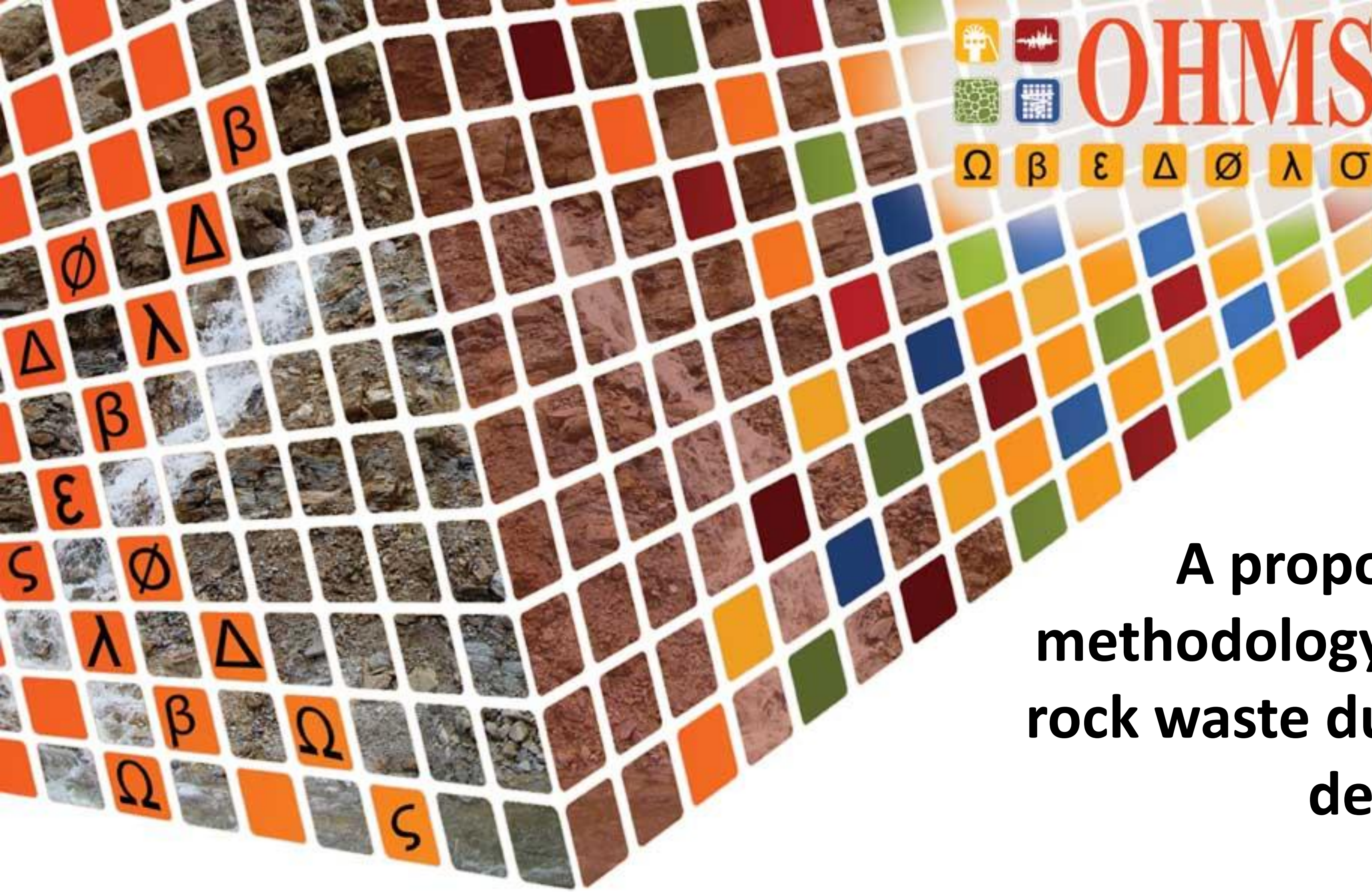

A proposed methodology for rock waste dump design

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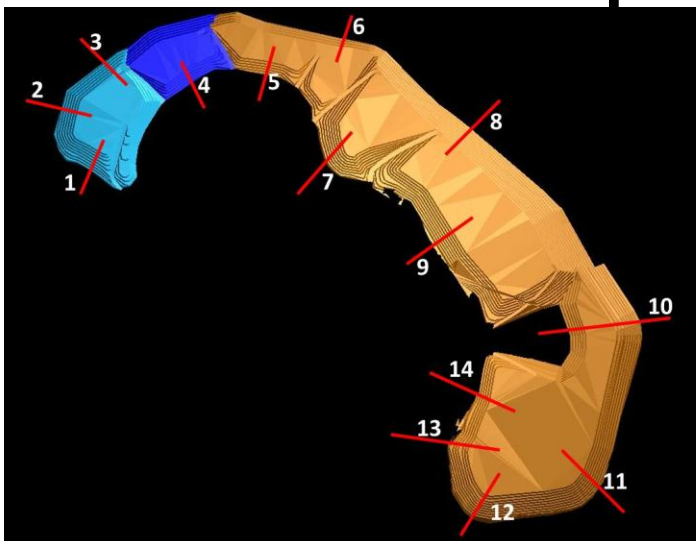
Problem statement

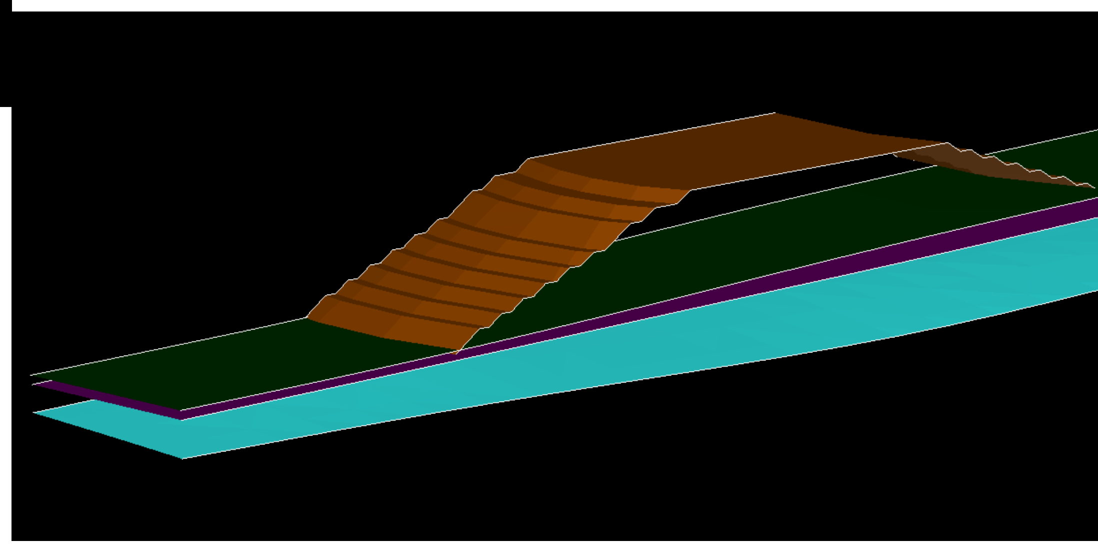
- Waste rock dumps are unavoidable when establishing an open pit operation.
- Limited footprint due to environmental and practical constraints.
- Therefore higher dumps are to be constructed.
- A sound waste rock dump design process becomes important

