Tampere University

Research Centre
TERRA Geo Road Rail

The effect of water content on permanent deformations in railway structure

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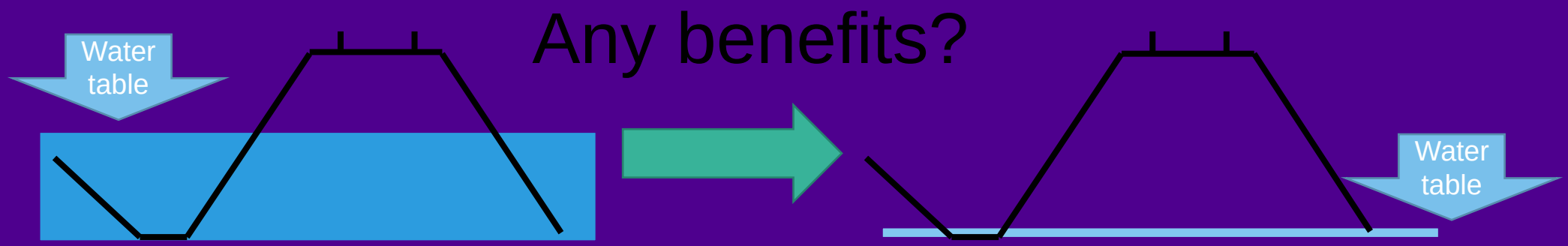
Why to research track drainage?

- Drainage is usually recognized as an important factor, but magnitudes of its impact doesn't exist.
- In the future, climate change is predicted to increase the annual precipitation and floods.
- In Finland, the FTA aims to faster and heavier traffic.
- The water content of sand materials has a great effect for its strength.
- The most important question is: To *what extent can unevenness problems be solved by improving drainage?*
- *Financial aspect: Improving drainage is a lot of cheaper than a massive overhauling of track substructure.*



Research methods

- FTIA started “drainage projects” with Tampere University in 2014
- Literature reviews about track drainage, soil moisture content, shear strength, frost heave issues etc.
- In-situ site inspections to study the current status of drainage and test new methods like dynamic cone penetrometer.
- In-situ measurements stations and monitoring.
- Analysis of track inspection vehicle results at monitoring sites.
- Computer based modeling of different drainage solutions.
- Laboratory test:
  - Sub-ballast materials from the track.
  - Normal soil laboratory tests like grading and capillarity.
  - Soil water retention curve testing.
  - Static triaxial testing.
  - Large scale cyclic triaxial loading tests.

In-situ measurement stations

- Three measurement stations were build up to study the effect of drainage and sub-ballast water content. Stations are located in southern Finland
- Measurement stations have sensors to measure water content of sub-ballast layer, rain gauge, water table level and track vertical deformations.
- The idea was to measure situation before and after drainage improvements
- Material samples were also collected from the sites.

