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WIP: Geotechnical and Structural Engineering Hands-on Modules for First Year Civil Engineering

Hadi Kazemiroodsari, Wentworth Institute of Technology

Hadi Kazemiroodsari is assistant professor at Wentworth Institute of Technology. His area of expertise are Geotechnical engineering and Earthquake engineering.

Andrew Summerfield, Wentworth Institute of Technology

Dr. Andrew Summerfield is an Assistant Professor of Civil Engineering at Wentworth Institute of Technology. He received his BSCE (2013) from Tufts University and his MS (2018) and PhD (2021) in structural engineering from Northeastern University. His graduate research focused on the structural dynamics of offshore wind turbines. He is interested in developing teaching materials that help engineering students understand the broader social and political ramifications of their work.

WIP: Geotechnical and Structural Engineering Hands-on Modules for First Year Civil Engineering

Abstract

This paper is a Work In Progress (WIP) Evidence-based Practice submission describing hands-on geotechnical and structural engineering modules designed for first-year civil engineering students. There is a need for hands-on modules that connect civil engineering concepts to interactive classroom activities in civil engineering first year courses. An effective module should engage students, teach fundamentals and clarify unclear questions for students. Geotechnical and Structural Engineering are two of the important subdivisions of civil engineering careers.

This paper focuses on presenting some hands-on geotechnical and structural engineering modules for first year engineering courses. These modules include, *Construction of Shallow Foundation and Bearing Capacity, Demonstration of Eccentric Loading on Shallow Foundation, Pile Driving and Load Transfer, Design and Build of a Seismograph to record the Ground Movement and Building and Loading Model Structures to Compare with Sketched Predictions of Deflected Shapes.* All these modules have been practiced by the authors in the upper-level elective courses such as Foundation Engineering, Dynamics of Structures, and Structural Analysis. In this paper the modules are simplified for use in the first-year engineering courses.

Construction of Shallow Foundation and Bearing Capacity and *Pile Driving and Load Transfer* are mainly demonstration modules while *Demonstration of Eccentric Loading on Shallow Foundation, Design and Build of a Seismograph to record the Ground Movement and Building and Loading Model Structures to Compare with Sketched Predictions of Deflected Shapes* are activities that involved students to be divided into groups of 4 -5. Each module was presented to a class of 15 to 25 students. Students mentioned in their course evaluations that the modules were one of the effective teaching sections of the class.

Introduction

Introducing foundational civil engineering concepts to first-year students presents a unique educational challenge. At this stage, students have limited exposure to real world applications and therefore it is difficult for them to connect theory with practice. Traditional lecture-based instruction alone may not address this need of students. This paper presents a series of hands-on modules designed to prepare first year students for the subsequent years of their civil engineering curriculum.

Teaching is an art and a very challenging profession [1]. To better transfer knowledge to students, a teacher might use various techniques, such as textbook reading assignments, in-class problem solving, group projects, video demonstrations, and physical demonstrations depending on the educational environment. Not all students learn the same way. Students learn by observing, listening, reading, or a combination of all. Therefore, for better educational results, instructors need to present material using different techniques. Felder and Silverman (1998) concluded that students prefer to learn by visual techniques rather than verbal ones [2].

First-year engineering students attend college with joy and enthusiasm. To some extent, they begin their future career. One of first year engineering instructors' jobs is to grow this enthusiasm, and the best way to do this is by bringing major-related hands-on modules into the classroom. This helps students to see themselves in the future while getting introduced to basic concepts of the major they chose.

It is important for students to visualize major concepts of civil engineering courses such as environmental, structural, and geotechnical engineering courses. Gilbert et al. [3] and Mladenov et al. [4] in their papers titled "*In-class and recorded physical demonstrations in enhancing student understanding of structural mechanics courses*" and "*Use of In-Class Demonstrations and Activities to Convey Fundamentals of Environmental Engineering to Undergraduate Students*" explained the challenges and effects of in-class demonstration in structural and environmental engineering courses.

E. S. Ferguson in "*Engineering and the Mind's Eye*" demonstrated that engineering is more than just equations. Ferguson emphasized that physical modeling has played an important role in educational practices in the last 100 years [5]. New teaching techniques combine physical and computer aided demonstration with traditional teaching techniques such as using whiteboards and blackboards and solving example problems.

