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Center for Infrastructure Engineering Studies

Incorporation of Hands-on Experiments in an Introductory Structural Analysis Course

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16. Abstract

A new teaching laboratory was developed for the junior course in CE-ArchE 217 Structural Analysis I. The primary objective of the laboratory was to give students “hands-on” experiences and build their understanding of structural analysis and their application to civil and architectural engineering structures including transportation structures such as bridges. The experiments were designed to foster creative thinking and to make the study of structural analysis more meaningful by incorporating the concept of design, model, test, observe, and discuss. Specific educational objectives of the hands-on experiments were:

- Acquaint the students with basic experimental techniques, computer modeling, equipment, and methods used in the analysis of structures
- Provide the students with opportunities to make experimental observations and relate them to theory and computer models, and further discuss the results, draw conclusion and communicate the findings in writing, as well as orally.
- Introduce the student to experimental research and laboratory modeling of experiments.

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Project Objective:

The primary objective of the laboratory was to give students “hands-on” experiences and build their understanding of structural analysis and their application to civil engineering structures including transportation structures such as bridges.

Project Abstract:

A new teaching laboratory was developed for the junior course in CE-ArchE 217 Structural Analysis I. The primary objective of the laboratory was to give students “hands-on” experiences and build their understanding of structural analysis and their application to civil and architectural engineering structures including transportation structures such as bridges. The experiments were designed to foster creative thinking and to make the study of structural analysis more meaningful by incorporating the concept of design, model, test, observe, and discuss. Specific educational objectives of the hands-on experiments were:

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- Introduce the student to experimental research and laboratory modeling of experiments.

Figure 1 illustrates an example of one of the labs that was developed including the instrumentation which consisted of new digital dial gauges and a strain indicator. In this case the students were able to see tangible examples of the principal of superposition concept for combining load cases and compare experimental results to theory.

