The 14th World Conference on Earthquake Engineering
October 12-17, 2008, Beijing, China

EARTHQUAKE RISK EDUCATION MODULE FOR HIGH-SCHOOL STUDENTS

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ABSTRACT:

Education of young people about earthquakes and their effect on the society is an essential aspect of reduction of earthquake risk, particularly in urban areas where earthquakes are an inescapable fact of life. Simply put: the more is known about the hazard, the better our preparation for it is.

This paper describes a lecture and a set of demonstrations prepared at the University of California Berkeley Earthquake Engineering Research Center (EERC) and the *nees@berkeley* George E. Brown NEES Equipment Site to educate middle- and high-school students about earthquakes. The lecture addresses the origins of earthquakes and mechanisms of fault rupture, as well as characteristics of ground shaking and its principal effects on structures. Furthermore, the lecture describes the principal means of making building structures more resistant to earthquakes. These ideas are used to entice students to construct structural models made of K'Nex toy construction components (www.knex.com). In a planned demonstration the students are asked to construct their own buildings in groups. Then, the constructed buildings are mounted on the instructional shaking table and tested to compare the response of the buildings to simulated earthquakes.

These lectures and demonstrations have already been presented to several groups of high-school students visiting EERC and *nees@berkeley*. Evaluations completed by the students are used to evaluate the impact of the lectures and demonstrations. These results offer concrete evidence on the effectiveness of the developed curriculum.

KEYWORDS: Earthquake engineering education, education modules, outreach to high-schools

1. EARTHQUAKE ENGINEERING EDUCATION OUTREACH GOAL

Educating our community and society at large about earthquakes relieves fears and promotes better preparedness for such a catastrophic event. Addressing middle- and high-school students in their classroom about earthquakes, about structural engineering, and the design necessary to ensure safety during earthquakes is a very effective way to propagate knowledge about earthquake engineering into our society. Students of all ages, elementary, middle and high school benefit from knowing what happens in earthquakes, what to expect in the future, and also learn about this interesting engineering job where they can design buildings to ensure the publics safety. At EERC and UC Berkeley we are focused on the San Francisco Bay Area communities and schools, particularly addressing the schools in the Oakland, CA and Richmond, CA school districts.

The principal goal is to provide the public with the basic knowledge about what to expect during and after earthquakes. The largest emotion from the community is an overwhelming fear that every building and bridge will be completely demolished with every seismic event. The most significant product of these presentations is to teach the students that they will be safe during earthquakes and that cracking of walls and a fallen book shelf are significantly different from a catastrophic and rare collapse. This key point requires several iterations of emphasis to ensure that the students gain a basis of understanding of why earthquakes happen, why they will remain safe during an earthquake, and what to do during an earthquake to keep safe.

The students also learn about a career in engineering where they can draw, create, and design structures for earthquakes. Crucial years for initial career development are those between the 4th and 8th grade. Thus, giving a focused look at the exciting careers in engineering to the younger students is very beneficial. A large challenge with presentations to high school students is that a PowerPoint slideshow and a few short shake table videos is not exciting enough for them to consider a career in structural engineering. Engaging activities such as a structural design competition with a scaled building is an effective way to get the students involved and a good way to leave a lasting impression. This activity challenges the students to think about what happens in an earthquake and why the buildings they live in need to be safe.

2. FINDING THE STUDENTS

Sometimes the biggest challenge with any outreach project is finding the students. An effective education module requires a teacher willing to provide time in the classroom and students that are willing to behave and listen. Finding the students requires first to communicate to the local schools that this type of outreach is available for their students. This usually involves printed or electronic announcements sent to school districts and to schools directly. The follow-up activity is to contact the interested teachers directly to describe the exact activities of the program and set dates for both presentations and field trips. It is important to keep in mind that teachers do not have the time to research suitable outreach programs, and that they have to plan them in their curriculum well before the start of the school year.