Mine planning for dumps



Plan view:
Mine planning for waste dump geometry

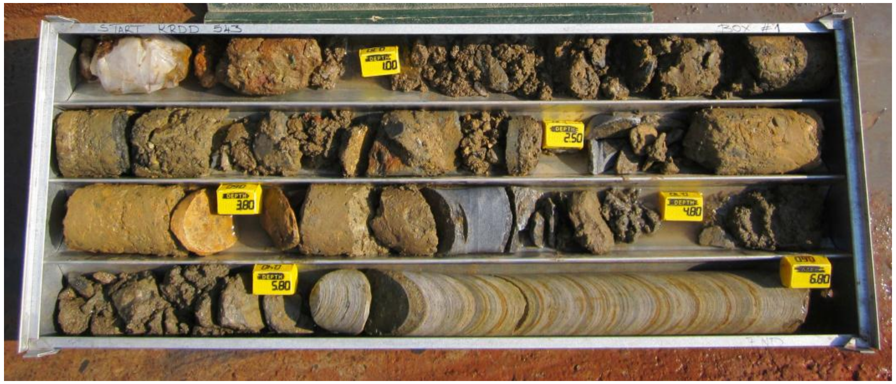
Isometric view:
Section 10



Site familiarization

Existing information, data collection, lab testing

- Review of existing data:
  - Soil and rock tests for dams
  - Boreholes (core logs and photos)
  - Terrain models of topography and dump design
- Data collection:
  - Rock samples
  - Soil samples
  - In-situ density (1731+-69 kg/m^3)
- Rock lab tests:
  - Base friction angles (saw-cut rock surfaces)
  - Direct shear test on open joints
- Soil lab tests (shear box tests and Consolidated un-drained Tri-axial):
  - Friction angle and cohesion (28+-1.5 deg, 10+-6 KPa)
  - Saturation (58+-14%)
  - Dry density (1732+-111 kg/m^3)
  - Void ratio (0.6+-0.1)
  - Permeability (1.6e-06 +-1.4-e6)

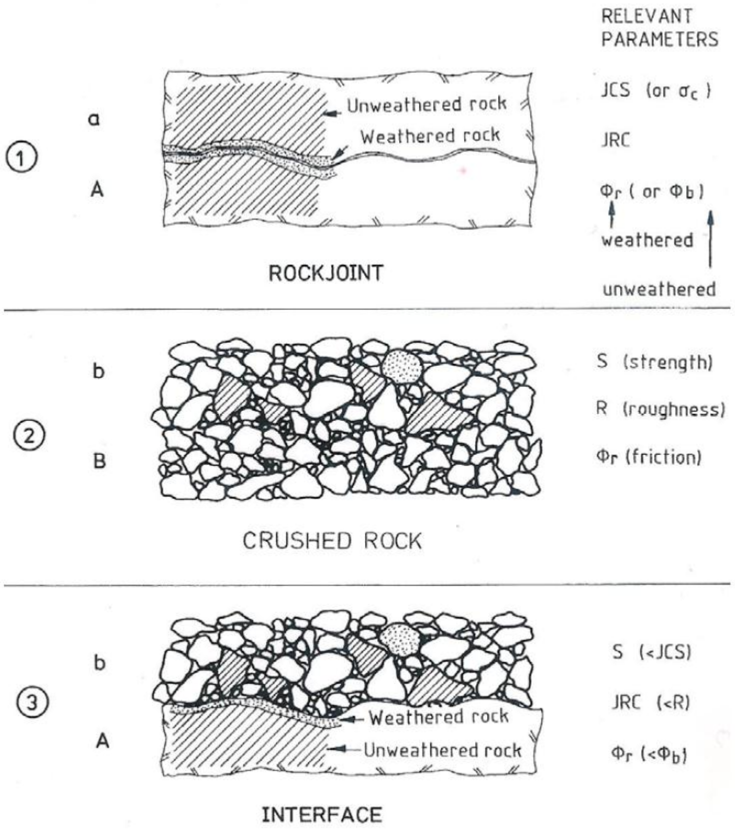


Proposed methodology

- Proposal to the audience: A waste dump is like a pit slope –established methodologies for design
- Foundation comprise typically a weathered zone followed by a transition zone and fresh rock interfaces at depth
- Some differences:
  - Waste material is non-homogenous. Strength of material varies
  - Type of materials (soils, rock) and placement can play a role in stability. Therefore densities/ rockfill strength highly variable
  - Ground water (rainy season + water table) ?