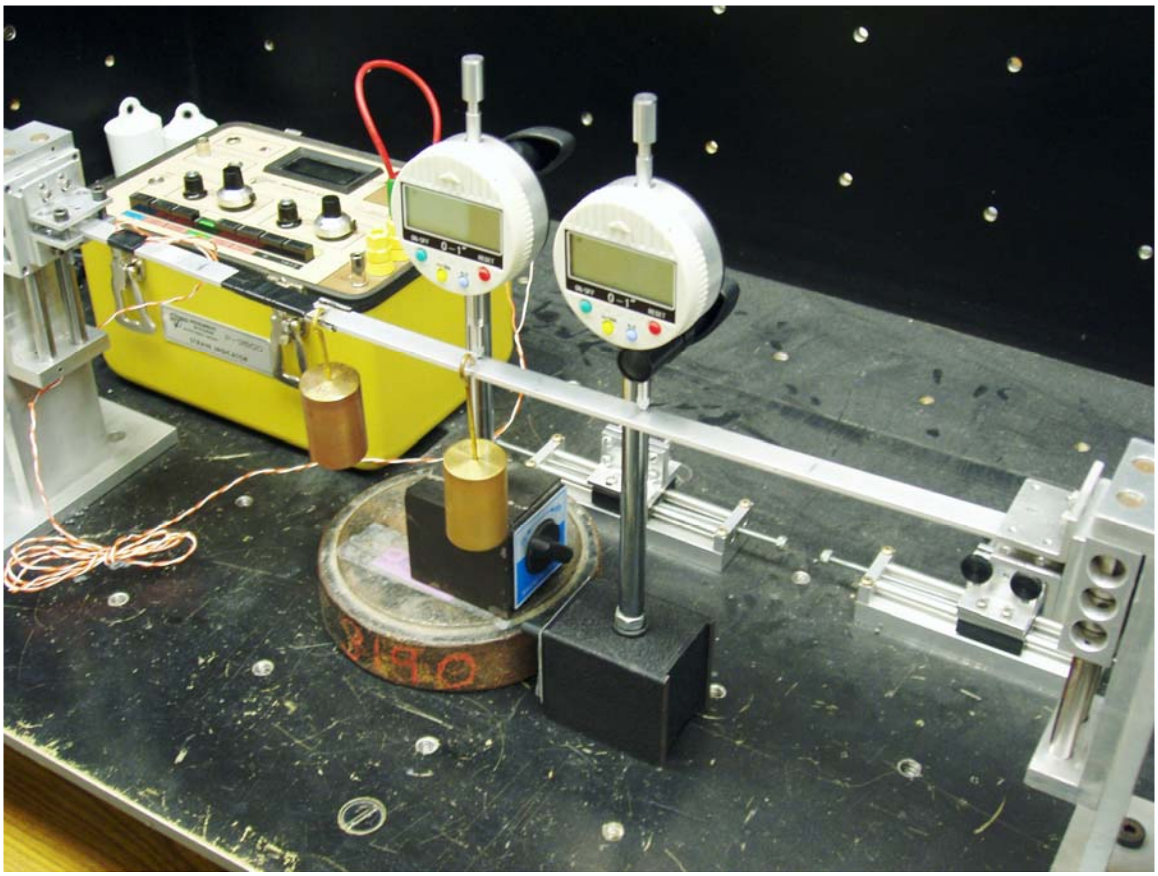

Figure 1: Experimental test set-up for the principal of superposition

In addition to new experimental labs that were developed, the students were also introduced to the use of RISA 2D^{TM} software. It is a modeling program that can be used to develop and analyze structural systems. The software package was used to model indeterminate structures and then compare software output to hand calculations using classical structural analysis methods. **Figure 2** illustrates a sample RISA 2D™ output for one of the members in an indeterminate two story frame with gravity dead and live load plus lateral wind load.

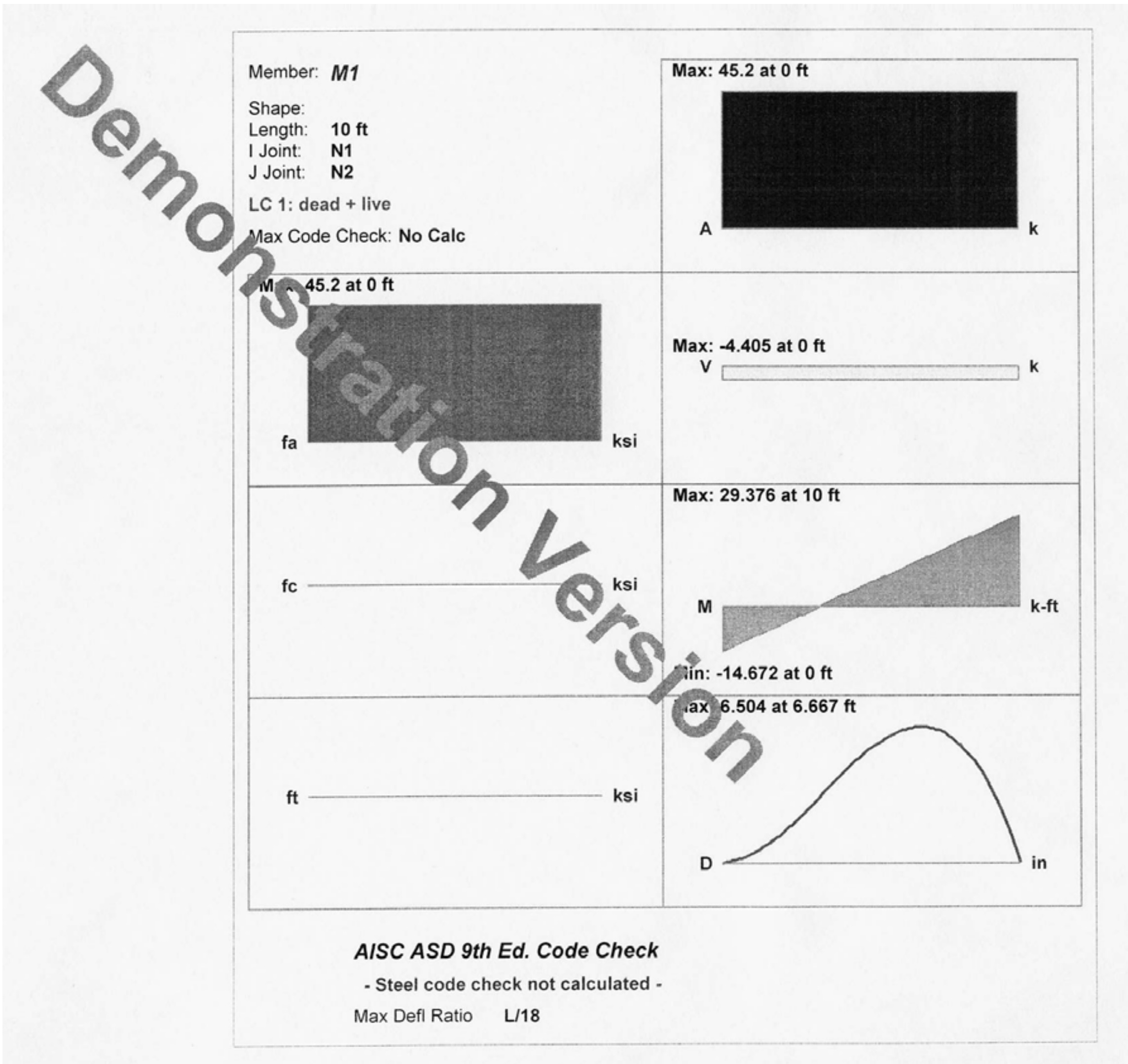

Figure 2: Sample RISA 2D™ Output for Sway Frame with Gravity and Lateral Loads

Benefits:

The overall benefits to the students included an enhancement to their understanding of computer models, use of commercially available software and the fundamentals of structural analysis. Approximately 80 University of Missouri-Rolla Department of Civil, Architectural and Environmental Engineering junior level students take this course every semester (~ 160 students annually). Therefore, the benefits to UMR and the department has been significant.

