INTEGRATION OF REMOTE MAJOR RESEARCH INSTRUMENTATION IN UNDERGRADUATE CIVIL ENGINEERING EDUCATION

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OUTLINE

- Introduction
- Description of remote centrifuge experiment
  - Pre online experiment activities
  - Post online experiment activities
- Discussion of post-experiment survey
- Conclusions
Undergraduate students have difficulty linking experiments performed in the lab to the theoretical part of the course. To overcome this shortcoming, physical modeling should be incorporated in undergraduate geotechnical engineering. In geotechnical engineering, reduced scale physical models tested in 1-g environment suffer from the limitation that soil behavior heavily depends on the stress level and therefore 1-g models would fail to simulate actual field conditions. Geotechnical centrifuge modeling overcomes this limitation by subjecting a small scale model to a high gravitational field that produces stress levels in the small scale model similar to those in the prototype.
By placing a small scale model in the centrifuge and subjecting it to a high gravitational acceleration, the stresses in the model increase to match that in actual field conditions.
A centrifuge experiment was introduced in undergraduate courses to examine the performance of a shallow footing constructed on a deposit made of dry sand.

The readily available tools at the RPI-NEES facility were used in this project.

The specific goals of this module are:

1. to test the viability of remote lab assignments taking advantage of NEES technology;
2. to introduce a unique physical modeling experimentation environment and make it conveniently accessible to students, faculty and other learners at the national level and eventually internationally; and
3. to save instructors and educational institutions resources (time, effort, and lab-space) by providing Web-based, sharable lab resources.
The following learning outcomes were set for the module. As a result of participating in the module/lab, students will be able to:

a) describe the actual stress distribution in the soil and the shape of the area loaded to failure;
b) design experiments using advanced procedures, instrumentation and applications; and
c) monitor, evaluate, analyze and design soil and soil-foundation systems using appropriate instrumentation, electronic data collection and state-of-the-art geotechnical engineering workplace applications and technologies.
A course module was introduced simultaneously at three schools [RPI (the institute hosting the centrifuge facility) and the two remote schools SMU and UNCC] in Spring of 2012.

Three graduate students participated in the class offered at SMU. Twenty-four students attended the class offered at RPI and eighteen students took the class at UNCC.

All students had taken at least one introductory course on geotechnical engineering prior to that semester and were familiar with topics such as soil phase relationships, compaction, permeability and seepage, effective stress and stress distribution, shear strength of soils, and bearing capacity of shallow foundations.

A lecture covering centrifuge concepts and scaling laws along with sample implementations.

The module was presented as a term project composed of two assignments; one before running the centrifuge experiment and one after running it.
COURSE MODULE (KOLB LOOP)

Concrete Experience (CE)
- Lecture to introduce the concept of stress distribution and bearing capacity
- Present schematics and photographs of building failure by bearing capacity
- Demonstrate the concept of centrifuge physical modeling and instrumentation

Active Experimentation (AE)
- Assignment: predict performance of the shallow footing to increasing the load on the footing
- Physical model experiment: footing loaded to failure

Reflective Observation (RO)
- Assignment: plan model footing along with instrumentation, sketch anticipated failure mechanism(s)

Abstract Conceptualization (AC)
- Classroom lecture(s) on the method of limit equilibrium and its application to bearing capacity
Students were asked to sketch the location of pressure sensors.

They were asked to define the soil parameters needed to evaluate soil strength and the lab experiments required for that.

Students were asked to predict the maximum column load that could be placed on a footing of predefined size.

Students were also asked to design the centrifuge model of the footing and the soil deposit assuming the test would run under a gravitational field of 25 g.
The final model design was shared with students. RPI students built the centrifuge model according to the final model design.

The centrifuge experiment was scheduled and students were able to view the testing remotely in real-time.

The experiment included two tests. The first test was to show stress distribution in the oils mass. The second test was designed to load the footing to failure to assess footing bearing capacity.

Recorded test results were made available to the students and they were then handed Assignment 2 of the project.

In this assignment, students were asked to compute the theoretical stress distribution and compare it against the experimental data at the four sensor levels.

They were also asked to predict the bearing capacity of the footing and compare it with the experimental results. Students were also asked to comment on the results and discuss the potential sources of differences, if any.
FINAL MODEL DESIGN

- **25 g**
- Shallow footing
- 10 cm x 10 cm
- Rigid container
- 0.5 cm
- 3.5 cm
- 4 cm
- 5 cm
- 25 cm x 25 cm
- 25 cm
- 91 cm

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Tactile Pressure Sensor (Sheet)
THE CENTRIFUGE EXPERIMENT
THE CENTRIFUGE EXPERIMENT
A total of 34 undergraduate students participated in this module from the three schools.

No comparative data were available given that the concepts covered by the experiment had not been taught in prior versions of the courses.

