Background and Research Goals
The goal of this research project was to develop two shaker tables in order to experiment with and demonstrate the effect of soil liquefaction and to build structures in the classroom. Soil liquefaction is a phenomenon where saturated soil loses its structural integrity during earthquake shaking and behaves like liquid. Structural earthquake engineering is an iterative process that strives to improve structural response to earthquake-induced forces. Earthquakes can cause walls to crack, foundations to move or settle, utility lines to rupture, and even entire buildings to collapse. In an effort to protect the public and avoid structural damage, engineers incorporate into their structural designs techniques that withstand these incredible forces. Some examples include cross bracing, tapered profiles, base isolation and tuned mass damping. In all cases, engineers develop an idea, test it, and then, based on its performance, re-engineer the structure until the desired outcome is reached.

Through this project students should be able to:
- Observe soil liquefaction and its potential destructive impact
- Identify the factors that make soils susceptible to liquefaction
- Identify the factors that make structures in liquefied soil susceptible to damage
- Explain why engineers need to study earthquakes
- Predict methods to improve and re-engineer the structure or soil profile to better resist damage
- Identify cause-effect relationships between earthquakes, liquefaction, and structures
- Describe how to apply what has been learned to new buildings and old buildings
- Summarize in a journal a record of observations and conclusions

Designs of Shaker Tables
Two shaker tables were designed for this project. One is powered manually using a crankshaft, while the other is powered using two DC motors. In both designs the shake plasters are designed to be free floating and supported with springs to the main frame. The plasters are also designed for motion along three axes, X, Y and Z in order to simulate both P and S waves during earthquakes.

Shaker Table Construction

- Crankshaft design
- Motorized design

Completed shaker tables: crankshaft and motorized designs

Shaker table fabricated, Kevin Cullinan of the UB CAS Machine Shop

Earthquake Experiment

Preliminary results of shaker table testing with three soil profiles:

<table>
<thead>
<tr>
<th>Composition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (0.75 to 1.00 mm)</td>
<td>Structure fails and sinks</td>
</tr>
<tr>
<td>100% Sand</td>
<td>Structure fails and sinks</td>
</tr>
<tr>
<td>100% Sorted Gravel (&gt;4 mm)</td>
<td>Structure fails</td>
</tr>
<tr>
<td>22% Clay 43% Silt 35% Sand</td>
<td>Structure fails</td>
</tr>
</tbody>
</table>

Soil Box Construction

Two of the soil boxes constructed were uniform, one completely of sand and one of sorted gravel. The third soil box is of Western New York (WNY) soil that was collected from Tift Nature Preserve, sifted to remove debris, and mixed. The soil boxes are then saturated with water. At this time the structure is placed in the soil profile boxes and then placed on the shaker table. Simulation of an earthquake is then implemented to determine if soil liquefaction occurs and what happens to the structure that is built on that type of soil.

Earthquake Experiment

- Structure fails and sinks
- Structure fails
- No Liquefaction
- Limited liquefaction

Spatial Analysis of WNY Geology and M-7 Earthquake

1) Local soils were classified into five types according to their potential to amplify ground shaking during an earthquake based on previous shear wave velocity tests.

2) Peak ground acceleration (PGA) was then calculated using a distance attenuation formula and separate amplification factors for each soil class. PGA is modeled here for a theoretical magnitude 7 earthquake with an epicenter in Buffalo, NY.

3) PGA relates directly to the Mercalli intensity scale, which is a description of how earthquakes are experienced by humans and infrastructure.

Classroom Implementation of Research

DIRECT: Shaker Table Experiments – The tables will be used in the classrooms to experiment with responses by different soils and structures. Students can operate the tables themselves and design their own structures for testing.

Triangulation Lab – Students will determine where three seismograph stations are located, given a known epicenter.

INDIRECT (INQUIRY-BASED): Emergency Evacuation – Given maps of local infrastructure and a modeled earthquake scenario, students will predict what infrastructure is likely to fail. They will then design their own emergency evacuation plans, taking into account traffic patterns and knowledge of which locations are most likely to be damaged based on maps of Mercalli Intensity.

Mass Movement – Teachers will use Abaqus simulation modeling to demonstrate different mass movements that cause structural damage.