SEISMIC STABILITY EVALUATION OF AN OLD DAM WITH A KNOWN SLIDE HISTORY

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SUMMARY

In performing the seismic evaluation for an existing dam, the investigators found knowledge of an old slide to be helpful in arriving at proper soil parameters. Seismic displacements were largely controlled by the fling component of the near field design earthquake.

INTRODUCTION

An earth dam about 11 meters in height was originally constructed in the early 1900s. Shortly after construction was completed, a significant slide occurred in the lower portion of the embankment but did not impede the operation of the reservoir. The embankment was repaired at the time of the slide and has subsequently been remodeled three times with a resulting increase in its overall stability. The dam is located about 300 meters from the trace of a major active fault. An extensive field investigation and laboratory testing program indicated the presence of a relatively weak residual clay layer underlying the embankment. The embankment material consists of a relatively dense gravely clay material. Figure 1 shows the cross section of the dam and the soil parameters for the embankment and foundation materials. The results of the simplified dynamic analyses (Ref. 1) indicated that the permanent displacements of the dam would be on the order of 1.5 to 2 meters for the design earthquake event which had a strong displacement pulse due to the near field fling at the fault and a peak acceleration of 0.75g. The large calculated embankment displacements are primarily due to the adverse downslope inclination at the weak clay layer.

STABILITY ANALYSES

Preliminary static stability analyses and pseudostatic analyses of earthquake loadings clearly indicate that the most critical failure surface is noncircular with its base passing through the weak clay zone. An important conclusion from the initial stability analyses was that the residual (effective) angle of friction for clay ($\phi' = 16°$) was the appropriate parameters to back fit the post construction slide failure. This residual

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friction angle was also considered appropriate for pseudostatic earthquake analyses as the clay layer had not been replaced in the post slide repairs and there was no assurance that earthquake motions would not destroy any regained strength on the old slide surfaces. The use of residual strength parameters for the clay layer in pseudostatic analyses indicated that yielding of the embankment would occur at accelerations exceeding 0.07g. Figure 1 shows the critical surfaces shown by the static and pseudostatic analyses.

DISPLACEMENT CALCULATIONS

Using the design earthquake motions (Figure 2), dynamic analyses using the results of a SHAKE analysis (Ref. 2) and the simplified procedures described in Ref. 3 were performed. A one-dimensional approximation of the critical cross section was developed through the full height of embankment. Corresponding acceleration time histories were computed at the crest and mid height of dam. Displacements were computed by performing double integration of the portions of the accelograms that exceeded yield acceleration values. Separate analyses were performed for both the positive and negative components of the acceleration time histories. The results of these analyses are shown in Figure 3. As shown, the computed displacements are substantially different depending upon whether the positive (smaller) or negative (larger) acceleration component was used for double integration. Close examination of the acceleration pulses for the design earthquake accelerogram clearly show that the differences in computed displacements is primarily due to the asymmetry of the fling pulses. Similar double integration calculations for design earthquakes from another major fault about 25 kilometers from the dam show only small differences between the positive and negative pulses.

REMEDIAL DESIGN

The remedial design involved the removal of the weak clay layer in the old slide area and replacement by granular drain rock and stronger embankment materials. The resulting buttressing of the downstream embankment reduced the calculated pseudostatic displacements for the design earthquake to less than 25 millimeters. Figure 4 shows the recommended cross section for the remedial design.

