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PERFORMANCE OF A TAILINGS DAM IN A HIGHLY SEISMIC ENVIRONMENT

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OVERVIEW

The large levels of mining production worldwide result in vast amounts of residues leading to the expansion of existing and construction of new tailings storage facilities (TSFs). As site availability is limited due to environmental restrictions, TSFs tend to generate substantial footprints with large storage volumes and, in some cases, heights of over 200 m, often raising stability concerns. This research project investigates the static and seismic response of tailings dams through Finite Element (FE) modelling, using the Imperial College Finite Element Program (ICFEP) (Potts & Zdravković, 1999). The numerical results are verified against instrumented recorded data at the El Torito TSF in Chile (Figure 1), with further study focusing in particular on the susceptibility to liquefaction, as the most disastrous mode of failure of such facilities.

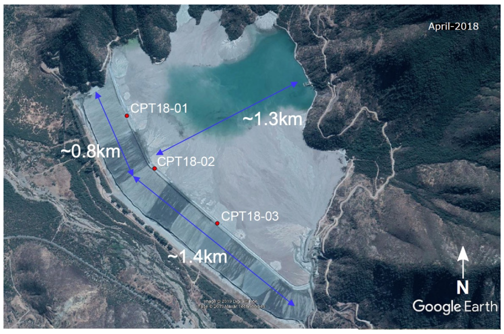

Figure 1: Plan view of El Torito tailings dam.

CONSTITUTIVE MODELS

ICFEP is equipped with a bounding surface plasticity model (BSPM, Taborda et al., 2014), and with a cyclic non-linear (CNL) model in the form of the Imperial College Generalised Small-Strain Stiffness model (ICG3S, Taborda et al., 2016), which are selected as suitable for modelling of tailings materials under static and dynamic loadings. The former is an advanced model, capable of reproducing the soil behaviour under monotonic and cyclic loading to liquefaction, while the latter is a simpler model capable of reproduces essential aspects energy dissipation through soil hysteresis.

The BSPM has been calibrated for El Torito tailings sand material, while both CNL and BSPM have been examined for the simulation of slimes. The geotechnical characterisation of tailings sand is described in Solans et al. (2019) and an indication of good calibration results is shown in Figure 2 for monotonic undrained triaxial tests.

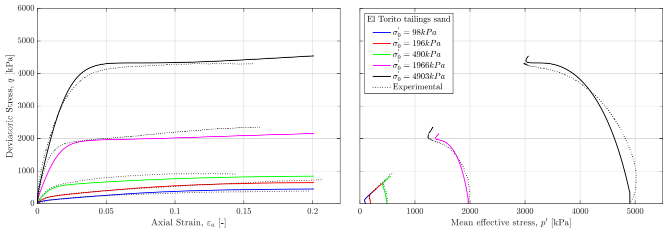

Figure 2: BSPM calibration results for undrained triaxial tests

NUMERICAL MODEL

A 2D FE plane strain numerical model of the El Torito TSF was developed in ICFEP (Figure 3). The model simulates a downstream construction of this TSF over a period of 22 years, to reproduce the "on-going" nature of the problem in a hydro-mechanically (HM) coupled analysis. Figure 3 indicates the constitutive models used for each of the TSF materials.

The Illapel 2015 earthquake was simulated post construction using the HM coupled dynamic formulation in time domain in ICFEP and generalised-a time integration scheme (Kontoe et al., 2008)

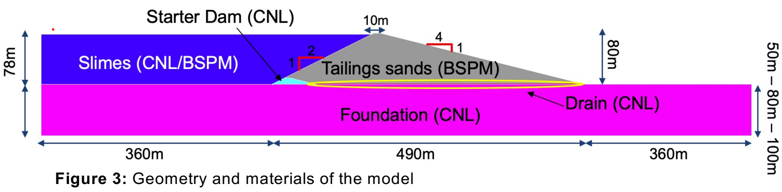

Figure 3: Geometry and materials of the model

RESULTS OF THE ANALYSES

Three CPTu results were available at the crest of the dam (Figure 1), and the relevant SBT chart is shown Figure 4 (left), indicating a threshold curve which suggests that part of the dam is susceptible to liquefaction. Figure 4 (right) also shows the good agreement between CPT-interpreted state parameter, Ψ, profile and that developed during the simulated dam construction.

