International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics

1991 - Second International Conference on Recent Advances in Geotechnical Earthquake Engineering & Soil Dynamics

14 Mar 1991, 2:00 pm - 3:30 pm

Permanent Deformation of Earth Dam Due to Earthquake

Jia-huan Qian
Hohai University, Nanjing, China

Zhen-son Hong
Hohai University, Nanjing, China

Li-zhen Zeng
Hohai University, Nanjing, China

Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, March 11-15, 1991, St. Louis, Missouri, Paper No. 7.8

Permanent Deformation of Earth Dam Due to Earthquake

Jia-huan Qian
Professor of Geomechanics, Hohai University, Nanjing, China

Zhen-son Hong
Graduate Student, Hohai University, Nanjing, China

Li-zhen Zeng
Graduate Student, Hohai University, Nanjing, China

SYNOPSIS: This paper combines the equivalent nodal force method suggested by serff et al, (1976) and equivalent inertial force method proposed by Taniguchi et al (1983, 1987).

The former is fine to ultilize seed's strain potential but the stress-strain curve is obtained only by static test, while the latter uses dynamic stress-strain curve, but the determination of direction of equivalent inertial force is rather difficult.

The writers use the equivalent nodal force by average shear stress (τ_{av}=0.65 τ_{max}) and assume it's direction to be coincided with static shear stress. Also dynamic stress-residual shear strain curve is obtained by dynamic testing.

INTRODUCTION

The Xian-lang-de earth dam with a height of 167 m. and a soil foundation of 40 - 70 m. along Yellow River, is a new designed dam. Inclined core is used with a curtain under the core (Fig,1). The permanent deformations are calculated by finite lement method both for two and three dimensional meshes with a 8 degree earthquake excitation.

During full reservoir, nearly all horizontal permanent deformation is towards downward. All horizontal and vertical permanent deformations can be checked by two and three dimensional calculation with max. difference of 13%

LABORATORY WORKS

All routine testings, including static and dynamic works, are delected. Here the writers only describe the formula of dynamical stress σ_d - residual shear strain γ_R ,

$$\frac{\frac{1}{2}\sigma_d}{p_o'} = \frac{\gamma_R}{a+b\gamma_R} \qquad (1)$$

where $p' = 1/2(\sigma_1'+\sigma_3')$, a and b are parameters varied with principal stresses ratio $K_c=\sigma_1'/\sigma_3'$ and cyclic number N.

For the limited space, here only listed are the parameters for fine sand of thin layers in foundation.

TABLE I. Parameters for Fine Sand

K_c \ N	a			b		
	5	10	20	5	10	20
1.5	0.052	0.061	0.069	3.380	4.290	5.230
2.0	0.042	0.050	0.060	3.320	4.233	5.211
2.5	0.031	0.039	0.049	3.260	4.176	5.192

For representing the variation of dynamic shear stress, use uniform equivalent stress τ_{av} and equivalent cycles N. Assume the stress is uniform in any element (Fig.2), the equivalent model forces are:

$$\left.\begin{aligned} F_h &= \frac{1}{2}\tau_{av}\,(x_i - x_{i+1}) \\ F_v &= \frac{1}{2}\tau_{av}\,(y_i - y_{i-1}) \end{aligned}\right\} \qquad (2)$$

where τ_{av} =0.65 τ_{max}

Consider the accumulation of permanent deformation along the direction of initial static shear stress, the direction τ_{av} coincides with static shear stress. The total nodal force is equal to the summation of forces acting on the same nodal from neighboring elements. The max. section of this earth dam is used for two dimensional analysis. The max. horizontal permanent deformation is 2.02 m, about 1.12% of the dam height (Fig.3) while the max. vertial permanent deformation is 1.85 m, about 1.1% of dam height (Fig.4)

The permanent deformations of grouted curtain are shown in Fig.5. The horizontal deformation

TWO DIMENSIONAL ANALYSIS

The calculation of FEM were both carried out for static and dynamical cases. The former was calculated by non-linear elastic method while the latter by non-linear iteration with shear strain (8° earthquake excitation). So degree of liquefaction was also estimated for fine sand which is not to be included in this paper.

of curtain top 0.66 m. is large so plastic material must be used for this part of curtain.

THREE DIMENSIONAL ANALYSIS

Due to the limit capacity of computer, only half of dam body is used for calculation. The half body is divided into twelve sections (Fig.6), forming 327 elements and 549 nodels. The max. permanent deformation for horizontal, vertical and longitudinal are 2.41, 2.21 and 0.41 m. respectively, occuring in different sections.

