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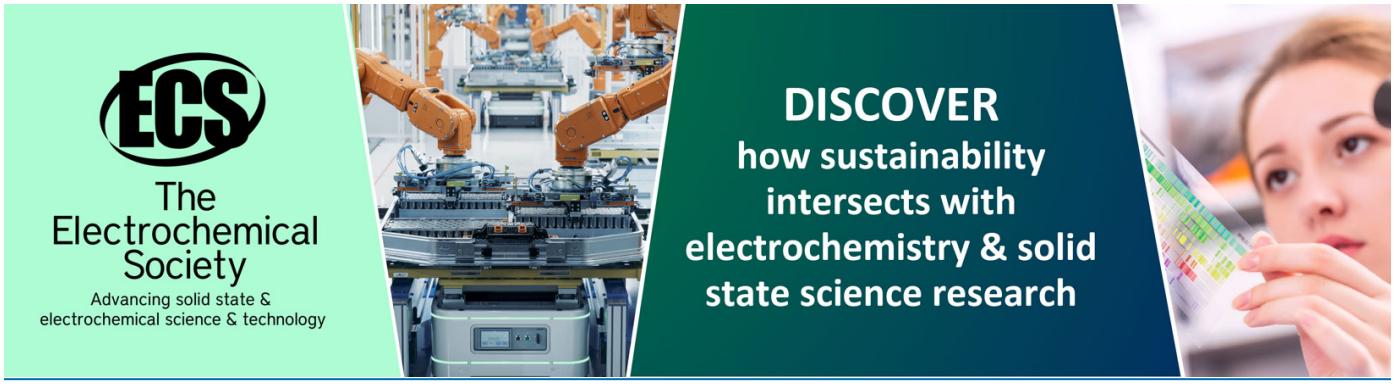

Investigation and Analysis of Old Houses' Aseismic Capability in Rural Areas of Jiangxi Province

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Abstract. Villages and towns are the most earthquake-prone areas in China, due to the backward economic conditions and the lack of aseismic awareness of residents in rural areas, earthquake damage in these areas tend to be severe. In order to understand the aseismic capability of old houses better in rural areas of Jiangxi province, investigation was carried out in numerous counties of Jiangxi. The structural types, construction time and aseismic construction defects of the old houses were mainly investigated; besides, in view of the old houses' aseismic construction deficiencies, combined with the existing research, the methods and countermeasures for enhancing the aseismic capability of old houses are given.
Keywords: Aseismic capability, old house, aseismic study, strengthening measures, disaster prevention and reduction.

1. Introduction

China is a country with frequent earthquakes and high proportion of rural population. At the same time, many villages and towns in China are located in seismically active zone [1]. However, due to the influence of geographical position, economic condition and historic culture, rural old houses lack professional aseismic design guidance, these houses have serious aseismic hidden dangers [2]. For example, in Yushu earthquake happened in 2010, nearly all of the old brick-wood structure and row-soil structure houses in hard-hit areas collapsed [3], in Wenchuan earthquake, most of the houses in rural areas collapsed or were badly damaged [4], besides, in Ludian earthquake, half of the rural houses in epicentral area were badly destroyed or collapsed [5]. Therefore, the aseismic capability of old buildings in rural areas should be emphasized and strengthened.

2. The Overview of Old Houses' Aseismic Capability Survey in Rural Areas of Jiangxi Province

2.1. The Background and Overview of Survey

There have been many seismic records in the history of Jiangxi and the trend has become more frequent in recent years, especially the Jiujiang-Ruichang earthquake happened in 2005, caused the huge loss concerned 12 deaths and more than 18 thousand houses' collapse. In order to further grasp the status of old houses in rural areas of Jiangxi, investigation was carried out in numerous counties governed by Jiujiang, Shangrao and Fuzhou, the information of structure type, layout plane, purpose, foundation and structural characteristics of these old houses were mainly collected. Through the investigation it can be found that there exists serious aseismic hidden dangers for these houses.

2.2. Main Structural Types and Analysis

The raw-soil structure houses in the survey area are mostly single-storey, the upper part of doors and windows is generally equipped with wood lintel, the retaining walls are made of adobe and mud, the roof adopts the form of purlin on the gable, most of the roofs are made of grey tiles, the foundation of these houses mostly adobe lime-soil foundation or rubble foundation. This kind of houses is generally built in the 50s and 60s, and the amount is relatively rare, these houses are mostly used for living or storing sundries. The status of raw-soil house is shown in figures 1-2.

