Experimental and analytical research of strengthened masonry

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ABSTRACT. The presence of existing brick masonry buildings in the building stock within area with high seismic activity requires careful assessment of their seismic behaviour and retrofitting measures. Strengthening with RC jackets, although traditional, is still highly applicable. This paper presents results of a complete programme for experimental and analytical study of this strengthening method applied symmetrically on both sides of the walls on the whole wall area. Cyclic load tests on masonry walls were performed to evaluate their in-plane shear behaviour and identify shear strength, stiffness and energy dissipation. Two series of unreinforced and strengthened brick walls were tested with the purpose to compare their behaviour under cyclic horizontal loading. The results from the tests showed that the strengthening method leads to significant improvement in the shear resistance of the jacketed walls. Analytical models were used to predict the shear resistance of walls. Good agreement with experimental results was obtained with a model based on tensile strength of masonry.

KEYWORDS. cyclic tests, masonry, RC jacket, strengthening, analytical

1. INTRODUCTION

The main structural elements in masonry buildings are the masonry walls. They are responsible for the load transfer and the global stability of the building when subjected to vertical and horizontal forces. The combination of the gravity and horizontal loads, such as seismic actions, attracts axial forces, bending moments and shear forces. All these contribute to the imbalance of the building and may lead to damage or collapse of the building. A large number of existing unreinforced masonry buildings are still present and operational throughout the world. Their presence in the building stock within area with high seismic activity requires careful assessment of their seismic behaviour and retrofitting. Moreover, the existing unreinforced masonry buildings are composed of inhomogeneous material, not capable to carry tension forces. Additionally, many masonry building do not satisfy the latest seismic design provisions.

2. STRENGTHENING METHOD

The seismic behaviour and resistance of unreinforced masonry buildings can be improved by strengthening or retrofitting in cases of seriously damaged walls. Usually, traditional strengthening methods are applied, with the common use of reinforced concrete jackets. However, there is insufficient knowledge about the seismic behaviour of jacketed masonry, due to lack of experimental and analytical investigations. The design of those walls is usually based on empirical relations which may result in over- or under-design. Therefore, this paper focuses on two issues: (1) to compare the behaviour of the unreinforced and strengthened masonry with RC jackets subjected to lateral in-plane cyclic loads, and (2) to suggest a reliable analytical method for evaluation of the seismic resistance and performance of the jacketed masonry buildings.

3. EXPERIMENTAL PROGRAM AND ANALYTICAL ANALYSIS

Based on the extensive literature review, an experimental test program was established, aiming to identify the mechanical properties of masonry and its components. Based on the obtained results, the effects of variable wall geometry and precompression level were considered on the performance of the unreinforced and jacketed masonry walls, tested in real scale and subjected to alternating cyclic in-plane forces. The analytical models for reinforced masonry were used to investigate the capacity of the jacketed masonry due to the similarity of both structural materials and the similar behaviour when exposed to horizontal actions. The effectiveness of the strengthening method was verified experimentally and an increase in the seismic resistance of the strengthened masonry walls was obtained when compared to the resistance of the reference unreinforced walls. However, the ductility performance was not improved.

An analytical model for evaluation of RC jacketed masonry walls was proposed, based on the contribution of the masonry and the horizontal reinforcement. The contribution of the vertical reinforcement to the resistance of the walls was ignored, because the tests were performed without anchorage of the vertical reinforcement in the top and bottom beams. This approach was used in order to study the behaviour of the strengthening structural material, rather than to investigate the behaviour of a strengthened structural element - wall. Based on the obtained results, the proposed method for evaluation of the seismic performance of jacketed masonry walls was used to study the strengthening effects on an existing building.

4. NUMERICAL ANALYSIS

The elasto-plastic force-deformation relations for unreinforced and strengthened masonry walls, based on the experimental results, were implemented in a displacement-based analysis software, through a newly developed analysis module. The capacity spectrum method was applied to validate the efficiency of the strengthened material and to assess the seismic resistance of the building.

The research presented in the paper follows the concept of the new generation of design codes for masonry buildings. The obtained results enable application of the analytical approach for design of masonry buildings in cases of strengthened masonry buildings.

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