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Research Status and Experimental Thinking of Brick Masonry Reinforcement at Home and Abroad

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Abstract

Based on China's basic national conditions of "small earthquakes cause disasters, medium earthquakes cause major disasters, and large earthquakes cause major disasters", an earthquake of magnitude 7.5 or more occurs about every 5 years. A large number of masonry structure houses in China have not been designed and constructed according to seismic fortification standards, which has caused irreparable economic losses and casualties. The earthquake disaster is not directly caused by the earthquake phenomenon, and solving the structural failure is the main means of disaster prevention. It is very important to make the structure have enough seismic ability through strengthening, so as to reduce the possibility of its evolution into a disaster body.

Keywords

Steel fibers, Masonry structure, reinforcement, mortar surface layer.

1. Introduction

Concrete, Research background and significance of masonry reinforcement Masonry structure refers to the stressed structure made of blocks and mortar. It has a long history and wide application range, and has been used as the main building structure for a long time. Data show that about 50% of the world's buildings are masonry structures. However, based on the analysis of previous earthquakes in the world, the earthquake damage of masonry structure is particularly serious, so it is particularly urgent to strengthen and transform the masonry structure in service. Strengthening method of masonry structure In the early years of the founding of the People's Republic of China, a large number of masonry structures were built in our country, which existed for a long time, coupled with low construction standards at the beginning of construction, non-standard operation and other reasons, in the past few years, many safety accidents occurred, causing irreparable loss of life and property to the people. With the acceleration of urbanization, the seismic performance of buildings has become an important guarantee for public safety. Masonry wall is the main component of traditional building structure, its seismic performance has been widely concerned. The purpose of this research is to evaluate the improvement effect and application value of NPR reinforced masonry wall through systematic experiment on its seismic performance. In the past year, our research group has preliminarily completed the relevant literature research and pre-experiment stage through project establishment, fund application and experimental design. Through exchanges and cooperation with relevant scientific research institutions, we have collected a large number of cutting-edge research results on masonry wall reinforcement technology, and on this basis, developed a detailed experimental program, and carried out tests accordingly, and completed the main test work in November 2023. After that, the detailed test data processing work was carried out. Then, related patents and papers were written, and an academic report was held.

2. Current Research Status

2.1. Domestic Research Status

After the Tangshan earthquake, many masonry structures collapsed and were damaged. After the 1980s, Chinese scholars began to study the field of building structure reinforcement and renovation, translated many foreign literatures, did a lot of reinforcement and renovation tests, analyzed the seismic performance, and put forward their own theories. "Building seismic reinforcement Technical Code" (JGJ116-98) was released in 1998, with the maturity and perfection of reinforcement technology, this century has issued a number of reinforcement codes, regulations, the domestic seismic reinforcement theory is becoming more and more perfect.

Zhu Bolong et al. [1] conducted a low-cycle reciprocating test to study the seismic performance of transverse and longitudinal walls reinforced with 25 pieces of steel mesh cement mortar. The test shows that the shear strength of the transverse wall increases after one or two layers of reinforcement. In the study of longitudinal wall, it is found that the energy dissipation capacity, shear strength and wall integrity are improved after reinforcement. Based on the test data, the formulas for calculating the shear strength of the horizontal and longitudinal walls after reinforcement are put forward.

Weng Dagen et al. [2-4] used a pseudo-static device to carry out horizontal loading and applied horizontal low-cycle reciprocating loads on the wall pieces reinforced by glass fiber cloth (GFRP) and the wall pieces repaired by earthquake damage. The test finally proved that the seismic performance of the wall was enhanced by the reinforcement of glass fiber cloth.

Deng Mingke [5] studied the seismic performance of unreinforced bending masonry walls reinforced by high ductivity concrete (HDC), adopted pseudo-static test to study the failure mechanism and seismic performance of unreinforced brick masonry reinforced by HDC surface layer, and analyzed the influence of factors such as the strength of mortar on the surface layer and reinforcement methods, so as to provide design basis for HDC wall reinforcement.

Laurie et al. [6] designed 30 pieces of low-strength brick walls to study a large number of weathered and old masonry walls existing in reality. By analyzing the pseudo-static test results, it is found that the seismic performance of the brick wall is obviously improved after the brick wall is reinforced by the cement mortar surface layer of one side steel mesh. The calculation formula of shear capacity of reinforced brick wall is also proposed.

Wang Tianxian et al. [7] completed the test of four KP1 load-bearing brick walls. The test was carried out in two stages. In the first stage, the unreinforced wall was first loaded to the state of shear failure through low-cycle repeated test, and then the cracked wall was reinforced with the surface layer of double-sided steel mesh cement mortar, and the pseudo-static test was carried out. According to the test results, it is verified that the seismic performance can be effectively improved, and the emergence and development process of cracks after reinforcement, failure mechanism, strength and ductility are analyzed, and the suggested calculation formula of the shear resistance of the reinforced wall is given.

Zhao Liang et al. [8] summarized the previous test data and analyzed the pseudo-static test results of the masonry brick wall reinforced with 89 pieces of cement mortar surface layer, and concluded that: combining the four failure modes of the reinforced wall, the hysteretic curve shape like shuttle shape is the most full, and the seismic performance is the best, followed by the bow shape, and the S-shape is the worst. The grade of masonry mortar is positively correlated with the shear strength, and the ductility decreases. Finally, the formula of skeleton curve is fitted and verified.

