K_{od} Apparatus, Type TK-1

Longgen Zhu
Tongji University, Shanghai, China

Lizhi Xu
Tongji University, Shanghai, China

Jian Du
Tongji University, Shanghai, China

Proceedings: Third International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
April 2-7, 1995; Volume III, St. Louis, Missouri

K_{od} Apparatus, Type Tk-1

Paper No. 2.27

Longgen Zhu, Lizhi Xu and Jian Du
Tongji University
Shanghai, China

SYNOPSIS The lateral pressure coefficient K_{od} of soil under the cyclic load is an important parameter in designing structures against wave, earthquake, and wind. The Lateral Pressure Coefficient Apparatus, Type TK-1 under the cyclic load, written in the simplified form of K_{od} Apparatus, Type TK-1, is especially developed to study and determine K_{od}. Its structure, specifications and test results have shown that this apparatus has superior performances, met the requirements to study and determine K_{od}.

INTRODUCTION

The lateral pressure coefficient K_{od} under the cyclic load is an important parameter of soil. It is the ratio of the lateral cyclic stress to the vertical cyclic stress under the condition that there is no lateral deformation (rigid boundary condition). Then we have in terms of the total stress

$$K_{od} = \frac{\sigma_{3d}}{\sigma_{1d}} \tag{1}$$

and in terms of the effective stress

$$K_{od} = \frac{\sigma'_{3d}}{\sigma'_{1d}} = \frac{\sigma_{3d} - u_d}{\sigma_{1d} - u_d} \tag{2}$$

where
σ_{3d}= total lateral cyclic principal stress.
σ_{1d}= total vertical cyclic principal stress.
σ'_{3d}= effective lateral cyclic principal stress.
σ'_{1d}= effective vertical cyclic principal stress.
u_d= pore water pressure produced by the cyclic stress.

The K_{od} Apparatus, Type TK-1 is especially developed to determine and study K_{od}. Up to now, no report has been published about this kind of apparatus. So, it is a creative one and will provide a measure for the study of K_{od}.

STRUCTURE

According to the requirement of measuring and studying K_{od}, the rigid container of the K_{od} Apparatus, Type TK-1 and the amplifier of the measuring system have been designed and manufactured by ourselves, and the cyclic and static loading system of the CKC Cyclic Triaxial Apparatus has been adopted as the cyclic and static loading equipment. Its layout is shown in Figure 1, it is mainly composed of the following parts.

1. Rigid Container

The rigid container is an important part of the K_{od} Apparatus, Type TK-1. It is mainly composed of a piston, a piston cover, piston sheath, sheath, piezoelctric ceramic cylinder and a pedestal .etc. as shown in Figure 2.

The lower intake and drainage system of the sample is composed of the pipe lines of the pedestal, the porous stone on the pedestal and valves. The upper pipe line of the sheath, the lateral porous stone and valve make up the upper intake and drainage system of the sample. In order to study the K_{od} value under the non--drainage condition, the following sealing methods are taken in the cell of sample to guarantee no drainage of the sample under the condition that the upper and lower valves are closed.

(1) During the process of loading the sample vertically, a relative vibrating displacement will occure between the piston and the piston sheath. If the piston and piston sheath are fitted too close, friction will be big enough to make the piston unable to move. If they are fitted loosely, the pore water will flow easily through the space between the piston and piston sheath. How to seal the interstice between them

is a very important problem. So, the piston and piston sheath are ground to get the interstice matched. An oil groove with a width of 2cm and a depth of 0.2cm is carved on the piston sheath, and a sealing oil regulator is used to add pressure to the sealing oil in the oil groove.

(2) An 'O' sealing ring between the sheath and the pedestal.

(3) Upper and lower sealing washers made of teflon are set between the piezoelctric cylinder and the sheath, and liquid rubber is coated on the washers to reinforce the sealing.

