Salt tailings

Geotechnical characterization of a complex material

Jelle van der Zon
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Background

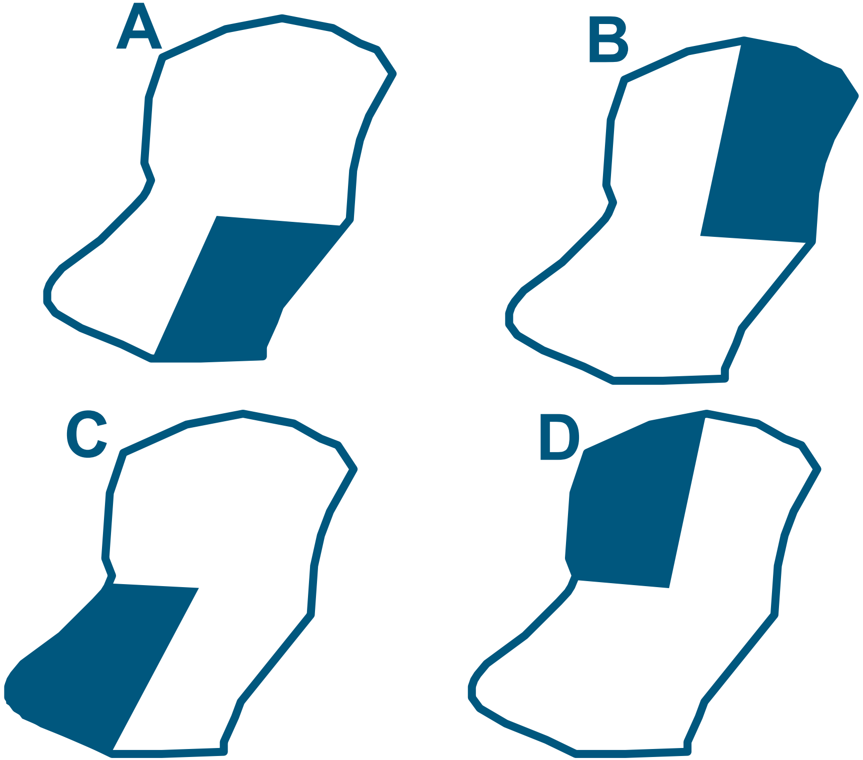
- Project (including large scale GI campaign) was performed for a client in potash industry in Jordan.

- Potash is a collection term for mined salt that contain potassium in water-soluble form. It is an important raw material for fertilizer production.
- The potash is not harvested in pure form, but as carnallite ($KCl.MgCl_2.6H_2O$) following evaporation and precipitation in salt ponds.

Background

- In refineries, the potassium is separated from the other salts.
- This generates a waste stream rich in regular NaCl salt. These salt tailings are of little value and disposed of in tailings areas.
- At the client's location, these salt tailings are hydraulically transported to the tailings area.

