TECHNICAL NOTE

On The Accuracy of Vibration Predictions of Ground-Supported Machine Foundations
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MTR & Associates

Design of heavy machinery with reciprocating, impacting, or rotating masses require proper dynamic analysis to evaluate machine/foundation system frequencies and resulting vibration amplitudes to avoid resonance and excessive vibrations that may be detrimental to the safe operation of the machinery.

This technical note examines the results of MTR/DYNA for predicting vibration response of ground-supported machine foundations. The calculated results are compared with actual measured data to validate the accuracy of the program for predicting amplitude versus frequency response. The results of both elastic and nonlinear soil that considers the effects of confining pressure and soil nonlinearity on shear modulus are presented.

The benchmark vibration test consists of a circular concrete slab, approximately 2 feet in thickness and 9 feet in diameter, constructed at ground level and subjected to different modes of vibration. The test site is a level ground underlain by a deep uniform layer of silty clay deposit. The measured small-strain soil shear wave velocity ranges from approximately 460 ft/sec at the ground surface to about 600 ft/sec at a depth of about 32 feet below grade. The ground water table is at 16 ft below grade. The total static weight of the concrete slab, applied ballast and vibrator is 30,970 lb.

A series of harmonic forces were applied with a vibrator mounted on the slab over a frequency range of 6 to 30 Hz. Four sets of tests were performed for each vibration mode by varying the load using eccentric settings corresponding to 0.105, 0.209, 0.314 and 0.418 inches. For each eccentric setting and vibration frequency, the acting forces and foundation responses were recorded with carefully installed and monitored measurement devices. To maintain reasonably good contact between the base and the ground surface and to avoid displacing the soil as long as possible, the torsional tests were performed after the vertical tests. Throughout the test program a number of special check tests were performed; these included tests performed after the initial test series to determine reproducibility, the effects of time, and to compare methods of securing the ballast. Typical measured responses for the vertical and torsional modes are shown in Figures 1 and 3, respectively.

MTR/DYNA was used to predict the vibration response of the foundation. Two sets of analyses were performed with both elastic and nonlinear soil modeling. For elastic analysis, the measured small-strain shear wave velocities obtained in the free field were used. For nonlinear analysis, the measured shear wave velocities were adjusted to reflect an increase in confining soil pressure due to the weight of the foundation as well as to account for the effects of soil softening due to an increase in soil shear strains from displacement of the foundation.

The results of measured vibration amplitudes and those predicted from the elastic and nonlinear soil analyses are compared in Figures 1 and 2, respectively, for the vertical vibration mode and in Figures 3 and 4 for the torsional vibration mode. As seen from the above results, there is a marked difference between the observed and predicted foundation response both in terms of the resonant frequency and vibration amplitude if elastic soil behavior is assumed. However, when the soil properties are adjusted to reflect nonlinear soil behavior, the predicted results are in good agreement with the measured data. These findings are consistent with those reported by other investigators.

It is important to note that the soil shear strains used in this study are based on the measured displacements of the foundation slab during various tests. In actual applications, however, an iterative scheme may be used whereby the soil shear moduli are adjusted in each iteration until the resulting soil shear strains are compatible, within a specified tolerance, with the calculated displacement of the foundation.

