EARTHQUAKE INDUCED CRACKING OF DRY CANYON DAM

by

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SYNOPSIS

A seismic stability analysis was made to study the performance of an old earth dam which was damaged during the 1952 Kern County, California earthquake. The major objective of the study was to provide a basis for selecting a failure criterion for interpreting the results of cyclic load triaxial tests when the data is to be used in seismic slope stability analyses. The results suggested that strength defined by the cyclic deviator stress required to cause five percent total accumulative axial strain in a specified number of uniform cycles would lead to results comparable to field observations of an incipient failure.

INTRODUCTION

The Dry Canyon Dam was constructed in 1911-1912 primarily of fine to coarse silty sand using hydraulic filling techniques. It is located about eight miles north of the Los Angeles city limits. In 1952 it was subjected to a magnitude 7.7 earthquake at an epicentral distance of 46 miles (3). A two-inch wide longitudinal crack developed along the crest of the dam which extended to at least 13 feet deep. The nature and position of this crack suggested a potential failure of the upstream slope. Using the available data, a slope stability analysis was made following the method proposed by Seed (4). In this method the "strength" of the soil is defined as the pulsating stress required to cause a given amount of accumulative strain in cyclic loading triaxial tests. To interpret the laboratory test data it is necessary to select this limiting strain based on engineering judgement of what it means in terms of the corresponding deformations which will develop in the field. Very little data are available to provide a basis for selecting this limiting strain; five and 13 percent have been previously proposed (1, 4). Therefore this study was conducted to provide information to aid in the selection of a valid failure strain criteria for cyclic loading triaxial tests.

DESCRIPTION OF DAM

At the time of the earthquake the Dry Canyon Dam was 530 feet long at the crest and 63 feet high at the maximum section. It is

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founded on about 60 feet of recent alluvium consisting mainly of silty sand and gravel, overlying a thinly bedded sandstone and shale bedrock. A sketch of the maximum section is shown on Fig. 1. The approximate nature and limits of the several zones are given on the figure.

Subsequent investigations showed that the boundaries between the various zones were not nearly so well-defined as indicated by the construction drawing reproduced on Fig. 1. The soil was heterogeneous and stratified in thin layers of silt and sand ranging from a fraction of an inch to two or three inches thick. It was difficult to detect well-defined differences between soil samples from different zones except that the hydraulic fill was finer and less dense than the soils in the other zones. The ranges of grain sizes from the three major zones are shown on Fig. 2.

Because of the heterogeniety of the soil it was difficult to obtain truly representative samples for testing. Accordingly, several "average" samples of the hydraulic fill were mixed together to form the basic sample from which all laboratory test specimens were prepared. A grain size curve of this composite sample is shown on Fig. 2 where it is also compared with the range of grain sizes obtained from all the samples in three major zones of the dam.

From strong motion records of the earthquake made at Taft (0.18 g) and Pasadena (0.05 g), the maximum ground surface acceleration near the dam was estimated to be about 0.15 g. This included a small allowance for some amplification between the bedrock and the surface of the alluvium. The Taft record was modified to give $a_{max} = 0.15$ g. This motion was applied to the base of the dam and used as the basic input motion in a seismic response analysis to obtain the equivalent average seismic coefficient (7). The results indicated that the true erratic time history of seismic coefficient could be replaced by an equivalent of ten uniform cycles (2) of seismic coefficients of 0.1 and 0.18, for potential slip surfaces extending for the full height and top 1/2 of the dam, respectively.

Triaxial test specimens of the soil were prepared from the bulk sample to 50 percent relative density, saturated using a backpressure and subjected to ordinary static tests and to dynamic cyclic loading tests. Strengths for soil at other densities were obtained by extrapolation, assuming the strength to be directly proportional to relative density (5). Results of a typical cyclic load test are shown on Fig. 3. Note that there is no well-defined failure point so that failure must be defined in terms of an allowable axial strain.

RESULTS AND CONCLUSION

Seismic stability analyses (4) were performed using the above determined seismic coefficients and pulsating loading strengths defined by different axial strains. Results of analyses performed using failure defined by 20 percent axial strain are summarized on Fig. 4. The most critical slip circle extended only over the top half of the dam and had a minimum factor of safety of 1.27.

The results of other analyses using different failure strain criteria are summarized on Fig. 5. A failure strain criterion of about five percent in cyclic loading triaxial tests leads to a theoretical factor of safety of 1.0.