Figure 1. Raw-soil structure.

Figure 2. Interior wall.

Timber structure is one of the main structural forms of old houses in the survey area, most of them are single-storey and the main structural form of these houses is column and tie construction. The vertical load of this kind of structural house is mainly transmitted by the wood frame, there is usually a column base stone under the timber frame column to prevent the column from getting wet or damaged and most of the roofs are made of grey tiles. The columns of this kind of house are connected by cross beams, which constitute the main bearing system of roof truss. This kind of house generally built in 70s, mainly used for living. The status of timber structure house is shown in figures 3-4.

Figure 3. Timber structure.

Figure 4. Bearing system.

Brick-wood structure is the most widespread house type in investigation area; most of them are two-storey, generally built in the 80s and 90s. The walls of this kind of houses are usually made of sintered bricks and a small number of these houses are made of gravel and brick, the slab consists of planks and wooden beams, the roof adopts the form of purlin on the gable. Layout plane of these houses is relatively uniform, the bay mainly consists of three parts, the central bay tend to serve as hall, the bays on both sides are used as living or storage, besides, the second floor of these house is usually used as an attic for storage. The status of brick-wood structure house is shown in figures 5-6.

Masonry houses account for a relatively small proportion in survey area, most of them built in the 90s. The main characteristics of this kind of house include that all the walls of the house are constructed with sintered brick, the floor is prefabricated, the stairs are poured with concrete, the top part of the doors and windows are all equipped with lintel and most of them are two-story. These houses usually adopt gravel masonry foundation; some of these houses also have a cantilevered balcony on the second floor. The status of masonry house is shown in figures 7-8.

Figure 5. Brick-wood structure.

Figure 6. Wooden slab.

Figure 7. Masonry structure.

Figure 8. Wall and slab.

2.3. Aseismic Structure Defects of Old House

Due to the long history of these houses and the lack of maintenance of components, there are many aseismic structural defects in mentioned four house types, as shown in figures 9-12.

The main defects of raw-soil structure houses are as follows: 1) There is no drainage system built around the house and the external walls are easy to be washed and soaked by the rain. 2) The roof frame purlin was placed on the gable with no pad, which made the gable force uneven and easy to produce vertical cracks in the wall. 3) There is no reliable tying between longitudinal wall and transverse wall; the gables are easy to be damaged with the form of out-of-plain failure. 4) The wooden roof is affected by biological and climate factor, the state of corrosion is severe.

The main defects of timber structure houses are as follows: 1) The column foot is prone to offset, which makes the column base stone under the stress state of eccentric compression. 2) Wood columns commonly have vertical cracks, which seriously weaken the bearing capacity of the wood columns. 3) The wooden component nodes have looseness or even invalid connections, which reduces the integrity of the bearing system. 4) Wood components are severely affected by biological factor, a large number of wood components show signs of being eroded by termites.

The main defects of brick-wood structure houses are as follows: 1) The foundation bearing capacity is insufficient, the foundation is directly built on the weak soil layer. 2) The foundation is poorly integrated; the foundation was built by gravel instead of sintered brick or concrete. 3) The quality of building materials is poor, and the masonry mortar is not produced according to the specified mortar mix ratio. 4) The walls of many brick-wood houses were constructed by sintered bricks and gravel, which greatly reduces the integrity of the walls.

The main defects of masonry structure houses are as follows: 1) The layout plane of structure is unreasonable, the “top-heavy” layout is common among these houses 2) Ring beam and structural column are not set, and the rigidity and integrity of the house are poor. 3) Many houses’ exterior walls are not treated with plastering. 4) The foundation is shallow, which affects the stability of the house. 5) The site selection of the housing site is not desirable.

Figure 9. No pads under the purlins.

Figure 10. Column foot cracks and offset.

Figure 11. The wall built by different materials.

Figure 12. Shallow depth of foundation.

