INTERNET LIVE SHAKE-TABLE TESTING FOR EDUCATION IN EARTHQUAKE ENGINEERING

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Abstract – *There is great enthusiasm about the potential of computers for enhancing student learning in science and engineering. The Structural Engineering Department at the University of California, San Diego (UCSD) has initiated the Webshaker Pilot Project with the goal of facilitating accessibility to live, on-demand, experimental testing earthquake engineering applications. The project is presented in two steps: (1) Webshaker (http://webshaker.ucsd.edu), initiated with the goal of demonstrating feasibility and worthiness of a web-based, real-time monitoring and control system for civil engineering applications, and (2) Quaky (http://e-quake.ucsd.edu/quaky), a new pilot interactive, web-based demonstration facility that brings a live working shake-table experience into the homes and classrooms of young people, in particular to those in grades K-6. Use of live interactive testing websites for education is discussed. The developed educational content and educational assessment tools are highlighted. Further refinements continue to evolve based on student feedback.*

Index Terms – Internet, WWW, Education Evaluation, Shake-Table, Dynamic testing, Earthquake

INTRODUCTION

In the following sections, the Webshaker project is presented first, with emphasis on the website developments and educational outcomes. The Quaky project is presented next, addressing considerations of relevance to the intended K-6 grade audience.

WEBSHAKER

Background for the Webshaker Project

Earthquakes are among the most devastating natural disasters, causing loss of life and billions of dollars in damage worldwide. Currently, the effect of earthquakes on structures is a major component of research and education, in the broad areas of Civil Engineering and Seismology.

In the realm of education, Internet availability of experimental setups (Carlson 1996 and MacIsaac 1996) and related computational simulations allows for: 1) efficient use of time and resources, 2) flexibility in accessing information on a 24-hour, 7-day (24/7) basis, and 3) convenience of self-paced learning with the aid of physical models (e.g., Soh and Gupta 2000). The Webshaker education/research project (http://webshaker.ucsd.edu & http://e-quake.ucsd.edu/quaky) was initiated with the goal of providing such a learning environment for applications in Dynamics within courses such as introductory Physics, Mechanics, Structural Dynamics, and Earthquake Engineering.

This internet-enabled remote testing project may be viewed as a prototype for implementation within other disciplines of engineering and science. Thus, the horizon for on-demand real-time testing is being facilitated on an unprecedented worldwide scale.

Website

The developed website allows students to conduct shake-table tests on simple structural models. The Webshaker setup consists of a structural model attached at the base to a bench-top shake-table (Figures 1 and 2). The table motion is used to simulate the lateral shaking caused by actual earthquakes. The attached model is used to determine the dynamic response (shaking) of representative buildings during the selected earthquake (input table excitation). For example, in Figure 1, users monitor the response of a model representing a simple single story structure. Both the shake-table base and the model are instrumented (with accelerometers and displacement transducers) in order to measure the model response. Through the website (Figure 3), users can view the model and shake-table (e.g., using Windows MediaPlayer®), select the type and amplitude of base shaking signal, run and see the live shaking test take place, and view/download the corresponding recorded displacement and acceleration graphs.

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A personal computer controls the input motion and the acquisition of output response from the instrumentation, and this data is displayed graphically. The computer also acts as a web-server (Fig. 2), allowing the remote Internet user access to all functions available on the website. An attached digital video camera along with video streaming software transmits the live picture to the user throughout.

FIGURE. 1
THE WEBSHAKER SHAKE –TABLE AND MODEL (http://webshaker.ucsd.edu)

Using a standard web-browser such as Internet Explorer or Netscape Navigator, users are able to select a dynamic base excitation, run the experiment, download the results (Fig. 4) of the experiment (i.e., model response in terms of acceleration and displacement time histories / response spectra recorded by the installed instrumentation), view a real-time streaming video of the shake-table and the mounted test structure, and finally conduct a numerical simulation of the executed experiment. This simulation computes the response of a single-degree-of-freedom (SDOF) linear model, subjected to the known base acceleration, using the classical Newmark predictor multi-corrector algorithm for the Average Acceleration case (Chopra 1995, Filiatrault 1998).