Process of disposal



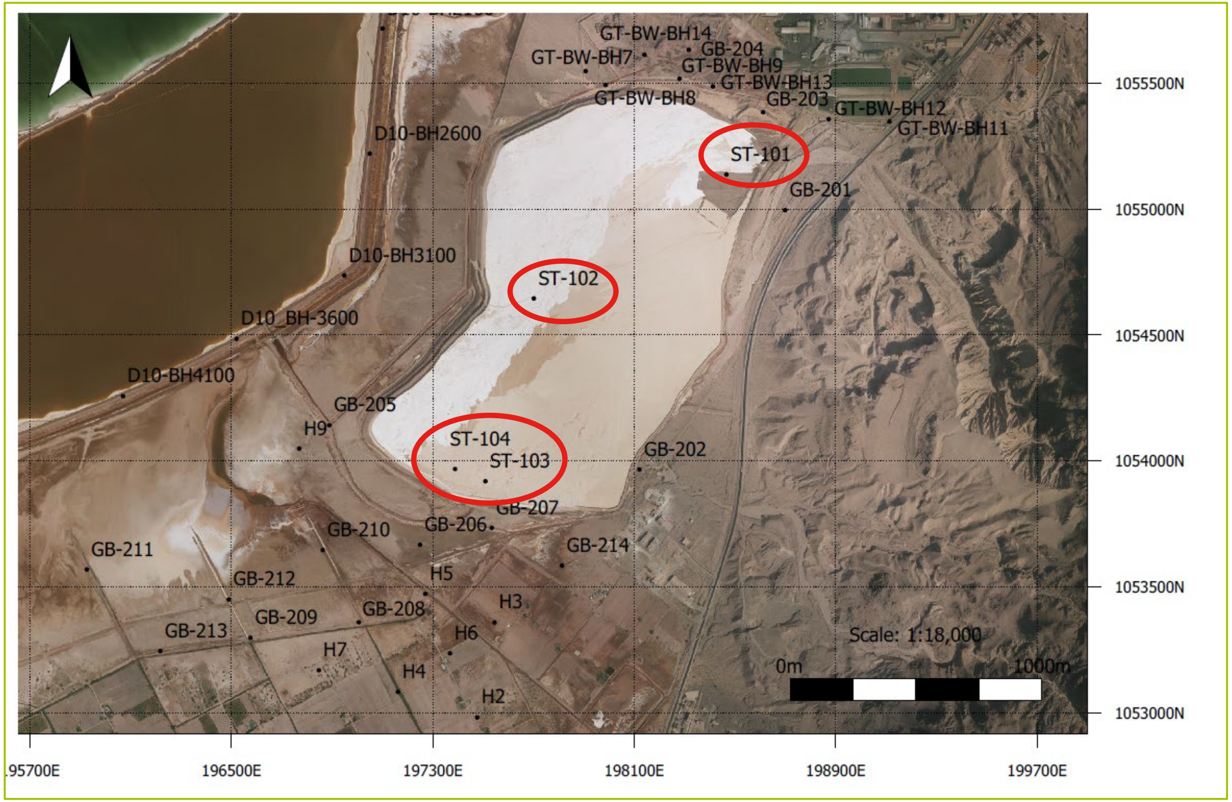
Raise ~0.5-1.0 m/year.
Drying and wetting cycles

The project

- As part of the ‘zero-liquid discharge’ policy of the client, a sealing of the tailings area had to be designed. The policy is aimed on reduction of spoiling still valuable materials and minimization of the environmental impact.

- A GI campaign was performed to better understand the carrying capacity and behaviour of the salt tailings.

Overview GI



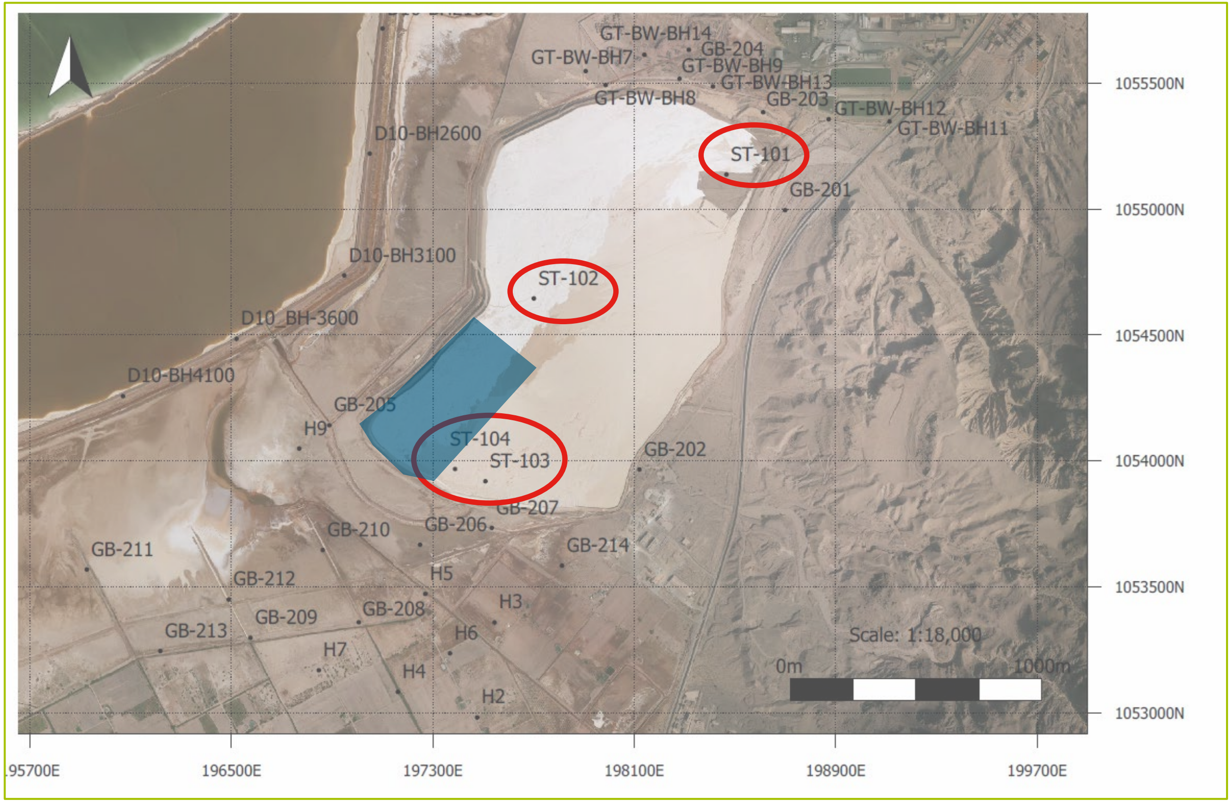
4 boreholes in the salt, rotary drilled (double core).