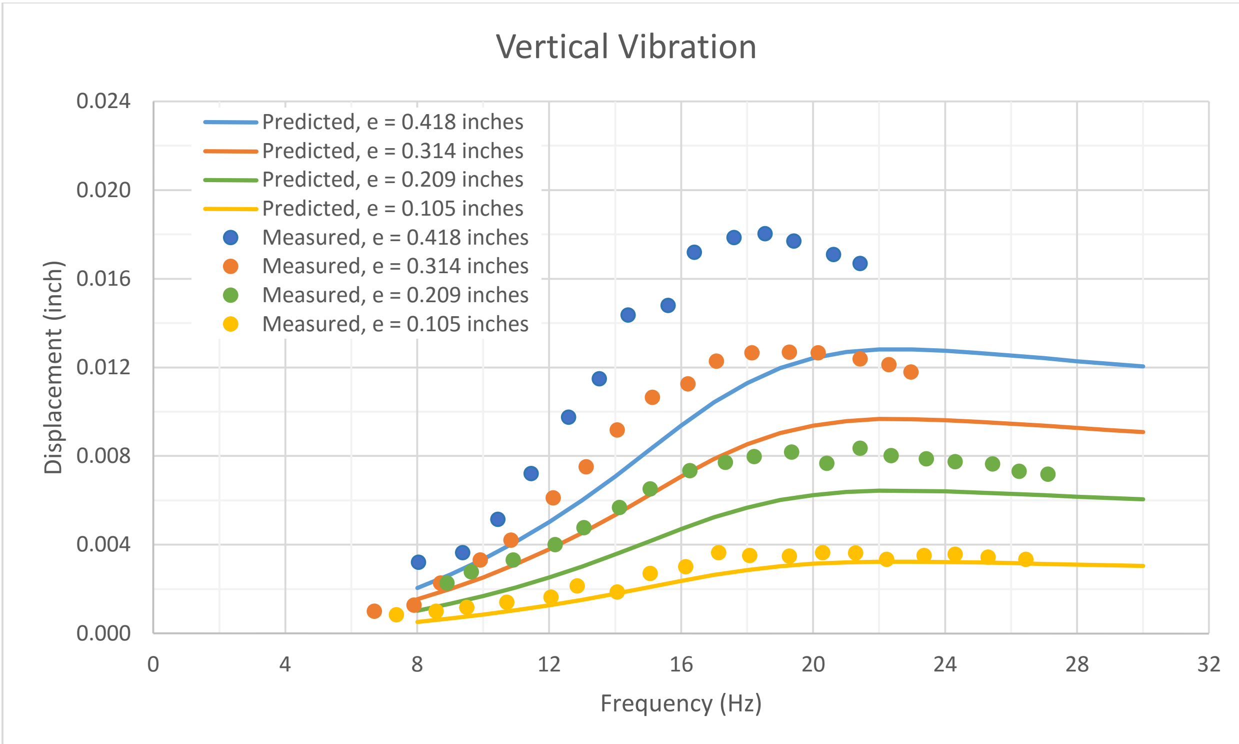

Figure 1 – Predicted vs Measured Foundation, Response, Vertical Mode, Elastic Soil