The focus of this pilot study was to determine how to most effectively run a remote lab and to gain insight into student learning based on student self-reports regarding their learning and their reflections on the assignments and the centrifuge technology.

All opinion questions were designed using a five point Likert scale from ‘Strongly Disagree’ to ‘Strongly Agree’.
Students' general opinion about the centrifuge experiment and associated assignments. Overall, students felt they were ‘just about right.’

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Too challenging</td>
<td>Just about right</td>
<td>Somewhat easy</td>
<td>Too simple</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.8%</td>
<td>82.3%</td>
<td>5.9%</td>
<td>0</td>
<td>1.9</td>
</tr>
</tbody>
</table>
In general, students felt that the pre-experiment activities were quite useful in preparing them to conduct the experiment.

<table>
<thead>
<tr>
<th>Regarding the assignments and classes prior to conducting the centrifuge experiment:</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>the in class lectures and discussion prepared me for conducting the experiment</td>
<td>0</td>
<td>20.6%</td>
<td>23.5%</td>
<td>50.0%</td>
<td>5.9%</td>
<td>3.4</td>
</tr>
<tr>
<td>the remote lecture(s) and discussions(s) prepared me for conducting the experiment</td>
<td>0</td>
<td>3.0%</td>
<td>30.3%</td>
<td>48.5%</td>
<td>18.2%</td>
<td>3.8</td>
</tr>
<tr>
<td>the in-class lectures and discussions prepared me for analyzing the results of the experiment.</td>
<td>0</td>
<td>17.6%</td>
<td>35.3%</td>
<td>35.3%</td>
<td>11.8%</td>
<td>3.4</td>
</tr>
<tr>
<td>the remote lecture(s) and discussion(s) prepared me for analyzing the results of the experiment.</td>
<td>0</td>
<td>6.1%</td>
<td>36.4%</td>
<td>45.5%</td>
<td>12.0%</td>
<td>3.6</td>
</tr>
</tbody>
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Students found the experiment to be a very effective way to learn geotechnical engineering concepts.

<table>
<thead>
<tr>
<th>The centrifuge experiment was an effective way:</th>
<th>1 Strongly Disagree</th>
<th>2 Disagree</th>
<th>3 Neutral</th>
<th>4 Agree</th>
<th>5 Strongly Agree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>to learn about the actual stress distribution under a loaded foundation</td>
<td>0</td>
<td>2.9%</td>
<td>0.0%</td>
<td>29.4%</td>
<td>67.7%</td>
<td>4.6</td>
</tr>
<tr>
<td>to learn about the actual bearing capacity of a shallow foundation</td>
<td>0</td>
<td>2.9%</td>
<td>2.9%</td>
<td>41.3%</td>
<td>52.9%</td>
<td>4.4</td>
</tr>
<tr>
<td>to visualize the failure mechanism under a shallow foundation</td>
<td>0</td>
<td>2.9%</td>
<td>8.9%</td>
<td>35.3%</td>
<td>52.9%</td>
<td>4.4</td>
</tr>
<tr>
<td>to link field conditions, traditional lab experiments and centrifuge physical modeling</td>
<td>0</td>
<td>2.9%</td>
<td>9.1%</td>
<td>30.3%</td>
<td>57.7%</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Students wanted to conduct more experiments using the centrifuge technology.

Eighty two percent of the students reported that they had a strong desire to build the physical model to be tested.

Ninety eight percent of the students said they would recommend the course to their friends or colleagues.

Students noted in their comments that they thought the course was interesting and enjoyable, that they learned a lot because it was new material that was not included in previous courses, or that access to the centrifuge made it possible.

A number of students commented about the real world nature of the experience and how practical it was.
I think the experiment helped me apply what I learned from my assignments to a real life situation. It was challenging but we were well prepared.

I thought the experiment was very useful to actually see a lab test being performed that could possibly be used in future design considerations. Anyone can look up equations or theory in a textbook or on the internet, but actually getting to see how those relate to real world situations is very useful and for me, it helped me understand certain concepts better.

I really enjoyed the project, it was time consuming but worth it, and I used resources (office hours) which helped a lot.

I think it was an interesting project but very challenging.

The principles of the centrifuge tests were fairly easy. However, the assignments provided enough challenge for students to analyze and make deeper conclusions about experiment results.
CONCLUSIONS

• The implemented course module appears to have enhanced students’ understanding of geotechnical systems and the link between elementary soil testing and system design.
• Testing a soil-foundation system helped the students identify the lab experiments needed to design of the system.
• Students were able to acquire actual system response test data that are similar to field data and used it to compare against the outcome of using theoretical analysis.
• Such a comparison stimulates critical thinking to identify the approximations in the theory and/or the setting of the experiment that may lead to differences between computed values and measured data.
• Our results indicate that remote research facilities can be made conveniently accessible to students and faculty; thereby helping in saving institution resources.
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Thank you for your attention!

Questions?