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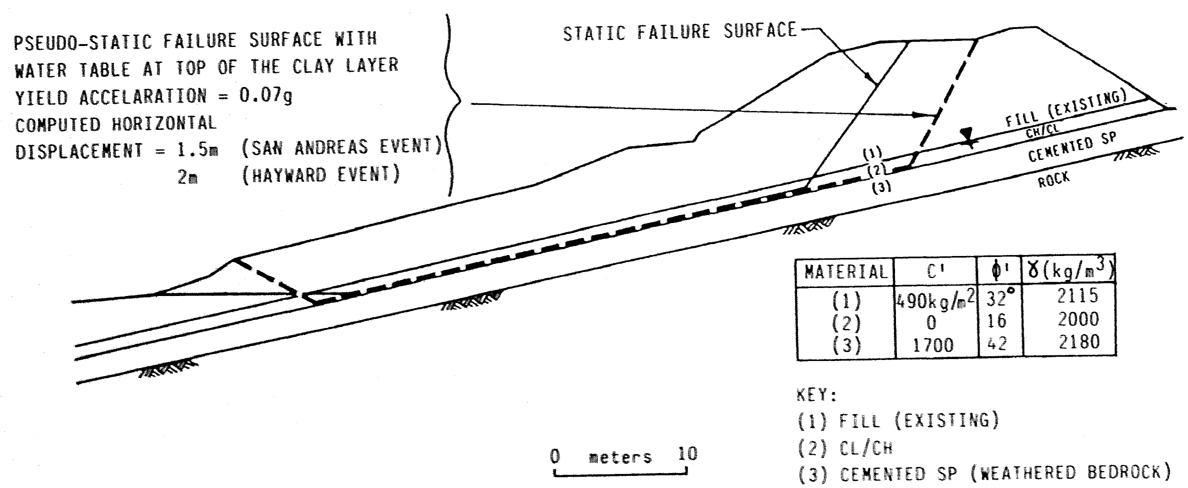


WATER TABLE	F.S.
AT TOP OF CL/CH LAYER	1.30
1.5m ABOVE CL/CH LAYER	1.15
3m ABOVE CL/CH LAYER	1.06

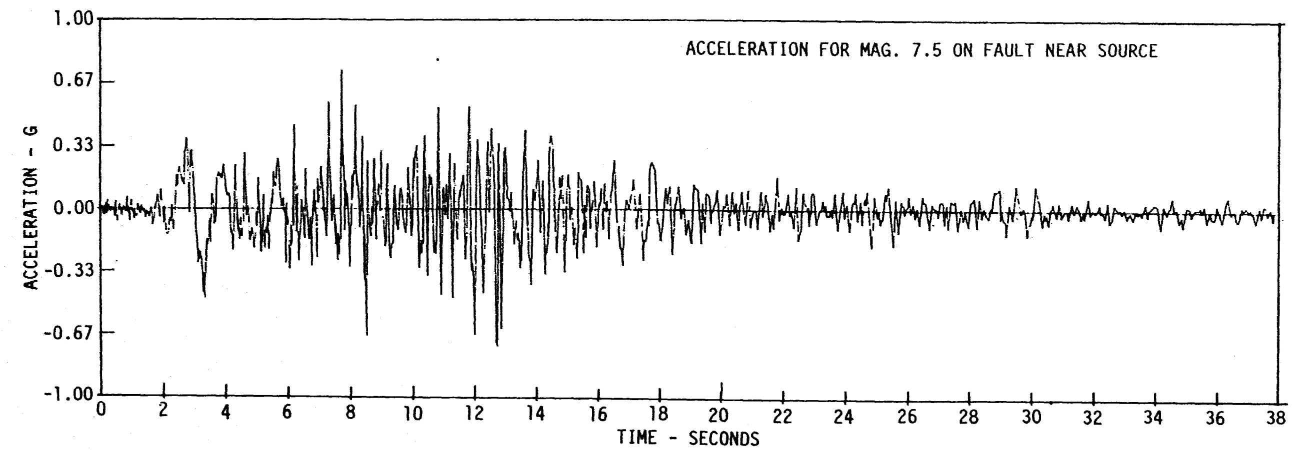
MATERIAL	C'	ϕ'	$\gamma(kg/m^3)$
(1)	$490 kg/m^2$	32°	2115
(2)	0	16	2000
(3)	1700	42	2180

KEY:
(1) FILL (EXISTING)
(2) CL/CH
(3) CEMENTED SP (WEATHERED BEDROCK)