This paper describes the design and implementation of the following modules in geotechnical and structural engineering: Construction of Shallow Foundation and Bearing Capacity, Demonstration of Eccentric Loading on Shallow Foundation, Pile Driving and Load Transfer, Design and Build of a Seismograph to record the Ground Movement, and Building and Loading Model Structures to Compare with Sketched Predictions of Deflected Shapes.

Foundation Engineering Demonstration

Materials

Materials that are used for these demonstrations are: transparent plastic/glass box, soil, wood (Depends on the need of the instructor 2"x2" to 6"x6"), and soil, weight and regular tools such as hammer. Figure 1. presents the materials needed for the demonstrations.

Figure 1. Material used for demonstrations

In the next section different demonstrations for shallow and deep foundations are presented.

Shallow Foundations

Construction of Shallow Foundation and Bearing Capacity

Construction of a shallow foundation involves preparing the site, excavation, soil compaction and leveling, temporary support system, dewatering in case of need, place reinforcement, pouring concrete, backfilling the foundation and compacting the soil. All these steps can be demonstrated on a small scale using the set up shown in Figure 2. For this test the instructor did not include the reinforcement installation and pouring concrete and represented the foundation in the format of a 2”x2” wood. However, if available steel wire and concrete or gypsum can be used to build footings. Figure 2. presents the demonstration for construction techniques of shallow foundations.

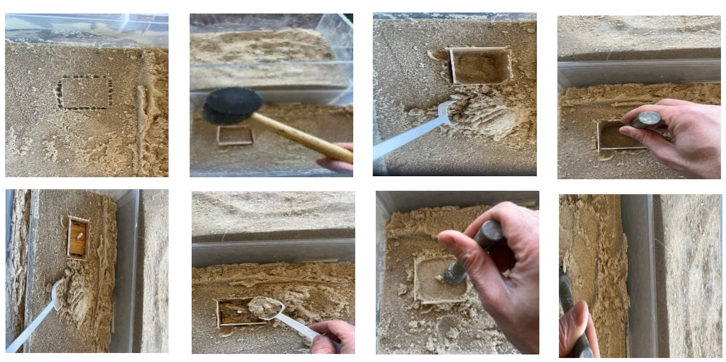

Figure 2. Demonstration of the construction of shallow foundation

After construction the column can be loaded. By drawing the failure plane, the concept of bearing capacity can be presented as well. This demonstration is expected to take 30-45 minutes of the class time.

Demonstration of Eccentric Loading on Shallow Foundation

Eccentric loading is the condition in which the column is constructed with an offset from the center of the footing. The concept of eccentric loading is a difficult concept for students. However, a simple demonstration of a shallow foundation that is under eccentric loading could help better understanding of this concept. In theory the column should be placed and loaded in a rhombus area which offsets at B/6 and L/6 from the center of the footing in which B and L represent width and length of the footing. The schematic drawing shown in Figure 3 shows the allowable zone of column construction. The rhombus in the middle of the figure is the zone in which the eccentric column can be placed and loaded.

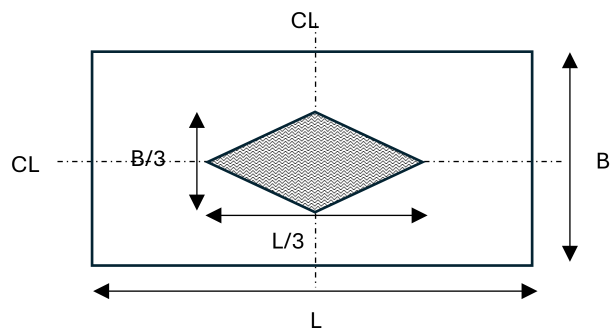

Figure 3. Allowable zone for eccentric column construction (figure not to scale)

To demonstrate the effect of eccentricity an in-class group activity is recommended. In this activity a piece of square wood is provided for each group. The dimensions of this piece can vary depending on the availability and need of the instructor. Students are asked to measure the dimensions and decide the location at which the column should be loaded. The distance from the column location to each side of the foundation is measured. Students should decide the column location based on two criteria. The column should be as close as possible to the edge of the foundation (maximum eccentricity in both L and B direction), and at the same time foundation should stay connected to the ground while loading. Figure 4 presents the in-class activity to demonstrate the concept of eccentricity.

