***** INSTRUCTOR'S GUIDE *****

INTRODUCTION TO DYNAMICS OF STRUCTURES

A PROJECT DEVELOPED FOR THE
UNIVERSITY CONSORTIUM ON INSTRUCTIONAL SHAKE TABLES

http://ucist.cive.wustl.edu/

Required Equipment:

- Instructional Shake Table
- Two Story Building
- Three Accelerometers
- MultiQ Board
- Power Supply
- Computer
- Software: Wincon and Matlab

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Introduction to Dynamics of Structures

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Objective: The objective of this experiment is to introduce students to principles in structural dynamics through the use of an instructional shake table. Natural frequencies, mode shapes and damping ratios for a scaled structure are obtained experimentally.

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NOTE: If you do not have the Real-Time Workshop installed on your computer, you must add the following directory to the MATLAB path before proceeeding with this experiment (c:\matlabr11\toolbox\rtw).

4.0 Experimental Procedure: Sample Results and Discussion

4.1 Transfer function calculation

Please answer the following questions.

- How many natural frequencies does the structure have?
- What are the values of the natural frequencies?
- Are these values the same in the two transfer functions? Why or why not?

ANSWER

Figure 1 provides example acceleration records obtained from the ground, first and second floor for the white noise input.

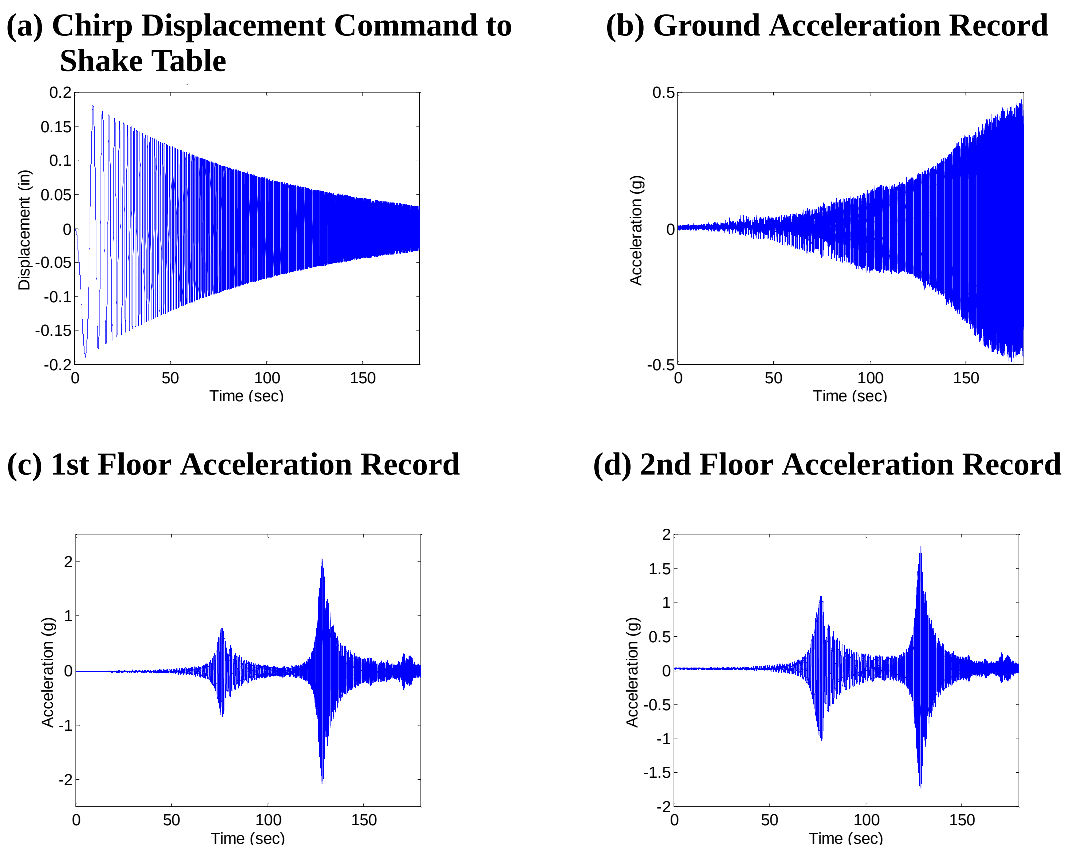

Figure 1. Typical time history records for a) shake table command signal, b) acceleration at ground level, c) first floor acceleration, and d) second floor acceleration.