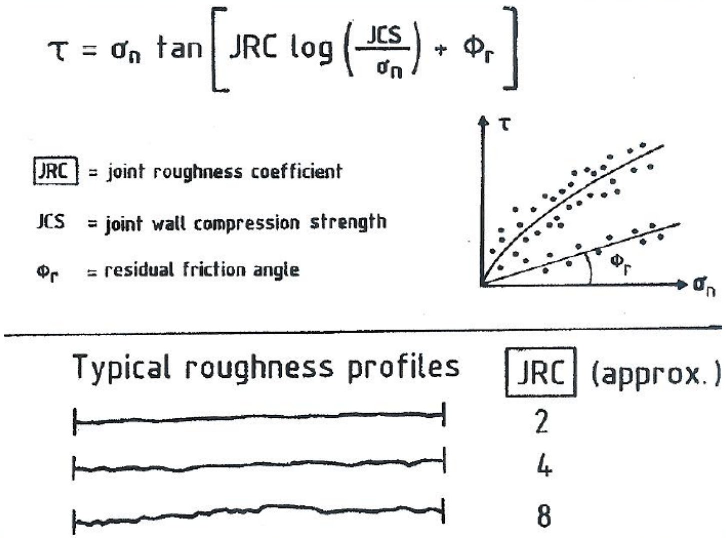
On the differences:

- How does one handle the non-homogenous and anisotropic materials?
- **A model is a simplification of reality…**
- Barton (2008):
  - At points of contact in rockfill (just like for example joint interfaces) contact stresses can develop.



On the differences:

- The geotechnical result is that dump fill material interfaces develop shear strengths. Barton found from large scale tilt and triaxial tests the envelopes are non-linear and stress-dependent. Just like discontinuities.
- The interfaces between the rockfill and/or rock foundations, can be dealt with as discontinuities in designs and simulations. Modelling codes allow the insertion of joint networks which may simulate the contact interfaces that interact in rockfill.
- In modelling codes the established joint shear strength estimation constitutive laws such as Barton-Brandis are available.



Model input parameters/geometry

- Existing information and lab results
- Construct strings files from boreholes for weathered, transition and fresh rock zones.
- Build DTM using our proprietary scripts and combos of terrain model software.

Modelling Programme

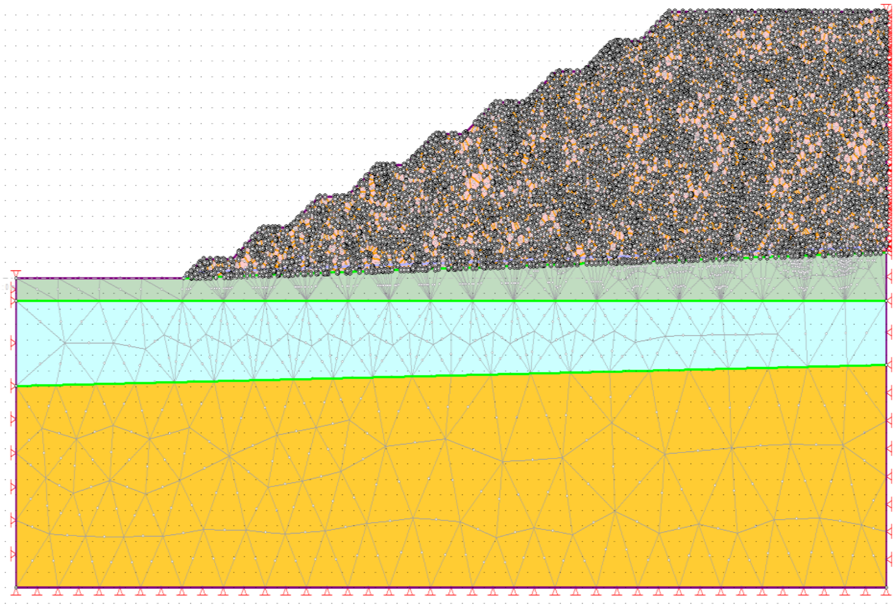
- Phase2D
- FE code
- Why?
  - Can reduce waste dump in sections -> plain strain condition valid.
  - Non-homogeneous materials (variability),
  - Constitutive laws for joints like Barton Brandis.
  - In elastic behaviour of waste rock material
  - SSR -> FOS ->POF
  - Joint networks to cater for the interfaces between dump material (like Voronoi type).