There are two types of base motion available for conducting experiments: 1) harmonic, and 2) earthquake-like motions. For the harmonic motion, the user specifies the base motion amplitude, frequency (Hz), and duration (seconds) of a sine wave. The other form of input signal is an earthquake-like motion. These motions are constructed by scaling selected acceleration records from historic events, such as the California 1994 Northridge earthquake, among many others.

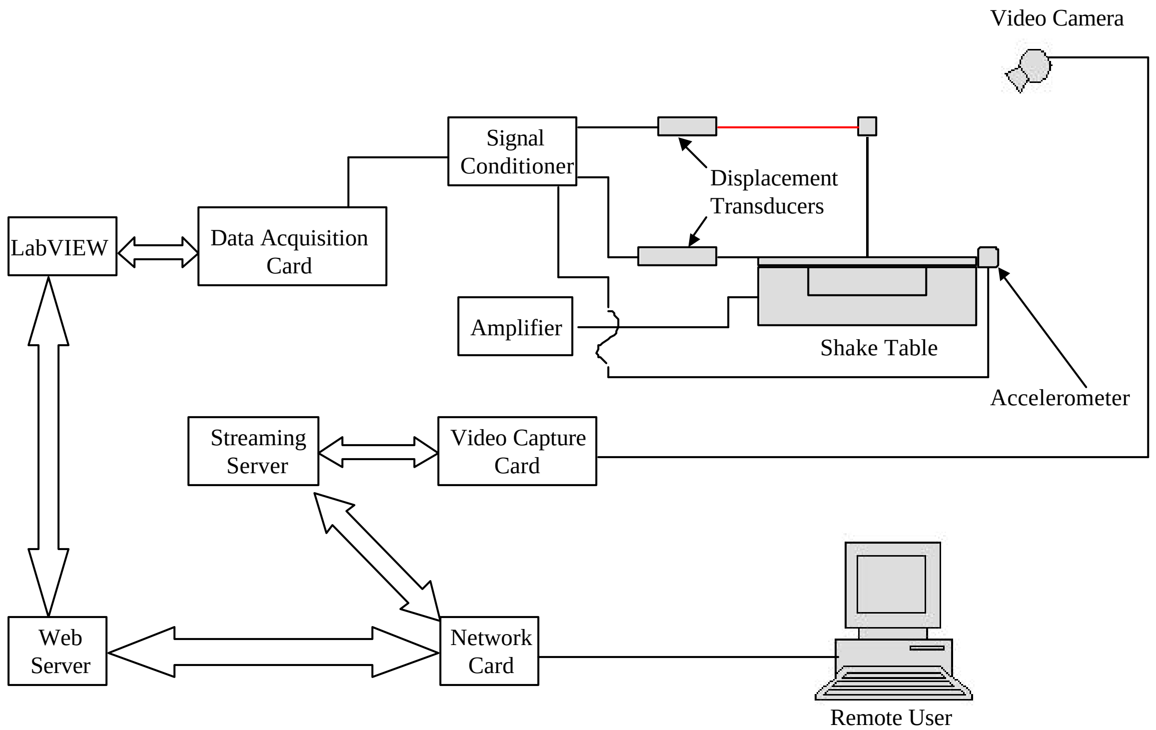

FIGURE. 2
SCHEMATIC OF THE WEBSHAKER SITE

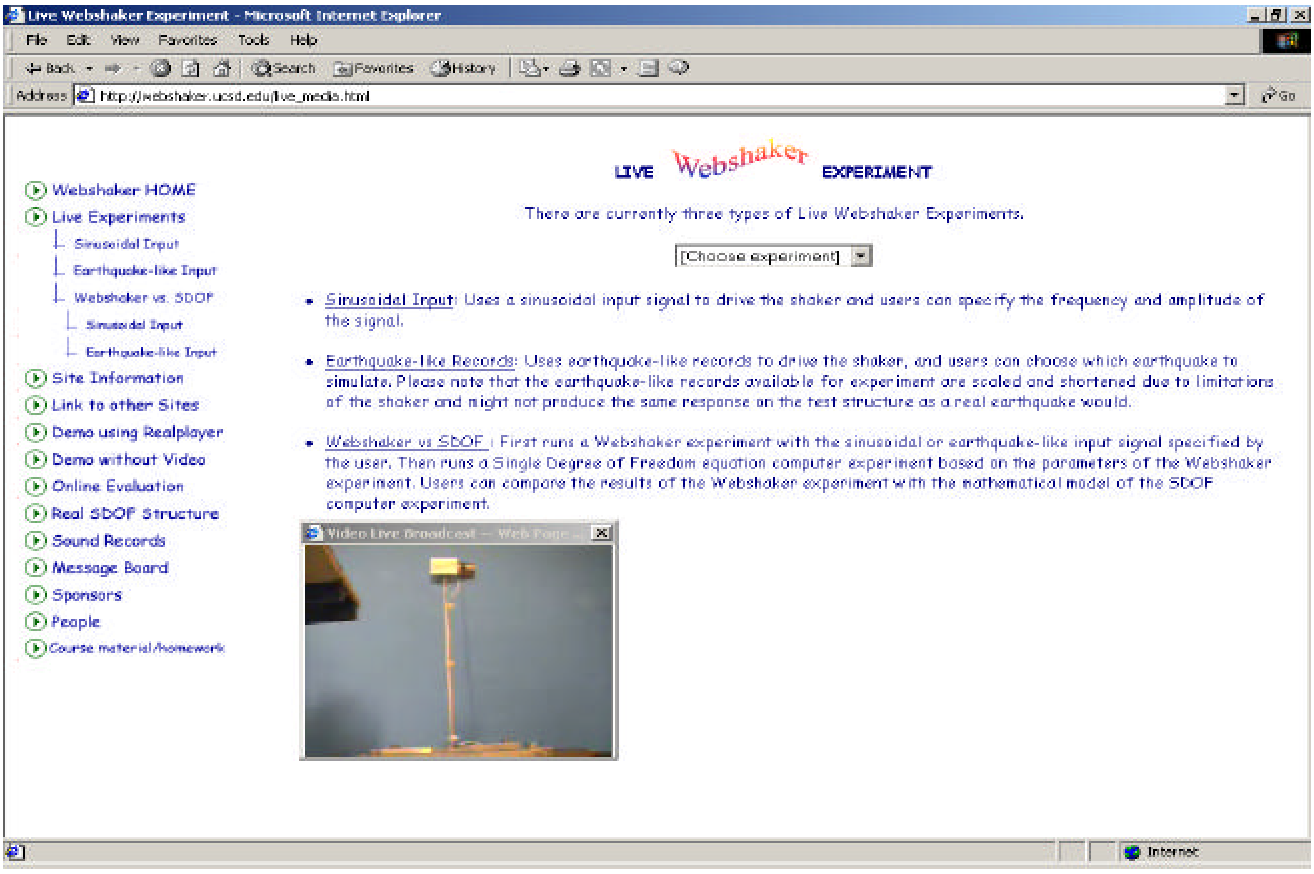

FIGURE. 3
LIVE EXPERIMENT PAGE FOR THE WEBSHAKER SITE (http://webshaker.ucsd.edu)

Additional features of the website are a collection of sounds recordings taken from historical earthquakes, a selected set of links to other earthquake-related websites, class notes and presentation materials, and an on-line message board.

Value Within the Classroom

In our Earthquake Engineering courses at UC San Diego (UCSD), Webshaker is already being utilized. For instance, in an exercise focused on the concept of resonance, students are asked to identify the dynamic parameters of the Webshaker model using two different experimental approaches. They are asked to compare the results and discuss their findings. This last step represents a self-check of the reliability of the outcomes, and should a contradiction arise, the student can go back and re-run the experiment to verify the findings. As opposed to an assignment based solely on theory, students deal with the response of an actual physical structure (similar to practical engineering situations).

Compared to the conventional laboratory (lab) experience, the Webshaker remote access facility solves a series of logistical problems (restricted access to the lab, required supervision, presence of a qualified technician, …etc.). In this regard, a web-based lab is available 24-hours a day, allowing students to work unsupervised, at their own convenience. Since the student has full control of the system, they can conduct their own "what-if" testing scenarios, and revisit the experiment whenever they think of new issues to explore.