Air as flushing medium for three boreholes (permeability tests).

Brine used as flushing medium for one borehole (sampling for lab) (ST103)

Nothing is conventional when trying to characterise this material (soluble, friable, cementation)

Overview GI



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Overview GI (salt tailings)

- 4 boreholes
- 37 SPT tests
- 14 permeability tests

- 30 density tests
- 28 point load tests
- 2 UCS tests (30 were planned)

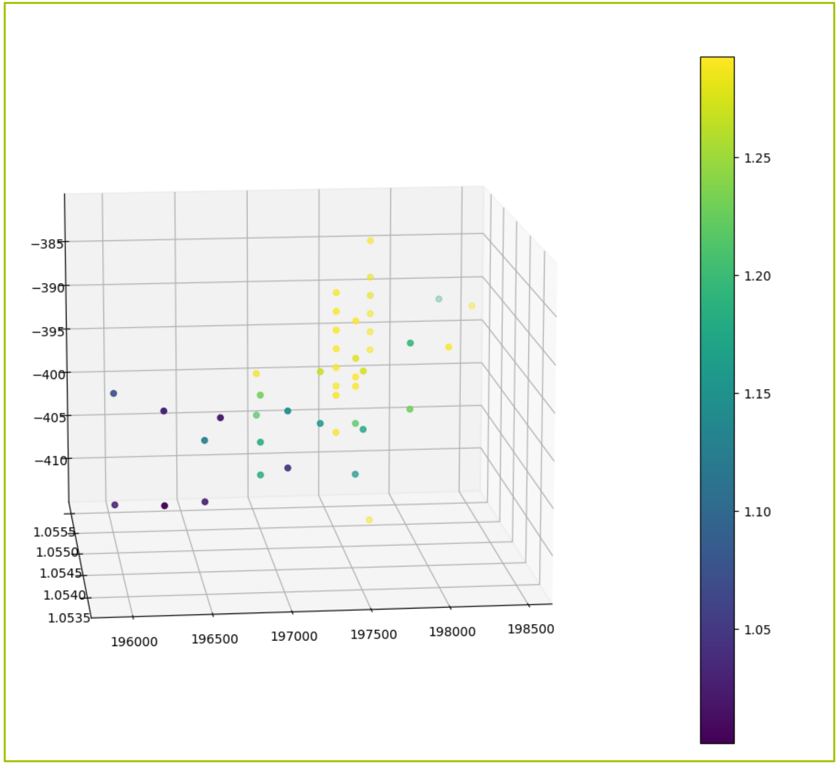
Results - Boreholes and in-situ testing

Fragmented disks of salt, or even pulverised material. Samples were highly disturbed during drilling (even when using double coring)

Mass strength of salt highly influenced by the presence of dust (brown salt).

Results - Monitoring brine density

- Brine density was monitored in all boreholes (also around the tailings area).
- Decreasing brine density with distance from the tailings mountain (mixing with freshwater aquifers).
- No clear information obtained from chemical composition analysis.