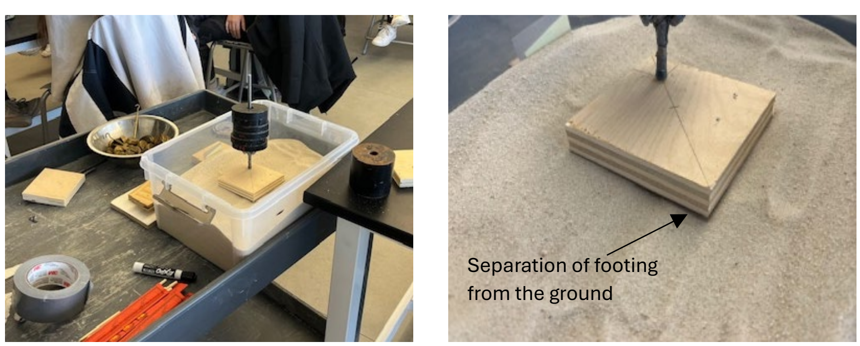

Figure 4. In class activity to demonstrate the concept of eccentricity

The activity can be upgraded to a more challenging one by asking questions such as:
"The foundation is constructed 2.5 cm (one inch) below the ground surface. Do you think this idea will help the column to carry more load? How much load could you add before the foundation fails? (Hint: Calculate q min and q max)". This module is expected to take 60-75 minutes.

Deep Foundations

Pile Driving and Load Transfer

Similar to shallow foundations, coupling traditional teaching techniques with demonstration could help students to understand deep foundation concepts better. Figure 5 demonstrates single pile driving as well as end bearing and side friction load transfer systems. This demonstration is expected to take 15-20 minutes of the class.

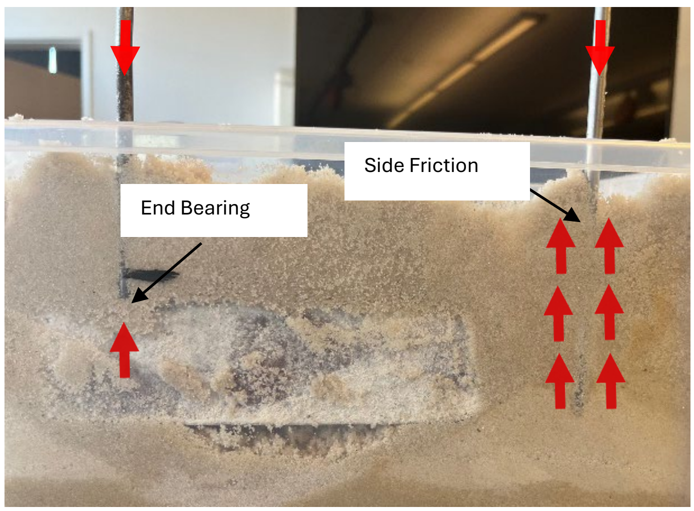

Figure 5. Deep foundation load transfer

The authors recommend supplementing these activities with construction videos or site visits, when possible to further reinforce the concepts.

Earthquake Engineering module

Design and Build of a Seismograph to record the Ground Movement

Earthquake engineering is an exciting and unique topic for first year civil engineering students. The concept of designing buildings for earthquake load is not something that many first-year engineering students notice prior to attending college. Working on this module, students practice combining Artificial Intelligence (AI) and problem-solving. To conduct this module, in addition to the material shown in Figure 1, shaking tables are required. However, if shaking table is not available the instructors could use plywood on wheels as a shaking table. In this module, students are introduced to the idea of a seismograph and are asked to come up with a system that can record the motion of the shaking table. The key point about this module is that the seismograph should be connected to the shaking table and cannot sit outside of shaking table. Students use AI tools to generate preliminary design alternatives, compare different options and make informed design decision based on engineering judgment. After construction and testing the systems, students are asked to explain the system and thought process behind their seismographs. Figure 6 presents some seismographs built by students.

