AN INDUCTIVE LEARNING APPROACH TO TEACHING EARTHQUAKE RESPONSE SPECTRA

H. Benjamin Mason¹, Michael H. Scott¹, David S. Hurwitz¹, Kamilah Buker², and Rachel Adams²

ABSTRACT

Understanding response spectra is a key component in the educational development of earthquake engineering students. To teach this fundamental concept, a deductive learning approach is typically employed where theory and computations are presented first, followed by applications and possibly demonstrations employing physical models. With an inductive learning approach, physical models and applications are presented first, followed by the supporting theory and computations. Mass-spring desktop learning modules (DLMs) were designed and implemented to facilitate the inductive learning approach for response spectra. Two groups of DLMs, one with constant mass and one with constant stiffness, were built from inexpensive materials and designed to have modes of vibration easily excited on a portable instructional grade shake table. In addition, accelerometers are attached to the masses and connected to an open source, Python-based software module to visualize time history response of the DLMs. Preliminary results based on classroom observations and interviews with four instructors at Oregon State University indicate that the DLM-based inductive learning approach improves student learning and retention of response spectra concepts.

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Earthquake Response Spectra

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Understanding response spectra is a key component in the educational development of earthquake engineering students. To teach this fundamental concept, a deductive learning approach is typically employed where theory and computations are presented first, followed by applications and possibly demonstrations employing physical models. With an inductive learning approach, physical models and applications are presented first, followed by the supporting theory and computations. Mass-spring desktop learning modules (DLMs) were designed and implemented to facilitate the inductive learning approach for response spectra. Two groups of DLMs, one with constant mass and one with constant stiffness, were built from inexpensive materials and designed to have modes of vibration easily excited on a portable instructional grade shake table. In addition, accelerometers are attached to the masses and connected to an open source, Python-based software module to visualize time history response of the DLMs. Preliminary results based on classroom observations and interviews with four instructors at Oregon State University indicate that the DLM-based inductive learning approach improves student learning and retention of response spectra concepts.

Introduction

Even though earthquake response spectra are a fundamental concept in earthquake engineering research and practice, teaching these fundamental concepts to undergraduate, as well as graduate, students is often a challenging task. Some of this difficulty is due to the frequent adoption of a deductive learning approach to teaching response spectra, where equations and theory are presented first, followed by applications. This approach follows directly from modern modes of earthquake engineering research that rely on computing, simulation, and numerical methods and it often leaves visual and tactile learners without a firm understanding of response spectra. In many classrooms, the teaching of earthquake response spectra stops at theory and equations and

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does not incorporate physical demonstrations or applications.

In contrast to deductive learning, the inductive learning approach begins with applications and demonstrations, then proceeds to theory and equations. In fact, before the advent of modern computing, earthquake engineers developed response spectra concepts using the inductive approach. Suyehiro developed the original “seismic vibration analyser” in the 1920s to measure the movement of pendulums during strong shaking [1]. This “analyser” led to the creation of modern response spectra, whose mathematics and computational techniques were formally established by Housner [2], Biot [3], and Newmark [4], and whose transformation of earthquake engineering was made possible by the proliferation of computing power since the 1960s.

To support the adoption of inductive learning approaches to teaching earthquake response spectra, two desktop learning modules (DLMs) were designed and constructed from relatively inexpensive components along with a Python-based interface for graphical display of the modules’ response. DLMs are portable physical models that allow instructors to use interactive teaching methods [5,6,7] and that can also foster the development of robust problem-solving skills in students [8]. The response spectra DLMs were adopted for four in-class demonstrations at Oregon State University (OSU). Instructor feedback indicates the likely adoption of DLMs in future course offerings while student feedback showed the power of simple demonstrations in conveying an abstract concept.

Response Spectra DLM Description

The design, material specification, and construction of the response spectra DLMs summarized herein are described elsewhere in further detail [9]. Each DLM consists of four mass-spring systems, as shown in Fig. 1, where one DLM has systems with constant mass and varying stiffness while the other has systems with constant stiffness and varying mass. The masses and spring stiffnesses were chosen so that each system has a natural period that can be easily excited on a portable shake table or by hand. Note that one system in the constant mass DLM is attached to the platform with no spring (infinite stiffness) to represent the ground motion when the DLM is used on a shake table.

Attached to each spring is a wooden ball of mass 142, 84, 48, and 21 grams for the constant stiffness DLM, while the constant mass DLM utilizes the 21 gram mass. Both DLMs are constructed using 21 mm diameter tempered-steel compression springs of varying lengths: 0, 70, 150, and 230 mm for the constant mass DLM and 31 mm for the constant stiffness DLM. The springs have mass per length of 0.22 grams/mm, which is significant compared to the wooden ball masses, but also important for classroom discussions on the “massless spring” assumption of single degree of freedom response. The natural period of each mass-spring system is excitable on a shake table with frequency range 0.1 to 10 Hz. Free vibration tests of the DLMs indicate the damping ratio of the systems varies from 1% to 2%.

Accelerometers were attached to each mass in order to record the systems’ response during excitation. Accelerometer data is logged using Teensy 3.2 microcontrollers and a Python script translates the logged data to a text file. A second Python script creates a graphical user interface (GUI) that displays the motion of each mass in real time. A fully instrumented constant mass DLM is shown in Fig. 2 along with the Python GUI. Additional detailed on the instrumentation protocols and Python scripts can be found at the project’s github page: https://github.com/OSU-Geomatics/OregonState_DLM.
Response Spectra DLM Classroom Use

The response spectra DLMs were used by four instructors at OSU during the 2016-17 academic year. The course demographics included two graduate courses with enrollment less than 15 students and two undergraduate courses with enrollment of 50 and 110 students. Each instructor incorporated different in-class activities that promoted inductive learning with the DLMs. All instructors required the students to participate in a think/pair/share activity before using the DLMs to predict the response patterns, and they asked students questions before using the DLMs and encouraged the students to ask questions before, during, and after each DLM demonstration. Compared to previous course deliveries where the DLMs were not utilized, all instructors noticed more active engagement of students in learning response spectra. In addition, all instructors indicated that they will use the DLMs in future course deliveries and that the response spectra DLMs sparked their imaginations for developing additional DLMs to convey other concepts outside of structural dynamics [9].

In addition to instructor interviews, student feedback was gathered in the 110 student undergraduate course. Over 95% of students either “Strongly Agreed” or “Agreed” that the DLMs were effective in showing the effects of mass and stiffness on structural response. When posed with the simple Yes/No question of whether the DLMs should be used in future offerings of the course, 97% of students responded “Yes” and indicated in written comments that the DLM demonstration was an “excellent, hands-on, visual approach for teaching an abstract concept.”

Conclusions

An inductive learning approach to teaching earthquake response spectra allows students to observe physical behavior that can further support their understanding of computational techniques. Although the inductive learning approach requires more preparation time on the part of an instructor compared to an exclusively deductive approach, the results of using response spectra DLMs indicates increases in active student learning and instructor innovation, which are essential for conveying such an important topic in earthquake engineering.
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