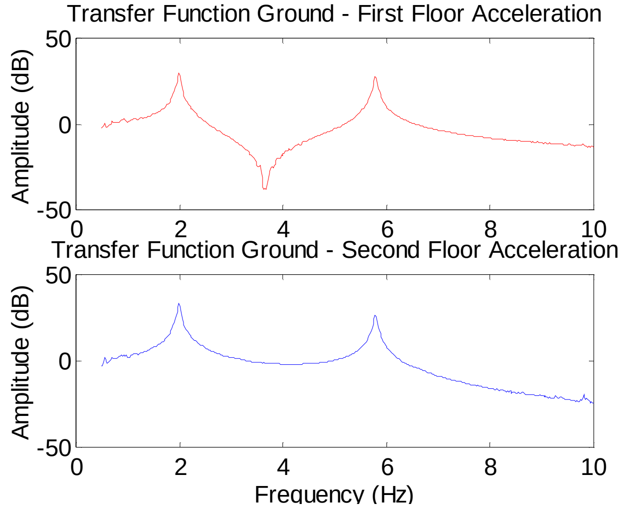

Figure 2. Sample transfer function plots for the test structure.

Figure 2 provides typical transfer functions for the test structure.
The system has two natural frequencies.
The natural frequencies of this structure are: 2 Hz and 5.8 Hz.
The two values are the same in both plots.

4.2 Determination of Mode Shapes

Please do the following.

- Sketch each of the mode shapes of the structure.
- Obtain the number of nodes in each mode shape.
- Does this result satisfy equation (35)? Explain.

ANSWER

The mode shapes of the test structure are shown in figure 3. The first mode has zero nodes and the second mode has one node.

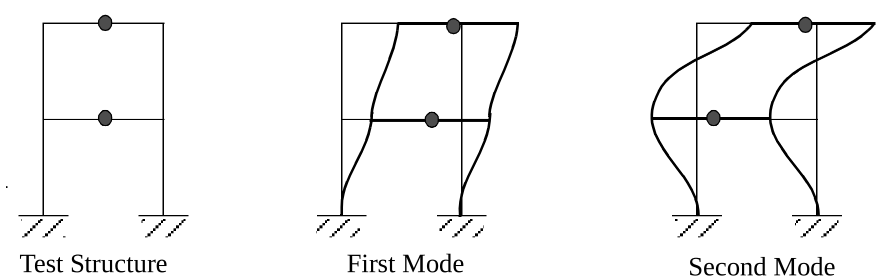

Figure 3. Diagram of mode shapes for the test structure.

4.3 Damping estimation

4.3.1 Exponential decay

> Please do the following.
>
> - What is the damping ratio obtained using this method?
> - Compare this damping ratio with that obtained in 4.3.2.