A very successful way to contact the teacher is to invite local teachers to your facilities. The UC Berkeley EERC and *nees@berkeley* Equipment Site have had great success with Oakland teachers: we hosted sixty-seven teachers as part of the Partnership for Oakland Science Inquiry Teaching (Project POSIT). This program encourages teachers to further develop their science programs by integrating field trips and design activities to enhance learning. The teachers were given presentations, lab tours and demonstrations very similar to the ones that would be given in their classroom. The teachers were also given the K'Nex (www.knex.com) toy components and asked to construct a building that was shaken on a small shake table later that day (Figure 1).

The POSIT program was a huge success as shown from post-event participant surveys. Teachers that enjoyed the presentation and demonstrations shared their contact information. From this point organizing a presentation in their classrooms required emailing and calling the teacher to setup a date and time. The initial contact required a brief description of the presentation and field trip planned for the students and referencing the teacher to the nees.berkeley.edu website showing the end product of recent outreach efforts. It was utilizing these contacts that made it possible to have a steady stream of presentations and field trips through the UC Berkeley EERC and *nees@berkeley* facilities.

Figure 1: Interactive outreach with Oakland teachers through the POSIT program

The outreach program needs to determine how to best meet the needs of the teachers. In the example of Oakland Unified School District it was determined that earth science is taught in the 4th and 6th grades. Thus it was these teachers that had the most interest in the outreach activities. Another vital understanding was that no money was available to pay for transportation costs. This required that field trips to either be organized with parent drivers or UC Berkeley paid busses. By meeting these specific needs the teacher took a more active role to bring the outreach program to the students.

Each year these contacts need to be revived and renewed. Specific ways are to host additional teacher functions to communicate that this program is available for their students. These teacher functions should explain in detail the goals of the program and what can be taught to the students. Preservation of past contacts is also important so as to develop relationships with local teachers and schools. Contacts can be maintained utilizing email contacts that describe improvements to recent outreach activities and that this program is still available for local students.

3. IN THE CLASSROOM

Each classroom visit involved a 90-minute presentation to convey information to students. The presentation used multiple communication strategies in order to keep student attention. These strategies included organizing the information into short five to ten minute modules each consisting of three to four power point slides, one to two videos and a physical model demonstration. Each of these components is described in detail below.