The rigidity of the container is analysed as follows: The piston, the sheath and the pedestal of the rigid container are made of stainless steel body. The bottom of the cell and the porous stone of its side wall are made of compressed metallic grains. Their rigidity is far greater than that of the sample. The piezoelectric ceramic ring is the frail part of the cell. The ratio of radial strain of ε_r to that of the sample ε_R is analysed as follows:

$$\frac{\varepsilon_r}{\varepsilon_R} = \frac{2EsR}{tE} \qquad (3)$$

where, E is the young's modulus of the ring and equals $8.13 * 10^7$kpa. Es is the modulus of compressibility of the sample and ranges from 1700kpa to 7200kpa. t is the thickness of the ring and equals 5mm. R is the average radius of the ring and equals 33.4mm. Taking the maximum value of Es for analysis, the ratio of ε_r to ε_R equals $1.18 * 10^{-8}$, i.e, $\varepsilon_r << \varepsilon_R$. It can be seen from the analysis that the piezoelectric ceramic ring has played the role of a rigid boundary wall for the sample.

2. Cyclic and static loading system in the vertical direction on the sample

The loading system of CKC Triaxial Apparatus is taken as that of the K_{od} Apparatus. Type TK-1. This loading system is composed of an air exciter, electro-pneumatic controller and an air pump, etc. The exciting frequency varies from 0.01-3HZ. The wave form of the vibrating force is the sinusoidal wave, or the triangular wave, or the square wave. The sum of the cyclic and static pressure in the vertical direction is not less than 700KPa.

3. Measuring system

(1) Measuring system for the cyclic vertical stress of the sample

The measuring system for the cyclic vertical stress of the sample is composed of the Dynamic Vertical Stress Sensor, the Amplifier of the K_{od} Apparatus. Type TK-1 and recorder, etc. The SC-16 Optical Recording Oscilloscope is used as the recorder. The Dynamic Vertical Stress Sensor is composed of the circular sheet of the piezoelectric ceramic, etc. The σ_{1d} signal detected by the Dynamic Vertical Stress Sensor will be amplified and put into the SC-16 Optical Recording Oscilloscope. The wave form of σ_{1d} will be recorded on the ultroviolet light recording paper. The Dynamic Vertical Stress Sensor is placed close to the sample and near the bottom of the loading piston, which less the effect of friction between the piston and the piston sheath on measurement of σ_{1d}.

(2) Measuring system of the cyclic lateral stress of the sample

The measuring system for the cyclic lateral stress of the sample is composed of the Dynamic Lateral Stress Sensor, an amplifier of the K_{od} Apparatus, Type TK-1 and the SC-16 Optical Recording Oscilloscope, etc. The piezoelectric ceramic cylinder is used as the converter element of the Dynamic Lateral Stress Sensor.

(3) Measuring system for pore water pressure of the sample

The measuring system for pore water pressure of the sample is divided into the upper path and the lower path. They are composed of the pore Water Pressure Sensor, an amplifier of the K_{od} Apparatus, Type TK-1 and the SC-16 Optical Recording Oscilloscope, etc.

(4) Measuring system for the static vertical stress of the sample

The measuring system for the static vertical stress of the sample adopts that of the CKC Cyclic Triaxial Apparatus. This measuring system is composed of the Force Sensor, Interface SM--1000 (strain gauge) and the Amplifier Sensotec SA-series, etc. The value of force is directly read from the Digital Voltmeter and its maximum range is 5KN.

(5) Measuring system for the vertical deformation of the sample

The displacement measuring system of the CKC Cyclic Triaxial Apparatus is adopted to determine the vertical deformation of the sample. This system is composed of the LMA-111C55 Displacement Sensor (Differential Transformer), Sensotec SA-Series Amplifier, etc. The value of the deformation is read from the Digital Voltmeter. It ranges from -3.81cm to 3.81cm.

