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A Time for Examination and Action

USING SHAKE TABLES IN THE PRE-COLLEGE CLASSROOM: MAKING THE IMPACT OF EARTHQUAKES COME ALIVE

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ABSTRACT

Lack of earthquake awareness in the East underscores the importance of building a conceptual understanding of the effects of seismic events on the built environment. Simulation activities remove seismic events from the realm of television coverage of something that happened elsewhere and place the societal implications of earthquake education into the classroom.

The shake table is a device which makes tangible an earthquake and its aftermath. Classroom use of student-made shake tables can link hands-on experimentation to actual research. Students can become researchers, learning about the performance of structures in earthquakes. Simultaneously, they can learn about variables (design, materials, building function, height, soil, and the like) and social issues that can impact on the construction of buildings. Although a student-constructed shake table lacks the sophistication of the actual research shake table, it does illustrate to students that researchers test structures, they don't just design on paper and see what happens in real life.

There is a need for hands-on activities that encourage the critical thinking necessary for the passage of seismic building codes and other earthquake mitigation strategies. Only by making the possibility of an earthquake and its consequences real can we hope to convey the necessity of preparation. The student-made shake table, and associated experimentation, is an excellent way to begin this process.

INTRODUCTION

To study the effects of earthquakes on structures, researchers at the National Center for Earthquake Engineering Research (NCEER) mechanically re-create earthquakes in their laboratory at the State University of New York at Buffalo (UB). Part of this work involves sophisticated testing of structural models of buildings, bridges, and pipelines on an earthquake simulator, commonly known as the shake table.

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The shake table is 12 feet by 12 feet square and made of concrete poured around a steel frame. With five degrees of freedom, it is among the most versatile shake tables in North America. It can move horizontally and vertically, as well as roll back and forth, rock side to side, and twist on a central axis.

Although weighing about 16,500 pounds, the shake table is considered to be lightweight in comparison to other seismic simulators used for similar testing. This lightweight design enables it to support 50 metric tons or 110 thousand pounds during testing. The table is powered by six hydraulic actuators, four located beneath the table and two more are attached to the sides. Together, they move the table in whichever direction the simulated earthquake requires.

A computer system is used to control table motion. The system enables researchers to input any one of a thousand previously recorded earthquakes into the table and simulate their vibrations. In addition, researchers can create their own earthquakes and test anything beyond existing recordings on the Richter scale.

While a structure is tested on the shake table, it is monitored with sensors to determine the amount and direction of movement at various heights, the amount of stress placed on structural components due to swaying back and forth, and the severity of earthquake vibrations at various points on or within it. NCEER researchers can use this information to determine how vulnerable a structure may be to earthquake forces. The sensors can also be used to determine the effectiveness of earthquake protection devices in limiting adverse conditions caused by earthquakes.

NCEER runs approximately 25-30 experiments on the shake table each year. These have included the testing of six story steel structures, three story concrete structures, brick structures, bridges, and even computer systems.

SHAKE TABLES IN THE CLASSROOM

Building a Shake Table

Students can construct their own shake tables and then use them to test structures. Although this classroom version lacks the sophistication of the actual research shake table, it does convey to students that researchers test structures -- they don't just design on paper and see what happens in real life. In addition, the use of a shake table gives a greater degree of consistency to earthquake simulations used for experimentation than the standard shake-the-utility-cart "earthquakes." It also allows the user to "shake" the table in two directions simultaneously which can sometimes be more consistent with movement from an actual earthquake.

This shake table[ii] consists of a box (with flaps cut off) and an inner box insert that serves as the floor of the table. The movement of this shake table is created by pulling on the kite string from each end of the box. The rubber bands also help simulate shaking.

[ii]The directions given are based on those provided at a session at the Northwest Earthquake Workshop for Teachers held in Seattle, Washington in August, 1990. There are other shake table designs that have been used in schools. Directions for those other tables can be found in the "Plate Tectonic Cycle" of the I.Science Mate Curriculum from Math/Science Nucleus in Fremont, California. Additionally, a mechanical shake table for classroom use can be purchased from Environmental Volunteers in Palo Alto, California.

