] strengthened the masonry structure by adding layers of seismic isolation. In terms of earthquake damage detection and prediction, Zhang M Q [4] used appearance inspection, component material strength inspection, vibration test and other inspection methods to test the safety and seismic performance of a rural masonry structure house in Hebei Province, and put forward brief treatment suggestions. Zang S L [5] used the fuzzy comprehensive evaluation method to analyze the seismic performance of old masonry buildings in Liaoning Province, and the prediction results were close to the actual earthquake damage results. In terms of seismic performance, Zhang Y Q [6] used the stochastic finite element method to numerically analyze the material parameters of the ancient masonry structure, and verified that the stochastic finite element method can reasonably reflect the mechanical performance of the structure under a certain working condition; Huang Y [7] used a numerical simulation method to analyze the impact of the wall opening rate on the seismic performance of the masonry structure of the building, and showed that the increase in the opening rate reduces the bearing capacity and stiffness of the wall. In addition, there

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are many studies on masonry structure walls as infill walls of reinforced concrete frame structures [8]–[10]. However, it is relatively rare to use periodic load calculation to study the stress characteristics and crack development law of the wall of masonry structure. Based on the above research, this paper takes different types of walls as the research object, and uses the dynamic loading method to simulate the stress change characteristics and crack development law of the wall under dynamic action.

2. Investigation and analysis
Conducted a survey of masonry structure houses in a town located in the north of Guangxi. The area is mainly divided into two types of masonry structure buildings, new buildings and old buildings. The new buildings are mainly low-rise masonry structures newly built in recent years (as shown in Figure 1(a)). The masonry walls are mainly made of red ordinary sintered bricks, the floor slabs and other structures are made of reinforced concrete, the mortar is cement mortar, and the foundation is mainly made of reinforced concrete. The old buildings are mostly single-story masonry houses with a long history. The wall materials are mainly gray sintered bricks, and the walls are supported on stone foundations. This article mainly focuses on the research on the walls of old buildings. The walls of old buildings are mainly divided into three types. The first type is the walls constructed entirely of brick masonry. The walls are carried on a rubble foundation or a block stone foundation (such as Figure 1(b) and (c) shown). The second type of wall is provided with windows, and the window eaves use wooden strips as the load-bearing structure (as shown in Figure 1(d)). The third type of wall is equipped with doors. The door forms are divided into two types: load-bearing structure with wooden slats as door beams and arched "beams" made of bricks as load-bearing structures (Figure 1(d)–(f) Shown). Most of the wall mortars are lime mortar, and the roofs are mostly sloping roofs. The sloping roofs use round wood as load-bearing beams and square wooden strips as purlins. The roof surface is covered with gray tiles or asbestos tiles (Figure 1(h)) Shown).

3. Research model finite element analysis
3.1. Wall model establishment
According to the three types of wall features obtained from the investigation, three types of wall models were established, namely, a pure wall model (Model a), a wall model with windows (Model b), and a wall model with doors (Model c). As shown in Figure 2, a brick body of $240\text{mm} \times 115\text{mm} \times 90\text{mm}$ is used, the brick body strength grade is M7.5, the tensile strength design value is 1.93 MPa, the elastic model is 16700 MPa, the Poisson's ratio is 0.2, and the friction coefficient is 0.7. In order to accurately simulate the mechanical performance of the wall, a concrete beam was designed on the upper part of the wall, and a uniform load was applied to simulate the gravity transmitted from the roof and other structures in the actual structure. At the same time, a concrete beam was designed at the lower part of the wall for Simulate the stone foundation in the actual structure. The wall width is $1200\text{mm}$ and the
height is 1170mm. The cross-section size of the concrete beam designed for the upper and lower parts of the wall is 115mm×115mm. The window size in Model b is 480mm×450mm, and the door size in Model c is 480mm×810mm.

3.2. Model loading scheme
In order to simulate the impact of earthquake and other dynamic loads on the wall, periodic reciprocating loads are used to load the wall. The load is designed for 5 cycles, each cycle is 1 loading step, and the loading is carried out according to the loading step. The model loading diagram is shown in Figure 3. The first to second cycles simulate the force of the wall when the load is small, and the third to fourth cycles simulate the force of the wall when the load suddenly increases and reaches the peak. The fifth cycle simulate the situation where the load is changed from large to small. The model is loaded by displacement loading, and the loading point is one side section of the concrete beam on the top of the wall. Adopt hierarchical loading, that is, the first to second cycles are first-level loading, the loading displacement is -1mm~1mm, the third to fourth cycles are second-level loading, the loading displacement is -2mm~2mm, the fifth cycle is also the first-level loading.

4. Results and discussion
4.1. Checking calculation of wall structure
According to the literature [11], the following formulas are used to check the wall structure measures.

\[
\beta = \frac{H_0}{h} \leq \mu_1 \mu_2 [\beta] \quad (1)
\]

\[
\mu_2 = 1 - 0.4b_s/s \quad (2)
\]

Where, \(H_0\) is the height of the wall, \(h\) is the thickness of the wall, \(\mu_1\) is the correction coefficient for the allowable height-to-thickness ratio of self-supporting walls, \(\mu_2\) is the correction coefficient for the allowable height-to-thickness ratio of walls with door openings, and \(s\) represents the width of the wall here. \(b_s\) is the width of the door and window opening, \([\beta]\) is the allowable height-to-thickness ratio. The calculated results are shown in Table 1.

| Model | \(H_0/mm\) | \(h/mm\) | \(\beta\) | \(\mu_1\) | \(\mu_2\) | \(\mu_1\mu_2[\beta]\) |
|-------|-------------|-----------|-----------|------------|------------|-------------------|
| Model a | 1170        | 115       | 10.17     | 1.45       | 1.00       | 26                |
| Model b | 1170        | 115       | 10.17     | 1.45       | 0.84       | 26                |
| Model c | 1170        | 115       | 10.17     | 1.45       | 0.84       | 26                |

It can be seen from Table 1 that the Models a to c all meet the requirements of structural verification.

