SEISMIC RESEARCH OF UNREINFORCED MASONRY BUILDINGS

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Abstract

This project focused on the seismic performance of unreinforced masonry (URM) buildings. Specifically, our analysis stemmed from the observations and data collected from various buildings in the city of Christchurch that were affected by the 2010 earthquake of magnitude M7.1 and later aftershocks including one of magnitude M6.3. There was a need for more quantitative information of the effects of metal rod anchors in URM buildings, and so multiple tests were scheduled to collect data that would later be organized in a way that could be easily understood by both engineers and non-engineers.

Project Overview

Many of the Christchurch buildings that had been damaged during the 2010 Canterbury earthquake were unreinforced masonry buildings. We partnered up with a team of researchers that had come together to document and interpret observations of the damage levels of each building, and to also provide additional evidence that explained other possible causes for the damage levels of a group of Christchurch buildings. In order to back up the already documented qualitative information of the buildings, we were to investigate and organize any new quantitative information that both engineers and non-engineers could understand and use as a reference for future building codes.

During our first on-site project in the city of Wanganui, the plan was to conduct several tensile tests for anchors in an unreinforced masonry building. I had not been familiar with anchors, since I had not studied them in any of my previous courses yet, but I soon found out that an anchor is a device such as a metal rod, wire, or strap, for fixing one object to another. In the case of this specific project, the anchors were metal rods with diameters of either 12mm or 16mm that were to be embedded, at different lengths, into the masonry walls.

The purpose of the different anchorage embedment was to see whether combinations of bent rods, straight rods, grout adhesive, and a couple of epoxy adhesives would show us different strength levels of the fixing combinations.

Therefore, we installed over ninety anchors which were either straight, meaning parallel with the floor, using both epoxy and grout adhesives, or bent, meaning at an acute angle from the floor, and also using both adhesives. During our installations I learned that the drilled holes needed to be cleaned, which would help both adhesives to bond better with the bricks since the dust could act as an unwanted middle layer. When it came to using grout, the holes also needed to be saturated with water. In the process we found out that this saturation step needed to last a few hours, and at times we even left the water running over night. It had not been expected that the saturation step would need to last as long as it did, so we had to create a contraption that could run the water through multiple holes at once. It was great to practice using creativity during the installations, and after some discussion, the conclusion was to assemble multiples hoses together so that the water's pressure would help it run in multiple directions. This invention provided us with a more efficient way of saturating multiple holes at once, and it allowed us to later observe the differences between holes that were less saturated than others. Next we had to fill the holes with either grout or epoxy and then quickly insert the rod anchors before either adhesive dried up. Out of the two types of adhesives, grout was the more difficult one to use. The mixing instructions for grout were simple enough to follow, but when we needed to fill the drilled holes with it, we had to create another device to help push enough grout into the hole so that we could then immediately drive the rod anchor into the same hole.

The overall installation, and being able to observe the hardships of each step, allowed me to see that the performance of the anchors also depends on the installation process and how well it is conducted. It was helpful to go through the installation process ourselves, and not just test the tensile strengths of pre-installed anchors, because it allowed us to observe why spacing between anchors made a difference, the advantages and disadvantages of installation with two different adhesives, and learn about the precautions needed to take when working with different tools and materials.

When we began testing the tensile strengths of each anchor we had installed, a computer program was set up in order to record the outward displacements of the rods as they were pulled out and to graph the strain vs. stress curves. At times we encountered unforeseen obstacles, such as having some anchors yield before they reach the expected force failure, and some of the bricks still being damp from the saturation process, which meant the bond of adhesive and brick could have been decreased in quality. For each wall section, that we had installed anchors into, bed-joint shear tests were needed to note the sole horizontal failure modes of the bricks. Finally, both brick and mortar samples were also carefully cut out, labelled, and stored to later test their compression strengths. Looking over the results, it was interesting to note that most of the bent rods did not provide a higher resistance to tensile testing, compared to the failure points of the straight anchors. The bent rods failed at about the same force values that the straight rod anchors failed at, which makes us believe that the orientation of anchors may not highly affect the tensile strength of anchors. Further testing is required to be sure of this assumption, because the combinations of bond quality of each adhesive and embedment depths also need to be taken into account.

With all the data collected, all the tests' information was organized into spreadsheets. As part of the bed-joint shear tests, the height measured from the ground floor to each test location was used to calculate the overburden weight (□□+□) on the section, which is the amount of pressure or stress imposed on a layer of masonry. The building's average masonry cohesion value (□) was then calculated by averaging each test location's masonry cohesion value using the equation,

$$□_□ = 0.75\,□\frac{□_□}{□_□} - □_{□+□}\,□$$

with □□being the force at which the first sliding of the brick occurred and □□ being the area over which the force is applied: the standard dimensions of a brick. Each brick sample was also tested to see what its compression strength was, and the same was done for each mortar sample. All the brick samples were cut to be of the same dimension, but the mortar samples varied in size so their compression strengths had to be revised. By using each mortar sample's measured height to thickness ratios, and the guidelines in the "Commentary to Assessment and Improvement of URM Buildings for Earthquake Performance", the mortar compressive strength correction factors were determined by using Table C2-1 (shown below).

Table C2-1: Height to thickness ratio correction factor for mortar compressive strength

h/*t* ratio	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Correction factor	1.3	1.225	1.15	1.075	1.00	0.925	0.85

The compressive test results that had previously been recorded were then divided by their corresponding correction factors, and the average correction strength would be equal to the average mortar compressive strengths.

In addition, there was a need to analyze detailed photographs taken of over three hundred buildings from Christchurch that had been affected by the 2010/2011 Canterbury earthquake swarm. Primary discussions focused on deciding which parameters were the most important to indicate when we went through the photographs, and then the different parameters were divided into two main sections: those in diaphragm-to-wall connections and those in parapet restraints. For each of these categories it was also necessary to identify the parameters for both adhesive anchors, and through plates. Many of our conclusions focused on through plates since more information was provided for these retrofits. We were able to explain our conclusions through graphs and provided summaries for the charts that provided the most evidence. The graphs that provide the most helpful evidence show that the overall database contains over one hundred samples of through bolts in diaphragm-to-wall connections, but adhesive anchors in diaphragm-to-wall connections, and both types of retrofits in parapet restraints each have sample amount in the 20s range. Other graphs explained that increased damaged occurred when through plates were spaced farther apart. We observed that the most significant damage level contributor in the first level was the decreased spacing between through bolts, and that most significant contributor in the roof level was the increased spacing. It was difficult to make conclusions for adhesive anchors, since there was more photographic evidence and support for through plates.

Due to limited time, we were unable to analyze more buildings with adhesive anchors as the main seismic retrofits and add more graphical and analytical information to the overall database. The study of different retrofits in unreinforced masonry buildings is still in motion, and I was privileged to take part in the beginning steps and help further its future research.

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References

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