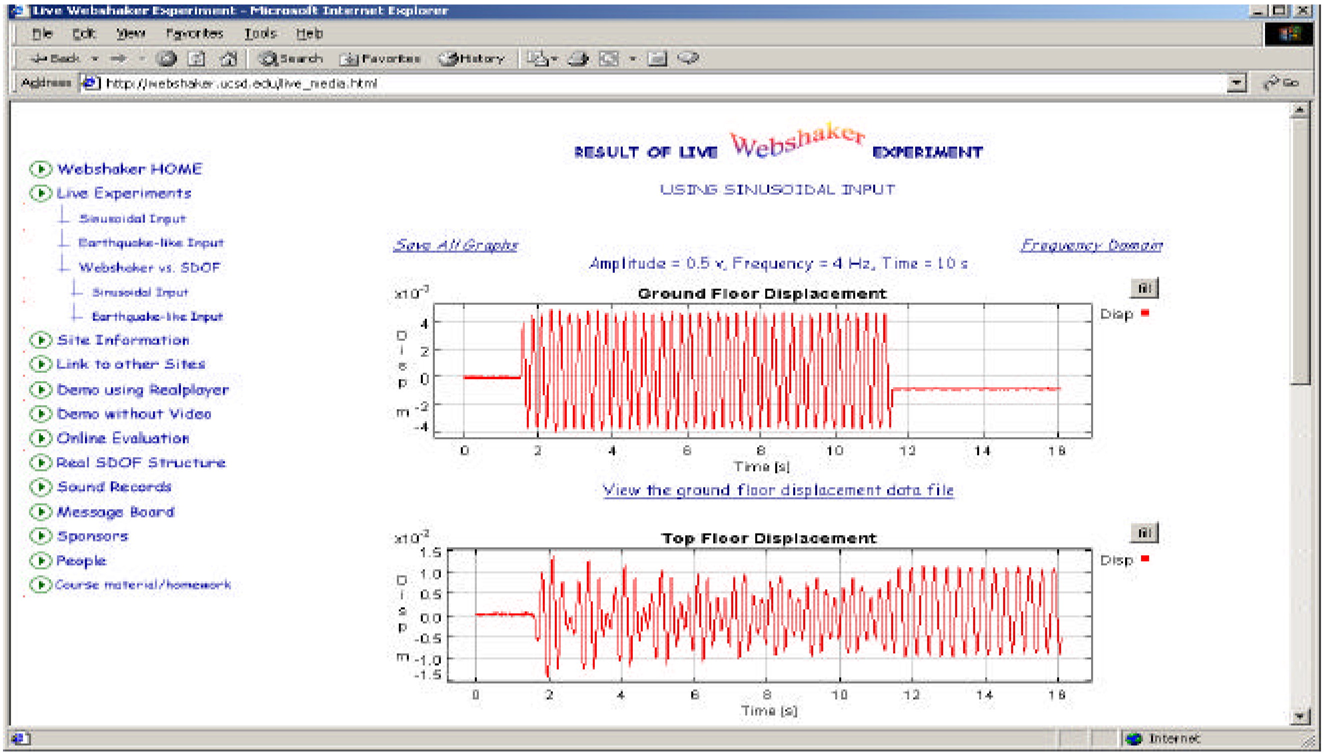

FIGURE. 4
GRAPHICAL REPRESENTATION OF RECORDED DATA

In the development of this facility, we aspired to enhance the traditional educational process. Among the main objectives were:

- Motivating students by facilitating a convenient unsupervised self-learning environment.
- Fostering a versatile environment for collaboration and interaction within the classroom, in the form of classroom projects.
- Bringing elements of the research testing experience right into the classroom. Generally, this experience is currently only studied "second-hand", through published technical articles and textbook reports.
- Allowing otherwise effort-intensive experiments to be executed routinely for research/educational purposes.
- Working towards development of courses with experimentation content that can be effectively delivered off site, greatly enhancing the educational experience (Marion and Hacking 1998).

Student Feedback

This feedback is now being compiled using a professional on-line evaluation form available at the Webshaker site. Two versions of the evaluation form (http://webshaker.ucsd.edu/survey.html) are available, one for students and one for other users. The student evaluation form is composed of two-parts. Part 1 is intended to gather background information, including year of enrollment, related introductory classes, web-access location and connection speed, and familiarity with experimental testing procedures and the World Wide Web.

