DYNAMIC TESTING OF A TIMBER FLOOR DIAPHRAGM IN AN UNREINFORCED MASONRY BUILDING

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ABSTRACT :

The flexibility of timber diaphragms in unreinforced masonry buildings has been reported to have a significant effect on the seismic performance of the complete structure. In New Zealand, there currently exists a need to improve the knowledge and expertise associated with the performance of timber diaphragms to assist the seismic assessment of unreinforced masonry buildings and design of seismic retrofit solutions. To address this issue, a series of modal tests were conducted on the third floor timber diaphragm of the Nathan Building located in Auckland's Britomart Precinct, which is a building typical of New Zealand historic unreinforced masonry construction. Preliminary analysis indicates that the fundamental horizontal natural frequency occurs at 20.5 Hz which reasonably matched the finite element model, which predicted a frequency of 18.49 Hz. Further testing, system identification and finite element updating is required to determine accurate dynamic diaphragm properties. An investigation of typical New Zealand diaphragm details was also conducted to aid future testing and finite element modelling.

KEYWORDS: Dynamic testing, forced vibration, diaphragm, unreinforced masonry building, New Zealand

1. INTRODUCTION

Unreinforced masonry (URM) buildings have proven to perform poorly in earthquakes due to their brittle nature and inability to dissipate hysteretic energy. In New Zealand, the introduction of by-laws (DBH 2004) mandating the seismic upgrade of these earthquake-risk buildings, combined with the potential loss of human life and destruction of its heritage structures, has necessitated research focussed on mitigating these adversities. To address a comparative absence of a national platform of knowledge and expertise associated with seismic retrofit or rehabilitation of New Zealand's earthquake-risk buildings, a collaborative research programme named Seismic Retrofit Solutions was initiated in 2005 (Retrofit Solutions (n.d.)).

Typical multi-storey URM construction in New Zealand consists of solid URM walls and timber floor diaphragms. It is widely recognised that the behaviour of these light timber diaphragms is crucial to the seismic response of the complete structure (Abrams 1995; Bruneau 1994). A problem currently exists that researchers and practitioners must predict building response and formulate retrofit solutions based on limited laboratory data and inadequately validated modelling techniques. Practitioners have communicated the need for better data on the dynamic characteristics of heritage timber diaphragms in order to improve the accuracy of their seismic assessments with particular emphasis on data associated with diaphragm stiffness and level of damping.

This article has two purposes. The first is to present typical New Zealand timber diaphragm details collected from case studies of actual URM buildings, that will aid future test planning and ensure representative finite element (FE) modelling. The results from a series of modal tests conducted on the third floor timber diaphragm in the Nathan Building, one of New Zealand's heritage URM structures, is then presented with comparison to a FE model. This form of testing is conducted in the linear-elastic range and is used to establish modal properties such as natural frequencies, mode shapes and modal damping. These results can later be used to refine the initial FE model using sensitivity-based updating techniques that are well established in the mechanical and aerospace industries (Friswell and Mottershead 1995).

2. PREVIOUS RESEARCH

Bruneau (1994) reported that most URM building earthquake-induced failures in the last 20 years were related to the performance of timber diaphragms. This likely motivated the many research studies that aimed to determine the influence of flexible timber diaphragms on the seismic performance of URM buildings (Abrams 1997; Paquette and Bruneau 2003; Tena-Colunga and Abrams 1996). The lack of in-plane shear connection to