Experimental Evaluation of the Seismic Performance of Hospital Sprinkler Systems

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Abstract

This paper discusses the experimental set-up and procedures for the seismic testing and evaluation of a sprinkler system in hospital model. Concrete compression tests are ran to ensure compliance with ACI 355.2 anchor testing qualifications. Maximum shear strength of the anchor is found to include within the piping system model. Frame and piping system within the model is tested under input motions as guided by AC 156.

Introduction

Located on the Pacific Rim, Taiwan frequently experiences earthquakes. When an earthquake occurred in Kaohsiung in the southern part of Taiwan in March 2010, the piping system in a hospital structure failed, resulting in the evacuation of all patients on that floor. Failure in critical facilities such as hospitals in times of natural disasters is intolerable as they as are crucial to the care and safety of patients and victims. Thus, the National Center for Research on Earthquake Engineering (NCREE) models the hospital room of failure in order to study the dynamic properties of hospital sprinkler systems, and ultimately suggest innovative safety codes to improve the performance of nonstructural components in times of disaster.

Testing of nonstructural components requires a more complicated process as there is no uniform safety code. There are far too many different possible shapes to create a uniform code. Thus, in this testing of the piping system in the hospital model, the anchors or fasteners must be tested separately to determine their tensile and compressive properties. The testing of the anchors must comply with the ACI 355.2 standards. One such criteria states that the compressive concrete strength must be within their ranges: 17 to 28 MPa for low-strength concrete, or 46 to 60 MPa for high-strength concrete.

Testing of the sprinkler system uses the AC156 input standard. Applicable to nonstructural components with fundamental frequencies above 1.3Hz, the input motion has frequency of 1.3 to 33.3Hz. Data is recorded for every 1/3 octave for analog equipment and 1/6 octave for digital equipment.

Concrete Compression Test

Concrete specimens must be tested to determine if its compressive strength complies with the qualifications defined by ACI 355.2. This is done by the standard testing process for concrete. Six concrete specimens are poured into cylindrical shapes of 15 cm diameter and 30 cm height. The specimens are then tested under compression in 3 occasions in which the concrete has been set for 7 days, 14 days, and 28 days, respectively.

As seen in Figure 1, the maximum compressive strength of the concrete after 28 days of setting is between 20 to 25 MPa and falls within the specified range. This indicates that the concrete indeed complies with the anchor testing qualifications.

Anchor Strength Test

Experimental Set-Up

The shear strength of the anchor must be determined in order to accurately predict piping reaction in virtual models of the hospital model. The experiment is set up as in Figure 2, The anchor is embedded into a concrete slab (as tested in the compression test). The concrete slab has a crack to simulate weakened embedment strength to comply with testing standards. The concrete rests on two rollers on one end, and is attached to the actuator on the other end. Dimensions of the testing set-up are shown in Figure 3 of the appendix. Eight tests are run in which the actuator pushes until the anchor (or in some cases, the rod attached to the anchor) fails. The different modes of failure for the six separate tests are shown in Figure 4. Compiled data results are shown in Figure 5. Shear strength ranges from 9kN to 13kN.

Sprinkler System Shake Table Test

Experimental Set-Up

The sprinkler system is installed in a frame structure modeled after a patient room of a hospital structure. Restraints from ceilings and walls are included to create a realistic test that accurately reflects the patient room. A steel frame is used to reproduce seismic motions and simulate the piping system above the ground floor. Dimensions and set-up of the rooms and frame system are shown in Figure 6 and Figure 7, respectively. The locations of instrumentation are detailed in Figure 8. The input motion based on the AC156 standard will be used to investigate the dynamic properties of the sprinkler system.

Conclusion

Results from the concrete compression test confirm that ACI 355.2 qualifications are met for the testing of the anchors. Several cycles of shear testing on the anchors indicate that the maximum range of shear strength is between 9 and 13 kN. Unfortunately, due to time restraints, final testing of the piping system and sprinkler system was not scheduled until after the duration of this internship. Thus, results from the final testing are not available.