Materials:
Kite string -- 12, 8" pieces
Scissors
Rubber Bands -- 4
Marker
Ruler
Cardboard Box Insert -- dimensions approximately 11" wide x 15" long
Box with top flaps cut off -- dimensions approximately 12" wide x 16" long x 6 - 1/4" high

Directions:

INSIDE BOX INSERT
1. Make holes 1 inch in on all four sides. There should be 4 holes (see Figure 1).
2. Make additional holes l/2 way along width and length on two ADJACENT SIDES. You should now have a total of 6 holes.
3. Punch out holes with scissors. Additional holes made in direction #2 won't be punched out as big as those made in direction #1.

OUTSIDE BOX - ON TWO ADJACENT ENDS ONLY
1. Make a hole 3 l/2 " down and 8 l/4 " along the long side of one end of the outside box (see Figure 2). This hole should be in line with the hole made l/2 along the length of the inside box insert.
2. Make another hole 3 l/2" down and 6 l/4" across on the short side of the box in line with the hole made l/2 way along the width of the inside box insert.
3. With scissors, punch out the marks you have just made.

FINAL DIRECTIONS (see Figure 3)
1. Take the 2, 8" pieces of kite string and tie around the two end holes that were put midway along the two sides of the inner box insert. Note: Leave enough string to be pulled through the outer box. This will be used to control the shaking of the inner table from the outer box.
2. On both of the opposite short sides of the box, make a hole 2 l/2" down and 1 1/4" in on the right side. Repeat on the left side. Then make another set of holes 4" down and 1 1/4" in, both on the right and left sides. You should now have 4 holes on EACH of the short sides of the outer box or a total of 8 holes. Now thread the 4 rubber bands through the top of the paper clips (see Figure 4). You should have 4 threaded paper clips.
3. The next step is to put the "floor" or inner box inside the outer box of the shake table. This is done by threading the rubber bands through 1" holes on the inner box and both of the 2 1/2" and 4" holes on the short sides of the outer box.
4. Finally thread the string through the outer box. This string will be used to cause and control the shaking of the inner box or "floor" of the shake table (see Figure 5).

Considering Variables

The experimentation phase should be initiated by having the students focus on what they will be manipulating and what they will be keeping constant. Will it be building design? The materials that are used? The height of the building? The soil beneath the building? If students decide to focus on one aspect, others need to be kept constant. Otherwise, when comparisons of different designs or heights are made, it will be difficult to know what specifically made a structure stand up or fall.

This concept of variables is very important. The following are some of the different variables that should be considered by student researchers:

- Design of building -- whether the building is in the shape of a rectangle or an irregular shape such as that of an L, T, U, H, +, O, or a combination of these shapes. Another part of the building design which students should consider is whether the building has what is called a "soft" first story or an open floor supporting heavy structural or nonstructural walls above it.
- Materials used to construct the building -- e.g., steel, concrete, wood. Whereas older students might want to try using wood or small pieces of metal in the construction of their buildings, other materials are more appropriate for younger students. Materials that have been successfully used include: paper plates, paper cups, sugar cubes (for bricks), peanut butter and frosting (for mortar), dry spaghetti, drinking straws, empty match boxes, note cards, and paper clips. Extra styrofoam peanuts used in packing can also be used for construction.
- Function of the building -- the importance of certain critical structures such as hospitals, nuclear power facilities, fire stations dictate the amount of earthquake resistance required for the structure.
- Height of the building.
- Soil underneath the building -- Soil is such an important factor that students should always have soil under the buildings they construct. To do this using the model shake table, an insert should be put on the shake table in which soil can be placed. A lid from a box containing paper or stationery makes a good insert.
- The number of earthquakes the building has previously withstood and the kinds of damage suffered, if any.
- Duration of earthquake.
- Severity of the earthquake -- how intense the shaking is at the location of the building.

