Curriculum Exchange: Visualization Tools and Online Courses for Teaching about Earthquakes

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Abstract

Four videos and visualizations of earthquake response and earthquake damage, and an interactive remotely controlled experiment have been developed to complement K-16 curriculum. The K-12 materials address content found in the California Science Standards. The university level module could be used in a geotechnical engineering or earthquake engineering course. All of these can be accessed from NEESacademy, a repository supported by the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) for earthquake engineering educational resources and cyber-enabled learning experiences.

Introduction

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) is an NSF-funded research center focused on large-scale earthquake engineering research. The mission of the NEES is to provide infrastructure for researchers to produce new knowledge and tools that will contribute to reduction of damage and losses from earthquakes and tsunamis. Developed in the early 2000s and officially opened in October 2004, NEES comprises 14 large-scale equipment sites connected by an advanced cyberinfrastructure that enables rapid data viewing and analysis, data archiving, remote viewing and participation, and the ability to run interconnected experiments using several laboratory sites[1]. The UC Santa Barbara NEES facility consists of permanently-instrumented geotechnical test sites designed to improve understanding of the effects of surface geology on strong ground motion. The instrumentation at these sites includes surface and borehole arrays of accelerometers and pore pressure transducers designed to record strong ground motions, excess pore pressure generation and liquefaction that occurs during large earthquakes. An instrumented structure is also monitored to improve understanding of soil-foundation-structure interaction (SFSI) effects[2].

In response to the critical shortage of engineers entering the workforce, K-12 science standards are being revised to include more engineering[3], and a number of NSF-funded and privately funded initiatives are underway to develop and deliver engaging hands-on engineering-based activities to K-12 classrooms.[4,5] Although NEES is primarily a research consortium, it has as a strategic goal to "support the development of the researcher and practitioner talent pipeline through effective education and outreach programs."[6] Therefore researchers and the research facilities are encouraged to develop engineering-based education and outreach materials as outcomes of the research projects. The NEES research site at UC Santa Barbara has developed several videos incorporating elements of the research equipment and outcomes for use in outreach and education. Visualization tools are extremely useful when teaching about how earthquakes shake the ground and the response of buildings to that shaking. These and other earthquake engineering related education and outreach resources are archived in NEESacademy[7], a portal to support effective organization, assessment, implementation, and dissemination of learning experiences developed through NEES.

Visualization Resources

Four videos and visualizations are targeted to specific audiences:

(1) *Grade 6 – 16 students.* Animations[8] compare the response of two model buildings to two earthquakes. The model buildings are very simple one-story structures with steel columns and a concrete roof; one structure has diagonal braces and the other doesn't. These models were designed to study the passage of waves through the soil column below the structure, up through the foundation and into the structure. Often the observations of ground shaking recorded on the foundation of structures are not the same as those recorded on open ground due to the interaction between the soil and foundation. Understanding these interactions at a relatively simple site using a simple structure is a primary purpose of this facility.

The videos were created with data recorded on these test structures from the two earthquakes. The two events were both located directly below the site and had magnitudes M3.1 and M3.6. Animation of the structures was created with Blender (http://www.blender.org/), an open source 3D content creation suite. The animation shows distinct resonances of the structures and seismic wave arrivals are clearly visible. This activity aligns with teaching a 6th-grade California standard that states students should know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region. By comparing the two videos, students can distinguish between the characteristics of the larger event. They can also see braced and unbraced frames respond differently to an earthquake. The braced frame has much more stiffness and the roof slab does not vibrate as much as the unbraced frame.

Figure 1. Animation of two experimental structures vibrating during a M3.1 earthquake. The animation is created from recorded data.

(2) *Grade 6 – 16 students*. One of the model buildings has a shaker mounted on the underside of its roof. This shaker runs nightly to excite the structure and capture data with sensors that are mounted on the structure and in the foundation. An animation of the vibration of the model building to the shaker excitation[8] shows the response of the structure to this synthetic input. This video clearly shows the impact of resonance (a topic taught in all physics classes) on the response of the structure.

Figure 2. Animation of the experimental structure subjected to a 1DOF shaker test.

(3) *Grade 6 – 16 students*. Visualization Services group at the San Diego Supercomputer Center created an animation of the ground excitation at the site from an M4.1 earthquake. Using data recorded in boreholes, the animation clearly shows the amplification of the earthquake signal as it approaches the ground surface. These visualizations created from actual earthquake data provide new insight into ground and structural response to strong shaking. The animations are available in NEESacademy[9] and are used as teaching tools for practitioners, K-12 students, and college-level engineering courses. This also aligns with 6th-grade California standards, where students should know how to determine the epicenter of an earthquake and know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, and the local geology.

