VIBRATION TESTS OF NORTH FORK DAM MODEL

by

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SYNOPSIS

Vibration tests were conducted on a 1/24-scale model of the North Fork Dam, a double curvature arch dam, to determine natural frequencies, mode shapes, and damping ratios. The measurements were made by inducing vibrations at the crest and at the base of the dam. Typical data are included in the presentation. The measured results were compared with calculated results using a linear elastic three-dimensional finite element method.

INTRODUCTION

The North Fork Dam, located near Auburn, California, on the North Fork of the American River, is 155 ft high from the foundation and has a crest length of 620 ft. It has an overflow spillway 200 ft long and depressed 3 ft below the normal crest elevation. A model of the dam including a 1/4-mile section of the reservoir was built to a scale of 1:24 of the prototype. Vibration tests were conducted on the model for the purpose of determining the dynamic response characteristics of a concrete, arch dam. Completion of the new Auburn Dam five miles downstream will inundate the North Fork Dam completely. Prior to elimination of the North Fork Dam, vibration tests similar to those conducted on the model are planned to be conducted on the full-scale dam.

OBJECTIVES

The objectives of the study were to evaluate the use of physical models and three-dimensional finite element methods for earthquake response predictions.

RESULTS AND DISCUSSION

Mode shapes, frequencies, and damping ratios were determined from vibration tests of the model using two vibrators mounted on the crest of the dam and from tests with a vibrator mounted at the base of the dam on the downstream foundation. Nine velocity transducers mounted along the crest of the dam and three along a vertical section at the maximum height were used to monitor the response. The fully instrumented dam with the vibrators mounted on the crest is shown in fig. 1. The crest-mounted vibrators were run in phase and 180 degrees out of phase to determine natural frequencies of the symmetric and nonsymmetric modes. Typical velocity-frequency plots and mode shapes associated with vibration excitations of the crest are

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shown in figs. 2 and 3, respectively. The vibration excitation of the base resulted in lower natural frequencies as the force level was increased. Figure 4 shows typical velocity-frequency plots for force levels ranging from 5000 to 40,000 lb. The modes shapes and frequencies at the 20,000-lb force level are shown in fig. 5. Damping determined by turning off the crest vibrators at a resonance peak was about three percent of critical and was about 10 percent of critical when the base was vibrated at the 20,000-lb force level.

The analysis was performed using a three-dimensional finite element computer program, Structural Analysis Program (SAP). The dam, modeled with 110 solid elements and 278 nodes, is shown in fig. 6. The boundary simulated total fixity at the canyon walls. The reservoir was assumed to exert a static water pressure on the dam. This load, the mass of the vibrators, and an apparent mass to account for the mobilized water were included in the analysis. The Rayleigh-Ritz technique was used to determine mode shapes and frequencies. The calculated frequencies were higher by factors of 1.5 to 2 times the measured frequencies.

CONCLUSIONS

Better definition of symmetric and unsymmetric modes can be obtained by using two vibrators on the crest. It appears that the frequencies from the base vibration tests at low force levels approach those obtained from crest vibration tests. The damping ratios obtained from base excitation tests were higher than those obtained during crest vibrations. The higher ratios were probably due to the larger vibration amplitudes and the effects of the soil under the dam foundation. The overprediction of the natural frequencies by the analysis method could be due to the analysis scheme, the assumed base fixity of the dam, and the water mass approximation. Current efforts include a refined analysis method that will incorporate the response of the foundation and soil; also scheduled is an experimental study on the magnitude and distribution of pressure at the reservoir-dam interface during vibration.