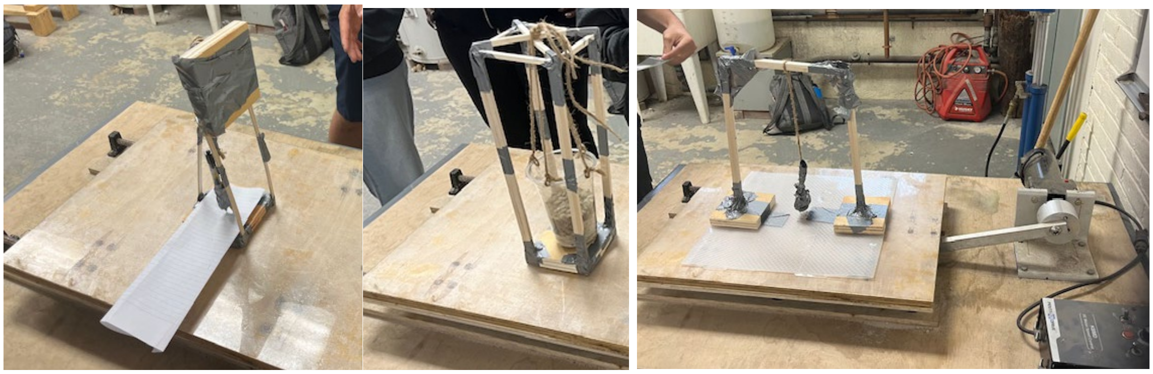

Figure 6. Seismographs built in class by students

Structural Engineering Module

Mola Model to Demonstrate Deflected Shapes of Structural Frames

The ability to sketch the deflected shape of a structure under loading is a crucial part of developing an intuition for structural behavior. Sketching is an excellent activity for first-year engineering students because there is a low barrier to participation—students do not need to understand Euler-Bernoulli beam theory before they can sketch their guess for how a structure will react to different loads. As they progress through their education, they will be aided in their acquisition of structural engineering theory by their ability to sketch visual representations of the physical behavior that equations represent abstractly. In the authors' experience, students often express reluctance to draw, citing the fact that they have "no artistic ability." When students are not encouraged to draw until later in their college careers, like junior-level structural analysis courses, this reluctance can be hard to overcome, and students might feel that sketching is an extra task rather than a learning aid. The sooner instructors get engineering students comfortable with using sketching as a thinking process, the more useful it will prove later in their careers.

This activity asks students to sketch their predictions for how a small model structure will deflect under several different load cases. They also are asked to explain their reasoning for their "modeling" decisions. Then, they actually load the structure—in other words, apply point loads using their fingers—and they take pictures of the actual deflected shapes of the structures. They then have to sketch copies of the actual deflected shapes and explain any discrepancies between their prediction sketches and the actual deflected shapes.

The activity also helps students to establish a stronger link between observed physical behavior, verbal descriptions (or models, if you will) of that behavior, and an ability to sketch this behavior. For this lab, the instructors made use of the Mola Structural Kit 2. The Mola Model is an improvement over truss-focused classroom structural tools because connections can be either fixed or pinned and because members visibly develop bending. Only one Mola kit was used, which limits cost, and student groups rotated who was using the kit.