ANSWER

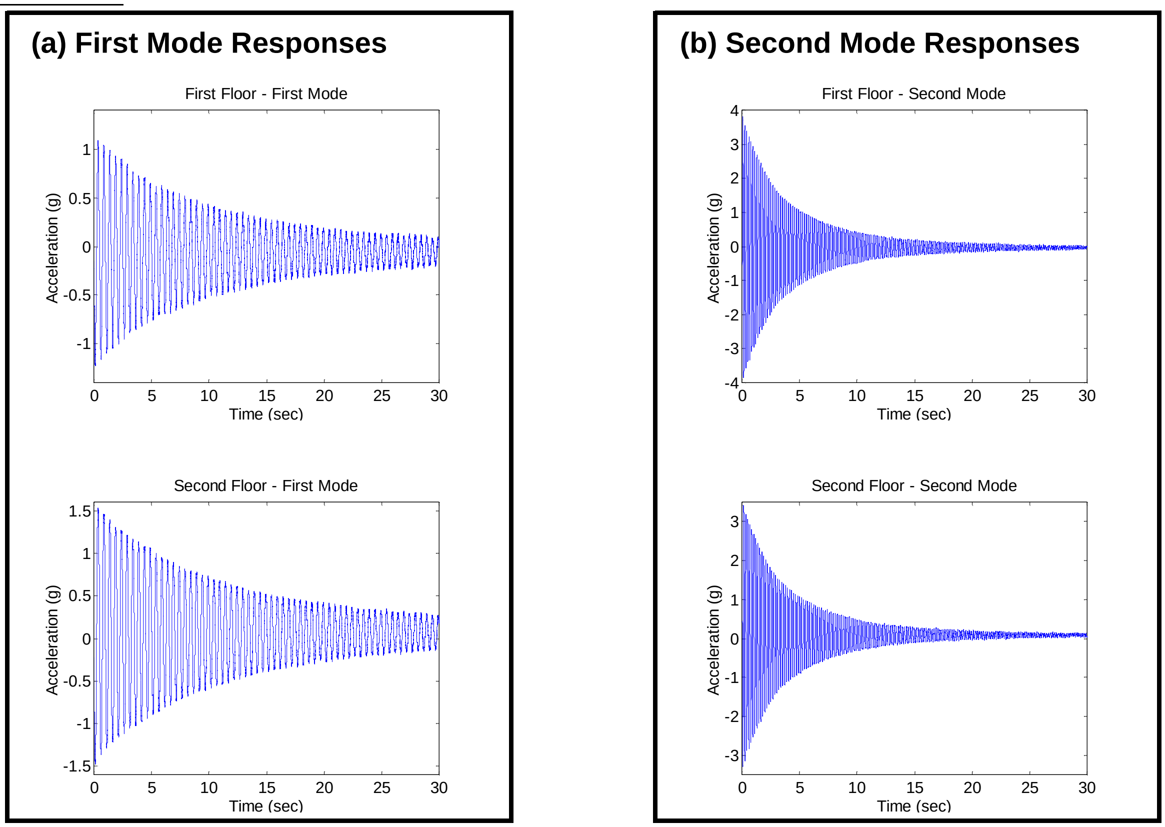

Figure 4. Free response of test structure in (a) Mode 1 and (b) Mode 2.

ANSWER

To use the decrement method, the following calculations are performed.

MODE 1: (using *y*-values from MATLAB plots)

floor 1: $y_1 = 0.363$, $y_2 = 0.348$

$$\zeta = \frac{\delta}{2\pi} = \frac{\ln\frac{y_1}{y_2}}{2\pi} = \frac{\ln\frac{0.363}{0.348}}{2\pi} = \boxed{6.716 \times 10^{-3}}$$

floor 2: $y_1 = 0.498$, $y_2 = 0.469$

$$\zeta = \frac{\delta}{2\pi} = \frac{\ln\frac{y_1}{y_2}}{2\pi} = \frac{\ln\frac{0.498}{0.469}}{2\pi} = \boxed{9.549 \times 10^{-3}}$$

MODE 2:

floor 1: $y_1 = 1.985$, $y_2 = 1.920$

$$\zeta = \frac{\delta}{2\pi} = \frac{\ln\frac{y_1}{y_2}}{2\pi} = \frac{\ln\frac{1.985}{1.920}}{2\pi} = \boxed{5.299 \times 10^{-3}}$$

floor 2: $y_1 = 1.778$, $y_2 = 1.721$

$$\zeta = \frac{\delta}{2\pi} = \frac{\ln\frac{y_1}{y_2}}{2\pi} = \frac{\ln\frac{1.778}{1.721}}{2\pi} = \boxed{5.186 \times 10^{-3}}$$

4.3.2 Bandwidth method

ANSWER

Please do the following.

- From the transfer functions obtained in 4.1 estimate the damping ratio using the half power bandwidth method described in 2.4.2. What is the damping ratio associated with each natural frequency?
- Compare the damping values for each of the two modes.
- Discuss the advantages and disadvantages of these two methods?

Using the bandwith method, the following calculations are performed.

MODE 1: (estimating values from plots)	$f_a = 1.935$ $f_b = 2.035$	$\zeta_1 = \dfrac{f_b - f_a}{f_b + f_a} = 2.5\%$
MODE 2: (estimating values from plots)	$f_a = 5.73$ $f_b = 5.85$	$\zeta_2 = \dfrac{f_b - f_a}{f_b + f_a} = 1.04\%$

The computed damping values are approximately the same order of magnitude using both methods. The half-power bandwidth technique results in significant errors when the damping in the system is small because: 1) the actual peak in the transfer function is difficult to capture, and 2) interpolation is required to estimate the half-power points. On the other hand, the decrement technique is more effective for lightly damped systems.

5.0 References

CHOPRA, A. K., *Dynamics of Structures,* Prentice Hall, N.J., 1995

HUMAR, J. L., *Dynamics of Structures*, Prentice Hall, N.J., 1990

PAZ, M., *Structural Dynamics*, Chapman & Hall, New York, 1997