PROPOSAL NARRATIVE

I. Abstract

The Architectural Engineering major places heavy emphasis on structural dynamics and the role of wind and seismic loading in building analysis and design. Buildings of high importance critical to community function, such as hospitals, often utilize supplemental damping devices such as supplemental viscous fluid dampers or base isolators to reduce the overall demands on the structural system. The design and analysis of these dampers are typically not taught at the undergraduate level, and is frequently performed by mechanical engineers, in lieu of structural engineers.

To better understand and research building behavior with supplemental damping devices, our multi-disciplinary team plans to design and fabricate an interactive, reconfigurable, multi-story model of a building. This building structure will be dynamically tested and analyzed using the ARCE Department's seismic shake table. The building model will be left with the university to serve as a model for undergraduate students enrolled in ARCE 483 and ARCE 412. Students will work together to test the structure under a variety of conditions and compare the findings with predictions from computer models. This model also has the potential to be used in core mechanical engineering courses, such as the Mechanical Vibrations course, ME 318.

Funding is sought to cover expenses for the dampers and materials for the model.

II. Introduction

A 3-story, 7' tall model, with a 3' x 4' footprint was chosen for the model, to accommodate size limitations of the seismic shake table. Each floor will have removable steel weights, with a capacity of up to 500 lbs per floor, to allow for experimentation with multiple mass configurations.

Figure 1: Shake Table

The model is intended to be used on the shake table located in the Architectural Engineering department's seismic lab. The shake table serves as a dynamic earthquake lab with unused potential, as it is mainly used only by the Earthquake Engineering Research Institute (EERI) club.

The table can move back and forth simulating various earthquake ground motions, as well as motions programmed by students. The seismic lab also has accelerometers and strain gauges that can be applied to the model to detect the real-time motions and forces of the members. The data from these devices will be compiled and analyzed by students to interpret the effectiveness of damping the model.

III. Objective(s)

(1) Construct a versatile building demonstration model

(2) Leave the ARCE and ME departments with a lasting model that can be utilized by future students and integrate its use into ARCE courses

(3) To accurately predict structural behavior in buildings using supplemental damping devices

(4) To determine critical variables in damper efficiency

(5) To compare the actual behavior of the model under seismic loading with predicted behavior by common analysis techniques

IV. Methodology

Design of the structure and dampers began in Fall 2015 and the project team enrolled in a three unit ARCE 400 course. The majority of design has been completed, but the team is still iterating connection design.

Figure 2: Rendering of the design

Aluminum tubing was chosen for the majority of the structural elements, bolted steel connections were chosen for the necessary "moment" connections, and clevises were chosen to simulate "pinned" connections. The model will be connected to a steel base plate, which will bolt to the shake table. Viscous fluid dampers, were chosen as the supplemental dampers. The connections are being designed to allow multiple bracing and damper configurations, spanning diagonally in each bay, for maximum versatility.

The construction phase of the project will take place in the winter and spring quarter of the 2015-2016 academic year, as the project receives funding to purchase materials and the spring quarter will enroll in an three unit ARCE 453 course. Students will fabricate most of the components using the machine shops on campus. The connections and first story will be constructed and tested initially (as shown in Fig. 3) to verify that the elements will work properly as a system before constructing the entire model.

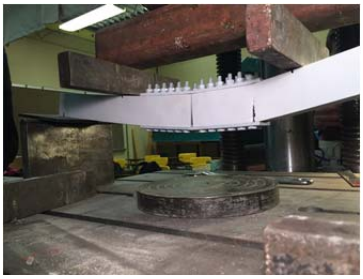

Figure 3: Bolted Connection Test

The testing phase of this project will take place in spring and involve forced vibration tests on the building using the shake table. Acceleration values will be recorded from different forcing functions to obtain a building stiffness and critical damping values. These values will be compared to different configurations of dampers and braces in the building to determine the effectiveness of the dampers and the degree of precision of the measuring instruments. The structural response will be documented various configurations of dampers engaged.

When the model has been sufficiently tested, the team will produce an instruction manual for the model so that professors and other students can safely use it. The team will also propose a series of experiments and possible future senior projects incorporating the model.

V. Timeline

January 2015	Test initial connections to confirm design adequacy.
February 2015	Construct one-story model & test viscous dampener efficiency
March 2015	Construct 3 story model
April 2015	Perform experimentation on building
May 2015	Final data processing
June 2015	Create report to Baker and Koob Learn by Doing Endowment
	Present project to ARCE students and faculty

VI. Final Products and Dissemination

The physical model will be tested and analyzed by the team to determine the effectiveness of various damper configurations and the accuracy of the structural predictions. The team will also verify the model is indeed safe within the recommended capacity.

The finished structural model will be left at the university as a new demonstration model for the Mechanical and Architectural Engineering departments, providing a physical example of structural dynamics and mechanical vibrations. Students will have the opportunity to take data to analyze the structure's motion and the distribution of the horizontal forces to its components. This will provide a creative and interactive learning experience that would otherwise not be available at Cal Poly, and will serve as an illustration and product of the "Learn by Doing" philosophy of the university. Ideally, it will also be used as a vehicle for future senior projects and a user's manual will be left for future students.

VII. Budget Justification

$3000 is budgeted for the purchase of the viscous fluid dampers. The remaining $2000 will purchase aluminum tubing, steel plates and various fasteners that will be used for the erection of the building. Remaining funding will come from miscellaneous donors. See cost analysis below.