Modelling methodology

- For various slope heights, OSA's provided by the mine evaluate FOS, POF.
- Include the effect of perched water at base and crest
- Evaluate various combinations of rock dump materials compositions.
- Determine to what extend the dump composition has an influence on slope stability

Modelling methodology

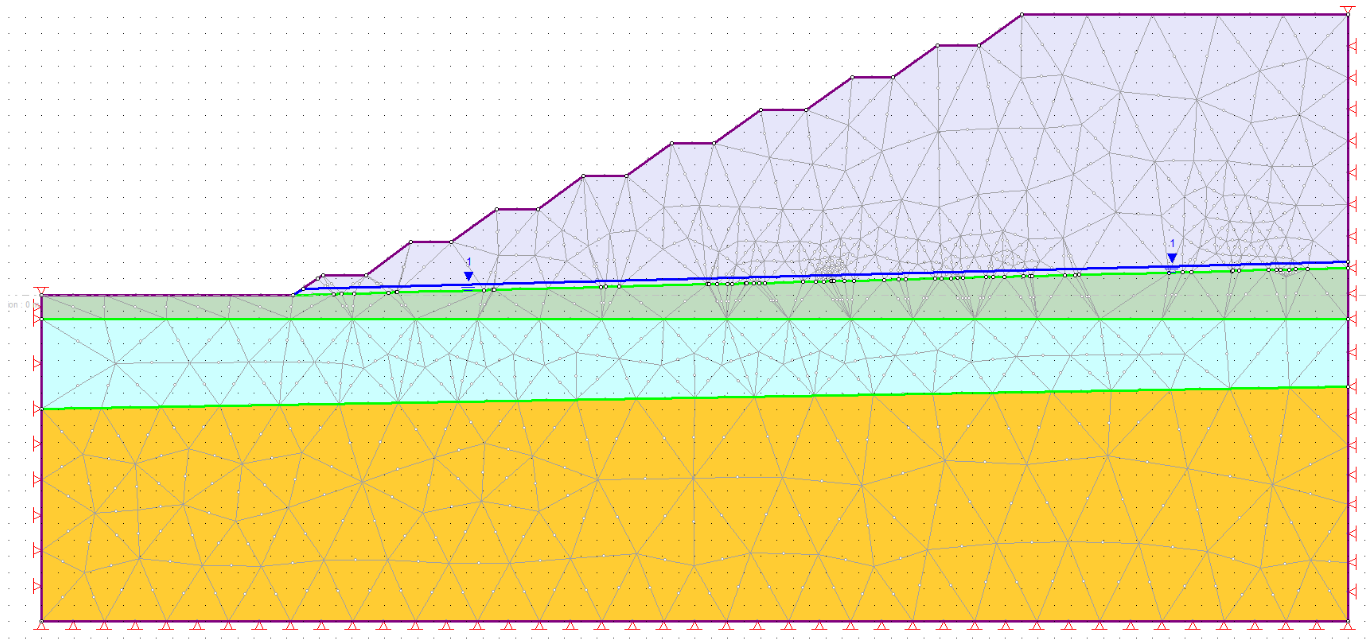
- Rock dump material only



	Height**	OSA	BFA
s12	124	23	35
s10	110	22	38
s11	96	22	37
s8	95	17	29
s9	94	14	21
s7	93	21	35
s1	86	20	37
s2	69	22	37
s13	75	20	34
s4	68	20	32
s3	64	17	28
s5	60	22	34
s14	49	20	33
s6	35	16	26