Lab Reports:

For the experimental labs that were conducted, students were required to prepare formal lab report analyzing experimental data and comparing it to theoretical calculations. An example lab description is presented in **Appendix A**.

APPENDIX A

Sample Lab Requirements for Lab #2 CE-ArchE 217

CE-ArchE 217 Structural Analysis I
University of Missouri-Rolla
Fall 2006

Experimental Lab #2
Influence Lines for Bending Moment

Objective:

The objective of this experiment is to determine, using resistance-type strain gages, the influence lines for bending moment along the length of a beam. This will be compared with the theoretical solution.

Theoretical Background

The bending moment in a simply supported beam of span ***L***, and subjected to a point load ***W***, varies linearly as shown below. The bending moment at any section varies as a function of the load position.

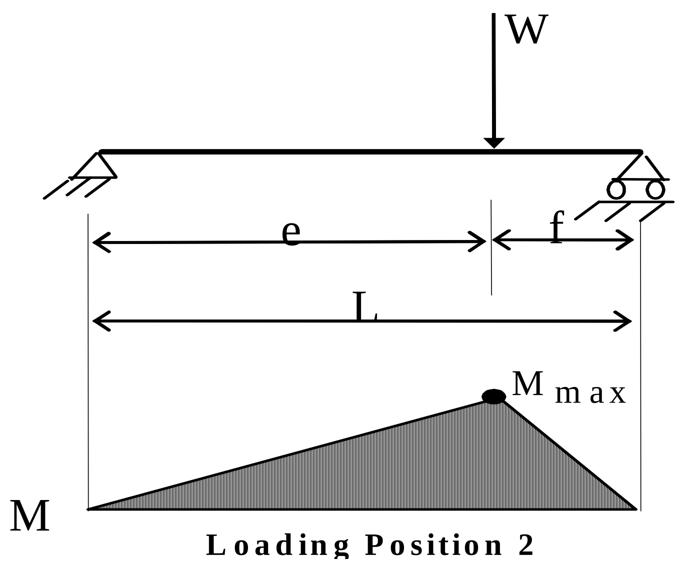

Figure 1

$$M_{max} \quad \frac{W e f}{L}$$

Figure 1

In Figure 1 :

	M	= <u>internal</u> bending moment
	W	= applied load
	e	= distance from left support
	f	= distance from right support

L = length of beam

The axial stress, **σ**, in a rectangular beam is given by: $\sigma = \dfrac{Mc}{I}$

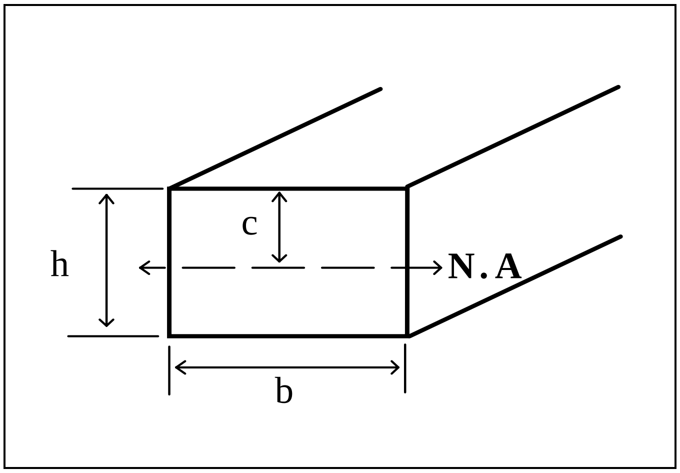

Figure 2

where, ***I*** = moment of inertia of the beam = $\dfrac{bh^3}{12}$

b = width of the beam cross-section

h = depth of the beam cross-section

c = the distance from the neutral axis to the point in question = $\dfrac{h}{2}$

The stress in the extreme fiber of the beam is then

$$\sigma = \frac{Mc}{I} = \frac{M(\frac{h}{2})}{I} = \frac{M}{\frac{I}{(\frac{h}{2})}} = \frac{M}{S}$$

where the **Section Modulus**, $S = \dfrac{bh^2}{6}$

The strain in the beam, **ε**, is related to stress by,

$$\sigma = E\varepsilon$$

where E is the beam Young's modulus.