3. The Methods and Countermeasures for Aseismic Strengthening

3.1. The Aesismic Strengthening Methods for Old House

As for the poor aseismic capability of raw-soil structure houses, Yu Wen et al. [6] conducted shaking table tests on raw-soil structure house models in Xinjiang region by using reinforcement methods like angle steel belt strengthening the wall, adding flat steel belt and wooden column to the roof, and adding inclined steel brace between the roof. The experimental results showed that those methods can effectively improve the aseismic capability of the raw-soil structure house.

For the problem of poor aseismic capability of timber structure houses, Lu Chenyi [7] proposed to improve it mainly by increasing the rigidity of mortise and tenon joints. For example, using clincher to embed the mortise and tenon joints, utilizing the bending characteristics of the clincher to increase the strength of the mortise and tenon joints. Ju Xingpeng et al. [8] proposed to use iron wire hoop or flat hoop to enhance the mechanical properties of cracked wood components.

For the problem of poor aseismic capability of brick-wood structure houses, Wang Mansheng et al. [9] verified through the shaking table test that adding reinforced concrete window frames to the doors and windows of unreinforced brick-wood structure houses can significantly reduce the number of cracks in the door and window openings of walls. Yang Wei et al. [10] proposed that reinforced polymer mortar ring beam could be added on the gable wall of brick-wood structure houses to improve the integrity of the house, the effectiveness of this method was verified by the shaking table test.

For the issue of poor aseismic capability of masonry structure houses, adding ring beam and constructional column is an effective way to solve this problem. In recent years, some new reinforcement measures have been proposed, for example, Liu Hang et al. [11] carried out research on the vertical prestress reinforcement technology of masonry structure house, the test results showed that masonry buildings strengthened with vertical unbonded prestressed steel can still maintain high bearing capacity under strong earthquakes.

3.2. Strengthening Measures for Earthquake Rresistance of Old Houses in Rural Areas of Jiangxi

Considering the large number of paddy fields and various vegetations in rural areas of Jiangxi, Liu Junxia et al. [12] explored the effect of adding modified jute and straw fiber on the mechanical

properties of raw-soil block, the test results showed that mechanical properties and water resistance of improved raw-soil blocks were enhanced. Chang Weihua et al. [13] discussed various reinforcement methods for raw-soil masonry walls, and carried out quasi-static tests, it was found that the wall reinforced by wood frame can also be greatly improved, considering the factors of reinforcement cost, the raw-soil structure houses in rural areas can give priority to the reinforcement of wood frame.

In the case of wood structure houses, Zhou Tiegang et al. [14] proposed that the wood columns and joists could be strengthened with angle steel, the wood column, purlins and eaves should be reinforced with thin steel sheets, and the joists and purlins could be strengthened with flat iron. As for the reinforcement of retaining wall, the method of setting mortar steel bar in horizontally caved groove of wall was adopted. The shaking table test results showed that these measures can effectively improve the aseismic capability of the reinforced object while ensuring the lower reinforcement cost.

For masonry wall, the PP-band reinforcement is a new type of reinforcement method. The main characteristics of this method are economical, efficient and easy to construct, Sun Baitao and Zheng Yinzhi [15-16] had respectively carried out shaking table test and quasi-static test on single-storey masonry house and masonry wall strengthened with PP-band, the results showed that the PP-band can greatly improve the aseismic capability of the reinforced objects. Considering the economic situation in rural areas of Jiangxi, the reinforcement of PP-Band is suitable for popularization.

4. Conclusions and Suggestions

Bsaed on the analysis above, the main conclusions and suggestions are as follows:

(1) Old houses in rural areas of Jiangxi province still have a certain proportion, but most of them are weak in aseismic capability. The aseismic capability construction old houses in rural areas should be emphasized.

(2) Most of the old houses in the survey areas are not properly designed and the selection of house location is relatively random. The aseismic conscientiousness of local people is weak. Earthquake safety knowledge should be popularized in these areas.

(3) Because the house involved in this investigation are relatively old, most of these houses lack of maintenance. The aseismic capability of these houses is pretty poor, existing serious hidden dangers. These houses should be reinforced or demolished according to local seismic fortification requirements.

(4) Considering the backward economic condition in rural areas of Jiangxi, the reinforcement and renovation of the old houses should be supported by the local construction department with funds and equipment and this work should be carried out by professional team.

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