Master Thesis

NUMERICAL SIMULATION OF STRENGTHENED UNREINFORCED MASONRY (URM) WALLS BY NEW RETROFITTING TECHNOLOGIES FOR BLAST LOADING

BY

YU SU

B.E., Civil/Structural

School of Civil, Environmental and Mining Engineering

The University of Adelaide

December 2008

DELARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Y. Su

10 December 2008

ACKNOWLEDGEMENTS

The author would like to express his sincere gratitude to his supervisors, Dr. C.Q. Wu and Associate Professor M. Griffith, for their invaluable guidance and supervision during the course of this study. Their good nature, patience, frankness, and technical expertise had a profound impact on the author's academic experience and personal goals. Special thanks are given to Stephen Carr, Computing Support, for helping with definitely improving the software and hardware environment.

Finally, the author extends his sincerest thanks to his family for the ongoing support, especially his father Guozhi and uncle Dachen.

PUBLICATIONS FROM THE THESIS

International Journal papers:

1. **Su, Y.**, Wu, C., Griffith, M.C. (2008). Mitigation of blast effects of aluminium foam protected masonry walls. *Transactions of Tianjin University, ISSN 1006-4982, Vol.14, 2008.* Also will be published in *the 2nd International Conference on Analysis and Design of Structures against Explosive and Impact Loads, Beijing China, 17-19, October 2008.*
2. **Su, Y.**, Wu, C., Griffith, M.C. (April, 2008 submitted). Numerical Analysis of FRP Repaired URM Wall under Out-of-Plane Loading. *Submitted to Construction and Building Materials.*
3. **Su, Y.**, Wu, C., Griffith, M.C. (August, 2008 submitted). Numerical Simulation of Mitigation of Blast Effects of Aluminium Foams on Masonry Structures. *Submitted to Journal of Performance of Constructed Facilities, ASCE.*
4. **Su, Y.**, Wu, C., Griffith, M.C. (2008 submitted). Mitigation of blast effects on masonry walls using retrofit technologies. *Submitted to Advances in Structural Engineering.*

International Conference papers:

1. **Su, Y.**, Wu, C., Griffith, M.C. (2008). Numerical analysis of out-of-plane loaded masonry wall using homogenization technique. *The 14th International Brick and Block Masonry Conference in Sydney, 17-20 February 2008.*
2. **Su, Y.**, Wu, C., Griffith, M.C. (2008 accepted). Numerical simulation of bond-slip models between FRP and masonry in pull tests. *The Tenth International Symposium on Structural Engineering for Young Experts, Hunan, China, 19-21, October 2008.*
3. **Su, Y.**, Wu, C., Griffith, M.C. (2009 submitted). Performance of retrofitted masonry walls under blast loads. *The 9th International Symposium on Fibre Reinforced Polymer Reinforcement for Concrete Structures, Sydney, Australia, 13-15, July 2009.*

ABSTRACT

Terrorism has become a serious threat in the world, with bomb attacks carried out both inside and outside buildings. There are already many unreinforced masonry buildings in existence, and some of them are historical buildings. However, they do not perform well under blast loading. Aiming on protecting masonry buildings, retrofitting techniques were developed. Some experimental work on studying the effect of retrofitted URM walls has been done in recent years; however, these tests usually cost a significant amount of time and funds. Because of this, numerical simulation has become a good alternative, and can be used to study the behaviour of masonry structures, and predict the outcomes of experimental tests.

This project was carried out to find efficient retrofitting technique under blast loading by developing numerical material models. It was based on experimental research of strengthening URM walls by using retrofitting technologies under out-of-plane loading at the University of Adelaide. The numerical models can be applied to study large-scaled structures under static loading, and the research work is then extended to the field of blast loading. Aiming on deriving efficient material models, homogenization technology was introduced to this research. Fifty cases of numerical analysis on masonry basic cell were conducted to derive equivalent orthotropic material properties. To study the increasing capability in strength and ductility of retrofitted URM walls, pull-tests were simulated using interface element model to investigate the bond-slip relationship of FRP plates bonded to masonry blocks. The interface element model was then used to simulate performance of retrofitted URM walls under static loads. The accuracy of the numerical results was verified by comparing with the experimental results from previous tests at the University of Adelaide by Griffith et al. (2007) on unreinforced masonry walls and by Yang (2007) on FRP retrofitted masonry walls. To study the debonding behaviours of retrofits bonded to masonry, and find appropriate solution to protect certain masonry walls against blast loading, various retrofitting technologies were examined. The simulation covers explosive impacts of a wide range of impulses. Based on this work, pressure-impulse diagrams for different types of retrofitted URM walls were developed as a design guideline for estimating the blast effect on retrofitted masonry walls.

The outcomes of this research will contribute to the development of numerical simulation on modelling retrofitted URM walls, improving the technique for explosion-resistant of masonry buildings, and providing a type of guideline for blast-resistant design.

CONTENTS

LIST OF FIGURES

LIST OF TABLES