Since the field observations suggested that the earthquake produced an incipient failure, and since a theoretical factor of safety of 1.0 resulted from using a failure criterion, axial strain = 5 percent in cyclic loading triaxial tests, the study suggests that this may be an appropriate failure criterion for interpreting data from such tests for use in seismic slope stability analyses.

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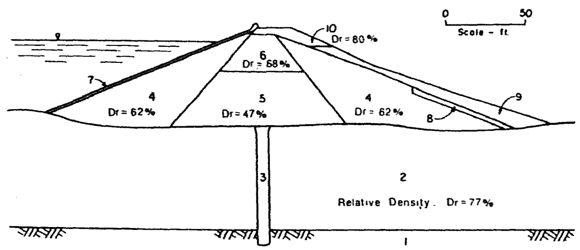
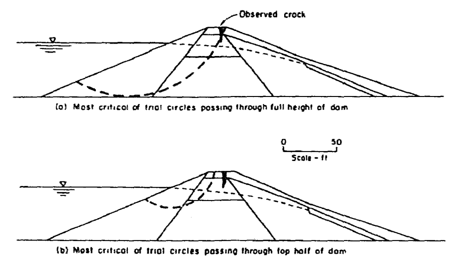


Boundaries between zones are very approximate

1 Bedrock (Shale and sandstone)
2 Recent Alluvium (silty sand and gravel)
3 Puddled Clay cut-off wall
4 Shell (silty sand) (1911-1912)
5 Hydraulic Fill (silt-sand) (1911-1912)
6 Wagon Rolled Core (1912)
7 6" Thick Concrete Face (1912 and 1933)
8 Sand Filter (1933)
9 Uncompacted SS and Shale (1933)
10 Compacted SS and Shale (1933)

Fig. 1 MAXIMUM CROSS SECTION OF DRY CANYON DAM. 1952



Case	Radius	K_c	Seis Coef	Factor of Safety	
				Before E.Q.	During E.Q.
(a) Full ht	100 ft	2.00	0.10	2.0	1.35
(b) Top half	40 ft	2.12	0.18	2.5	1.27

Failure criterion for cyclic loading triaxial tests ϵ = 20% in 10 cycles in pulsating loading triaxial tests

Fig 4 SUMMARY OF STABILITY ANALYSES

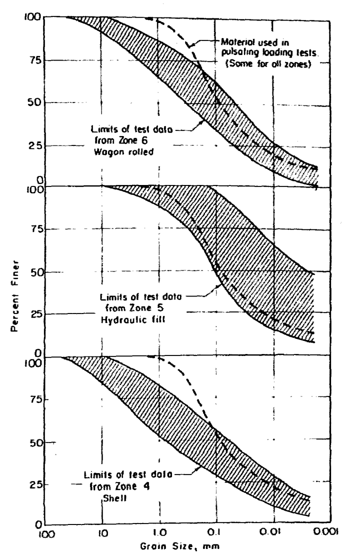


Fig 2 GRAIN SIZE DISTRIBUTION CURVES FOR SOILS IN DAM

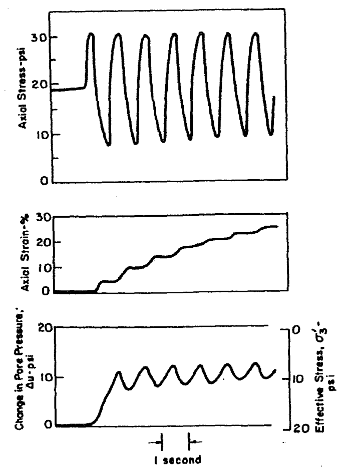


Fig. 3 TYPICAL PULSATING LOAD TESTING RECORD.

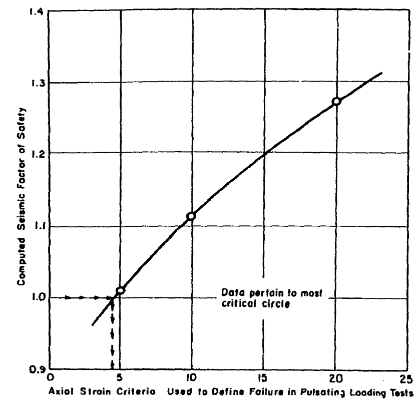


Fig. 5 SUMMARY OF SEISMIC FACTOR OF SAFETY CALCULATIONS.