Some Basic Experimenting

A starting objective for pre-college students could be that they understand there are a number of factors (variables) involved in the construction of "earthquake-safer" buildings. Students can be given the following:

Assignment: Some buildings withstand the shaking of an earthquake with little or no damage. Others collapse. You are to design a building that will withstand an earthquake. This structure should be built on either soil, sand, fish gravel or a combination of these. If desired, water can be mixed with the soil. Measure the amounts of water and soil components. Design and build a structure from the materials provided and simulate an earthquake. Earthquake simulation is defined as ten seconds of shaking either on the homemade shake table or a utility cart.

Materials: Sand, minimum of two types of soil, fish gravel and water; shallow cardboard boxes and measuring cups; building materials: paper plates, paper cups, straws, matchboxes, uncooked spaghetti, sugar cubes, peanut butter, single-serving cereal boxes, and the like.

Questions: What soil and water mixture did you use? How much of each did you use? What materials did you use in the building? Draw a diagram of your building. How did your building perform during the simulated earthquake? What conclusions can you draw? How do repeated earthquakes affect your building? How does a longer (20 seconds) quake affect your building? What is the effect of changing the amount of water in the soil mixture? What is the effect of using the same design and changing some building materials? If you used bricks (sugar cubes) and mortar (peanut butter or frosting) for your building, consider which makes the greatest difference, the mortar or the strength of the bricks. Try it and see.

Follow-up Assignment: What different ways could you classify your structures based on how they performed during the simulated earthquakes? Develop a classification system, giving examples from your experimentation. For example, you could classify your structures as having a regular or irregular shape. You could then classify them as performing a certain way during the earthquake based on this shape. You could also classify the damage that occurs to the buildings as minor, moderate, and major. What would you consider to be acceptable damage for each category? What implications can you draw from your classification system for future building? Should certain critical facilities (hospitals, schools) have one set of standards or a stricter set of standards than other structures? How would you rate your classmates structures?

CONCLUSION

The shake table can be used by students to test a variety of structures made from different materials, as well as to test bridges and pipelines. Design and construction of buildings can also be linked to societal issues such as the amount of money that is available. For example, students could be instructed to build a structure that could withstand 10 seconds of earthquake shaking for the cheapest amount of money or they could be given a dollar amount to spend for construction. In both situations, the various building materials could be given different dollar values. Dollar values could also be considered in repair after earthquake simulations. Additionally, classification exercises can form a basis for student understanding of building codes.

The shake table is a device which makes the aftermath of an earthquake tangible. Simulation activities remove seismic events from the realm of television coverage of events that happened somewhere else and set the societal issues of earthquake education right in the middle of the classroom. Only by make the possibility of an earthquake and its consequences real can we hope to educate students about the necessity of preparation.

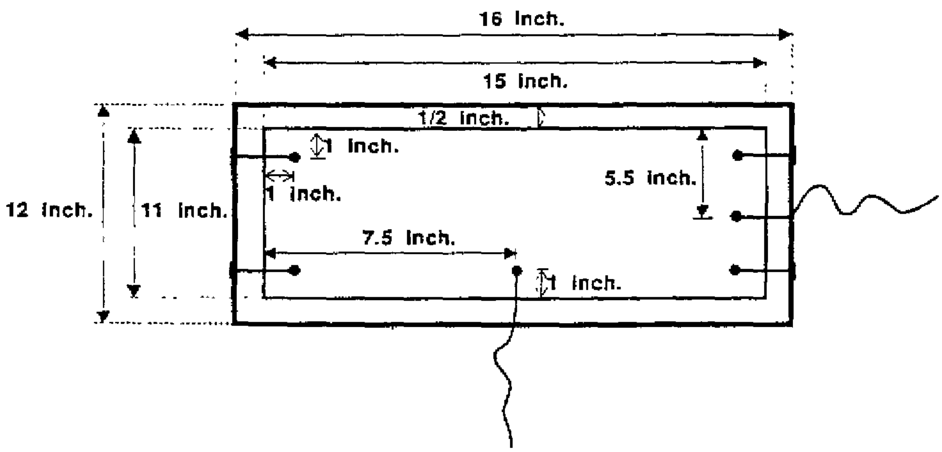

FIGURE 1. Dimensions.