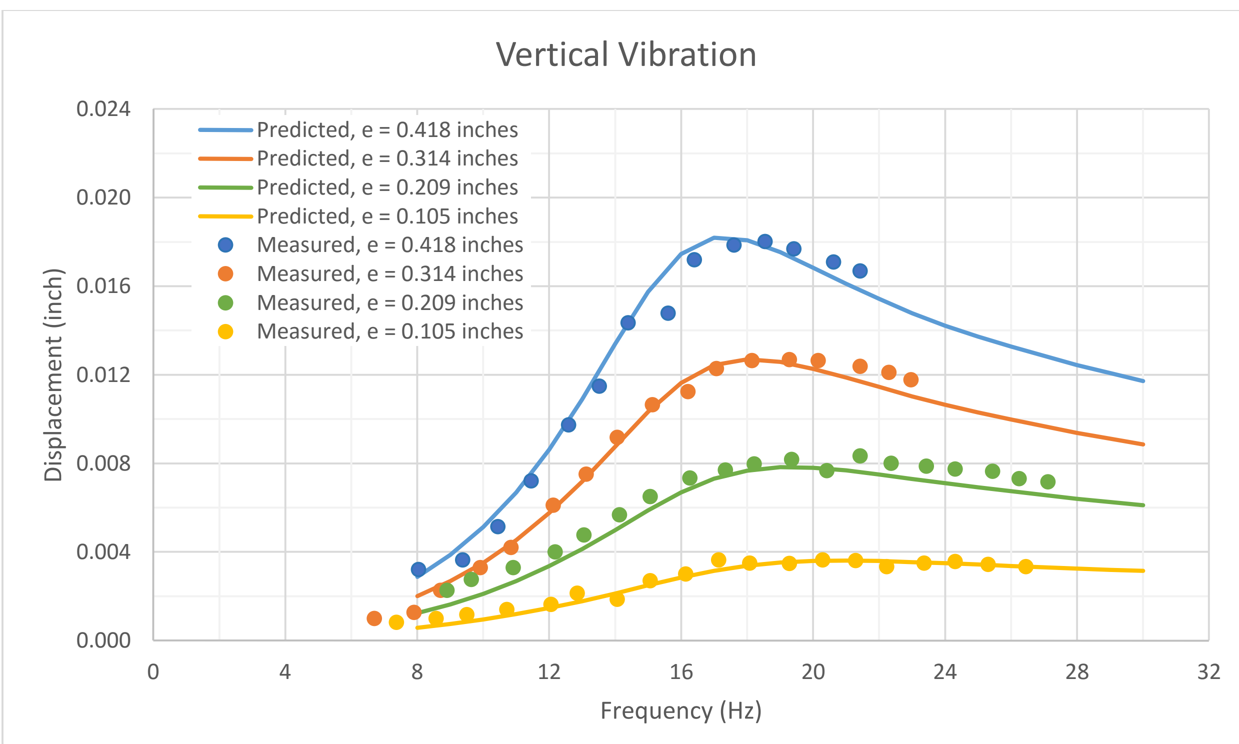

Figure 2 – Predicted vs Measured Foundation Response, Vertical Mode, Nonlinear Soil

