FINAL REPORT

I. Project Title
Poly Canyon Bridge House - Damage Detection Using Forced Vibration Testing

II. Student(s), Department(s), and Major(s)
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III. Faculty Advisor and Department
Peter Laursen – Architectural Engineering

IV. Cooperating Industry, Agency, Non-Profit, or University Organization(s)
Architectural Engineering Department
Tipping Structural Engineers (Future Work)

V. Executive Summary
The first goal of this research was to establish a non-detective test method that allows for the analysis and interpretation of a building after a seismic event. Typically, after an earthquake, architectural elements such as drywall, partitions, cladding, and ceilings need to be removed in order to inspect the structural system (beams and columns). These destructive inspections are costly and time intensive, especially in large commercial buildings. Each beam and column needs to be inspected. Even if the individual beam or column is undamaged, the architectural elements surrounding the beam or column needs to be removed. This is analogous to a doctor trying to fix a patient’s broken bone. If they didn’t have an x-machine, a doctor’s job would be substantially harder. A doctor wouldn’t know exactly what was broken or how to fix it without performing intrusive surgery. We have created a system analogous to an x-ray machine for buildings; we can detect what is damaged without having to tear the building apart.

We were able to do this by comparing computational models of a damaged building to a simulated damaged building. The Bridge House in Poly Canyon has removable braces that allows us simulate damage. A brace that is properly bolted into place is undamaged, and a brace that has been
removed simulates damage, i.e. it has failed during an earthquake. The figures below shows a bolted brace (one that is “undamaged” is on the left), and an unbolted brace (one that is “damaged” is on the right).

With the equipment purchased from the Baker Koob grant, we were able to measure how the building vibrates with different brace configurations. The plots below show how the roof (in blue) and how the floor (in red) vibrate for different brace configurations.

These experimental results where then compared against computer results using an algorithm to compare two different sets of data. The figure below illustrates the results we obtained. The figure to the left tells us that the mode shapes from the 4 computer models are significantly different, The figure on the right indicates which computer models and experiments are likely to match.

There are two important results. First, we were able to accurately able to show the highest correlation between every experimental brace configuration and its respective theoretical brace configuration. This means we correctly predicted our brace configuration and we correctly predicted what brace had been “damaged”. Second, we were able to get similar results to that of a perfect world situations. This further verified our test methodology.
The second goal was to establish and develop resources so experimental research can be incorporated into the classroom. The equipment and research done is now used for demonstrations and student driven experimentation in undergraduate and graduate classes. Specifically ARCE 412, ARCE 483, and ARCE 503. This will be further developed in a later section below.

VI. Major Accomplishments

(1) Successfully established a non-destructive building identification system that is capable of detecting simulated structural damage.

(2) Created an undergraduate and graduate classroom experiments for structural dynamics classes.

(3) The findings were disseminated at the 2015 Annual ASEE Conference.

VII. Expenditure of Funds

The travel, conference fees, and expenditures to the American Society of Engineering Education Annual Conference where $1885.73. At the conference, three papers were presented that utilized the research and equipment that the Baker Koob grant supported. The included papers were titled Influence of Boundary Conditions on Building Behavior, Creating an Experimental Structural Dynamics Laboratory on a Shoe-string, and Exploring the Relationship between Dynamics and Stability.

The remaining balance of the budget was used to fund equipment outlined in the original proposal. That includes a digital acquisition system made by National Instruments, accelerometers made by PCB, and various necessary cables that are also made by PCB.

VIII. Impacts to Student’s Learning

The goal of receiving the funding was to help graduate students conduct their research in pursuit of completing their thesis and research. Just as importantly, the findings from the research were incorporated into the class room. ARCE 412 (Structural Dynamics) uses the equipment purchased to test small models in the lab and verify computational results. ARCE 483 (Seismic Analysis and Design) takes the equipment out to the field and test the Bridge House. They then calibrate their models and develop an in-depth analysis to predict behavior. For ARCE 503 (Non-Linear Analysis), an experiment was derived that uses the equipment on an individual columns to show complex non-linear relationships and tie together multiple disciplines within structural engineering.