Fig. 1. Instrumented scale model of dam and reservoir

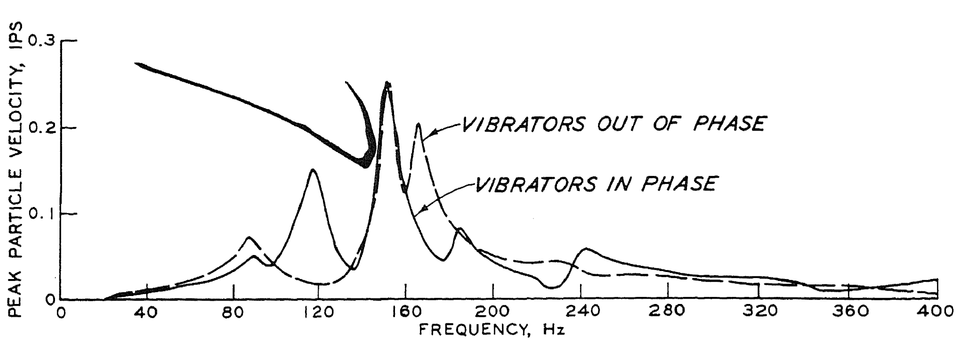

FIG. 2 TYPICAL VELOCITY - FREQUENCY PLOT FROM CREST VIBRATOR TESTS

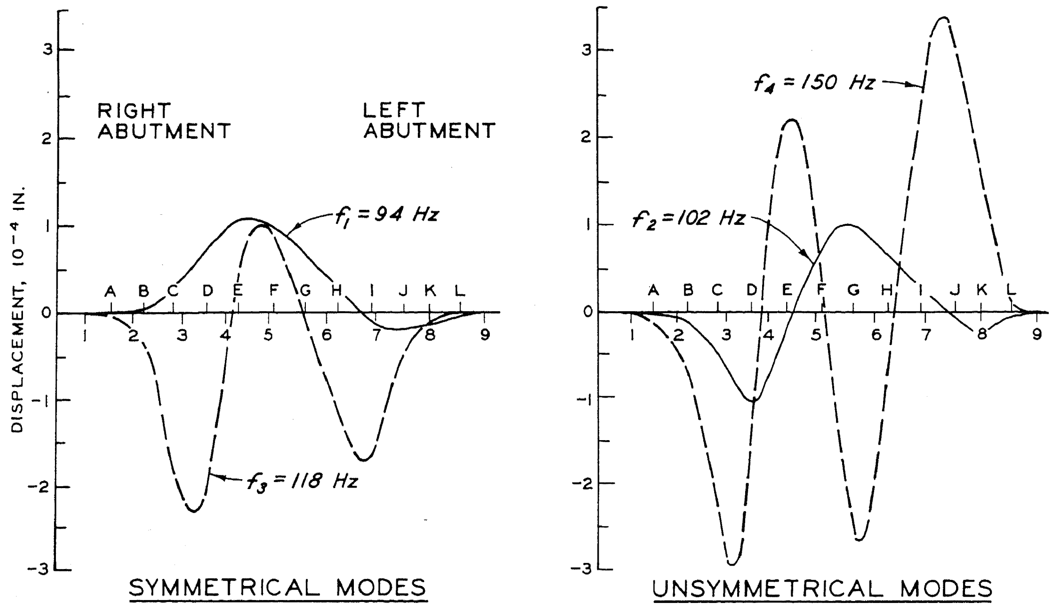

FIG. 3 MODE SHAPES FROM CREST VIBRATOR TESTS

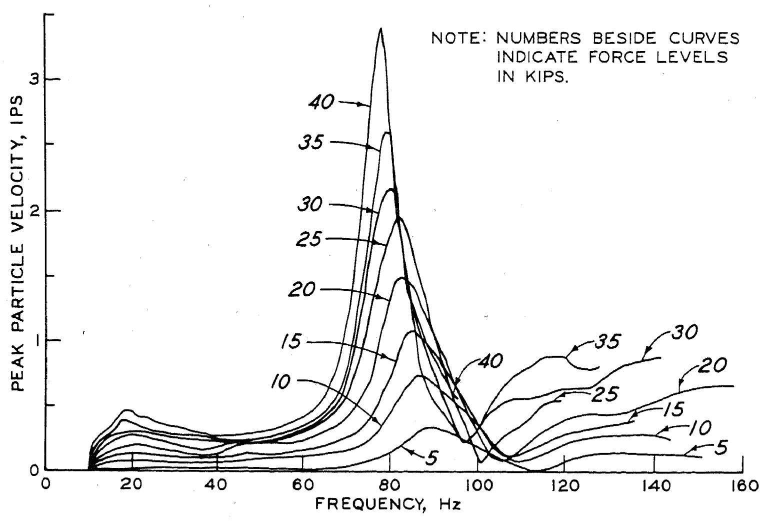

FIG. 4 TYPICAL VELOCITY - FREQUENCY PLOT FROM BASE VIBRATOR TESTS

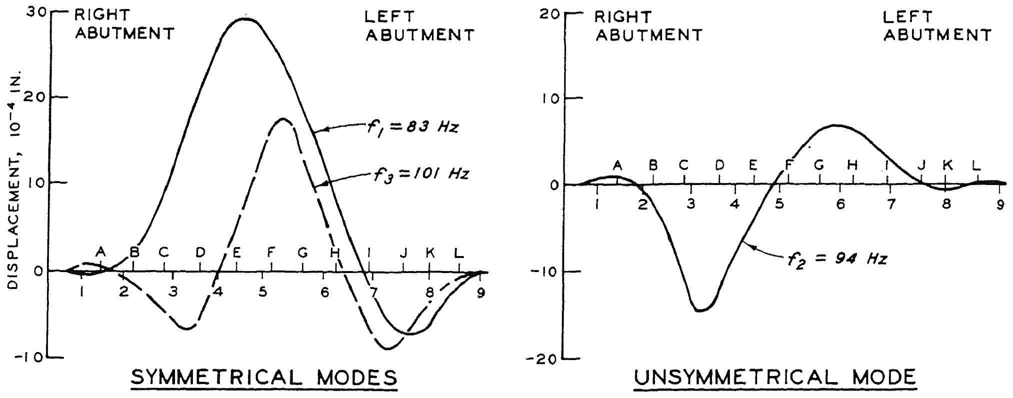

FIG. 5 MODE SHAPES FROM BASE VIBRATOR TESTS

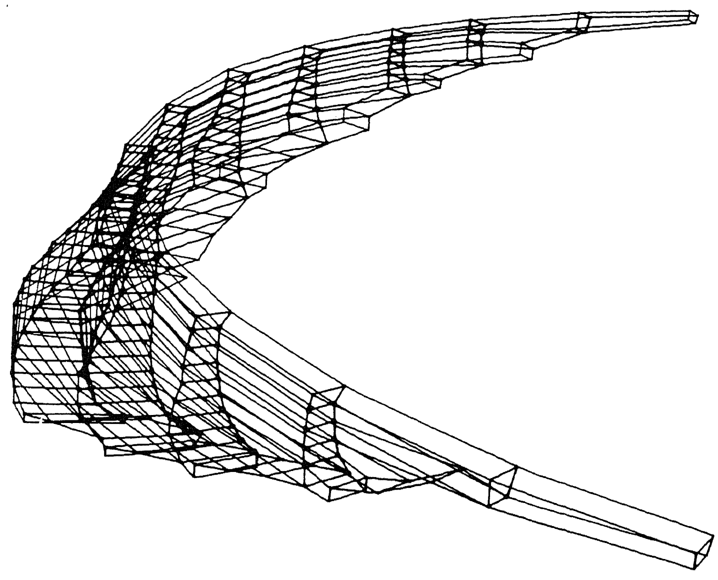

FIG. 6 FINITE ELEMENT GRID OF MODEL DAM