Except the longitudinal deformation, the horizontal and vertical deformation are only little larger than those obtained by two dimensional analysis results, so for usual cases, two dimensional calculation for earth dam is accurate enough for practical design consideration.

REFERENCES

Serff, N. (1976) et al, "Earthquake Induced Deformation of Earth Dams, "Report No. EERC 76-4, University of California, Berkerley.

Taniguchi, E. (1983) et al, "Prediction of Earthquake Induced Deformation of Earth Dams",Soils and Foundations,V.23, 4---126-132.

Taniguchi, E. (1987) et al, "Permanent Deformation of Embankments due to Cyclic Loadings". Public Works Research Institute, Tsukuba, Japan.

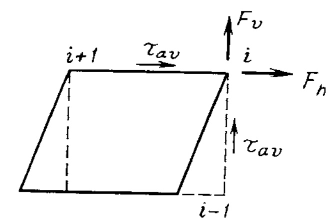

Fig. 2 Equivalent nodal forces

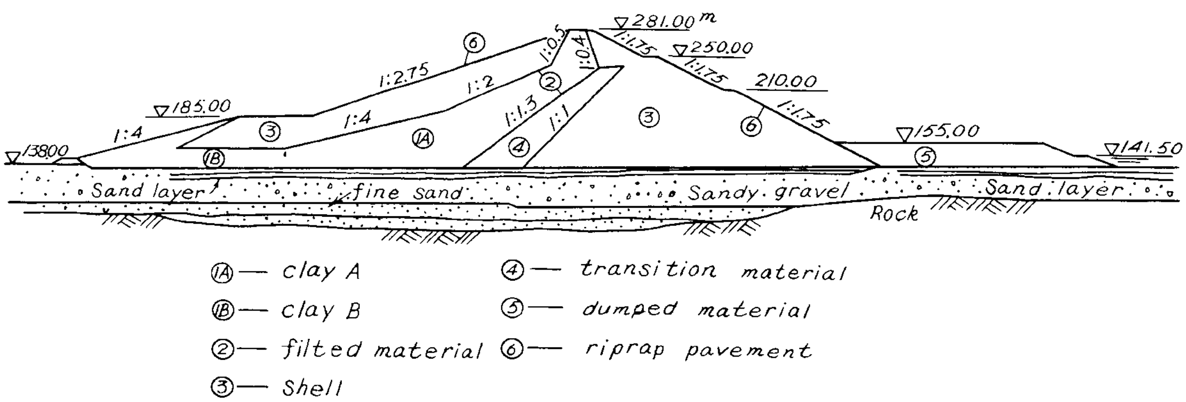

Fig. 1 Xian-lang-de earth dam

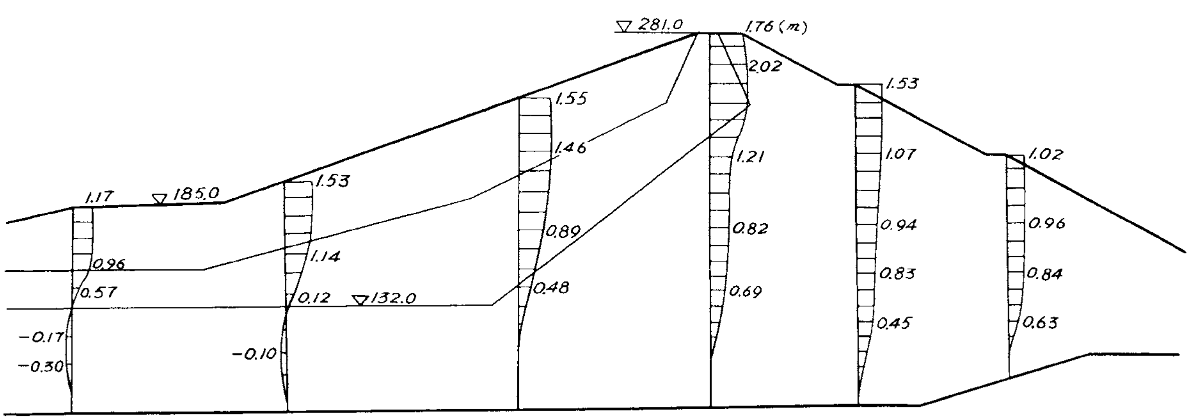

Fig. 3 Permanent horzontal deformations

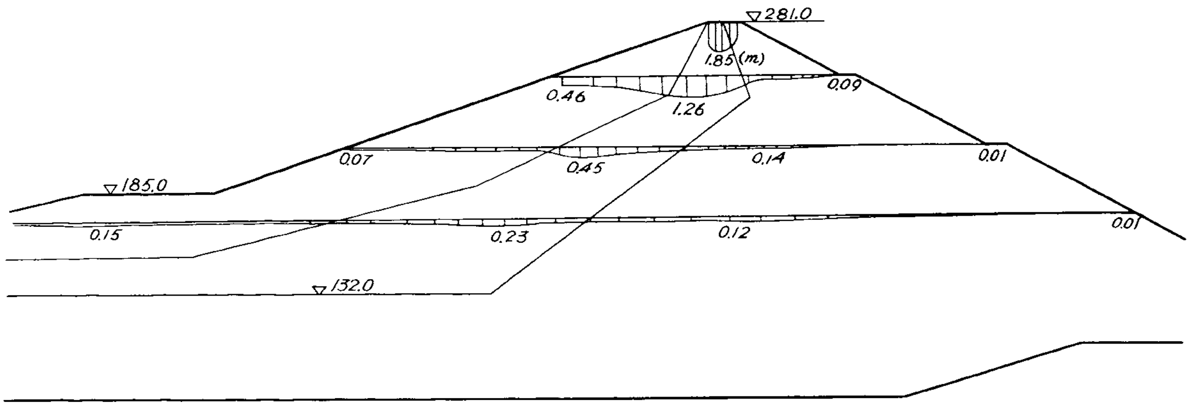

Fig. 4 Permanent vertical deformations

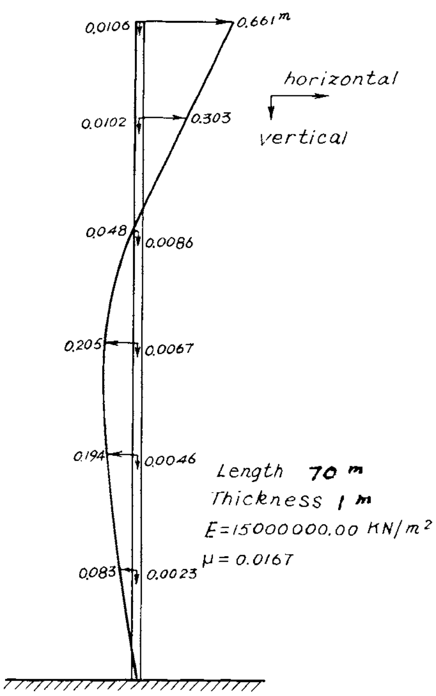

Fig. 5 Deformations of grouted curtain

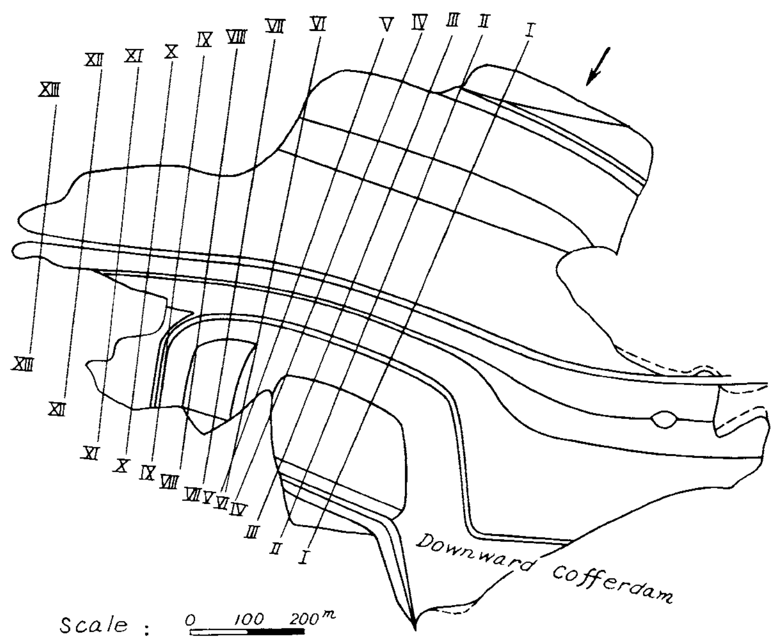

Fig. 6 Plan View