Abstract of dissertation

(論文の内容の要旨)

Seismic Retrofitting of Masonry Structures using Composite of Fiber Reinforced Polymer and Polypropylene

(FRP とＰＰ-バンドを用いた複合材料による組積造構造物の耐震補強に関する研究)

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Unreinforced masonry structures are highly vulnerable and have contributed a significant number of causalities during past earthquake disasters. Therefore, improvement of seismic capacity of unreinforced masonry structures is essentially important to reduce causalities for future earthquakes. In order to improve seismic capacity of unreinforced masonry structures, we have proposed a new composite material which can increase shear strength and deformation capacity of masonry walls. To investigate properties of newly proposed composite materials, we have carried out experimental and numerical studies. Fiber reinforced polymer (FRP) is a very strong but costly material. It can significantly increase the shear capacity of unreinforced masonry but exhibits catastrophic and brittle failure due to its low ductility. While polypropylene (PP) band is very cheap material but has large deformation capacity. In this study, an attempt has been made to utilize the large deformation capacity of PP-band and an increase in strength with minimal use of FRP.

In order to achieve above mentioned objectives a detailed study was planned which consist of numerical study and experimentation. Numerical study was carried out by modifying existing Applied Element Method (AEM) program to analyze the masonry structures retrofitted with such composite materials. Whereas experimental study consists of diagonal compression testing, out-of-plane bending test, volumetric study on FRP and shake table testing to evaluate the performance of newly proposed composite material and to verify the numerical results obtained after analyzing the same masonry wallets using modified 3D-AEM.

In numerical study, behavior of a newly proposed composite material was simulated using 3-D Applied Element Method (AEM). Verification of the proposed numerical model is achieved by conducting experiments on twelve masonry wallets. Out of twelve, six masonry wallets were tested in out of plane bending test and six were tested under in-plane forces in the form of diagonal compression test. Same wallet retrofitting scheme was selected for in-plane and out of plane experiments and all of them were analyzed using proposed 3-D AEM numerical simulation tool. Proposed numerical model has served satisfactory and has shown a fairly good agreement with experimental results which encourages the use of 3D-AEM to numerically simulate the behavior of non-retrofitted and retrofitted masonry wallets.

FRP volumetric study was carried out to find the optimum quantity and placement of FRP for strengthening of brick masonry wall system. Required objectives were achieved by performing diagonal compression tests on twenty masonry wallets. Masonry wallets were carrying different volume and arrangement of FRP strips. Response of masonry wallets with different volume and configuration of FRP strips were recorded using a digital acquisition system. Experimental results were carefully analyzed in order to propose an optimum and efficient retrofitting procedure of masonry wallets with FRP. Experimental results shows that correct retrofitting scheme can not only increase the efficiency but can also reduce the retrofitting cost and effort.

In shake table testing seismic response of masonry houses was evaluated under dynamic loading. A total of seven shake table tests were performed on 1-4 scaled brick masonry houses with timber roof. Out of seven model houses, one was non-retrofitted (URM), one was PP-band retrofitted, four were FRP retrofitted and one was FRP+PP-band retrofitted. In case of four FRP retrofitted house models, different FRP reinforcement and layouts of FRP were selected and their performance was compared to determine an optimum layout and reinforcement ratio of FRP retrofitted houses. In order to perform test on FRP+PP-band retrofitted house model, minimum reinforcement ratio of FRP was used with PP-band in the form of FRP+PP-band composite. Experimental results have determined that URM house model failure was brittle whereas use of PP-band has increased the ability of URM house to withstand a severe ground motion with intense cracking and energy dissipation. On the other side, FRP retrofitted masonry structure can also withstand a sever ground motion but up to failure structure remain perfectly elastic and when input motion increase the structural capacity than it suddenly collapse without any warning, ductility and energy dissipation. FRP is also an expensive material and if used alone may significantly increase the retrofitting cost. Whereas composite of FRP+PP-band is a good alternative which has increased shear capacity, energy dissipation capacity and ductility of house model at very low retrofitting cost. FRP+PP-band composite is a low cost and high performance composite material.