VARIATION IN SOIL PROPERTIES DURING DYNAMIC LOADING

by

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SYNOPSIS

This paper deals with the variation of soil damping and dynamic moduli as a function of dynamic stress levels (applied at 2 cps) and overconsolidated ratios.

INTRODUCTION

In recent years engineers and scientists have become increasingly aware of the role soils play in modifying and amplifying the earthquake signals and thus effecting the ground surface accelerations and the shaking to which the structures are subjected during earthquakes.

The two most important soil parameters that enter into analytical calculations of site response, including site amplification and the distribution of spectral frequencies, are damping factor η and dynamic modulus E_d. Several researchers (2, 3, 5 and 6) have in the past investigated the variations in soil damping and dynamic moduli as a function of strain levels. In this paper an attempt is made to relate the variations in the above parameters to the past soil geologic history as well as to the levels of dynamic stresses imposed on the soil samples.

Currently there are five common laboratory techniques for measuring soil damping (4). Only one of these can be interpreted without having to assume that soil responds as a linear viscoelastic body. This is the method in which the area within the hysteresis loop is measured and related to the total input energy. In this paper, both damping and dynamic moduli for soil with different overconsolidation ratios are determined experimentally during the 5th cyclic loading. Damping η is defined as:

$$\eta = \frac{1}{2\pi}\frac{D}{W} \qquad (1)$$

where D = the area (abc) within the 5th cycle of loading and unloading hysteresis loop in Fig. 1, and W = the area represented by (abd) in Fig. 1. Similarly, the dynamic modulus E_d is defined as:

$$E_d = \frac{\sigma_d}{e_r} \qquad (2)$$

where σ_d = dynamic deviator stress during the 5th cycle of loading, and e_r = the recoverable strain as shown in Fig. 1.

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INSTRUMENTATION AND TEST PROCEDURE

A modified conventional triaxial cell equipped with a reliable pore pressure measuring device was used in this study. During dynamic tests, the testing equipment consisted of three major components: a highly sophisticated material testing system MTS model 903.73; a triaxial cell; and a recording console. A photograph of these three major components is shown in Fig. 2, and a detailed description of this testing equipment can be found in (1). The triaxial cell was placed on a plate which was incorporated with the actuator of the load frame attached to the MTS system. Different types of dynamic loadings, including arbitrary function and cyclic function loadings, can be applied to the sample inside the triaxial cell through the actuator. The actuator can provide a maximum of 10,000 pounds of dynamic force and 15,000 pounds of static force at 3000 psi pump pressure and travel a distance of 6 inches ($\pm$ 3 inches). The cyclic function generator has a wide frequency ranging from 0.001 to 1000 cps and can either be load or stroke controlled.

Tests were performed on Seattle soil with a liquid limit of 52 percent, plastic limit of 26 percent, specific gravity of 2.71 and a natural moisture content varying between 24 and 26 percent. The soil was thoroughly mixed with water at a moisture content 5 percent greater than the Liquid Limit and was stored in a slury form in a constant-temperature humid room for about 3 months prior to testing. At the end of the storage period, test samples were consolidated for seven days in 2.8" diameter Shelby tubes under various vertical loads and tested in the triaxial cell under different confining pressures, thus resulting in varying degrees of overconsolidation ratios.

SUMMARY AND DISCUSSION OF TEST RESULTS

The results obtained from the above dynamic experiments conducted on reconstituted saturated Seattle clays under 40 psi confining pressure are summarized in Fig. 3. From these data, the following conclusions can be drawn.

1. For normally consolidated soils (overconsolidation ratio of one) dynamic modulus E_d decreases and damping coefficient η increases with increasing dynamic stress or strain levels. This is in agreement with the findings of most researchers to date.

2. For overconsolidated soils (overconsolidation ratio greater than one) the variations in damping and dynamic moduli with increasing dynamic stress levels are not as pronounced as in the case of normally consolidated soils. As a matter of fact, both η and E_d appear to be almost independent of dynamic stress levels when the overconsolidation ratio of the soil is above 8. The most obvious practical implication of this is that it may be permissible to assume stress or strain independent soil parameters in heavily glaciated regions or when the soil is heavily overconsolidated by physical means (such as compaction) without introducing serious and unacceptable errors in the analysis.

ACKNOWLEDGEMENTS

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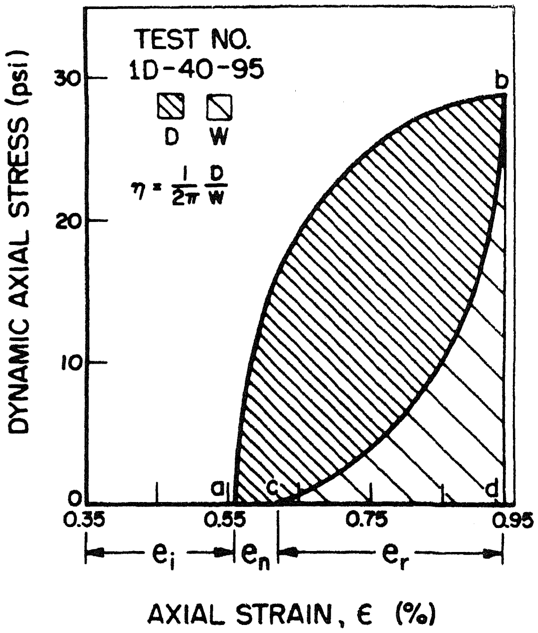

Fig. 1. Axial Stress-Strain Relationship during Triaxial Dynamic Loading.