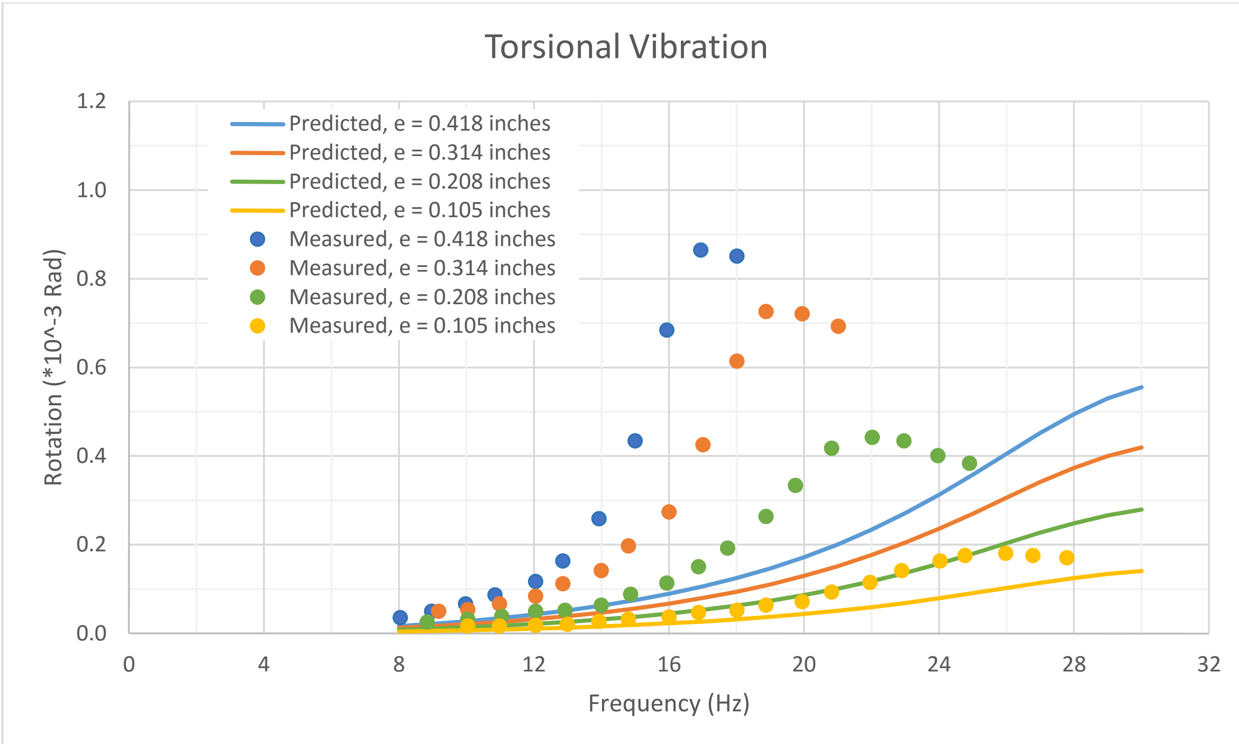

Figure 3 – Predicted vs Measured Foundation Response, Torsional Mode, Elastic Soil

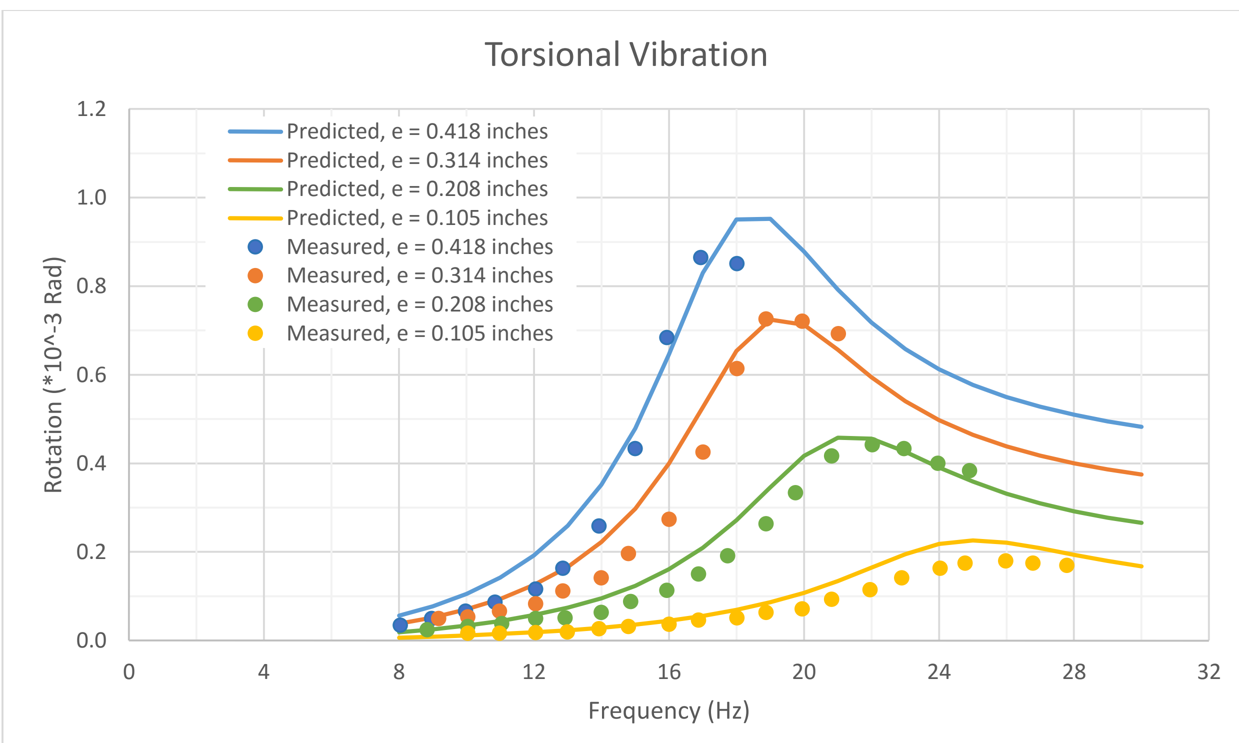

Figure 4 – Predicted vs Measured Foundation Response, Torsional Mode, Nonlinear Soil