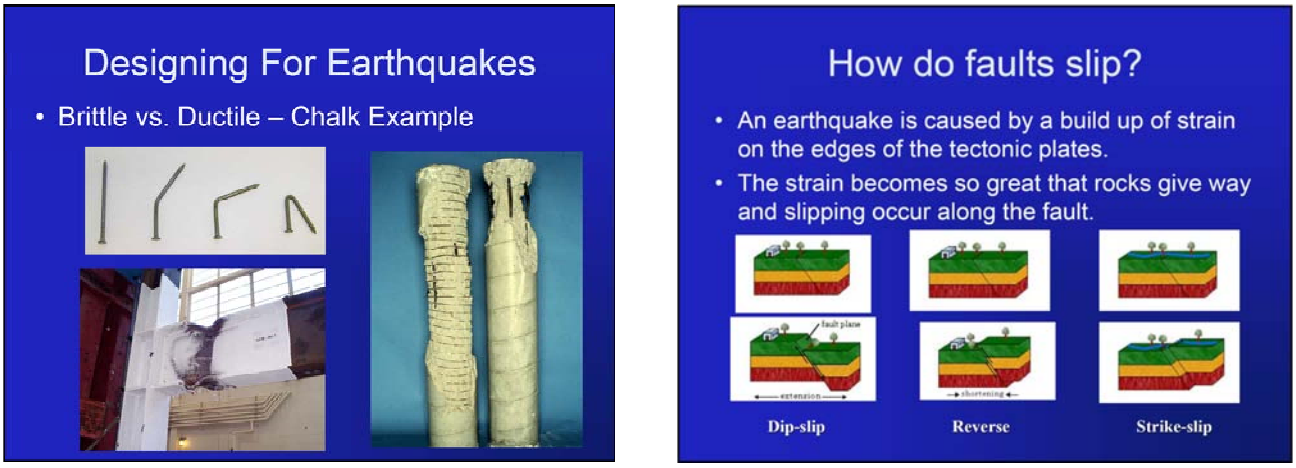

Figure 2: Example presentation PowerPoint slides

As might be expected, the greatest challenge in any presentation is keeping student attention. The idea of engineering is not a glamorous one in students' minds; this presentation attempts to change that. The most effective strategy has been to give a statement at the very beginning of the presentation of the amount of material to be covered in the presentation. Explaining that any unnecessary disruptions will cause the more exciting material to be missed helps to minimize problems of student talking and inattention.

The presentation is started with a video showing a shake table test in Japan where a building is shaken to complete collapse. Following this exciting video, pictures and diagrams of earthquake effects are used to keep student attention (Figure 2). Topics included explanations of the causes of earthquakes, how they affect buildings and what kind of damage can be expected in buildings following an earthquake. A total of ten videos are embedded into the presentation, each two to three minutes in length, are very important in keeping student attention. A popular video shows the use of the EERC and E-Defense shake tables. The EERC footage demonstrates a typical residential building built in San Francisco Sunset District and raises excitement by showing students of where we will be having the field trip. A video from the Consortium of Universities for Research in Earthquake Engineering (CUREE) shows students the effect of contents in earthquakes and how their book-shelves, desks and cabinets might respond during an earthquake at home or in the classroom.

Finally, live footage of the Loma Prieta Earthquake in a UC Berkeley classroom shows how students do not duck and cover showing particular dangers of earthquakes and but is important to teach the students how to protect themselves.

Throughout the presentation students are encouraged to interact with the speaker, ask questions and discuss their fears and concerns about earthquakes. Students are more interactive when the presentation discussed the failure of the Cypress Freeway when they heard a story about it from their parents. Students respond very well when a video of a typical San Francisco home shaken on the EERC shake table is shown. The information is more easily passed on when described in terms that they can easily relate to. Another method of enhancing learning is to keep the students active during the presentation. A valuable tool for describing fault types is to have each student put their knuckles together and by directing them to move one hand relative to the other they can distinguish the difference between strike-slip and dip-slip, how mountains are formed and how stress is built up in the soil prior to an earthquake and the sudden rupture of the fault is the earthquake.

During the presentation a physical model demonstration of an earthquake's effect on a building is performed. UC Berkeley Professor Jack Moehle developed a useful tool using 2x4 wooden blocks, several pieces of chalk, packing tape and some thin wire (Figure 3). The two blocks are pre-drilled with six holes to fit the chalk tightly. The blocks of wood are then fit together with three chalk pieces. The mini structure is then loaded with the students' least favorite books. After a little suspense the structure is shaken showing the brittle effect of unconfined concrete in buildings. Next three pieces of chalk are wrapped in one layer of thin packing tape and the building is reassembled. Again the mini structure is loaded with books and shaken, but this time it does not collapse. Then an explanation is made showing how reinforcement cages provide the same effect for concrete buildings.

