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Abstract
During the first semester the team (Marco Eberth & Claire Anderson) designed and constructed a shake table for earthquake simulation. Prior to construction, the team consulted articles and Trinity's own earthquake enthusiast, Professor Geiss, and determined that horizontal ground motion was only necessary for testing the failure of buildings. The team determined a jigsaw would be sufficient in the driving mechanism of the shake table, and at lowest speeds the finished shake table was able to create a 2g earthquake. This was determined sufficient in testing considering a 1.24g earthquake typically results in "very heavy" damage. During the second semester Marco worked independently and constructed a seismic isolator: a system below the super structure of a building that creates a barrier between the ground movement and the movement the building experiences. Through dimensional analysis it was determined that the building and table were not dynamically similar; meaning that the earthquake was unrealistically violent for a light-weight scaled building. An accelerometer was utilized to determine the efficiency in performance of the seismic isolator. Using bearings as isolators, the top floor acceleration of the building was measured while the seismic isolator was measured simultaneously. There was an average of a 75% decrease in acceleration experienced by the building in comparison to the ground acceleration during the same simulated earthquake. During the second semester, Claire designed and constructed model columns, similar to columns used in the reconstruction of Classical architecture. Three different methods of reinforcement were used to join the column drums together, each type was tested on the shake table. The results were inconclusive due to restrictions of the accelerometers.

Seismic Isolator: Marco Eberth

Testing Methods: To test the ground acceleration a custom 3D printed iPhone case was made to hold the phone on the top floor of the building while running the Accelerometer application and record the maximum horizontal acceleration experienced while another iPhone was clamped to the ground and recorded the maximum ground acceleration. Flat Sliding Isolator: After the design of the Elasticom isolator was a failure the concept of the Flat Sliding Isolator was re-created and modeled using a 5" table drawer slide. It had the same components such as bearings and minor frictional forces. See below for Image 2 of Isolator Attached to Model Building.

Building Design Process and Specifications: The materials used for the design of the building were: 5’x5’ square wood dowels cut at 1’ length for the corner columns, 25’x25’ square wood dowels cut at 1’ length for the center columns, and 6’x6 hardwood for the flooring [see Image 1]. The average floor to floor height of a building is between 10’ and 13’, so in the model 1’ represents 10’ in the prototype. Essentially the building is 10 stories, with 10ft between each floor

Results & Conclusion: When testing the model building with the isolator attached the building experienced a horizontal acceleration 75% less than that of the ground acceleration [See Table 2 for Data]. After dimensional analysis was done, it was concluded that acceleration ratio was 1:2437994. This ratio was not realistic [later discussed in the Dimensional Analysis Section]. In theory, if this system was to be applied at full scale and 1.24g acceleration occurred during a Magnitude 10 earthquake, the building would experience .31g. The system would reduce the potential damage from “very heavy” to “moderate”, and a Magnitude 10 earthquake to a magnitude 7.

Seismic Isolator Dimensional Analysis Results & Conclusion: As discussed in the Results of the Seismic Isolator Dimensional Analysis ratio was unrealistically high. If this project were to be done again the dimensional analysis would have been done first based on a scale model design. The model would have to be significantly heavier and the shaker table would be more powerful to support the load and have a slower horizontal acceleration.

Model Design and Construction:

Dimensions – The prototype columns I used for modeling are found at a site in Sardis, Turkey, and they are 27 ft. high with a diameter of 3.8 ft. With a length ratio of 1:15, the resulting model columns are 3 in. high with a diameter of 1.14 in. They rest atop a base measuring ¾ in. in height, for ease of attachment to the table.

Materials – Marble was not a feasible material to use for the columns, due to time and money constraints, so a concrete formula similar to one used in replacement of column fragments at Sardis was used. The marble chip aggregate was too large to use for the model scale, so a marble powder to simulate the columns, the model was constructed using four separately cast cylinders. For the first reinforcement method, steel rod (1/8” in.) was used to “pin” the drums together, as seen in Figure 4a. For second method, the steel rod was inserted through the entire column and into the base, as seen in Figures 3a and 4c. The last method, to simulate the original construction method, lead solder was used to join the column sections together, as seen in Figure 4b.

Testing Procedure: The columns were mounted on the shake table, and an additional hammer pounds were added using a wooden superstructure. A seismic event that was determined to be dynamically similar to an earthquake with the 1:35 scale was created, and the acceleration difference between the top of the column and the table was recorded. After each test, the columns were surveyed to identify any structural damage incurred.

Results and Conclusion: Although the shake table was capable of creating a 4.5g earthquake, the accelerometers used were only able to record an event up to 2g. For shake table tests below this limit, the behavior of all three column constructions were the same. When the acceleration was increased beyond the 2g limit, the construction with the steel rod displayed the most desirable behavior, but the accelerations were not able to be recorded.

Shaker Table Specifications

Classical Architecture

Model of Classical Architecture: In conjunction with a thesis I’m working on the preservation and reconstruction of Classical Architecture, I chose to investigate the different methods of reinforcing marble column drums. Classical Greek and Roman columns are constructed by stacking a series of smaller marble drums atop another, reinforcing them with lead clamps. Lead, being a very soft metal, was replaced with steel rebar reinforcements during the reconstruction of the columns. Where the column fragments are missing, a new section is recast using a marble-aggregate concrete reinforced with steel rebar throughout. These three methods of reinforcement were modeled, tested on the shake table, and compared with each other to determine the most effective method of reconstruction.

Classical Column Dimensional Analysis Results: For a length ratio of 1:35, the shaker table as designed was capable of simulating the dynamically similar event.

References & Acknowledgements

References

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Discussion
As discussed in the fall portion of the project, the table used a D AQ board and computer program to determine the duration of the simulation. As the building testing was done it was noticed that sometimes the trigger needed to be pumped a few times to overcome the moment of inertia. From this the team tried using an external potentiometer to determine the amount of voltage supplied to the jigsaw. In the end the trials had to be run 48 trials at the slowest speed settings resulting in earthquakes around 2.0g. The iPhone application maxed out at just over 2.1g, which allowed this system to work.