Figure 9 shows the measurements of accelerometers AC1 and AC2 for dynamic event D2. By comparison with the output from dynamic event D1 (Figure 4), the maximum horizontal acceleration recorded in D2 is approximately twice as large as that recorded in D1. The measurements recorded by the other transducers in D2 are not presented here. The output from the other transducers follows the same general trend seen in D1. However, due to the higher intensity shaking, higher magnitudes were measured. Figure 10 displays the measured responses of earth pressure transducers EP1 to EP6 for dynamic event D2 in the same fashion as Figure 8 did for dynamic event D1. The measurements for dynamic event D2 are affected by possible changes in soil properties and residual pressures from dynamic event D1, which had taken place earlier. The trends of maximums, minimums and residual pressures are the same as seen in Figure 8. The magnitudes are higher because of the higher intensity shaking. As was done for dynamic event D1, the pressures determined using the M-O method are also shown in Figure 10. It can be seen that the difference between the measured and calculated pressures is more than that for D1. Figures 8 and 10 show that measured pressures were lower than the calculated pressures.

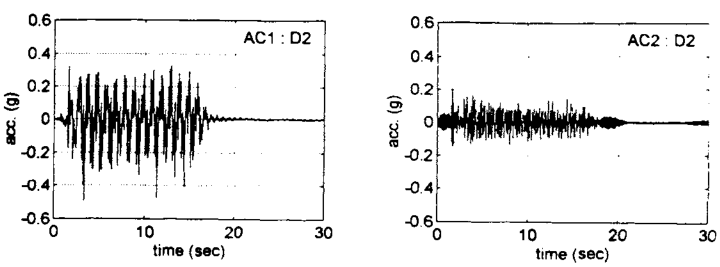

Figure 9: Accelerometer Recordings for D2

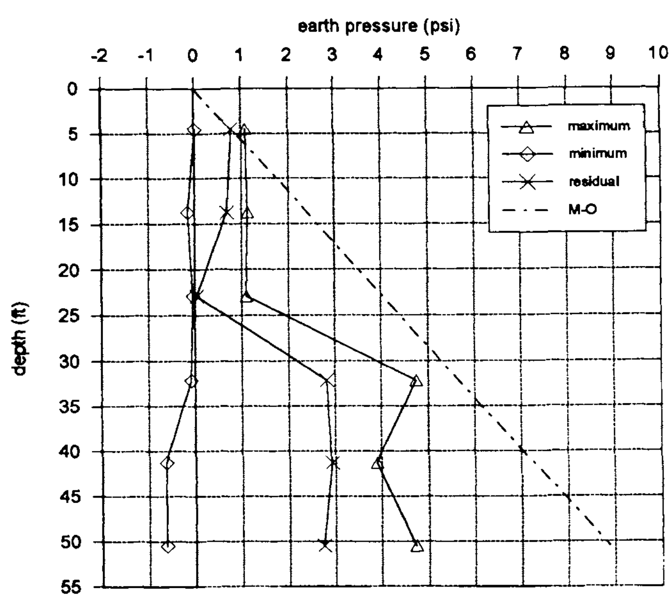

Figure 10: Dynamic Earth Pressure Components for D2

CONCLUSIONS

The following observations can be made from the test results:

- Measured static and dynamic pressures are lower than the calculated pressures using Coulomb's theory and the M-O method, respectively. For the dynamic earth pressures, comparisons can be affected by the choice of k_h and k_v.
- The differences between the measured and calculated pressures are greater in the higher intensity dynamic event (D2). However, results for D2 are affected by residual pressures and possible changes in soil properties due to the event D1 which had taken place earlier.
- Residual pressures are higher than the initial static values and are a substantial percentage of the maximum dynamic pressures.
- Amplification of accelerations occurred from the bottom to the top, both on the wall and in the soil.

Based on the results of other tests conducted at the University of Colorado, Boulder, these observations are generally true. However, some deviations can be expected for other types of test configurations. Further investigations incorporating different model configurations are necessary for more definitive conclusions.

ACKNOWLEDGEMENT

The work presented in this paper is a part of an investigation supported by the United States Bureau of Reclamation.

REFERENCES

Seed, H. B. and R. V. Whitman; "Design of Earth Structures for Dynamic Loads"; Lateral Stresses in the Ground and Design of Earth-Retaining Structures, ASCE Specialty Conference, Cornell Univ., Ithaca, N. York, June 22-24, 1970.