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STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA



July 11, 1963

Progress Report No. 13,
Contract DA-49-146-XZ-018
Stanford Research Institute Project PHU-2917
Progress during May and June 1963

INVESTIGATION OF STRESS PROPAGATION IN SOILS.

Prepared for
Defense Atomic Support Agency
Washington 25, D. C.

by Lynn Seaman.

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Introduction

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Under the current extension (see attached project history) of Contract DA-49-146-XZ-018, Stanford Research Institute (SRI) is continuing a fundamental investigation of stress propagation in soils. Specific objectives are to perform unidimensional stress propagation tests on three sands and one clay and to relate the observed stresses and particle velocities in the soils to the response of analytical models.

Progress during May and June 1963

The draft of the final report for Part III covering research performed from January 1962 to March 1963 was completed and submitted to the Project Officer in May.

In June an analytical study was begun of attenuating mechanisms in various soil models. The results will be used to evaluate data from the dynamic tests to be made later.

The axial force gages were redesigned to improve reliability. A new design for the stress gages was developed and prototypes are being constructed.

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Attenuation Mechanisms

The most important effect to be studied in the soil column is the rate at which stress, acceleration, and particle velocity attenuate with depth. The stress attenuation rate under a decaying surface pressure is of particular value. It should be possible to relate the attenuating mechanism of a soil to other soil properties such as locking characteristics or damping, thus relating experimental data with theoretical models.

With this in mind a review was made of the mathematical models for soil studied previously. The input pressure assumed is a shock front with an exponential decay of pressure with time. It was found that the peak stress attenuates with depth exponentially for an initial distance corresponding approximately to the propagation velocity times the pressure decay constant. Beyond this depth, the attenuation rate changes and no longer corresponds to a simple exponential.

For the standard linear viscoelastic model the attenuation of the initial peak is given by $\sigma/p_0 = \exp(-1/2 \rho \mu C_0 Z)$, where

σ is stress at the depth Z

p_0 is peak applied pressure

ρ is model density

μ is the reciprocal of viscosity of the dashpot in the model

C_0 is the initial propagation velocity of the stress

Z is the depth.

In the linear locking model that we have considered the attenuation is

$$\frac{\sigma}{p_0} = \frac{\alpha + e^{-\frac{2\alpha\theta C_0 Z}{1+\alpha}}}{1+\alpha}$$

under a pressure $p = p_0 \exp(-\theta t)$

where

α is the locking parameter, $\frac{2\alpha}{1+\alpha} = 1 - C_0/C_1$

C_1 is the propagation velocity during unloading

t is time

θ is the reciprocal of the time constant for the input pressure.

Analysis of the attenuation for the generalized viscoelastic model with constant loss angle has not been completed.

Gage Design

The first gages used for measuring axial force in the soil tube were semiconductor strain gages. Since these gages did not prove entirely satisfactory, a different type of measuring device using SR-4 strain gages was designed.

The modified stress gage is shown in Fig. 1. The gage has a thickness-to-diameter ratio of 0.09 and the PZT-5 sensing crystal occupies only the central third of the gage area. The gage can be sealed against penetration by moisture or air pressure. Six of these gages are being constructed.

Future Plans

Attenuating mechanisms of various soil models will be studied further. Tests will be made of the response and reliability of the new axial force gages. The new stress gages will be completed at the end of July when the necessary parts are received. Then static and dynamic tests will be conducted on the stress gages to check their characteristics.

