INFLUENCE OF WIND TURBINE FOUNDATION

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ABSTRACT

The 200 kw Mod-OA wind turbine was modeled using a 3 lumped mass-spring system for the superstructure and a rotational spring for the foundation and supporting soil. Natural frequencies were calculated using soil elastic moduli varying from 3000 to 22,400 p.s.i. The reduction in natural frequencies from the rigid foundation case ranged up to 20 percent.

INTRODUCTION

The foundation of the Mod-O wind turbine was designed for the static loads only (including wind). Caissons reaching down to hard shale support the tower. This allowed us to assume infinite rigidity of the system at the tower base in any natural frequency calculations. Subsequent field measurements taken on the tower verified the validity of this assumption.

When it was decided to upgrade the Mod-O to 200 kw and duplicate it at other sites, we were concerned about the design of the foundation for two reasons:

° The sites for the Mod-OA were unknown and thus the soil conditions were unknown.

° A computer program for a vibration systems analysis would not be ready for use in time for design.

MOD-OA FOUNDATIONS

We decided to make a parametric study of the Mod-OA foundation vibrations using the soil modulus as a variable. Dr. Paul Chang, et al. of Akron University made this study. Figures 1 to 5 summarize the significant features of this study, including the geometry of the structure, the mathematical model, and the primary results.

A square mat foundation for the tower was chosen for several reasons:

° The rocking mode is probably the dominant mode of tower-foundation vibration and large dimensions in plan view are optimum for resisting this type of vibration.

° Excavation and forming for the foundation are relatively simple. This is an important factor in remote areas.

° For a given cost you can probably get the largest concrete mass in a mat foundation which is of course advantageous for the vibration as well as the static loads.

° Since the foundation thickness is small and the plan dimensions are only slightly larger than the tower footprint, the use of the foundation could be universal; that is, wherever the tower could fit dimensionally, the foundation should also fit.

For the parametric study, the mathematic model consisted simply of a 3 lumped mass-spring system for the superstructure and a rotational spring for the soil. Calculation of the spring constant for the soil-springs was based on the theory for dynamic interaction between a rigid slab and an elastic half space. The fundamental rocking frequency was calculated for various soil moduli and the change in frequency from the base line frequency (i.e., completely rigid soil) was plotted against soil elastic modulus (Fig. 5). The mass-spring model was subsequently verified by finite analysis of the mat.

CONCLUSIONS

° For rigid soils (E > 20,000 p.s.i.), the effect of the soil on natural frequency is insignificant.

° For soft soils (E < 5,000 p.s.i.) the reduction of natural frequency can be 20% or more.

° The spring-mass model was accurate within 5 percent as compared to the finite element model.

° A systems analysis, which includes the foundation-soil, is required for Mod-OA towers with mat foundations placed on soft soils.

POTENTIAL AREAS OF FUTURE STUDY

° Foundation rocking coupled with vertical, sliding or twisting modes.

° Optimization of foundation types for various classes of wind turbines.

° Automatic design of foundations such that a minimum amount of soil information and design effort is required.

° Instrumentation of foundations to verify assumptions and math models.

° Effect of foundation-soil in earthquake analysis of wind turbines.

DISCUSSION

. Are there any building codes which apply to your foundation design?