References

ACI Committee 355. *Qualifications of Post-Installed Mechanical Anchors in Concrete and Commentary, An ACI Standard*. American Concrete Institute (ACI), USA. 2007. Print.

Chai, Juin-Fu. *Shaking Table Test for Nonstructural Components (AC156 and NEBS GR-63-CORE)*. June 2011. PPT File.

Goodwin, Elliot, Emmanual Maragakis and Ahmad M. Itani. *Experimental Evaluation of the Seismic Performance of Hospital Piping Subassemblies*. MCEER, University at Buffalo, The State University of New York. September 2007. Print.

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Appendix

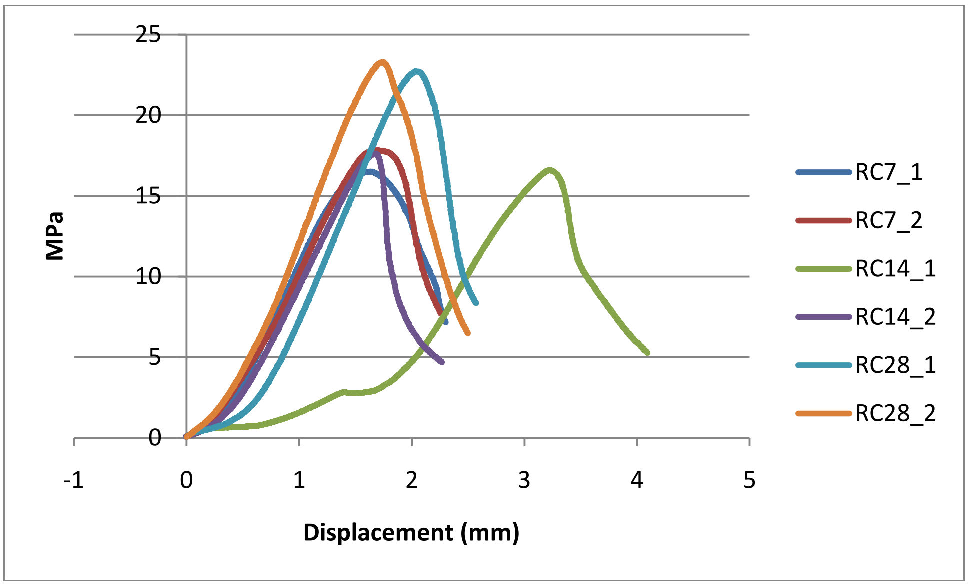

Figure 1. Compiled data for concrete compression test.