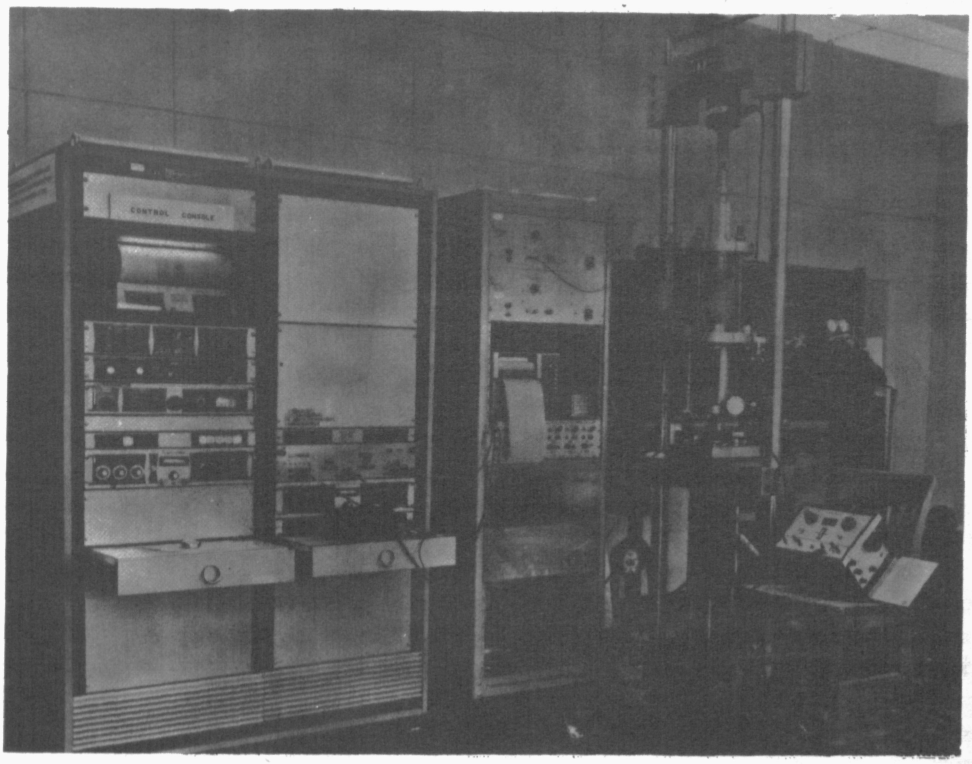

Fig. 2. A Photograph of Test Apparatus.

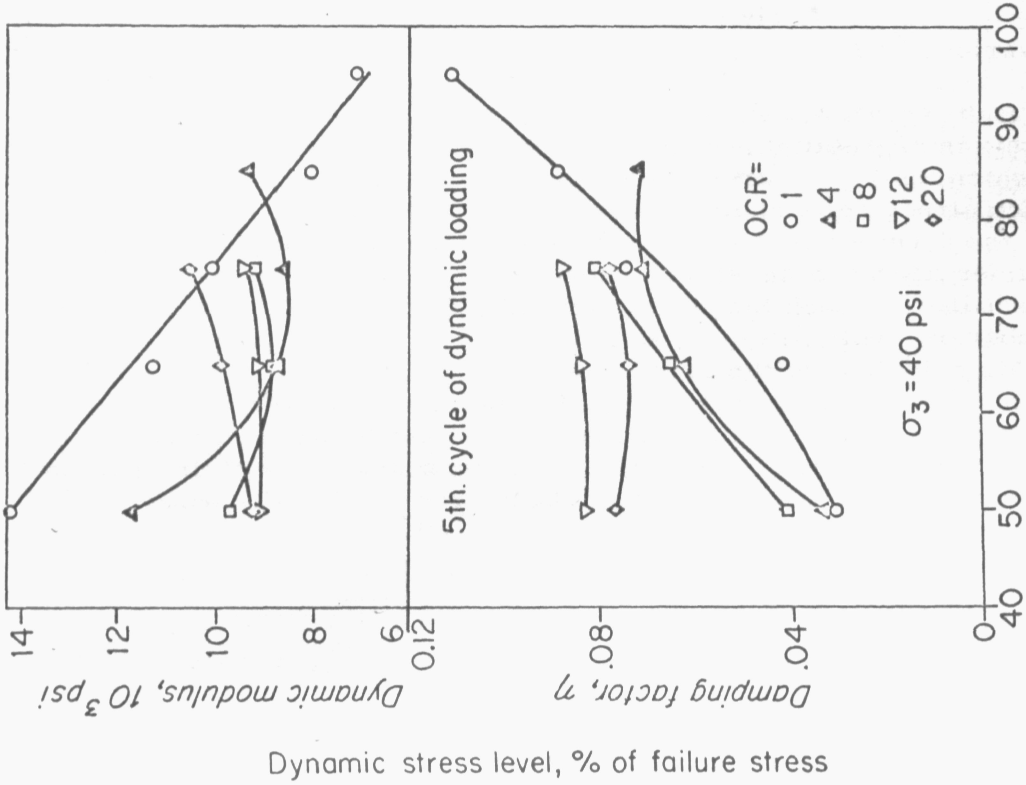

Fig. 3. Soil Parameters Vs. Dynamic Stress Levels