. The only applicable code is the ACI code which gives allowable stresses for reinforced concrete design. I am not aware of any code that spells out how to analyze the structure for forces and stresses.
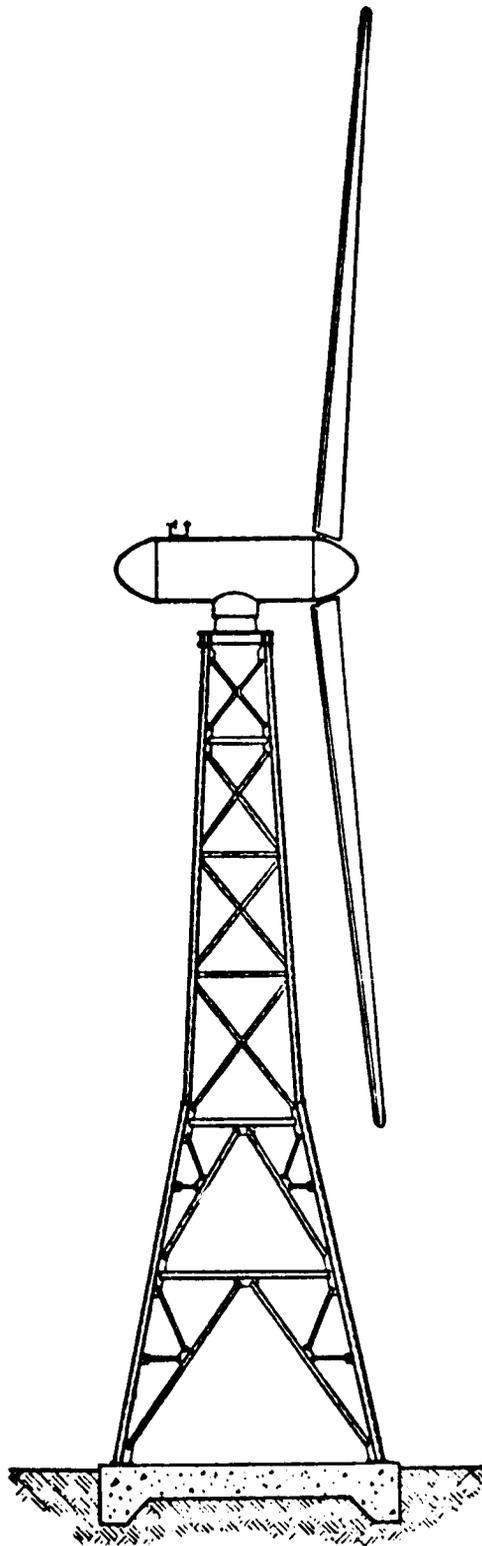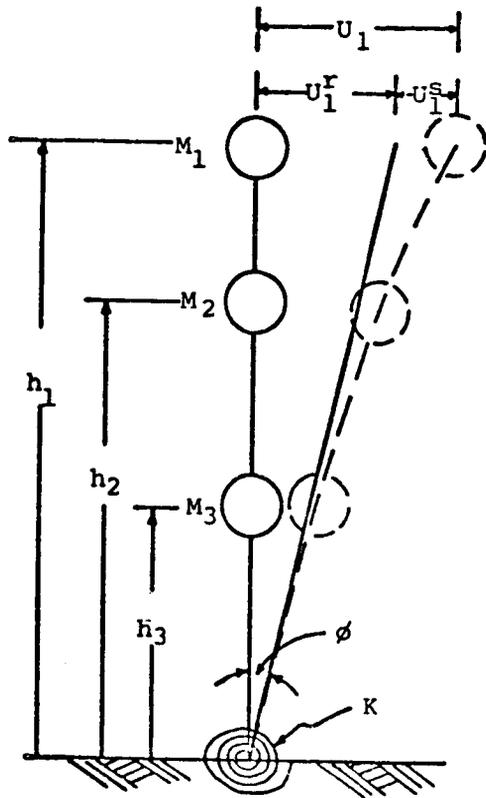
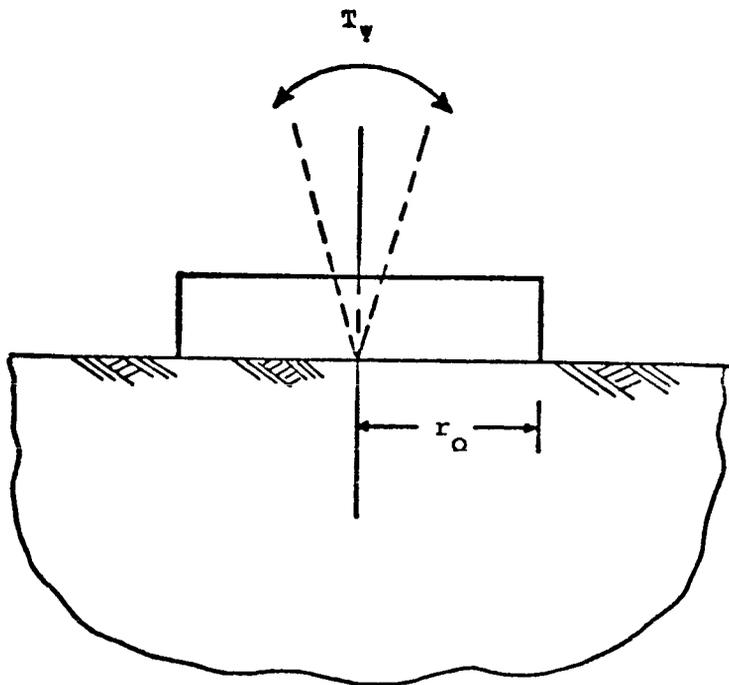Figure 1. - Mod-OA wind turbine.