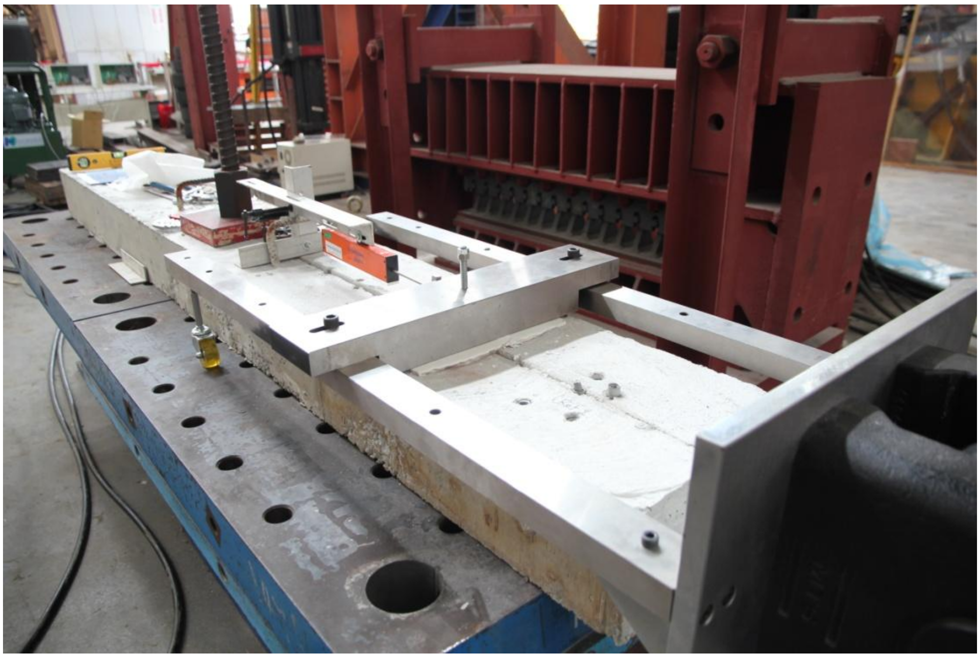

Figure 2. Experimental set-up for anchor shear test.

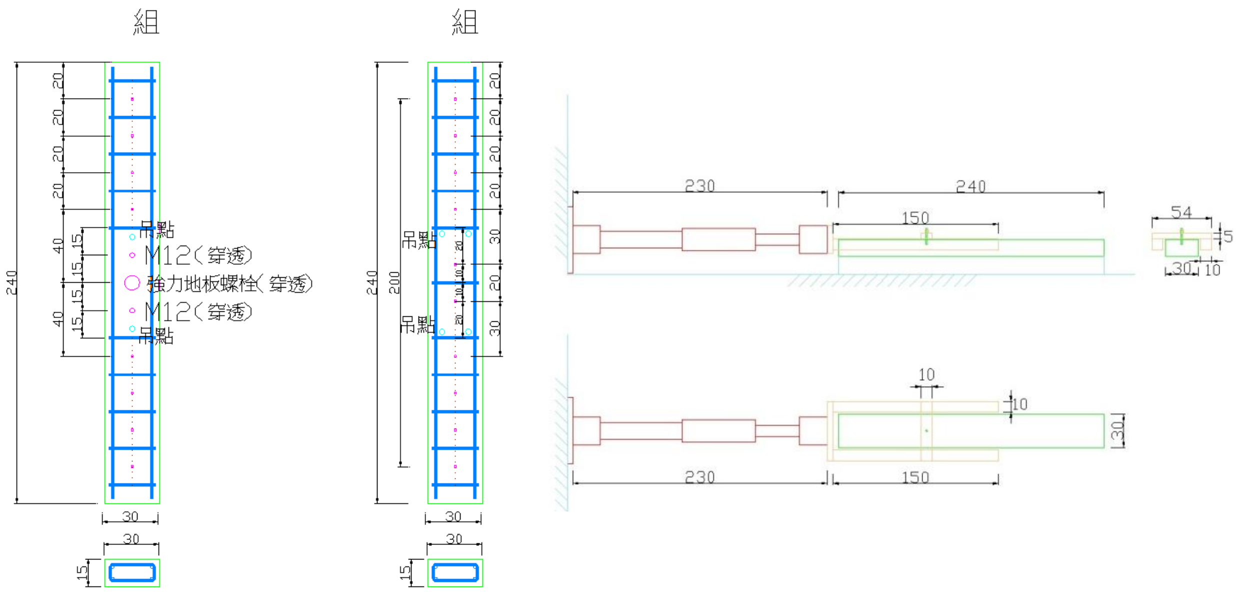

Figure 3. Dimensions and set-up for anchor shear test. The figure on the left shows the design of the concrete slab. The figure on the right shows the set-up ofr the actuator and the slab.

Figure 4. Failure point for three different shear test cycles. The rod failed in all three cases.