Modelling methodology

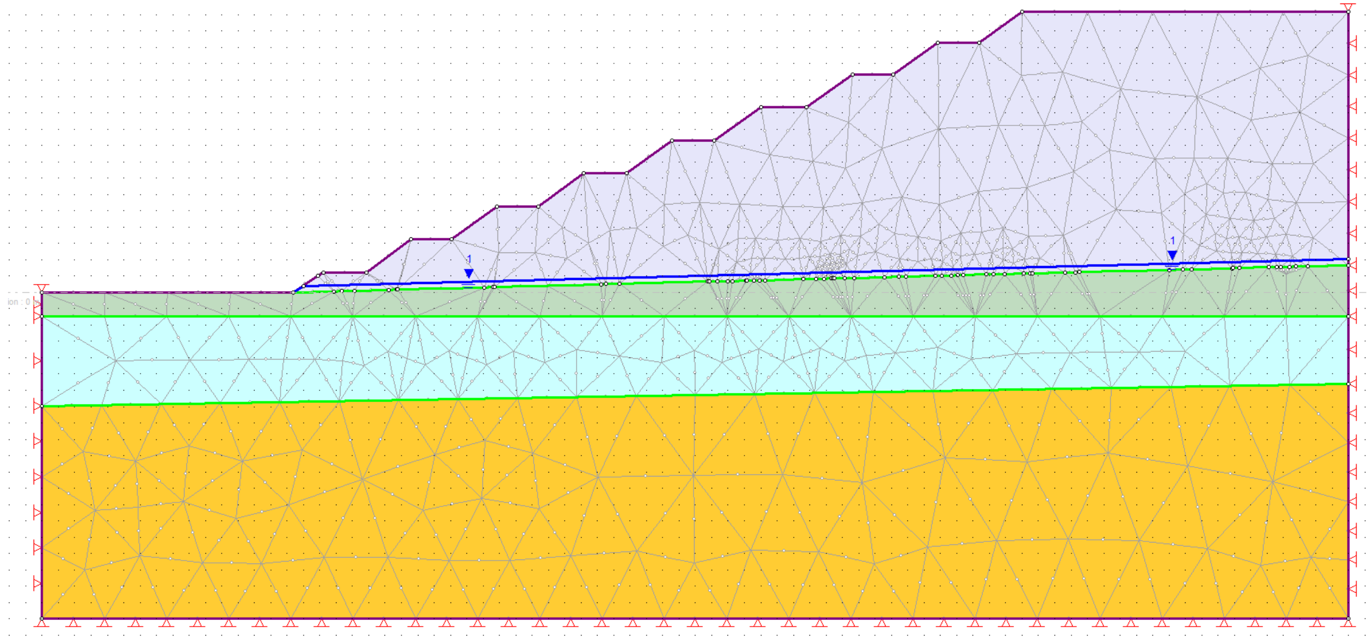
- Soil dump material only



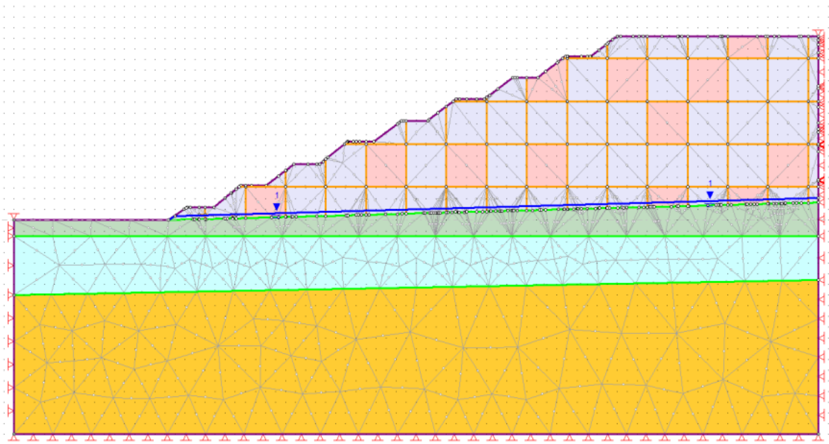
Rock Engineering, Geology, Seismology and Numerical Modelling based on science