Respectfully submitted,


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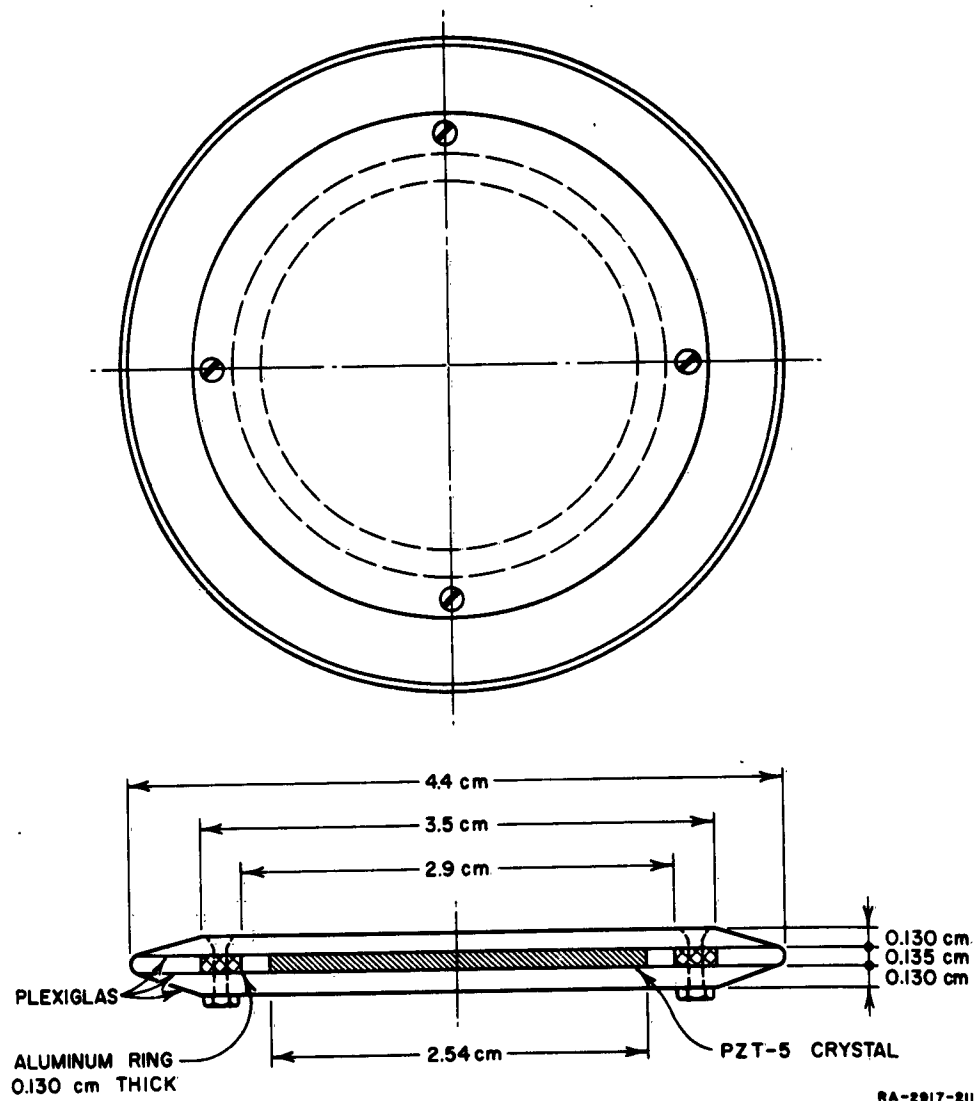


FIG. 1 MODIFIED STRESS GAGE

PROJECT HISTORY

Contractual

The original contract DA-49-146-XZ-018 between the Defense Atomic Support Agency (DASA) and Stanford Research Institute (SRI) was for the period June 1959 to December 1961. The final report under this contract was published in two parts, DASA-1266-1¹ covering the theoretical aspects of the research, and DASA-1266-2² covering the experimental work. The first extension of the contract was from January 1962 to March 1963; the final report for this contract period was submitted to DASA for review in May 1963.³ The present extension is from June 1963 to March 1964.

Technical

The response of three unidimensional analytical models to blast loadings has been investigated theoretically. The loadings had a pattern similar to airblast pressure-time curves from nuclear or high explosive detonations. The standard linear viscoelastic, the "constant $\tan \delta$ " viscoelastic, and a bilinear locking model were analyzed. The essential feature of the analyses was the rate of attenuation of stress and particle velocity with depth.

A 5-meter long column has been built for investigating one-dimensional wave propagation in soils. A blast loading was applied to the top of the soil in the column and measurements of stress, acceleration, and particle velocity were made at various depths in the soil. Peak particle velocity (obtained by integrating accelerometer output) appeared to be reproducible and related to applied pressure. Acceleration measurements were not considered sufficiently reproducible to assist in determining soil response. Stress gages were still in a developmental stage in March 1963. Insufficient data have been obtained to be able to relate the response of the soil to that of one of the analytical models.

REFERENCES

1. Lai, W., and F. M. Sauer, Propagation of Stress Pulses in Standard Linear Viscoelastic Materials, Stanford Research Institute, Project PHU-2917, Final Report, Part I, DASA-1266-1, August 1961
2. Kriebel, H. W. Feasibility Study of an Experimental Apparatus for Unidimensional Stress Propagation in Soil, Stanford Research Institute, Project PHU-2917, Final Report, Part II, DASA-1266-2, February 1962
3. Seaman, L., G. N. Bycroft, and H. W. Kriebel, Stress Propagation in Soils, Stanford Research Institute, Project PHU-2917, Final Report, Part III (out on review)