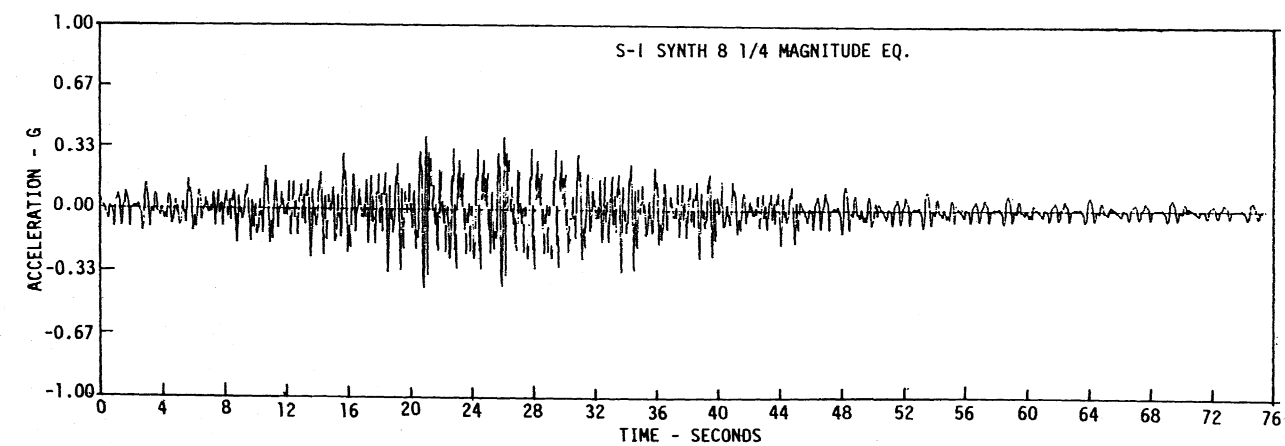
Figure 1

STATIC STABILITY ANALYSES

1981 CROSS SECTION



DESIGN EARTHQUAKE FOR NEAR FIELD EVENT



DESIGN EARTHQUAKE FOR MAJOR FAULT 25 km DISTANT