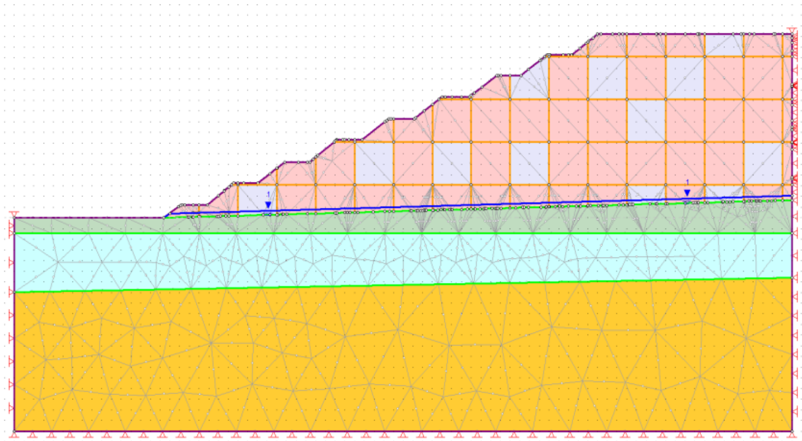
Modelling methodology

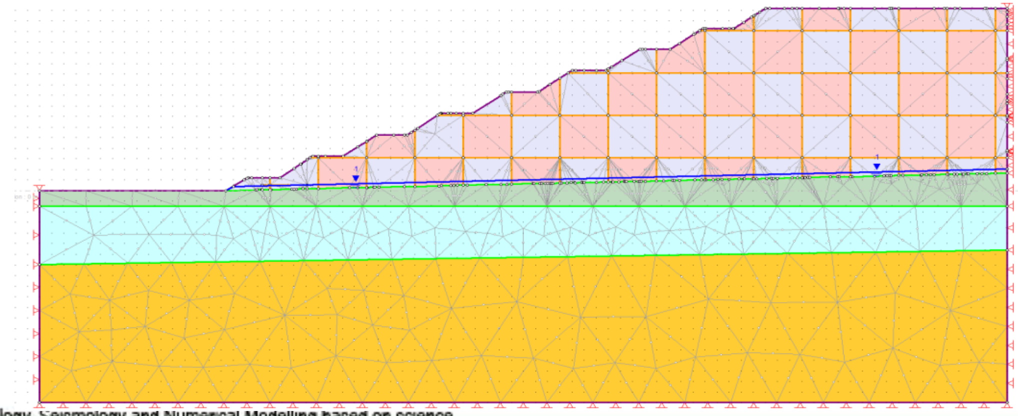
- Soil dump material only



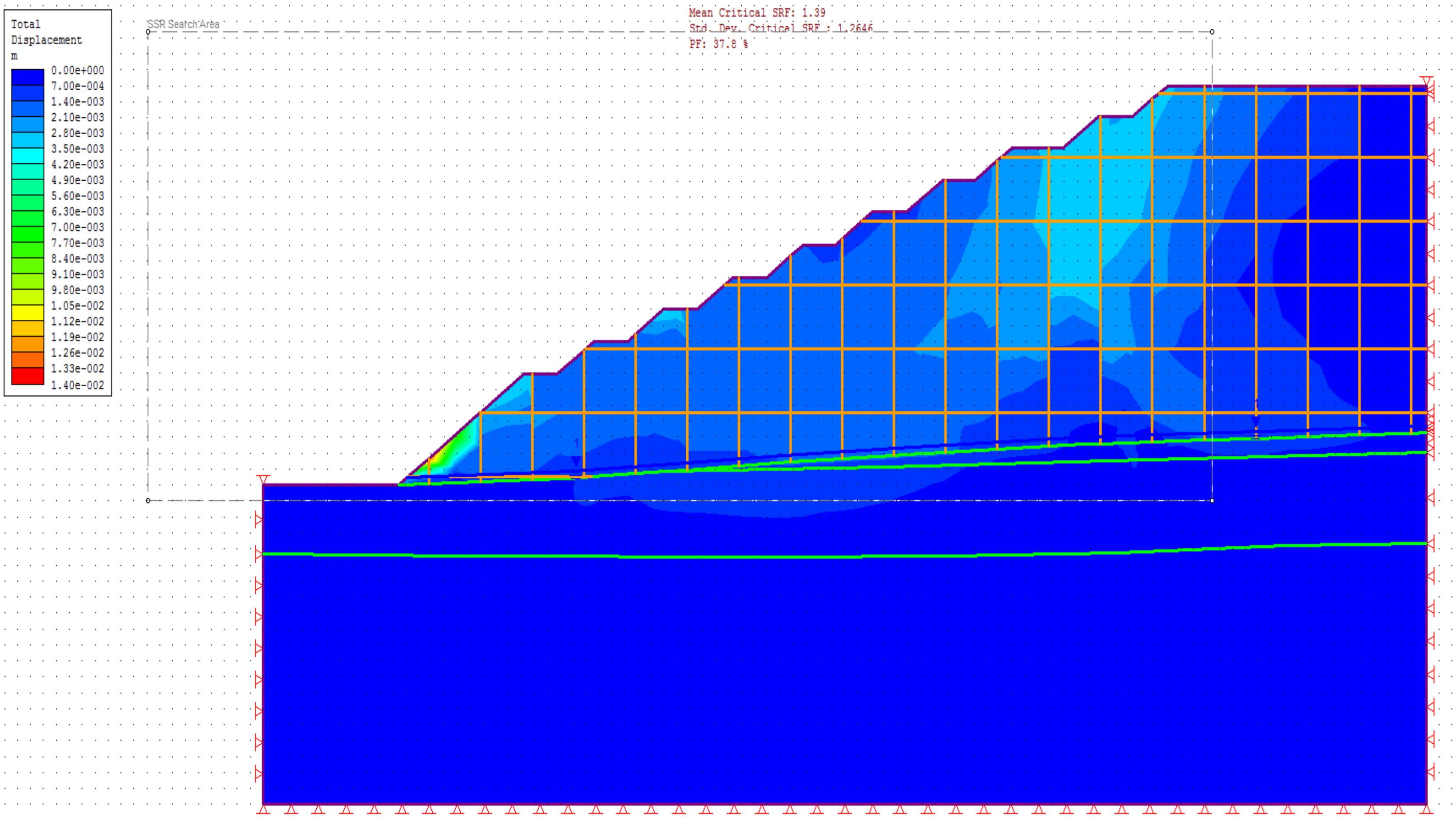
Other combinations of rock dump materials







Example results: Contours of total displacement for the critical SRF



Results

- The proposed waste dump designs are stable.
- Factors of Safety > 1.3
- Probabilities of failure < 10%
- Suggests optimization: that OSA can be steepened and heights increased.
- Regarded as acceptable for waste dump design.
- Addition of only 25% rock in the dump material increases FOS by 0.3 and lowers POF materially.
- Higher slopes, steeper OSA and BFA sections, lower factors of safety.
- Water accumulation at the base does not have an influence
- Water accumulation at the crest to be avoided and dumps to be constructed in layers to ensure compaction (optimal friction angles/strength of dump).
- Double benching increases POF locally, just like slopes

Conclusions

- Barton concluded his paper: “It is therefore extremely likely that rock dumps of different heights will have widely different factors of safety if formed with equal OSA”
- The results obtained with our method was aimed at design for a specific project and not research. So our results are probably not exhaustive to test against this notion. We did find though that the waste dump slopes behave in the model as expected from experience and the literature. Also, we did found that for slope heights of 96m, 110m and 124m (OSA =22 deg) that the factors of safety indeed vary significantly as 1.6, 1.48 and 1.15, respectively which is consistent with the Barton proposition.