ABSTRACT

THE HYSTERETIC BEHAVIOUR OF FERROCEMENT-RETROFITTED CLAY BLOCK MASONRY WALLS UNDER IN-PLANE REVERSED CYCLIC LATERAL LOADS: EXPERIMENTAL INVESTIGATIONS AND GRAPHICAL COMPUTER MODELS

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It is acknowledged that Trinidad and Tobago is an earthquake prone region. Nevertheless, the majority of houses in these countries are built using unreinforced masonry blocks which are inadequate for seismic resistance. The main type of masonry block that is used is the 100 mm hollow clay block. Therefore, there is an urgent need to adopt and implement an appropriate retrofitting scheme to address the problem. An apparently feasible solution is the use of ferrocement skins attached to the walls. In this way, the ductility of the ferrocement skin can be relied upon to absorb the seismic energy imparted to the house. Given the constructional advantages of ferrocement, the retrofitting can be undertaken by the homeowners themselves at a reasonable cost. This approach was recently identified by the National Earthquake Hazard Reduction Programme (NEHRP) 1992 as being technically sound based on research work conducted at the National Center for Earthquake Engineering Research (NCEER) in Buffalo, New York.

However, the work conducted at the NCEER does not consider an environment that is directly relevant to Trinidad and Tobago - the walls were subjected to a bearing pressure that is about four times that used in Trinidad and Tobago; the walls were not anchored at the base; the walls did not have openings, and the masonry elements were of solid masonry and considerably thicker than the masonry blocks used in Trinidad and Tobago. In addition, there is a scarcity of research data on the behaviour of ferrocement under in-plane load, or under cyclic load, as well as the behaviour of structural elements repaired or retrofitted using ferrocement.

The objective of this study was therefore to investigate the behaviour of ferrocement-retrofitted walls under in-plane, reversed cyclic load. An essential part of the study was the taking of a retrofitting perspective in that the walls all used a wall-to-floor anchorage device, and a construction practice was adopted which was believed to adequately simulate the actual field conditions. The aspect of behaviour on which emphasis was placed was the hysteretic behaviour, also known as the cyclic load-displacement behaviour, or the restoring force characteristics. This approach was taken given the fact that the current codes of earthquake design practice are based on ductility in which case the hysteretic behaviour of the element must be well understood if the ductility demand and allowable ductility are to be adequately assessed.

Twenty-three (23) walls were tested of which three (3) were unreinforced control specimens. Each wall was of dimensions 2.44 m in length by 1.83 m high. Four different types of walls were studied - walls without openings; walls with one door opening; walls with one window opening, and walls with both a window and a door opening. Three different types of meshes were used, and the effects of bearing pressure and type of ferrocement skin-to-masonry wall anchorage, were also investigated. A typical hysteresis loop was characterised in terms of a number of properties, and the variations in these properties were examined as functions of average applied displacement, and cumulative hysteretic energy. The averaged hysteretic envelope was also characterised in terms of a number of properties, and the variations in these properties were examined as functions of the physical test variables such as the number of layers of mesh.

A mathematical hysteretic model was proposed based on endochronic plasticity theory. The model is expressed in a differential form and therefore can be used for probabilistic seismic design using stochastic closed-form procedures. The model is applicable to any non-linear softening oscillator modelled as a lumped mass and is expressed in terms of a number of undetermined parameters which are then estimated by non-linear system identification. In the system identification, interactive computer graphics based on the Windows 3.x Graphical User Interface plays an indispensable role.

A non-linear finite element analysis methodology was also proposed as a means of replacing the costly physical wall with a virtual, numerically equivalent wall.

It was found that wall-to-foundation connection behaviour dominates the response for ferrocement-retrofitted walls with no openings but its effect diminishes rapidly with increasing size of opening in the wall. The proposed hysteresis model was found to be reasonably accurate, and the proposed finite element methodology was found to adequately simulate the physically observed test results.