Chang Yunpeng et al. [9] took the strength, thickness, wall thickness and vertical compressive stress of masonry mortar as the main research variables to conduct pseudo-static tests on 36 masonry brick walls to study the seismic performance after reinforcement, and concluded that the walls after reinforcement tend to swing failure and slip failure, with fuller hysteresis curve, increased energy dissipation capacity and slower stiffness degradation. The seismic performance of the wall reinforced by reinforced cement mortar, the wall reinforced by plain cement mortar and the wall unreinforced is weakened successively. The increase of vertical compressive stress makes the bearing capacity and stiffness of the wall increase, energy dissipation and ductility weaken, and shear failure is more likely. The formula for calculating the shear capacity of masonry brick wall is fitted.

2.2. International Research Status

W.k.so et al. [10] used the reinforced mesh cement mortar surface layer reinforcement method in 1974 to strengthen the undamaged wall on one side, the damaged wall on one side and the damaged wall on both sides. The pseudo-static test results show that this method effectively improves the shear bearing capacity of the reinforced wall. Double-sided reinforcement can improve the integrity of the wall and better seismic performance.

Abdullah et al. [11] used basalt fabric reinforced sarooj mortar (TRM) to conduct shear tests on one unstiffened specimen and three stiffened specimens with different conditions. The properties of unreinforced and reinforced specimens are analyzed and compared. The strengthened samples were able to resist out-of-plane bending moments 2.5 to 3 times higher than the unstrengthened samples (160-233% increase). In addition, reinforced walls were able to withstand higher deformation (deflection) than unreinforced samples, ranging from 20% to 130%. The results show that the use of TRM can effectively reinforce masonry with local materials (sarooj) that are compatible with existing masonry building materials.

Fiber-reinforced cement-based composites (FRCM) are widely used to reinforce existing structures, especially in earthquake-prone areas. After nearly two decades of scientific research, experimental evidence has demonstrated their effectiveness in enhancing the ultimate strength and displacement capacity of masonry walls. Design criteria for use in reinforcement practice still need to be formulated. Meriggi[12] adopted FRCM to carry out the shear reinforcement design method for masonry walls, and provided the calibration of partial coefficients for the calculation of limit states. The design relationship was validated on the basis of a test database containing 72 tests and is suitable for engineering applications. By considering 54 additional tests and comparing with FRCM reinforced wall, the possibility of using the same design form for composite mortar reinforced wall is studied. Finally, the increase of displacement capacity that FRCM and CRM are particularly useful for seismic reinforcement is estimated, and the design value of the ultimate displacement capacity is given.

Sandoli[13] conducted a monotone load test on H-shaped scaled reinforced masonry arcade in 2021, and compared the test results of 17 specimens reinforced with different thin steel bars with those not reinforced. It was found that the failure mode changed from shear failure to bending failure after reinforcement, and the ductility was enhanced, which could effectively improve its seismic performance.

Salvador et al. [14] designed a masonry wall with Windows in 2021 according to the Spanish seismic design code for structures. Fiber reinforced mortar (TRM) was used on both sides of the Windows to strengthen the seismic performance, and the shear strength, ductility and energy dissipation capacity were improved, among which the shear capacity was increased by more than 2.5 times.

Hossein et al. [15] conducted a pseudo-static test on three half-scale masonry brick walls in 2023, in which one wall was USM wall, one wall was non-prestressed glass fiber reinforced polymer bar (NSM GFRP) reinforced wall, and the other wall was prestressed NSM GFRP reinforced wall with symmetrical reinforcement through perforation. According to the experimental test results, the following conclusions are drawn: the non-prestressed reinforcement increases the wall's ultimate load to 1.38 times of USM, the horizontal failure displacement to 1.64 times, the prestressed reinforcement increases the wall's ultimate load to 1.58 times of USM, and the horizontal displacement to 2.27 times. Both improved energy dissipation, the damage was due to toe collision and sliding, and subsequently the GFRP bars were pulled out from the concrete foundation.

3. Conclusion

Design principles: Firstly, the design principles of reinforced masonry walls are determined, including the selection of reinforcement materials and the optimization of reinforcement methods. It is found that different types of reinforcement and reinforcement methods have a significant impact on the mechanical performance of the wall, and reasonable design can effectively improve the seismic performance.

Numerical simulation analysis: Through the introduction of numerical simulation technology such as finite element analysis, the damage process of reinforced wall under earthquake can be predicted more accurately. This method can make the seismic performance evaluation of the structure more detailed in the design stage, and greatly improve the reliability of the design.

Experimental research: The research group has carried out a lot of experimental research, including repeated loading test, failure mode analysis, etc. The results show that the seismic bearing capacity and deformation capacity of the reinforced masonry wall are significantly improved, and it also shows good ductility, which can effectively absorb and dissipate seismic energy.

Design optimization and standard formulation: Based on the test and simulation results, the research team proposed a series of design suggestions for NPR reinforced masonry walls, which provided theoretical basis and practical guidance for the subsequent reinforcement and renovation of masonry structures.

Improve building safety: Through the NPR reinforcement of masonry brick walls, not only improve the seismic capacity of the building, but also provide a safer living environment for the majority of people living in seismically active areas. Effectively reduce the casualties and property losses caused by the earthquake. Promote the technical progress of the construction industry: The successful implementation of the study provides new ideas and methods for the seismic design of building engineering, promotes the innovation of building materials and reinforcement technology, and improves the technical level of the entire industry. Social and economic benefits: It is estimated that the introduction of this technology can save a lot of reconstruction costs for construction projects, and also reduce the economic burden of post-disaster reconstruction due to its improved seismic performance. This will play a positive role in promoting economic development and social harmony. Basis for formulating policies and standards: The research results provide a scientific basis for the government and relevant

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departments to formulate seismic design standards, provide a reference for the national policy formulation in earthquake prevention and control, and promote the improvement of the overall seismic ability of the society.

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