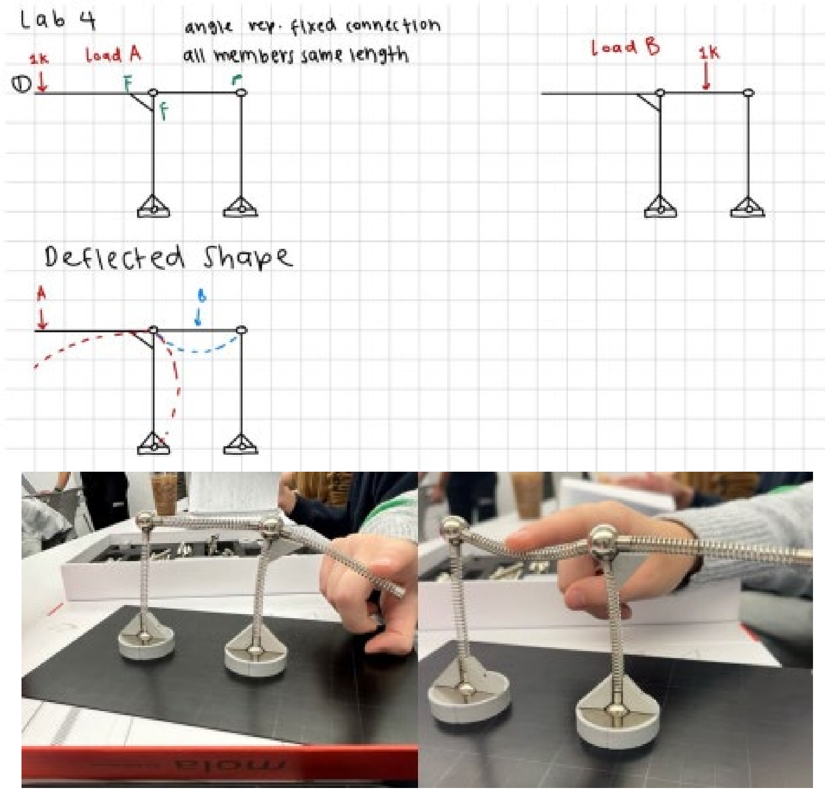

Figure 7. Predicted (top) and actual (bottom) deflected shapes for Structure 1

If budget does not allow, simpler structures using flexible elements like rulers can be devised to provide a similar experience. For instance, three different structures can be made using a flexible steel yardstick, two markers, and two textbooks: 1) a simply-supported ruler can be made easily by placing a ruler over two markers; 2) one marker can be moved closer to the other marker to create a back span-cantilever structure; 3) a ruler can be held between two textbooks at one end and supported by a pencil or marker to make an indeterminate structure with curvature that switches sign. Asking students to sketch their predictions for these structures under different loading conditions would achieve the same learning outcomes as use of the Mola Model.

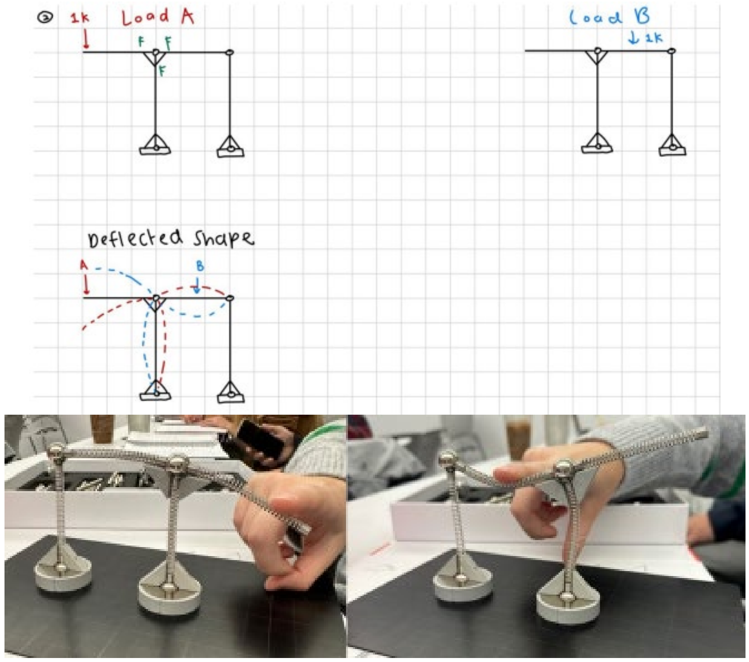

Figure 8. Predicted (top) and actual (bottom) deflected shapes for Structure 2

Conclusion

This paper presents multiple hands-on modules and activities designed for first year engineering courses to introduce concepts in shallow and deep foundations, earthquake engineering and structural engineering. The materials used for the demonstrations are inexpensive and readily available. All activities can be conducted as in-class group activities.

This paper provides a structured roadmap for integrating hands-on learning into geotechnical and structural engineering courses. The authors plan to evaluate the effectiveness of these modules by comparing student performance across multiple years in which the activities are implemented versus when they are not. Preliminary, students have provided positive feedback in their course evaluations regarding these modules.

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