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# Response of Non-Saturated Soil to Cyclic Loading

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# Response of Non-Saturated Soil to Cyclic Loading

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SYNOPSIS The response of partially saturated and dry sand materials under cyclic loading is controlled by the compressibility of the pore fluid. For dry sand the limiting axial and volumetric strain occurs within 5 to 15 cycles of load application and is a function of the number of cycles of cyclic stress, relative density, and effective consolidation pressure. In addition the axial strain is shown to be independent of the consolidation stress ratio for loose sand and decreases with increasing consolidation stress ratio for dense sand under a constant cyclic stress.

## INTRODUCTION

The response of partially saturated and dry soil specimens under cyclic loading is different from that exhibited by saturated specimens. The difference is due to the high compressibility of the pore fluid (water and/or gas) of non-saturated soils as compared with fully saturated soils in an undrained state.

## LABORATORY PROGRAM

A series of cyclic triaxial tests were conducted on saturated, partially saturated and dry sand material. The cyclic loading was imposed on the specimens by a varying both the axial and lateral stresses 180° out of phase with each other. (Axial-Lateral Cyclic Triaxial Test). Test results utilizing this experimental technique have been shown to agree with the standard cyclic triaxial test for saturated specimens (Chaney, 1978). Test specimens were prepared from clean Monterey No. 20-30 sand at two relative densities (Dr = 53.3% and 93.5%) using dry vibratory methods. Each test specimen was cylindrical in shape with a diameter of 35.6 mm and a height of 87.6 mm.

## EXPERIMENTAL RESULTS

Results from tests on dry sand will only be discussed due to space limitations (Chaney, 1978). The behavior of saturated and partially saturated sand specimens has been discussed previously by Chaney (1978). The axial ($\epsilon_1$) and volumetric strain ($\epsilon_v$) of loose sand (Dr = 53.3%) as a function of the number of cycles (N) and constant cyclic stress ($\sigma_{dp}$) is one of a readjustment of particles in a few cycles (N = 5 - 15) to a denser configuration as evidensed by reaching a plateau of limiting strain. This behavior is in agreement with results presented by Pyke (1973). The maximum $\epsilon_1$ or $\epsilon_v$ obtained at this plateau decreases with increasing effective confining pressure ($\sigma_{3c}$), and relative density (Dr) at a constant $\sigma_{dp}$. In contrast the limiting $\epsilon_1$ and $\epsilon_v$ increases with increasing $\sigma_{dp}$ at constant $\sigma_{3c}$ and Dr. This same behavior is also observed for dense sand (Dr = 93.5%).

The effect of $\sigma$dp and the consolidation stress ratio (Kc) on the limiting $\epsilon_1$ is shown in Fig. 1 for loose sand. A review of Fig. 1 shows that for loose sand the limiting $\epsilon_1$ is independent of $K_c$. In contrast for dense sand the limiting $\epsilon_1$ at a constant $\sigma$dp decreases with increasing Kc. The limiting $\epsilon_v$ at a constant $\sigma$dp for both loose and dense sand decreases with increasing $K_c$.

## CONCLUSIONS

(1) The limiting $\epsilon_1$ and $\epsilon_v$ experienced by sand under a cyclic stress is a function of N, $\sigma$dp, Dr, and $\sigma_{3c}$.
(2) The limiting $\epsilon_1$ and $\epsilon_v$ occur within 5 to 15 cycles of load application.
(3) The limiting $\epsilon_1$ is independent of Kc for loose sand and dependent on Kc for dense sand under a constant cyclic stress ($\sigma$dp).

## REFERENCES

Chaney, R. C. (1978). "Deformation of Earthdams Under Earthquake Loading", Ph.D. Thesis, Univ. of Calif., Los Angeles.

Pyke, R. M. (1973), "Settlement and Liquefaction Sands Under Multi-Directional Loading, Ph.D. Thesis, Univ. of Calif., Berkeley.

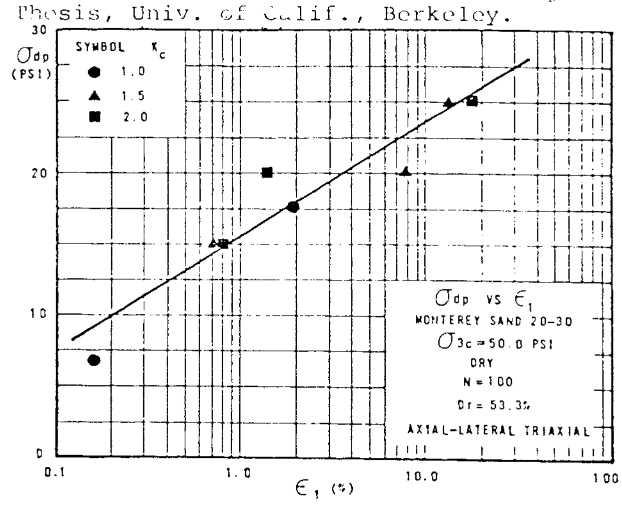


Fig. 1 - Effect of $K_c$ Ratio