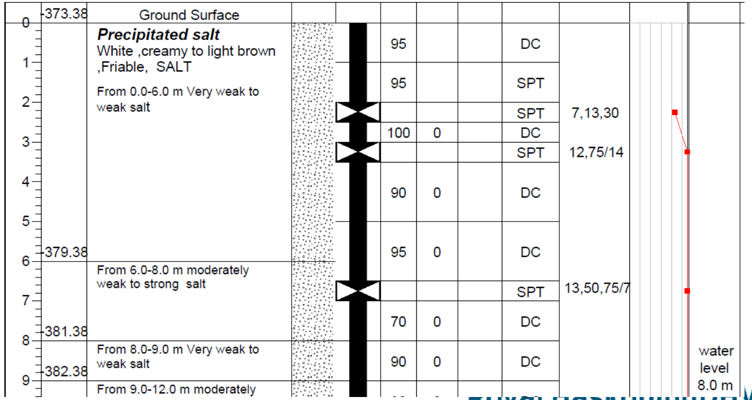
Results - Laboratory testing

- Only two UCS tests could be performed because samples were not of sufficient size.
- UCS tests done gave cohesive values of 450 to 700 kPa,but are not representative for the mass strength (only the best test samples survived drilling and coring).

- Other strength tests (e.g. Brazilian tensile test or bending tests) were not feasible as it needed cutting in the samples which was not desired (friable material).

- Testing programme was changed to point load testing (next best). Point load testing is an index method which provides with only an indirect measure of strength.

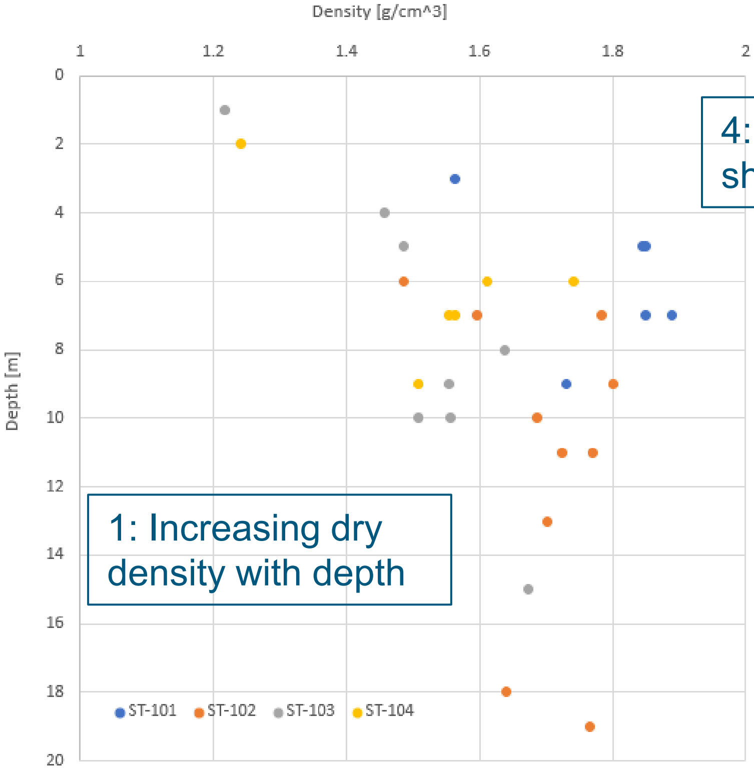
Behaviour of tailings – effect of depth



Salt tailings has little mass strength under no confining pressure (very low moisture contents (“dry”)).

