

Typical multi-storey unreinforced masonry construction in New Zealand consists of solid unreinforced masonry walls and timber floor diaphragms. It is widely recognised that the behaviour of these light timber diaphragms is crucial to the response of the structure as a whole. Lively in-plane shear rotation caused by their flexibility has been observed to cause significant corner damage to the unreinforced masonry walls in past earthquakes. There is often an absence of sufficient positive connection to the out-of-plane walls which significantly increases the likelihood of out-of-plane wall failure.

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, in particular their stiffness, level of damping and floor to wall force transfer capability.

A current research programme has been initiated to investigate the dynamic behaviour of the timber diaphragms in the Nathan Building, located in Auckland's Britomart precinct which is a structure typical of historic New Zealand unreinforced masonry construction. The timber diaphragm was tested in-situ using a dynamic mass shaker. The forced vibration test enabled determination of dynamic properties such as natural frequencies, damping ratios and modal shapes. Additional testing of the Nathan Building and other heritage structures is planned.

Dynamic properties that are attained will be published in an assessment guide that will accompany the NZSEE document *Assessment and improvement of the structural performance of buildings in earthquakes* that will aid in the design of retrofit solutions.

Also, laboratory experimental testing on seismic response of unreinforced masonry (URM) building with timber diaphragm will be conducted in Structures Lab at University of Auckland. The primary purpose of this research programme is to investigate the system level response of URM buildings. This includes diaphragms response, wall-diaphragm connection details, in-plane wall response, out-of-plane wall response, the influence of wall penetrations, and the response of masonry corners. In order to conduct the testing, a URM House 1 has been constructed.

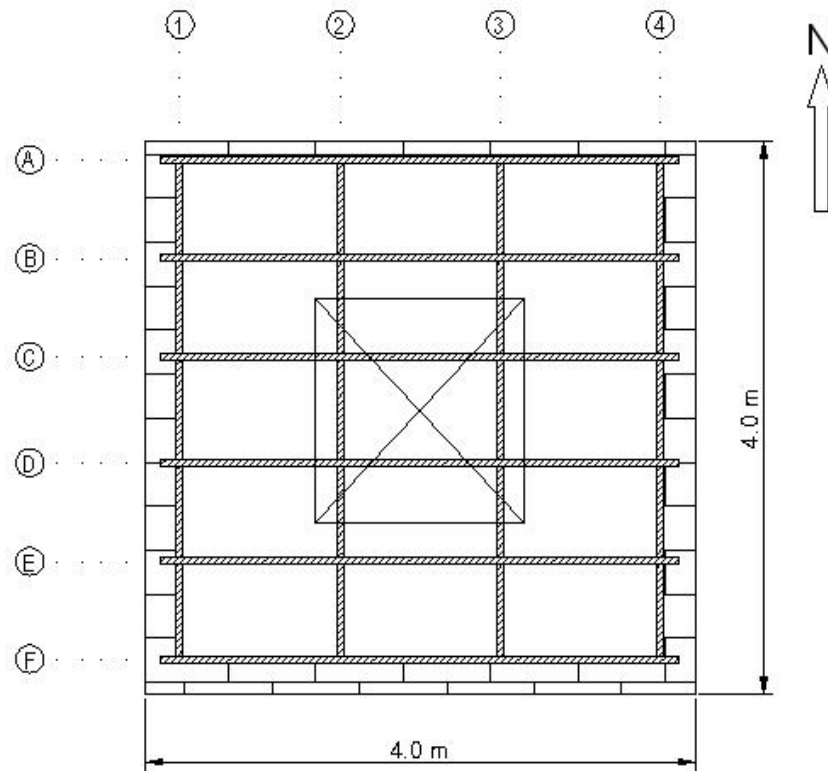
The dimension of the URM House 1 is 4 m × 4 m as shown in plan view of **Figure 1**. The north wall is one leaf 110 mm thick solid brick wall with 1.91 m height, whereas the south, west and east walls are two leaf 230 mm thick brick wall with opening(s) and 2.2 m height. For the two leaf thick walls the header course is at every fourth course. The south wall contains a door and window opening, while the west and east walls have a window opening only. The one leaf thick out-of-plane wall was designed to have a height/thickness wall ratio of 20, as this ratio has a strong influence on out-of-plane wall response when subjected to seismic excitation. The two leaf thick in-plane walls (west and east walls) were designed to investigate shear failure for all piers. The URM House 1 comprise a timber diaphragm consisting of six 45 mm × 140 mm joists at 704.5 mm centre to centre spacing and 45 mm × 140 mm blockings at 1149 mm centre to centre

spacing. The joists are supported by the interior leaf of the east and west brick walls and covered with a single straight (perpendicular to joists) 32 mm × 140 mm timber decking. The constructions of House 1 are shown in **Figure 2**.

The ANCO ENGINEERS MK-140-10-50 eccentric mass vibrator (shaker) will be used to test the URM House 1 for seismic response. The shaker will be located at the top of the URM House 1 on the timber diaphragm as schematically shown in **Figure 1**. The primary direction of the force selected will be the north-south and the others directions (west-east, northeast-southwest, and northwest-southeast) will be taken as secondary directions. The first expected failure will be the diaphragm-wall connection, and so retrofitting of the connection will be done before testing proceeds further.

This proposed research study shall be able to provide quantifiable data on the system level response of URM buildings by performing the testing of individual components. Also, this study allows several overriding opportunities to investigate load-path behaviour through URM buildings, hierarchy of failure modes (and therefore insight into how to retrofit, and to what level of strength), three dimensional response, excitation in multiple directions, and three dimensional finite element modelling. In addition, the research work shall be deliverable in any relevant New Zealand and international conferences, and a journal paper either in local or international.

Additional of two houses are plan to be constructed for further laboratory experimental investigation on this research study.



**Figure 1: Plan view of URM House 1**



**Figure 2: Construction of URM House 1**