

INTERNATIONAL WORKSHOP

ON SEISMIC STABILITY OF TAILING DAMS

Panel Discussion: Research Needs

Panel members: Prof. Idriss, Dr. Castro, Prof. Anandarajah, and Dr. Moriwaki
Chaired by: Prof Elgamal

Prof. Anadarajah

Geotechnical engineering is complicated. Tailing dams are very complex: soft material, liquefiable, inhomogeneous, seismic loading, 3D analysis

From an analysis point of view:

Failure

1. Simplified approach, limit equilibrium
2. Sophisticated approach

Deformation

1. NM sliding block
2. Finite element: Difficult to handle large displacements such as runoff

There have been some progress in

1. Constitutive model
2. Calibration
3. Numerical procedures
4. Verification

Unique requirements:

1. Identify the material to develop constitutive models, especially for silt: lab characterization and tests must be done to understand the soil behavior and the constitutive models for gravels
2. Validation of the procedure: more centrifuge tests, back analysis of failure
3. More education in geo-mechanics to understand computational mechanics

Dr. Moriwack

Five topics:

1. Residual strength of tailings deposits
2. Dynamic response and deformation analysis

3. Effectiveness of dewatering on phereatic levels and residual strength
4. Near source ground motions
5. Overall risk analysis

1. Residual shear strength:
How to quantify the effects of

- Confining pressures
- Fine content/clay content
- Water content
- Rate dependency
- Interbeddedness
- Degree of saturation
- Age
- Chemicals

How to evaluate (what are the standards):

- Lab testing
- In-situ testing

2. Dynamic response and deformation analysis

- Centerline versus downstream and in-between
- Simplified soil models
- User friendly and short computation time for extensive parametric analysis
- Spatial variation and time variation
- Nature of material geometry
- Stress versus strain: how much deformation
- Simplified analysis methods

3. Effectiveness of de-watering on phreatic surface and residual strength

- Effects of embankment
- Effects of under drain
- Effectiveness of soil formations
- Residual shear strength of unsaturated deposits

4. Near source ground motions

- Source directivity effects
- Shaking level versus duration
- Probabilistic versus deterministic
- Time history

- Effect of spectral shape
 - Number of time histories
 - Time histories of vertical motions
5. Overall risk evaluation (production/operation dominating)
- Seismic considerations
 - Geotechnical considerations
 - Construction considerations
 - Environmental considerations
 - Other technical considerations
 - Non-technical considerations
 - Easily understood by stake-holders

Dr. Castro

1. Characterization of tailings dams
2. Key properties of tailings dams
3. Numerical analysis (validation)
 - 1) History of construction of dams
 - CPT is good for testing fine refuse
 - Freezing-defrost changes water content and can cause softening
 - 2) Piezometer measurements
 - CPT has to be complimented by some other tests
 - Undrained strength from tip resistance
 - Field test sites: may need to use boats to go to sites in the ponds to do tests
 - 3) Undrained strength of tailings
 - Fixed piston sample
 - Osterberg sample (no actuating rod, stroke of push can be measured, good in soft materials)
 - Vane test (undrained test)
 - Fast vane test—peak undrained strength: vane test in field is done as quickly as possible

$$S_u = (q_p - \sigma_v)/N_k$$

- How to evaluate site specific N_k

- May have different materials at different depth, due to different ores being mined

3) Validation of numerical procedure (important)

- Not much chance in the field
- Idealized situation in lab may not be enough
- Nonlinear finite element analysis
- Check the typical stress- strain behavior
- Shape of the curve gives the best estimate
- Maximum shear strength, maximum acceleration, check whether it is a reasonable number
- Look final configuration, whether it is stable, whether it makes sense

Prof. Idriss

1. Ground motion issue (eastern part of USA)
2. Soil plasticity on cyclic resistance ratio
 - Examine the work in detail
 - Effect of fines on CRR

Dr. Kelvin Wu

1. In tailings, for coarse refuse, how wide a gradation is there in field variations?
2. In the west, in tailings dam for copper and gold, no seepage is allowed. The structure is not permeable; what impact do these factors have on stability? Has there been research on the long term effects on the stability of the dams?
3. Can ground motion be caused by large explosions in open pit mining?

Dr. Castro

1. Degradation of coarse refuse. If the refuse is well compacted, degradation is not a major concern. Geophysical tests can be done to determine the refuse's degradation with time.
2. Drainage helps the effective stress but increases environmental concerns.
3. In a spillway adjustment of a hydraulic fill dam, a small blast was used. Instrument in the dam recorded 10^{-2} % strain in the soil. This kind of operation needs to be done with extreme care. One can start with a small blast, gradually increase to find the upper limit.

Prof. Idriss

- There was one failure caused by blast (out of about approximately 80 failures, the majority of them caused by rain)

- Blasting increases the density of soils.
- Previous small shaking improves the stability of a dam.
- Existing coarse dams were not well compacted. Now there is better control.
- Control of fine content in the coarse dam can reduce water in the dam.
- Blast loading drops quickly and contains mainly high frequencies. Not a big problem.

Participant

There is a lot of variability in a structure. How can one take that into account?

Dr. Castro

Ideally one needs to try to know everything. Practically, try the best you can to investigate the soils in full depth. There are also variations within a site.

Prof. Anandarajah

These are new materials that need more fundamental studies such as mineralogy. There is no liquefaction evidence in lab tests. We need to characterize the materials in the field.

Prof. Idriss

- All cases of previous failure should be studied.
- One suggestion is to instrument some existing sites for earthquake response.
- We need to develop strategic ways to instrument some existing dams.

Participant

How should one characterize soil for the design of existing dams? How can we use the data for design purposes?

Dr. Castro

Design stage by stage, testing for each stage, make assumptions, and check them as construction goes.

Dr. Wu

Designers should be responsible to convey to stake holders what is important.

Prof. Idriss

Regulations should provide incentives for designers and owners. Take a strategic view before designing a tailings dam.

Prof. Saada

There is significant variability in material properties for tailings. We need to take new approaches that go beyond old concepts such as residual strength. We need to get out of the box of classic soil mechanics. Make soil mechanics advance beyond what we know now.

Participant

There are only a few types of instrumentation such as piezometers that are used in the field. We need to have outside agencies to step in to instrument some sites.

Prof. Idriss

Try to show incentives to property owners that instrumentation will benefit them.

Dr. Castro

Without information recorded by in-situ instrumentation, we cannot improve in terms of money saving designs. Instrumentation helps us understand the performance of tailings dams.

Participant

In design, there is the issue of finite element versus finite difference versus simple method for design/ practical method. Engineers are not likely to use FE. Safety factors are used for that purpose. Efforts are going back to simple calculations. Engineers need guidelines and procedures eventually, but research is needed before those guidelines can be set.