University of Technology, Sydney

Improvement in Seismic Performance of Stone Masonry Using Galvanized Steel Wire

Rudra Pun

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Rudra Pun

April 2015

In the Memory of Precious Lives Lost in Earthquakes

Abstract

This research is about using either freely available natural stone or rubble left behind earthquake disasters to build a seismic resistant house. The bottom line of this research is to develop a simple and effective technique for building a stone masonry house that will not collapse during the seismic event.

Traditionally constructed stone masonry houses are highly vulnerable to seismic loadings. In the past, most of the un-reinforced stone masonry buildings had collapsed causing many casualties during the earthquake events. In order to address this problem, various options have been recommended by the researchers for reinforcing new stone masonry buildings as well as strengthening existing buildings. However, developing an economically viable and socially acceptable option for improving seismic performance of the residential stone masonry houses is still remaining a great challenge.

In this context, a system of reinforcing rubble masonry using galvanized steel wire (GSW) mesh has been proposed in this research. A gabion like technique is adopted for wrapping the wall with a mesh. It is a simple technique, which can be easily learnt by the users and applied to build their houses. This method is suitable even in remote and isolated areas, where access to the technical inputs is not available. In addition, this technique seems to be useful during reconstruction phase after the earthquake disaster, for clearing up sites and building safer houses side by side.

The performance of the proposed reinforcement system was investigated both experimentally and analytically under static and dynamic loadings. Suitable materials for this research were identified and the required materials were collected. All specimens were prepared and cured in the laboratory environment. Wall specimens were constructed with due considerations to the owner builder construction mode, where owners themselves construct their houses. Both unreinforced and reinforced wall specimens were prepared for static test as well as shake table testing simulating strong earthquakes.

Two types of reinforcement schemes have been proposed in this research. In the first method, reinforcement mesh is woven around the wall using steel wire, whereas in the second method, pre-fabricated meshes are used.

Developing connecting techniques between adjacent meshes are some of the significant contributions of this investigation. This method makes this reinforcement system practicable using pre-fabricated meshes. Moreover, a simple method for tightening the mesh has been developed in this research. This tightening technique makes the proposed reinforcement system more effective in seismic performance than other types of external mesh by allowing limited deformation of the building during ground motions.

Most of the testing procedures required for this research were not covered in the existing standard methods. Therefore, several additional techniques required for preparing the specimens and testing have been developed during this research, which are given in the relevant sections. Two terminologies have been proposed for describing the strength of rubble wall in flexure.

Materials were tested for some basic properties as well as few reference parameters, which can be used for comparing the results of this research to the relevant cases. Static tests on unreinforced wall specimens have provided the basic strength properties of the wall, whereas testing on reinforced specimens have indicated potential effectiveness of the proposed scheme under dynamic loading. This has been verified by shake table testing.

A theory has been proposed for explanation of the behaviour of an externally reinforced beam and some relations have been derived. Deformation characteristics of a hexagonal mesh have been derived so that the theory developed for externally reinforced beam could be applied to the GSW reinforced wall. A set of analytical procedures have been developed and applied for the assessment of a single storey and two storey buildings.

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Abbreviations and Acronyms

A	Cross-sectional Area
AEM	Applied Element Method
A_h	Design Horizontal Seismic Coefficient
AS	Australian Standard
ASTM	American Society for Testing and Materials
B	Breadth
BS	British Standard
CFRP	Carbon Fibre Reinforced Polymer
cm	Centimetre
D	Depth of beam / thickness of wall
DEM	Discrete Element Method
E	Modulus of Elasticity
ε	Strain
F	Failure Load
f_a	Axial Stress
f_b	Bending Stress
f_c	Compressive Stress
FEM	Finite Element Method
f_s	Shear Strength
G	Modulus of Rigidity
g	Acceleration due to Gravity
GFRP	Glass Fibre Reinforced Polymer
GPa	Gigapascal
GSW	Galvanized Steel Wire
h, H	Height
HB	Hand Book
Hz	Hertz
I	Second Moment of Area, Importance Factor
IAEE	International Association for Earthquake Engineering
IS	Indian Standard
kg	Kilogram
kPa	Kilopascal
L	Length
l	Span
LL	Liquid Limit
LS	Lateral Span
LVDT	Linear Variable Differential Transformer
m	Metre
M	Moment
min	Minute

mm	Millimetre
MMI	Modified Mercalli Intensity
MPa	Megapascal
N	Newton
NBC	Nepal National Building Code
NSET	National Society of Earthquake Technology-Nepal
NSW	New South Wales
P	Point Load
PI	Plasticity Index
PL	Plastic Limit
PP	Polypropylene
R	Response Reduction Factor
RC	Reinforced Concrete
s	Second
s_m	Strain mobilising length
STP	Scrap Tyre Pads
T_a	Approximate Time Period
USGS	Unites States Geological Survey
UTS	University of Technology, Sydney
V_B	Design Base Shear
VS	Vertical Span
Z	Zone Factor
ν	Poisson's Ratio

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