Figure 2. – A simple model.

Figure 3. – Rocking of rigid footing on
elastic half space.

$$\overline{f}_1 = \frac{\text{First Natural Freq.(Non-rigid base)}}{\text{First Natural Freq.(Rigid base)}}$$
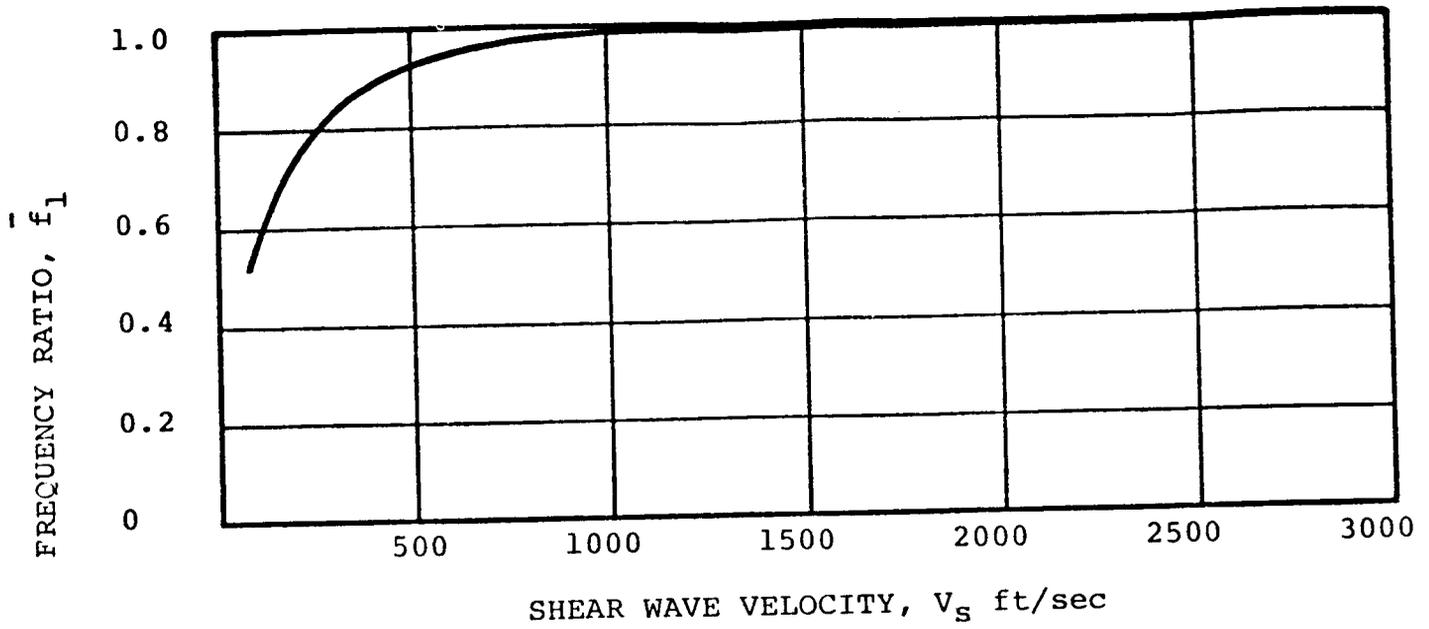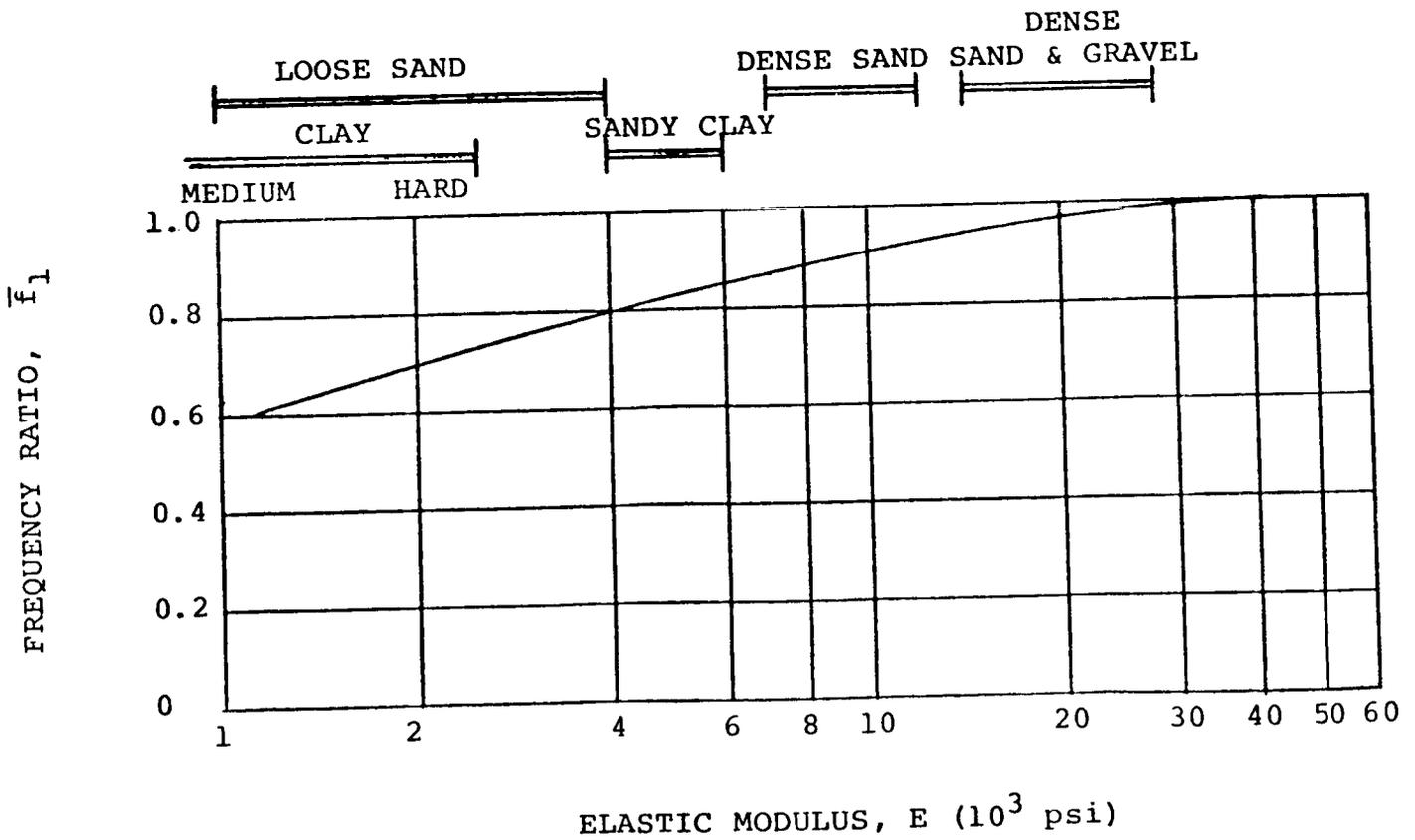

Figure 4. - Frequency ratio versus shear wave velocity.

Figure 5. - Frequency ratio versus elastic modulus.

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