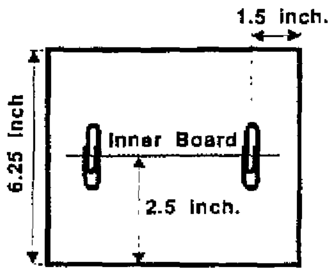

FIGURE 2 Side View.

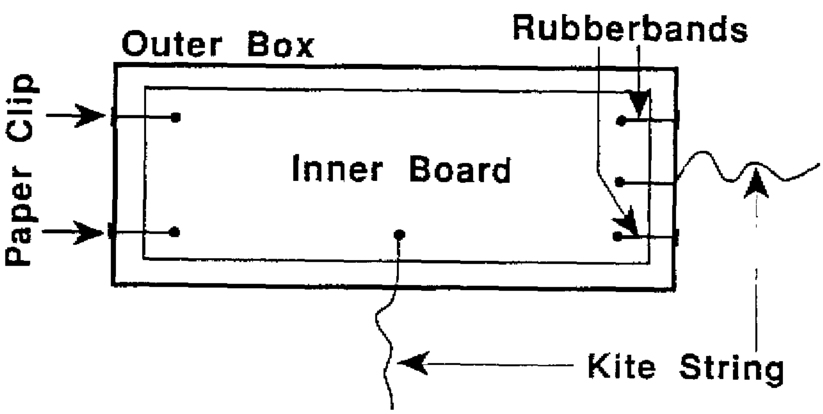

FIGURE 3. Top View.

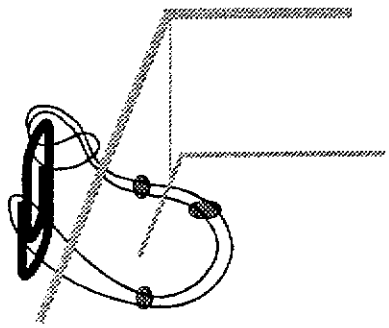

FIGURE 4. Threading rubber bands.

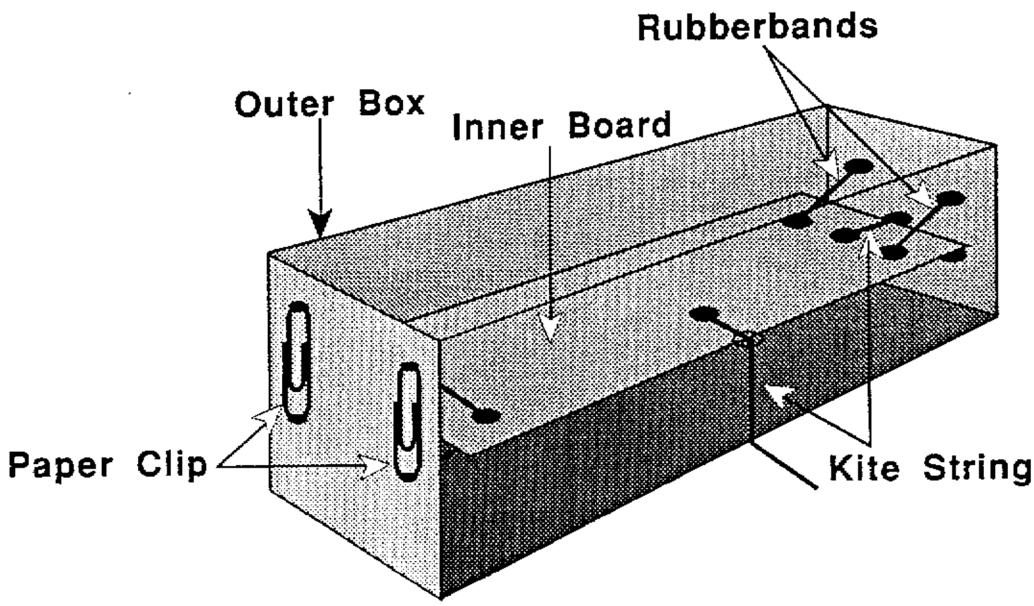

FIGURE 5. Perspective View.