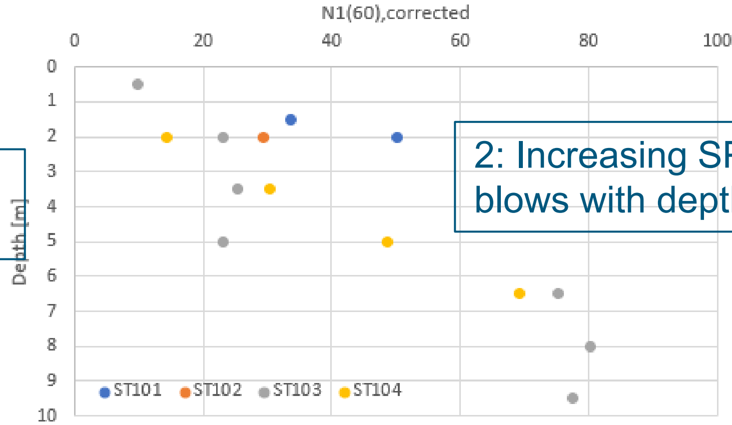
Completely opposite to salt crusts without confining pressure formed under precipitation but now above groundwater level.

Mass strength increases quickly with depth.

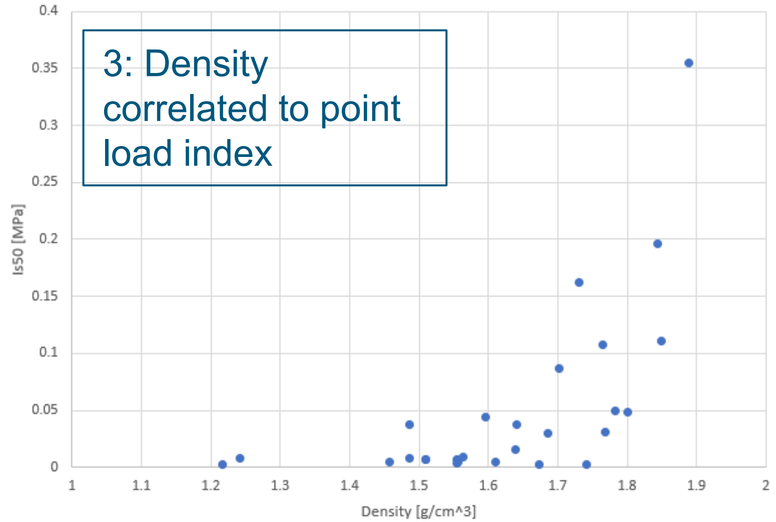


1: Increasing dry density with depth

4:High variability at shallow depth



2: Increasing SPT blows with depth



3: Density correlated to point load index

Behaviour of tailings – moisture content

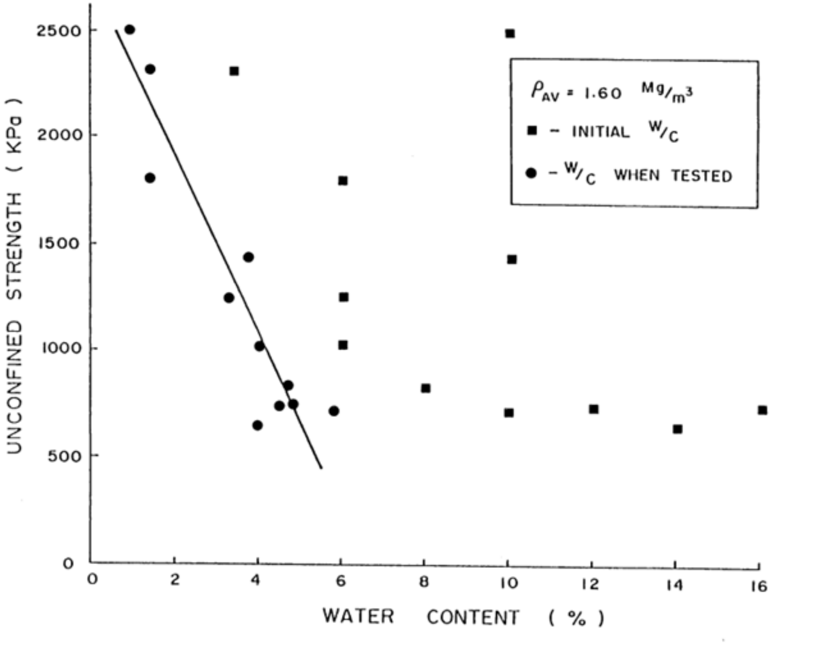
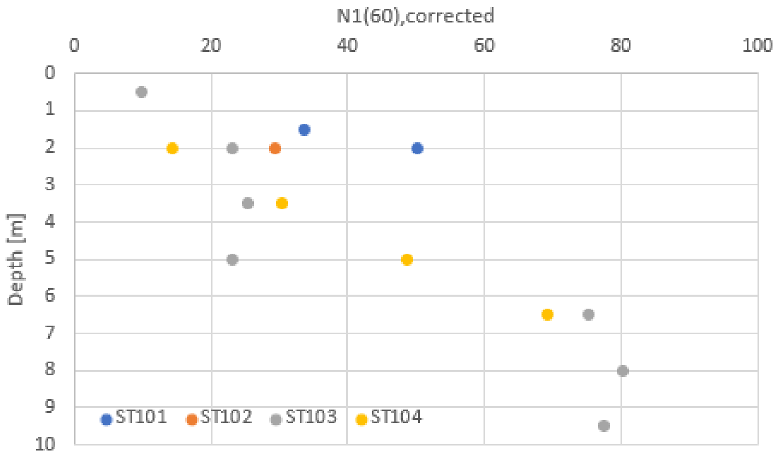
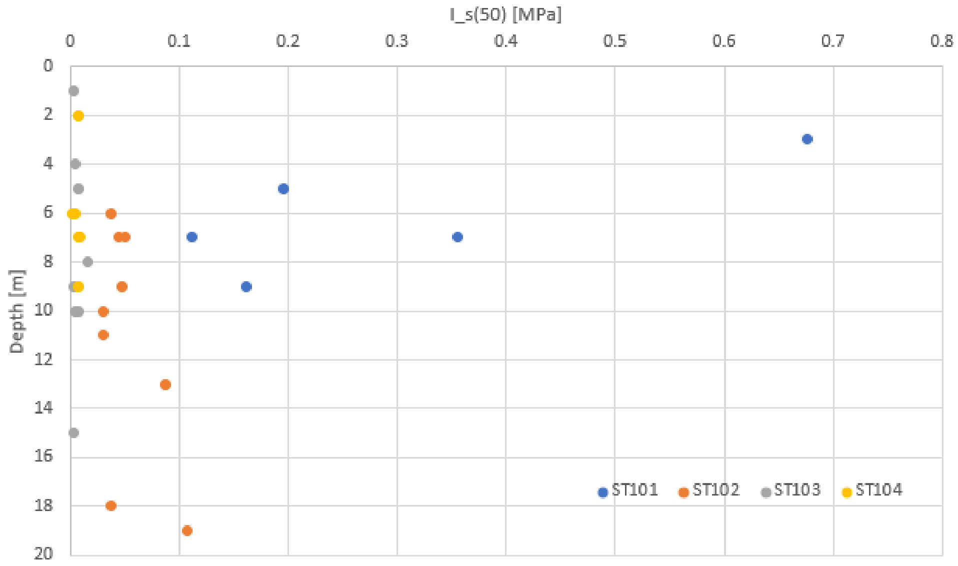


Figure 2.15 Unconfined Compressive Strength for Tailings Compacted with varying Water Contents (Pufahl et al., 1982)

Cohesive bond is broken by rewetting (even by saturated brine).
Wet salt tailings are very weak.

Behaviour of tailings – moisture content





Clear relation to the disposal strategy. Boreholes ST103 and ST104 have lower strength both in-situ and in the laboratory.

Geotechnical interpretation - conclusion

- Proces of increasing cohesion (cementation) are difficult to separate from high friction angle values in in-situ tests. Cohesive bonds arise from processes influenced by temperature, time and pressure.
- Cohesive bonds can be broken by rewetting as shown by the difference in strength between boreholes.
- Coring could not be done properly, little UCS tests could be performed. Point load index might provide indications of strength, but no proper database is available for salt (tailings). Tests were done to get an idea of the strength, but strength could not be verified due to a lack of decent samples.

Geotechnical characterization - conclusion

- Strength values are highly uncertain, but:
  - We know that the highest uncertainty and variability are in the top 5 meters
  - SPT values at depth are high and hence risks at depth are low.
  - GI provided enough information to get to a conservative parameterset that left enough room for engineering solutions.
  - Moisture content control is important in the engineering solution.

- In the future:
  - Retrieval of block samples
  - Other tests like bending shear tests or tensile tests
  - Testing anisotropy (deposition process)

- Much to discover still on this complex material

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