4.2. Stress analysis
Under the action of reciprocating load, the stress diagram of the wall of each model is shown in Figure 4. The figure lists the maximum loading displacement (1mm) of each model in the first cycle, the maximum loading displacement (2mm) in the third cycle and loading Stress graph at the end.
For the pure wall (Model a), the maximum stress appears at the lower right corner of the wall when the displacement load is the maximum in the first cycle, which is 0.95 MPa. When the displacement load of the third cycle is the largest, the maximum stress appears in the lower right corner of the wall, which is 5.54 MPa, and the stress gradually shows a trend of developing toward the upper part of the wall. Due to the influence of the previous two periodic loads, stress also appears in the lower left corner. Concentrated, the value is about 1.11 MPa. At the end of the cyclic load loading, the stress concentration is most obvious in the lower left and right corners. For Model b with window, the maximum stress appears in the lower right corner of the wall when the displacement load is the maximum in the first cycle, which is 1.41 MPa. At the same time, there is obvious stress concentration in the middle of the lower part of the window, the value is about 0.94 MPa, and the stress concentration also begins to appear in the lower left corner of the window. At the maximum displacement load in the third cycle, the stress in the lower right corner of the wall has reached 5.94 MPa, and the stress concentration in the lower left and upper right corners of the window is obvious, with values reaching 1.49 MPa and 1.98 MPa, respectively. At the end of loading, most of the wall was occupied by stress concentration. For Model c with a relatively large opening, the maximum stress appears at the lower right corner of the wall when the displacement load is the maximum in the first cycle, which is 1.54 MPa. Obvious stress concentration appeared in the upper right corner of the door, and obvious stress concentration also appeared on the left wall at the same height as the door. When the displacement load is maximum in the third cycle, the stress in the lower right corner of the wall is the maximum, and the stress concentration in the upper right and lower left corners of the door is obvious. At the end of loading, the stress concentration phenomenon covers the whole wall, and the stress concentration is the largest in the lower part of the door. The results show that under the same load, the larger the opening of the wall, the more obvious the stress concentration. Under the action of periodic load, the speed of stress concentration in the entire wall is greatly affected by the size of the opening.
4.3. Crack analysis

In order to show the development of cracks more intuitively, the displacement cloud diagram after magnifying the model shape by 10 times is shown in Figure 5 while keeping the value unchanged.

![Displacement Cloud Diagram](image)

It can be seen from Figure 5 that for Model a, when the first cycle displacement is 1mm, cracks appear at the bottom of the left wall. When the displacement is loaded to the third period of 2mm, the crack develops further and cracks diagonally at the bottom of the right wall. At the end of loading, on the basis of the front cracks, the bottoms of the walls on the left and right sides cracked obviously. For Model b with window, when the first cycle of displacement loading is 1mm, cracks appear at the bottom of the left wall, almost at the same position as Model a. At the same time, the lower right side of the window gradually cracks. When the displacement is loaded to the third period of 2mm, the cracks develop further. Between the upper left corner of the wall and the upper left corner of the window, and between the lower right corner of the window and the lower right corner of the wall, an oblique crack is almost formed, that is, the rule of oblique shape failure. At the end of the loading, the cracks in the model almost showed an x-shaped failure. For model c with a door, when the first cycle displacement load is 1mm, cracks appear at the bottom of the left wall, almost at the same position as Models a and b. At the same time, the lower part of the wall on the right side of the door gradually cracks, and the crack position Lower than the left wall. The bottom cracks on the left and right walls resemble a gentle diagonal line. When the displacement is loaded to the third period of 2mm, the
cracks on the wall further develop on the existing foundation. The top two corners of the door gradually expand to the two upper corners of the wall, showing a V-shaped failure. At the end of loading, the cracks on the wall showed almost V-shaped damage in the upper part, and flat V-shaped damage in the lower part. The results show that under the horizontal cyclical reciprocating load, cracks appear at the bottom of the non-porous wall, showing the characteristics of a ——shaped failure. For wall with windows, cracks show an X-shaped failure law. For walls with doors, cracks show a V-shaped failure pattern in the upper part of the wall, and an inverted V-shaped failure pattern in the lower part.

5. Conclusions
Investigate and analyze the walls of masonry structure houses in a certain area of north of Guangxi, divided into three types of walls according to the presence or absence of openings, established models for dynamic calculation and analysis, and obtained the following conclusions:

a. Under the horizontal reciprocating load, the stress concentration of the wall is greatly affected by the hole. The larger the hole, the more obvious the stress concentration.

b. Under the action of horizontal reciprocating load, the form of cracks changes with the holes in the wall, and the cracks in the wall with the same hole size have different laws with different loads.

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