Part 2 assesses quality of the site and asks the students to rate their experience. This includes rating certain specifics such as the Web-interface aesthetics, convenience, quality and benefits of video streaming. In addition, students are encouraged to provide further comments (the evaluation form for other users is similar). Both forms may be completed and submitted on-line.

Asked to comment on his experience with the Webshaker, a student wrote: "*...Running experiments on a shake table and seeing actual results truly enhanced my understanding of the principles involved. While I was using the site, there were some other students around who were watching what I was doing. They were all excited to watch me run my test and see the experiment going on*." Here, excitement is associated with the capability of remotely controlling the experiment with no supervision.

Dissemination

It is recognized that dissemination and wide adoption represents a major component of this Webshaker project. Effort is underway for using Webshaker in lower level engineering courses (Physics, and Mechanics courses), as well as other upper level undergraduate and graduate courses in Civil and Mechanical Engineering (e.g., Vibrations, Structural Dynamics).

QUAKY

In the development of this pilot website, we attempted to select an earthquake engineering concept that might be effectively conveyed to a youngster. It was decided to focus on the relationship between the frequency composition of an earthquake excitation and the stiffness of the building exposed to this earthquake. In particular, the combination of an earthquake composed primarily of frequencies matching the preferred shaking frequency of the building (resonance) may result in more damage.

The Quaky Project is a live interactive experiment of a real structural engineering experiment aimed at users in grades K-6. The current look of Quaky, as shown in figure 5, is bright and colorful in order to spark the interest of kids. Upon completion of the experiment, kids will have had the opportunity to learn the terms stiffness and frequency and understand the relationship between a particular earthquake motion and its effect on structures of different characteristics.

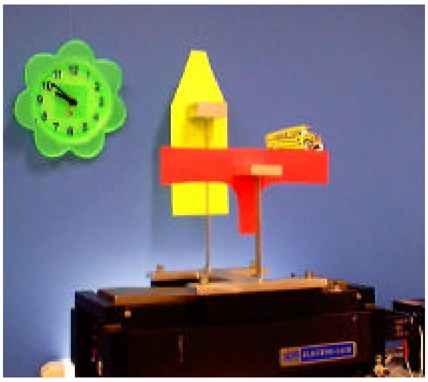

FIGURE. 5
VIEW OF THE LIVE VIDEO FROM THE QUAKY SITE
(http://e-quake.ucsd.edu/quaky)

The user is not expected to be familiar with experimental techniques and is therefore introduced to the setup of the live shake-table via an explanation page (Fig. 6) accessible from the homepage. Within this page is an explanation of how the models are used to represent a skyscraper building (Fig. 7) and a small bridge, and the characteristics of the models, named Skyscraper and Bridge, respectively, are presented (Figure 6).

Educational Applications

On the Quaky homepage, the user is encouraged to learn more about engineering terms and topics that are related to the experiment they are about to perform. Contained within the interactive activity are links to definitions of the terms, displacement and frequency. These definitions are specific to Quaky and are accompanied by diagrams and figures that should aid in making the terms clearer to younger users. The structural properties discussed are stiffness and frequency. The term stiffness is defined using words common to younger users such as, "resists being pushed sideways". The term frequency is not referred to as "natural" due to the abstract concepts that accompany such a technical definition. Abstract concepts are avoided in order to not confuse younger users and instead maintain their interest. Rather, the structures are stated to "prefer" a specific frequency at which they will shake the most.

The final step of the demonstration is to complete a quiz. This quiz is designed with the intention of focusing the user on the relationship between stiffness, frequency, and earthquake motion. Kids should be able to attribute the way a structure reacts to an earthquake base motion, to the properties (e.g., preferred or resonant frequency) of that structure.

If Quaky is successful, a young user might be motivated to find out more about earthquakes and earthquake engineering. To further encourage this, selected links to other earthquake web sites can be accessed from the Quaky homepage under the icon, "Click here for more earthquake links". An additional feature provided on the Quaky homepage is a link to an important list of things every kid should do during and immediately after an earthquake. This list is provided by FEMA For Kids (http://www.fema.gov/kids/knw_eq.htm).