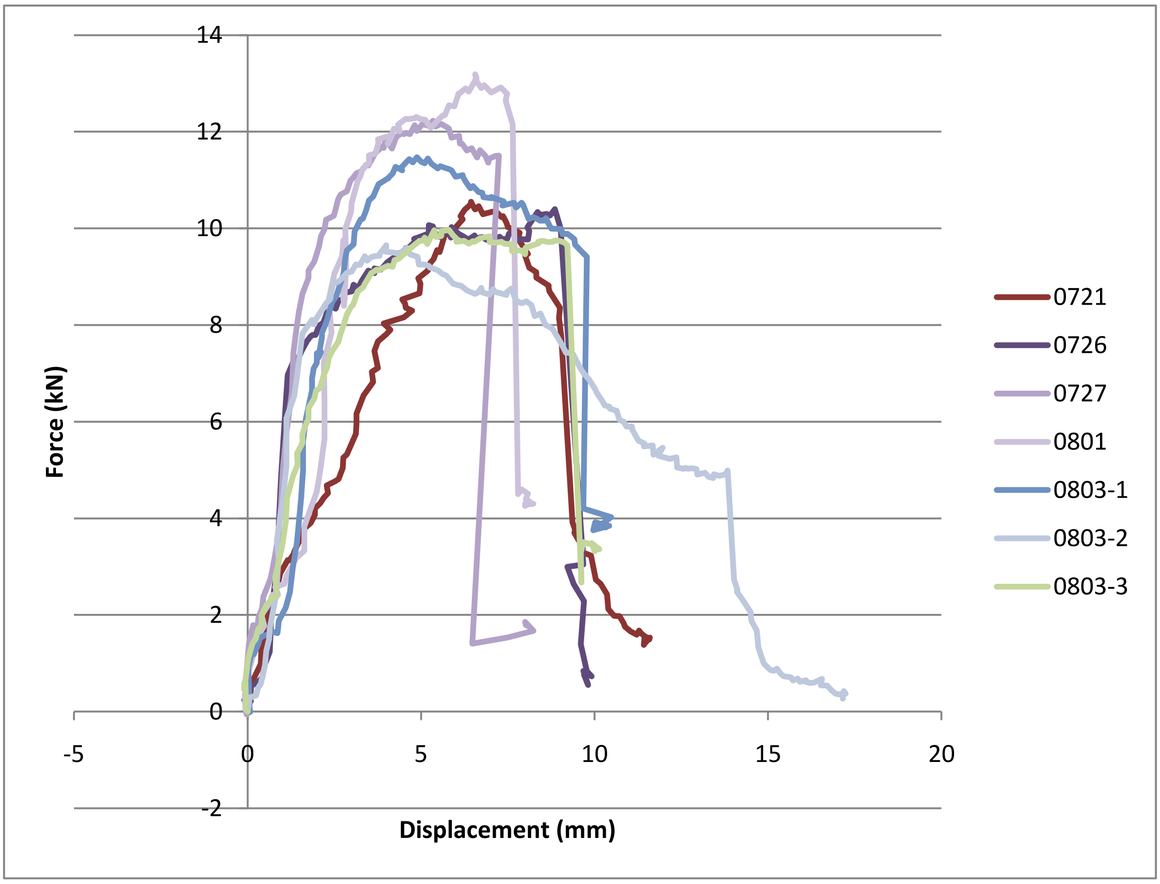

Figure 5. Compiled force-displacement graph for shear tests on anchor.