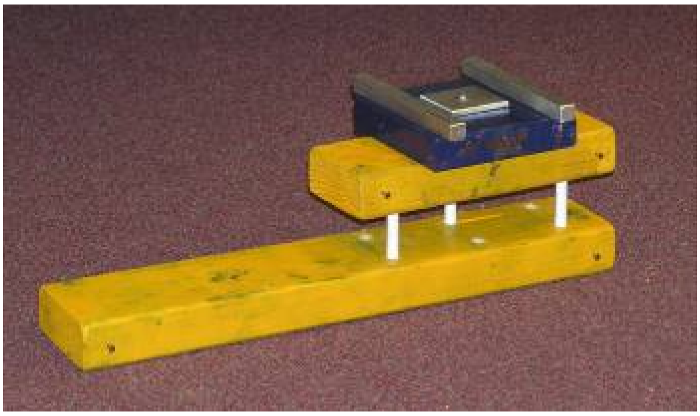

Figure 2: Brittle vs. ductile mini structure demonstration

Another wood block and chalk structure can be made, but this structure includes X-braces made from thin wire. The chalk used is not taped, but when shaken the students can see that braces can be effectively used to keep a building safe during an earthquake. The end product is that building design is simplified into a demonstration that uses basic materials that are familiar to students makes it easier for them to understand. The small addition of tape and wire x-braces strongly conveys the difference good engineering can make in an earthquake in a way that they can notice a local braced building or steel jackets on a local bridge structure. At the conclusion of the presentation, a hands-on building activity can be introduced.

The final module to be presented is the introduction of the building competition and field trip activity. This generally piques attention as most students prefer hands-on activities. Students are asked to create buildings either from paper or K'Nex toy construction components (Figure 4 and Figure 5). They are encouraged to draw on lessons from the presentation in their construction techniques. High school level students may be given additional constraints such as cost (limiting the number of pieces used), aesthetics or seismic performance measured with accelerometers placed at the roof. Framing the activity as a competition generally encourages more active student participation. As the presentation takes up the entire class period, the construction of the model buildings is overseen by the teacher during a follow-up classroom session. The teachers are left with the necessary materials and are given instructions and tips on how to guide students in this task. The next step is for the students to bring their model buildings to the Richmond Field Station to test them on a small shake table.

Figure 4: K'Nex building construction at an Oakland middle school

Figure 5: Example K'Nex structures built by students

4. INTERACTIVE FIELD TRIPS

Students can reach a whole new level of understanding about earthquakes by touring the *nees@berkeley* Equipment Site and the EERC shake table laboratories at the UC Berkeley Richmond Field Station. These facilities are constantly testing new structural components and analysis procedures that make it exciting for students to see real life research.

The field trip is broken down into several segments. The initial introduction explains to the students that they will be walking through a lab facility with very expensive equipment and gauges that they cannot touch. The best thing to do for the elementary school kids is to have them run back and forth between a nice grass areas that we have between our buildings. The goal here is not to make the children exhausted, but once they release some of that energy built up from the bus ride they appear to behave and listen more attentively. It is also good to have a few parent volunteers or UC Berkeley students to help keep the field trip organized. Each visiting student is given a hard hat before entering the lab facilities. A very successful way to engage the students, particularly those in middle school in younger, is to ask them to hold their hard hats with one hand or both hands at all times. This works fantastic to keep their hands from grabbing things or pushing one another.

The students are usually divided into two different groups. The first group is shown the inner workings of the shake table frits, through a demonstration based on a model made of the E-Defense testing lab in Japan. This scale model provides an interactive tool for students to alternate axis or rocking of the table in a way that simulates a real life earthquake. Then, if there are not ongoing tests, are able to walk on the shake table where they had seen full-scale dynamic testing from videos shown in the classroom presentation. The next stage is to move the group from the EERC shaking table laboratory to the *nees@berkeley* Equipment Site laboratory. The students are able to see experiments, for example on bridge columns under biaxial loading. Through seeing this research students have the chance to see how earthquake engineering benefits the community and makes structures even safer. When touring the laboratory facilities, every test, experiment and machine needs to be explained in a way that the students can understand. For example, showing the 4,000,000 lb universal testing machine means much more when put in the relation of 1,500 cars or the weight of a 2 story wood-framed house (Figure 6).

Figure 6: *nees@berkeley* Equipment Site tour showing range of students that benefit from outreach

Simultaneously the other group is testing their buildings on a small instructional shake table (Figure 7). This shaking table has an 8x8-inch payload surface to which we fabricated attachments for K'Nex buildings. We have organized an apparatus to allow up to three structures to be place on the shaking platform. Each structure is then weighted down with specially prepared masses placed at each story. The K'Nex structures usually receive one or two 100gram weights attached to each floor. Then the attached structures are excited at the same time. The shake table is driven through a sweep of oscillation frequencies and amplitudes to show the students the different mode shapes and demonstrate how such motion affects their design.