Figure 2

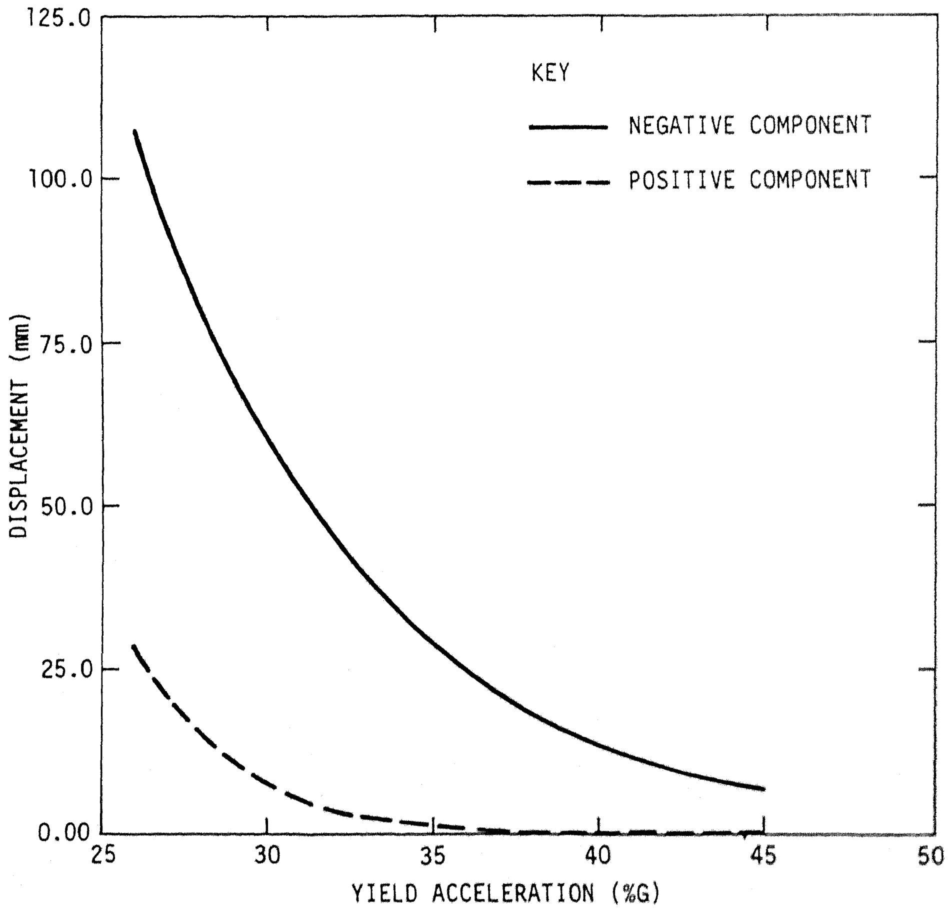


Figure 3

YIELD ACCELERATION VS DISPLACEMENT

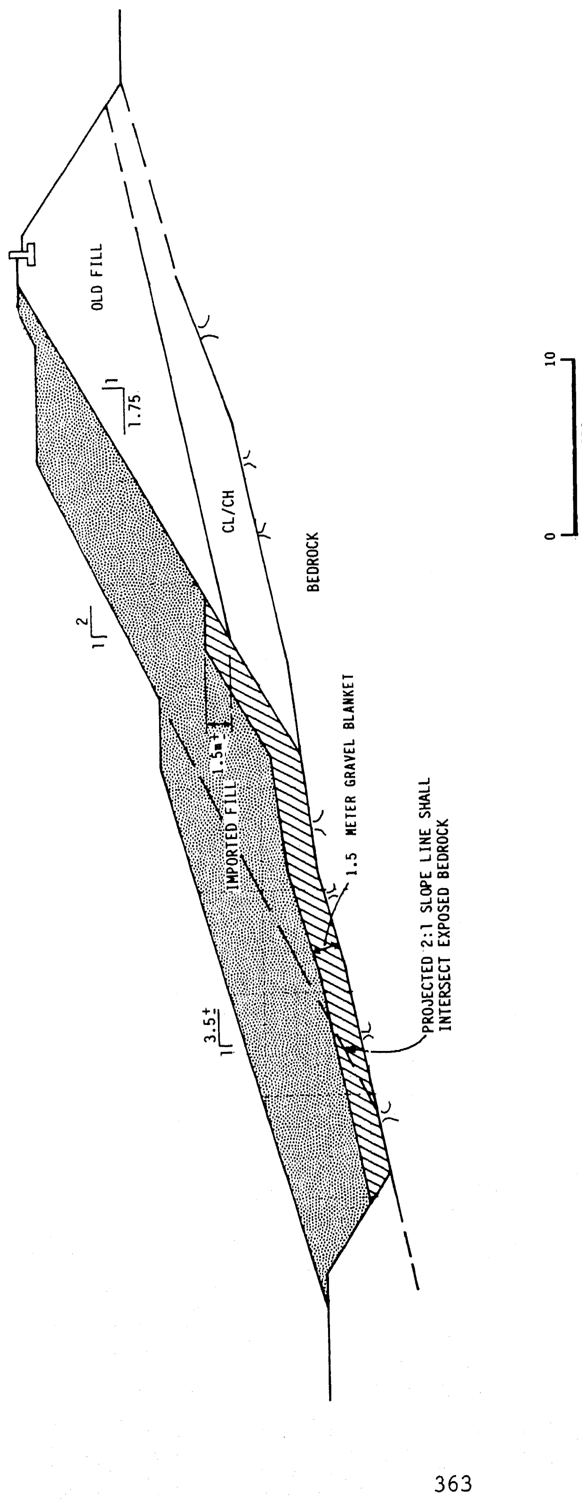


Figure 4

REMEDIAL CONSTRUCTION