Item	*Used for*	*Calculations*	*Total Quantity Required*	*Unit Cost*	*Total Cost*
Structure:					
Aluminum Tubing- 1.5"x2"x1/8"	Basic Structure, connection testing, extra beams, 1 story columns	*70lf for structure + 8lf for 1 story test + 14lf for extra beams + 40 lf for connection testing*	140 linear feet	$4/lf	$560.00
Steel Plates	500lb Removable weights at each level, 1/4" thick base plate	*3 floors *500 lb per floor + 200 lb baseplate*	1700 lb	$.75/lb	$1,275.00
Steel Bar- 1/4" x 1.5"	Structural moment connections	*30" per connection * 4 columns * 2 connections per column per level * 3 levels*	60 linear feet-77lb	$.75/lb	$57.75
Bolts and nuts	Structural moment connections	*36 bolts per connection * 24 connections*	864 bolt/nut sets	$100/1000 sets	$100.00
Steel Rod- 1/2" threaded	Leaning Columns	*7' per leaning column * 6 full height leaning columns*	42 lf	$9.50/6lf	$66.50
Rod ends	All pinned connections	*18 leaning columns * 2 connections each + 4 at column bases*	40 rod ends	$7 ea	$280.00
Steel Rod- 1.5" square	Clevis attachment for rod ends	*1.5"/clevis*40 clevises/12" per ft* 7.65 lb/lf*	40lb	$.75/lb	$30.00
Fasteners	Attachment of removable weights				$50.00
			Basic Structure Subtotal:		$2,419.25
Damping System:					
Dampers	Dampers	*2 dampers/side/story*2 sides at a time*3 stories*	12 dampers	$250 ea	$3,000.00
Fasteners	Damper connections				$50.00
			Damping System Subtotal:		$3,050.00

Warren J. Baker Endowment
for Excellence in Project-Based Learning
Robert D. Koob Endowment *for Student Success*

PROPOSAL BUDGET

Student Applicant(s): Blake Reeve Brianna Kufa Aden Malek Stepanians Sophie Ratkovich	
Faculty Advisor: Peter Laursen	
Project Title: Experimental Building Demonstration Model with Viscous Dampers	**Requested Baker Endowment Funding**
Travel *subtotal*	**$**
Travel: In-state	**$**
Travel: Out-of-state	**$**
Travel: International	**$**
Operating Expenses *subtotal*	**$**
Non-computer Supplies & Materials	**$5000**
Computer Supplies & Materials	**$**
Software/Software Licenses	**$**
Printing/Duplication	**$**
Postage/Shipping	**$**
Registration	**$**
Membership Dues & Subscriptions	**$**
Multimedia Services	**$**
Advertising	**$**
Journal Publication Costs	**$**
Contractual Services *subtotal*	**$**
Contracted Services	**$**
Equipment Rental/Lease Agreements	**$**
Service/Maintenance Agreements	**$**
TOTAL	**$5000**

Cal Poly Department of Architectural Engineering

Memo

To: Whom it may concern

From: Prof. Peter T. Laursen

CC:

Date: January 29, 2016

Re: Letter of support for the Senior Project entitled: 'Experimental Building Demonstration Model with Viscous Dampers'.

This memo serves as a letter of support for the team's funding application to the Warren J. Baker Endowment for Excellence in Project-Based Learning and Robert D. Koob Endowment for Student Success. This interdisciplinary team consists of Architectural Engineering students Blake Reeve and Brianna Kufa, and Mechanical Engineering students Sophia Ratkovich and Aden Stepanians.

Having taught ARCE students Blake and Briana in several courses at Cal Poly, including the senior level ARCE 412 'dynamics of framed structures', I have found them to be intelligent, dedicated and hard-working students. In the recent months, I have had the pleasure to interact with ME students Sophia and Aden. They have both taken ME 318 'Mechanical Vibrations' and I find them equally qualified to participate in this senior project. As such, the students are pursuing this senior project as an integral part of their undergraduate degrees and I am pleased to be their main advisor. Prof. Andrew Davol from ME is the co-advisor.

The Architectural Engineering major requires in-depth understanding of building dynamic response to seismic and wind loading. Similarly, the Mechanical Engineering major requires knowledge of dynamic response structures and mechanical elements. In an effort to enhance their knowledge of the response of dynamic systems and how to design them, the students decided to build a physical demonstration structure that can both visualize and quantify the dynamic response of a building subjected to simulated seismic loading. The students envision a reconfigurable model and further decided to implement viscous fluid dampers in the model. They wanted to explore and demonstrate how this type of device can be an efficient way to reduce earthquake effects in buildings of high importance to society.

I applaud the students for taking on such a comprehensive project and I am confident that it can be achieved. I strongly support this project because: 1) it exemplify Cal Poly's Learn by Doing philosophy, 2) it is interdisciplinary in its nature and 3) the model will serve future undergraduate students enrolled in ARCE 483 and ARCE 412 as an experimental test platform, where students will collaborate to test the structure under a variety of conditions.

The students strongly feel that the project will enhance their own learning experience at Cal Poly. Their work on this senior project will provide Cal Poly with an experimental model that will benefit future students. I strongly support the request for funding for materials for the model from the Warren J. Baker Endowment for Excellence in Project-Based Learning and Robert D. Koob Endowment for Student Success.

Sincerely,

Peter Laursen, PhD
Associate Professor
(805) 756-6303, email: plaursen@calpoly.edu