A computer attached to the instructional shake table is then used to run the structures through several earthquake ground motions. With accelerometers attached to the roofs and/or just with visual observation of roof displacements of each structure make it possible to gauge which structure performs the best. The outcomes of these small scale tests allow for a valuable evaluation of the buildings that the students can take part in. Interesting observations include: torsion problems with unsymmetrical braces, large drifts, rocking if not attached clearly, and capacity design. Finally, some of the buildings are shaken to collapse: this always excites the students, especially those whose building survives the most earthquakes (Figure 8). Students are able to compare buildings and observe what worked and what design decisions improve seismic performance.

Finally all the students are brought together to discuss the outcomes of all the building designs. They are encouraged to ask questions and several students are called upon describe the positive and negative designs of each building. This interactive approach creates a full circle of education for the students- they learn about earthquakes in the classroom, they think critically in a building design competition, they test the seismic performance of their designs then they reflect and bring together all the concepts discussed.

Figure 7: Shake table testing of students' buildings

Figure 8: Winners of the shaking table competition with their K'Nex building

5. GLOBAL OUTREACH

Recently, the EERC and *nees@berkeley* Equipment Site outreach efforts extended to an international high school group from Beijing, China. These students toured the main campus of UC Berkeley and were given a presentation and tour of the *nees@berkeley* Equipment Site and EERC facilities. The presentation and field trip was restructured to improve communication to the international students. A translator was used to translate each sentence. The biggest constraint on these presentations and field trips was time to conquer the language barrier.

In this particular case, everything required simplification otherwise: the presentation and fieldtrip would have taken twice as long. Instead of asking the students to build their own buildings, a small bridge made from K'Nex toy components, was tested to demonstrate the seismic effects of earthquakes on that K'Nex bridge structure. In the end, this outreach effort was, also, very successful. The visiting students from Beijing were able to learn about earthquake engineering research in the United States and were able to bring back a base understanding of structural engineering back to their home country.

6. LESSONS LEARNED

Outreach is important: we need to communicate about earthquake engineering to our local communities. Addressing middle- and high-school students during their formative years is very effective, too. However, this is not easy. It is vital to utilize the presentation strategies that work well and immediately replace the problem spots in the presentation. Reflecting on the goals discussed previously, lessons learned are primarily in the area of improving communication between the EERC and *nees@berkeley* Equipment Site outreach program to the students, teachers and parents.

Figure 3: Happy students after a successful field trip

Students need to be kept entertained and excited throughout the presentation. It is necessary to have exciting videos, flashy power point slides, interesting demonstrations, interactive activities and an energetic presenter is needed to keeps their attention. The older the students, the more difficult it is to maintain order in the classroom. High school students need to be given immediate activities and the presentation must be significantly reduced to about thirty minutes. The younger elementary school students handle the presentation, demonstrations and video very well with little interruptions and effective discussion about earthquake topics. It seems that the useful span of attention diminishes with increasing age of the students. Having complex slides or drawn out periods of lecture do not work during the presentation. The key idea is to keep everything really simple and change the complexity of the earthquake engineering talk specifically for the age group being addressed.

There is room for improvement in the organization of field trips. A disorganized field trip is easily taken advantage of by students, whereas having good communication to teachers, parents and students ensures that students are safe and the education quality is the highest.

Through presentations and field trips students can learn about seismic effects on buildings and alleviate their fears of catastrophic collapse. The building activities challenge students to think creatively to develop engineering solutions. The outcome is a positive and inspirational educational experience about earthquakes that develops the future engineers and researchers of tomorrow. Last, but also important, it is apparent that more outreach in the field of earthquakes and structural engineering gives us engineers a voice in our community.

ACKNOWLEDGEMENT

This education and outreach effort was supported in part by the US National Science Foundation through the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) and by the University of California Berkeley through the Earthquake Engineering Research Center (EERC) and the Summer Undergraduate Research in Engineering at Berkeley (SUPERB) program.