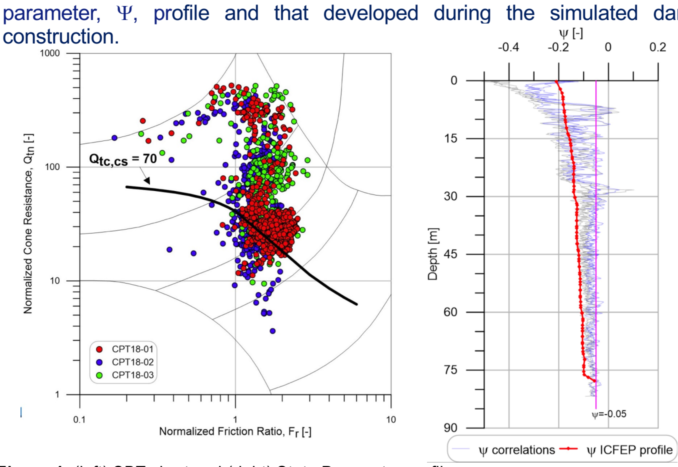

Figure 4: (left) SBT chart and (right) State Parameter profile

The Illapel earthquake record applied in the dynamic analysis of the El Torito TSF is shown in Figure 5. Some representative results from this part of the analysis are shown in Figure 6, as response spectral acceleration (PSA), and compared with the available recorded data on the dam. The comparison is very satisfactory in a wide range of periods / frequencies, indicating that the developed numerical model is robust and accurate.

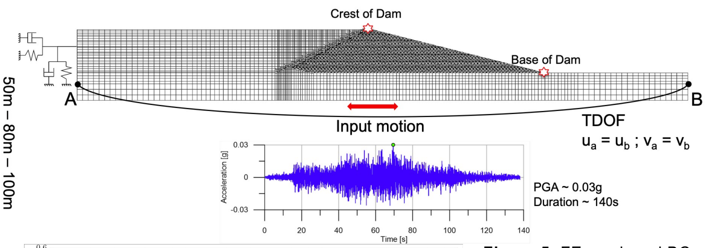

Figure 5: FE mesh and BCs employed in dynamic analysis

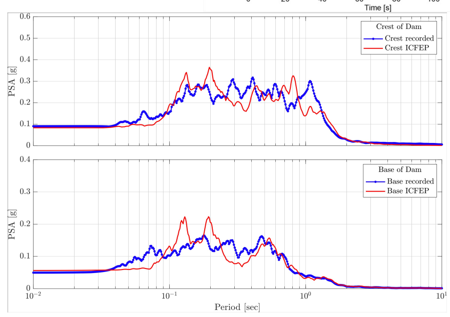

Figure 6: PSA results for recorded and simulated data

REFERENCES

Kontoe, S., Zdravković, L., & Potts, D. M. (2008), An assessment of time integration schemes for dynamic geotechnical problems. Computers and Geotechnics, 35(2), 253–264.

Potts, D. M. and Zdravković, L. (1999), Finite element analysis in geotechnical engineering. Theory, Thomas Telford.

Solans, D., Kontoe, S., & Zdravković, L. (2019). Monotonic and Cyclic Response of Tailings Sands. In 2019 SECED Conference. Earthquake risk and engineering towards a resilient world (pp. 1–10). Greenwich, London.

Taborda, D. M. G., Zdravković, L., Kontoe, S. and Potts, D. M. (2014), 'Computational study on the modification of a bounding surface plasticity model for sands', Computers and Geotechnics 59, 145–160.

Taborda, D. M. G., Potts, D. M. and Zdravković, L. (2016), 'On the assessment of energy dissipation through hysteresis in finite element analysis', Computers and Geotechnics 71, 180-194.

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