The strain in the extreme fiber of the beam is therefore given by:

$$\varepsilon = \frac{\sigma}{E} = \frac{M}{ES} \tag{1}$$

The influence line of the bending moment at a section represents the moment at the section when a load W that equals a unit value moves along the beam. The influence line at a section could therefore be evaluated experimentally by:

a) Measuring the strain at the extreme fiber of the section for a given position of the load W using electrical resistance strain gages.
b) Evaluating the corresponding bending moment at the section using equation (1) for the beam with a given *E* and *S*.
c) Repeating steps a) and b) for several loading positions.

<u>Lab Instructions</u>

In Class Procedure:

1. Measure the dimensions of the beam, ***L***, ***h***, and ***b*** and calculate ***I***, the moment of inertia. Record the dimensions on the appropriate charts. The length of the beam has been selected to equal 18.35 inches, and the beam material is Aluminum with a Young's modulus that equals 9.50(10)^3 ksi. The simply-supported beam with the corresponding positions of the strain gage and loads is shown in Figure (3).

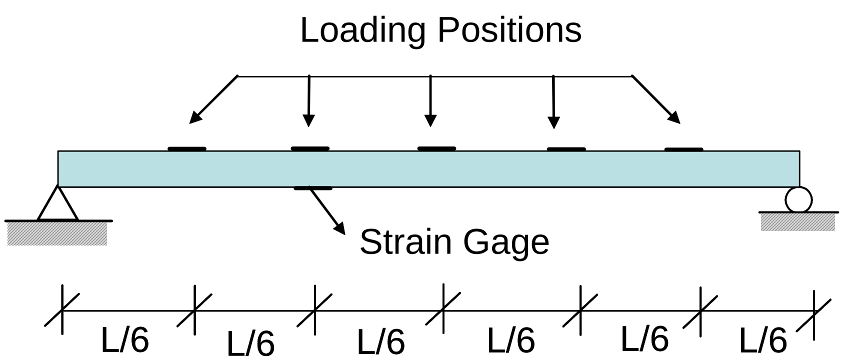

Figure 3 – Test Setup and Loading Positions for Simply-Supported Beam

Beam Properties			
Dimension		U.S.	SI
L	Length		
h	cross-section height		
b	cross-section width		
c	distance to extreme fiber		
E	Young's modulus		
I	Moment of Inertia		

2. Record the strain gage location.

3. Record the initial reading of the strain gage.

4. Place 400g on the load hanger at loading position #1. Record the distance ***e,*** and the strain gage reading in the data chart under Experimental ε.

5. Repeat step 4 for load positions #2 to 5, and record the corresponding values of ε.

6. Evaluate the experimental bending moment value using equation (1) and record it in the table under Experimental M.

Data Chart: (Simply-Supported Condition)			
Load position #	Distance ***e***	Experimental ε	Experimental M
1			
2			
3			
4			
5			

7. Repeat steps 2 through 5 for the cantilever beam using a load of 300g. The length of the cantilever beam has been to selected to equal a value of 9.18 inches. The test setup for the cantilever beam with the corresponding positions of the strain gage and loads is shown in Figure (4).

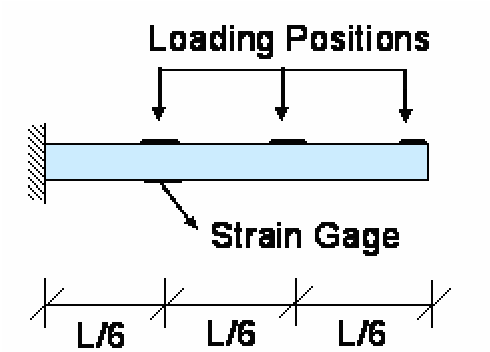

Figure 4 – Test Setup and Loading Positions for Cantilever Beam

8. Evaluate the experimental bending moment values using equation (1) and record them in the table under Experimental M.

Data Chart: (Cantilever Condition)			
Load position #	Distance from support	Experimental ε	Experimental M
1			
2			
3			

<u>Lab Report Write-up Requirements</u>:

Item 1. Show all Measured Values and Required Calculations. This includes measured bar properties, calculated moment of inertia (I), calculated section modulus (S); measured strain values, and calculated experimental bending moment at all loading positions for both the simply-supported and the cantilever case.

Item 2. Plot the experimental influence line for the bending moment at the strain gage location (for both the simply-supported and the cantilever case) using the data evaluated in item (1).

Item 3. Plot the analytical influence lines at the strain gage location using the theory discussed in class. Compare the analytical influence lines with the experimental influence lines determined in item (2).

> ***Note: Unit loads were not used in the experiment. The theoretical influence line values must be scaled to compare with the analytical results.*

Item 4. Discuss possible variables in your experimental tests which could affect your measured error between experiment and theory.