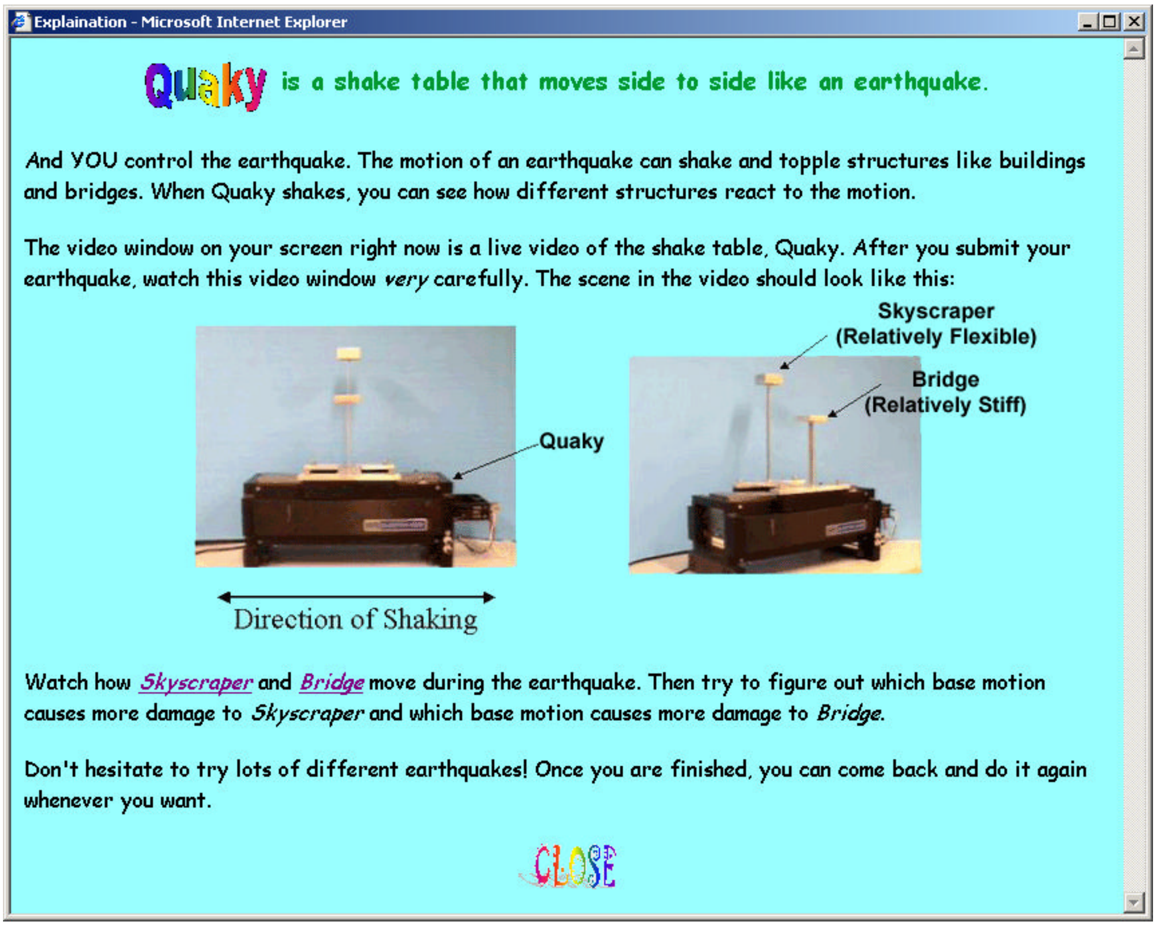

FIGURE. 6
EXPLANATION OF THE EXPERIMENTAL SETUP

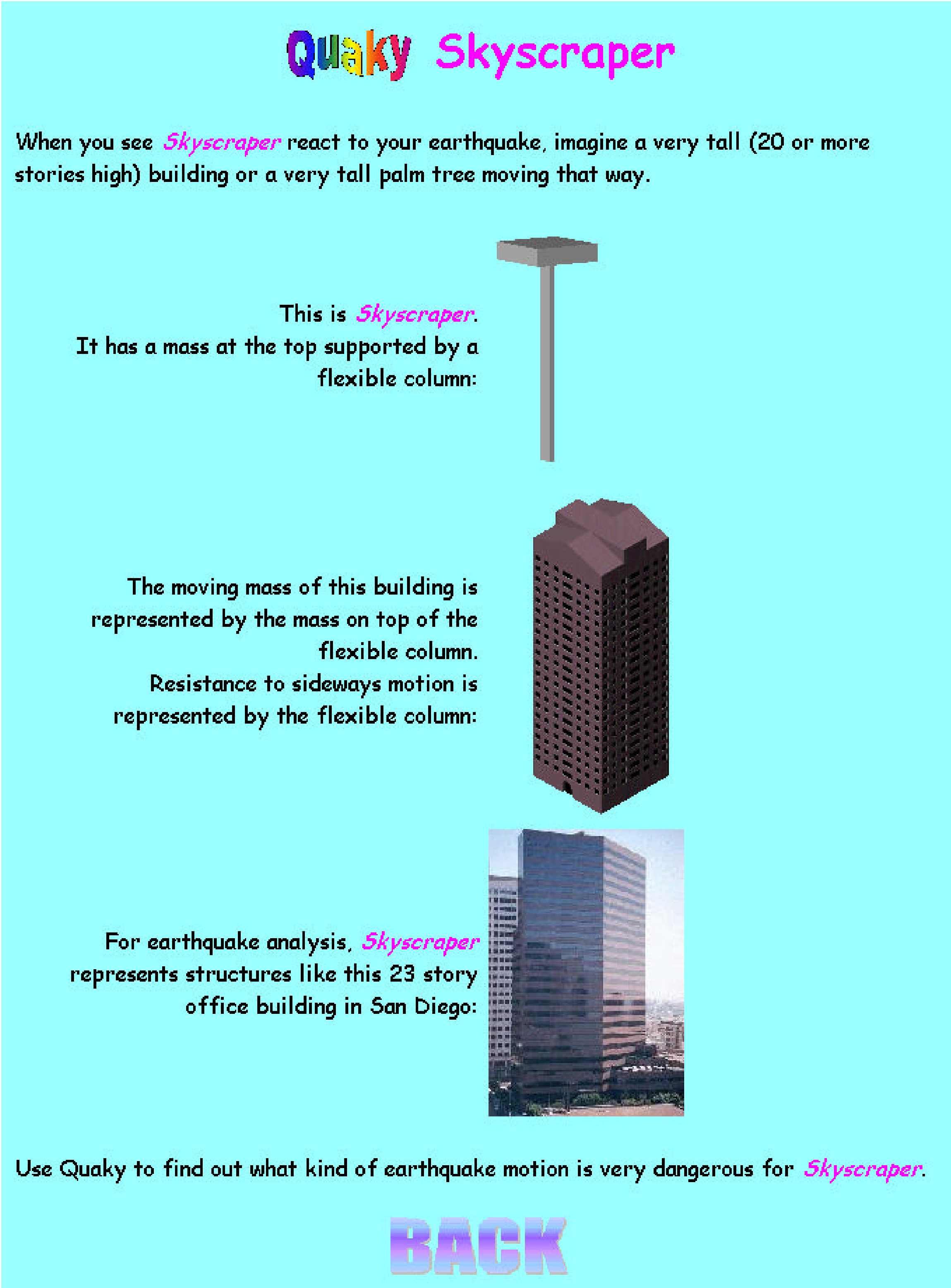

FIGURE. 7
EXPLANATION OF THE SKYSCRAPER MODEL

SUMMARY AND CONCLUSIONS

Internet web-based technologies are being employed to allow for real-time video monitoring, control, and execution of bench-top shake table experiments. The project attempts to actively engage students in a stimulating and informative "fun" educational environment. Simple structural models of relevance to education in Dynamics and Earthquake Engineering can be tested remotely over the Internet at http://webshaker.ucsd.edu and http://e-quake.ucsd.edu/quaky. In this paper, details of the developed Internet website were discussed and some of the experiences in using this website for education were summarized.

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