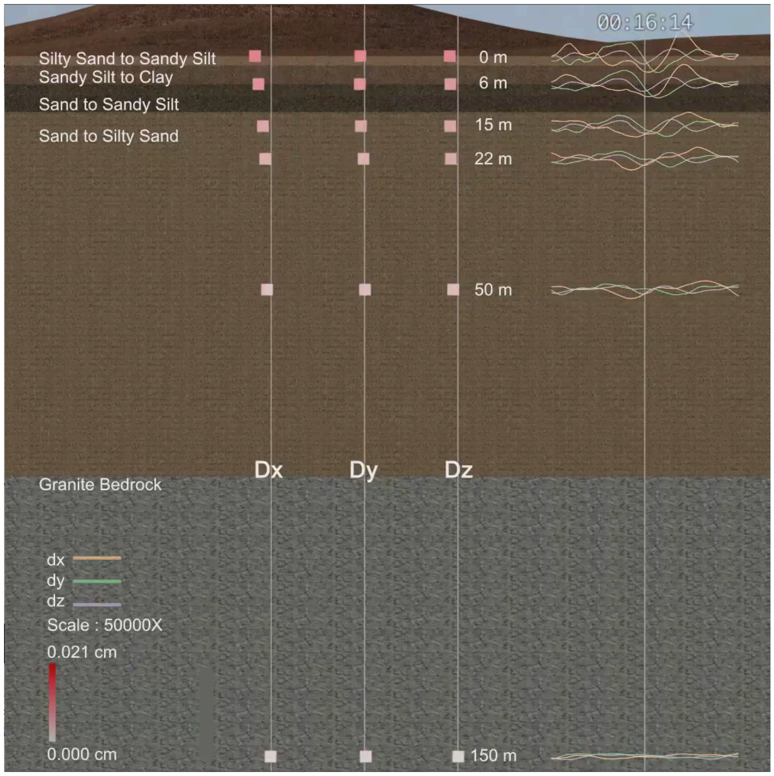

Figure 3. Animation (visualization) of the response of the soils at different depths to a M4.1 earthquake.

(4) *Grade K – 6 students and the general public.* In the summer of 2012, three student interns produced "A Case Study of Earthquake Damage and Repair." This is a film of the damage and reconstruction of the Santa Barbara, California, from the 1925 earthquake. In the film, original photographs of earthquake damage are shown along with contemporary views of these buildings. The film is narrated by a retired professor of geology, who discusses the inherent risks of living in earthquake country and the necessary mitigation required. Earth science is part of the 6th grade framework for curriculum in California. Through NEESacademy, this video[10] is available to the public. The video is also available at the Santa Barbara Historical Museum and the Santa Barbara Museum of Natural History.

Figure 4. A still photograph of a damaged hotel from the video "A Case Study of Earthquake Damage and Repair."

Interactive Remote Experiment and Visualization

Grade 12 – 16 students. A teaching module for freshman-level college physics and earthquake engineering students has also been developed. Through the NEES cyberinfrastructure, students anywhere in the world are able to remotely run the shaker and excite the model building using an Internet portal. While the experiment is running, students can view in real time the acceleration time histories of the structure and the foundation (Figure 5). After the completion of the shaking, the data from the experiment is stored for the students' use in homework assignments that were created specifically for this learning module. Assignments include using the data from the experiment to estimate the fundamental resonance frequency of the experimental structure. This module is currently in use in a college earthquake engineering class. It was designed with guidance from an assessment of the students and assessments are being conducted that will help refine the assignments that accompany the online module.

Figure 5. An example of a screen from the login module. Students run the shaker test remotely and observe the live experiment and the data streaming. The data are stored in files for their use in college class assignments.

Curriculum Exchange: In the curriculum exchange, we will demonstrate the videos and visualizations on a laptop computer, and provide links to where the resources can be downloaded.

Conclusions

Earthquake engineering research provides rich data from which engaging education resources can be developed. In the case of several of the resources described herein, data have been processed and "summarized" into visualizations to highlight important physical principles. These visualizations are short and easily adapted to a variety of classroom applications ranging from a demonstration by the teacher to inquiry-based exploration of concepts by the students. In another example discussed in this paper, the students collect the data themselves and manipulate the data to explore structural performance. While the goals and principles are similar to traditional experiments students perform in a university laboratory, in this case students are performing the experiment remotely through the Internet on a real test structure being used for research. Tying the data collection to a research facility provides real world context to the experiment and allows students to use state-of-the-art instrumentation and computer technology.

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