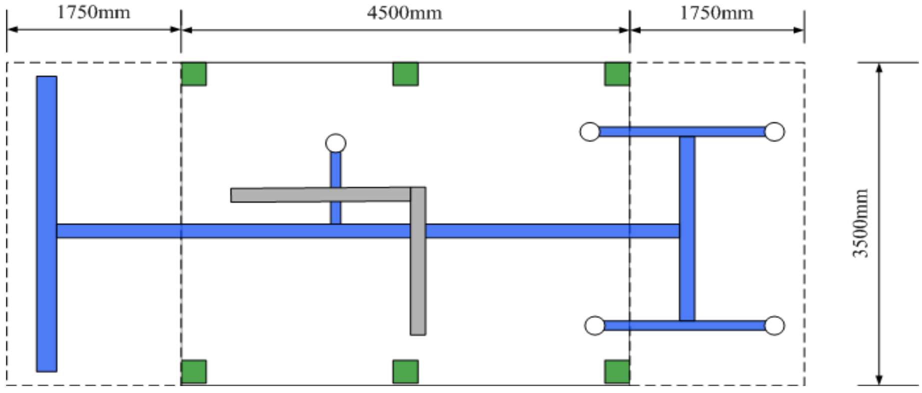

Figure 6. Dimensions of the hospital room model

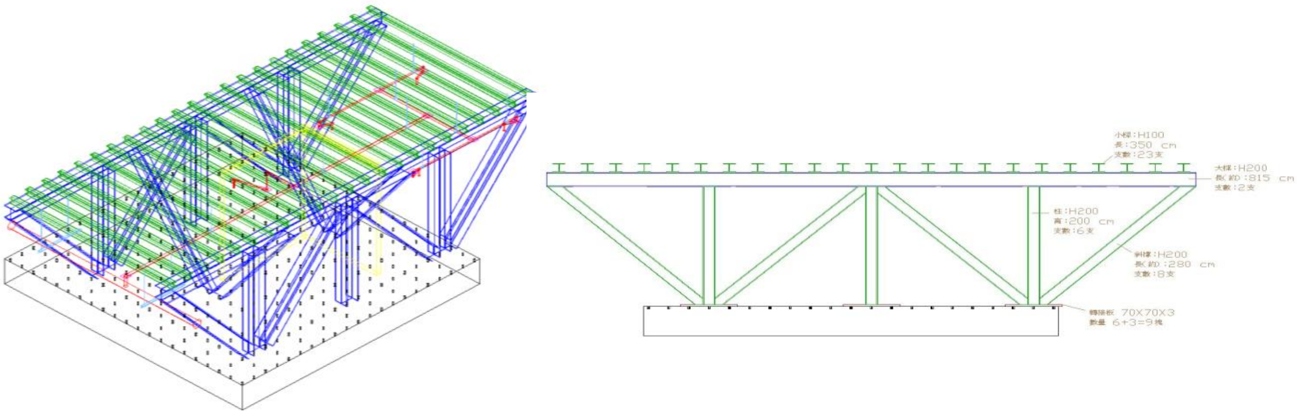

Figure 7. Dimensions and set-up of frame and piping.

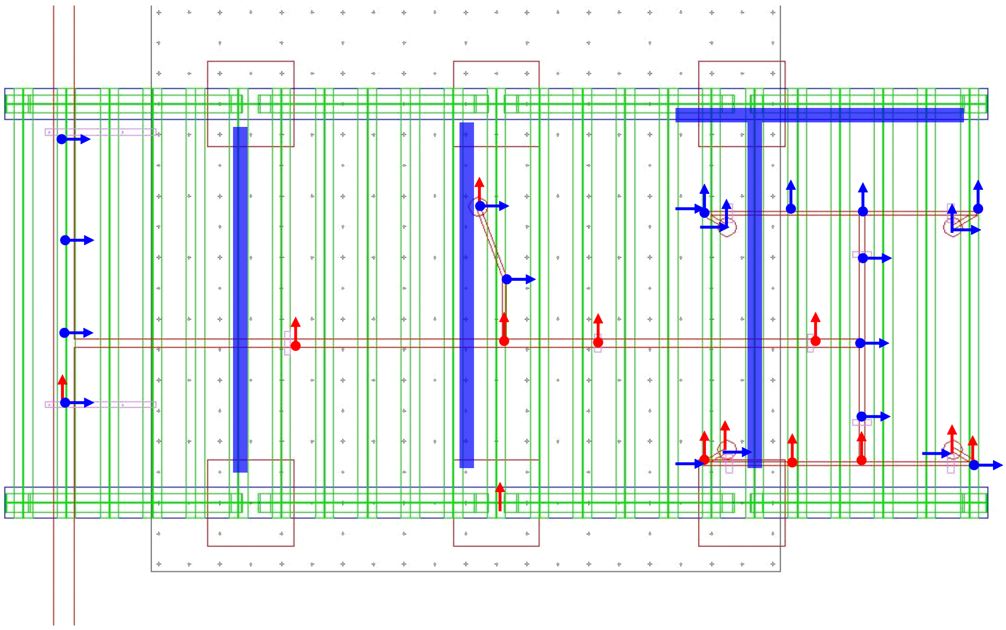

Figure 8. Location of accelerometers (red) and displacement transducers (blue),