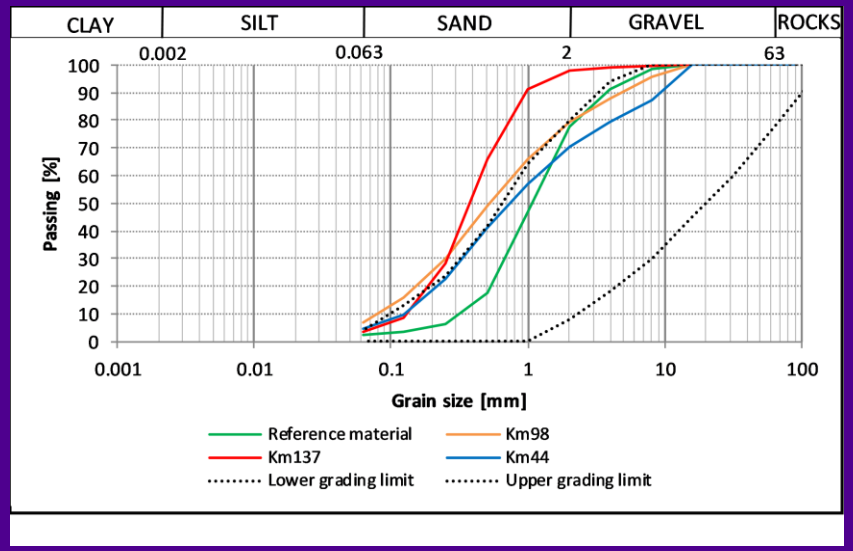
km44

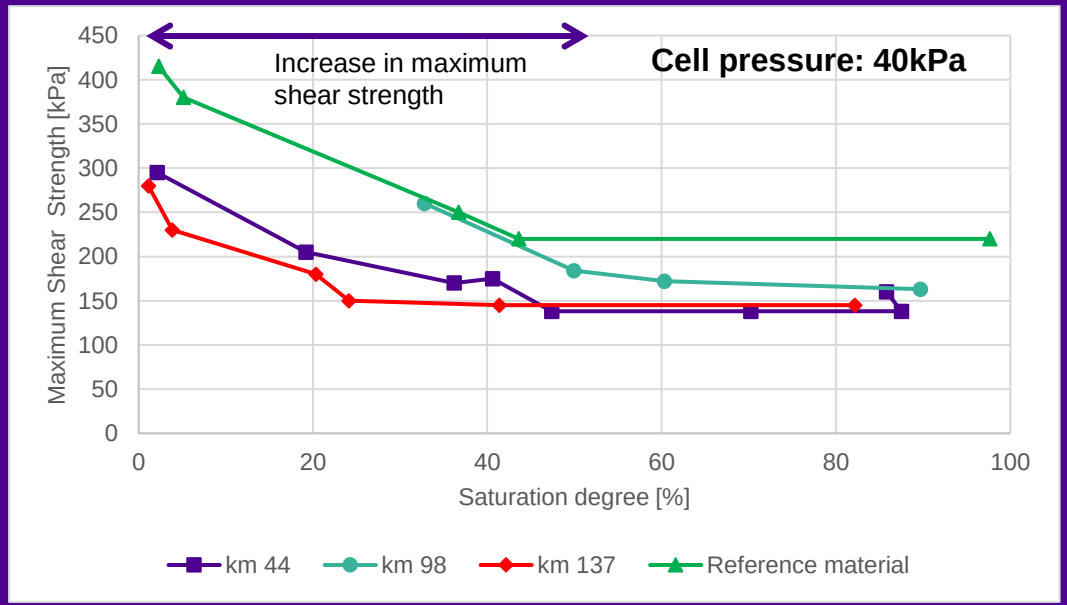
km98

km137

Material properties

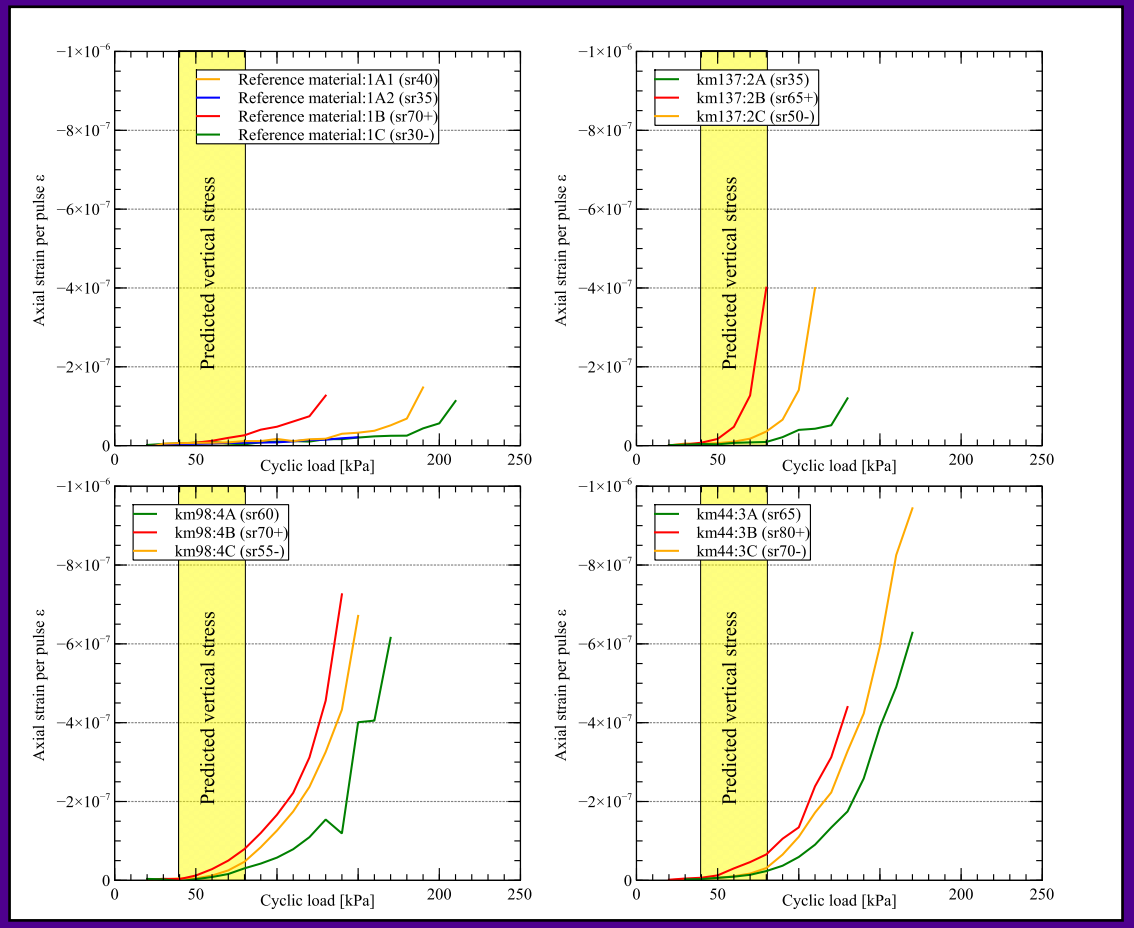
- The materials from measurement station locations were mainly too small grained, specially the km137. Also the fines content were on the top limit.
- The shear strength started to increase below 50 % saturation degree in static triaxial tests
  - The loading in the railway track is cyclic -> more tests are needed





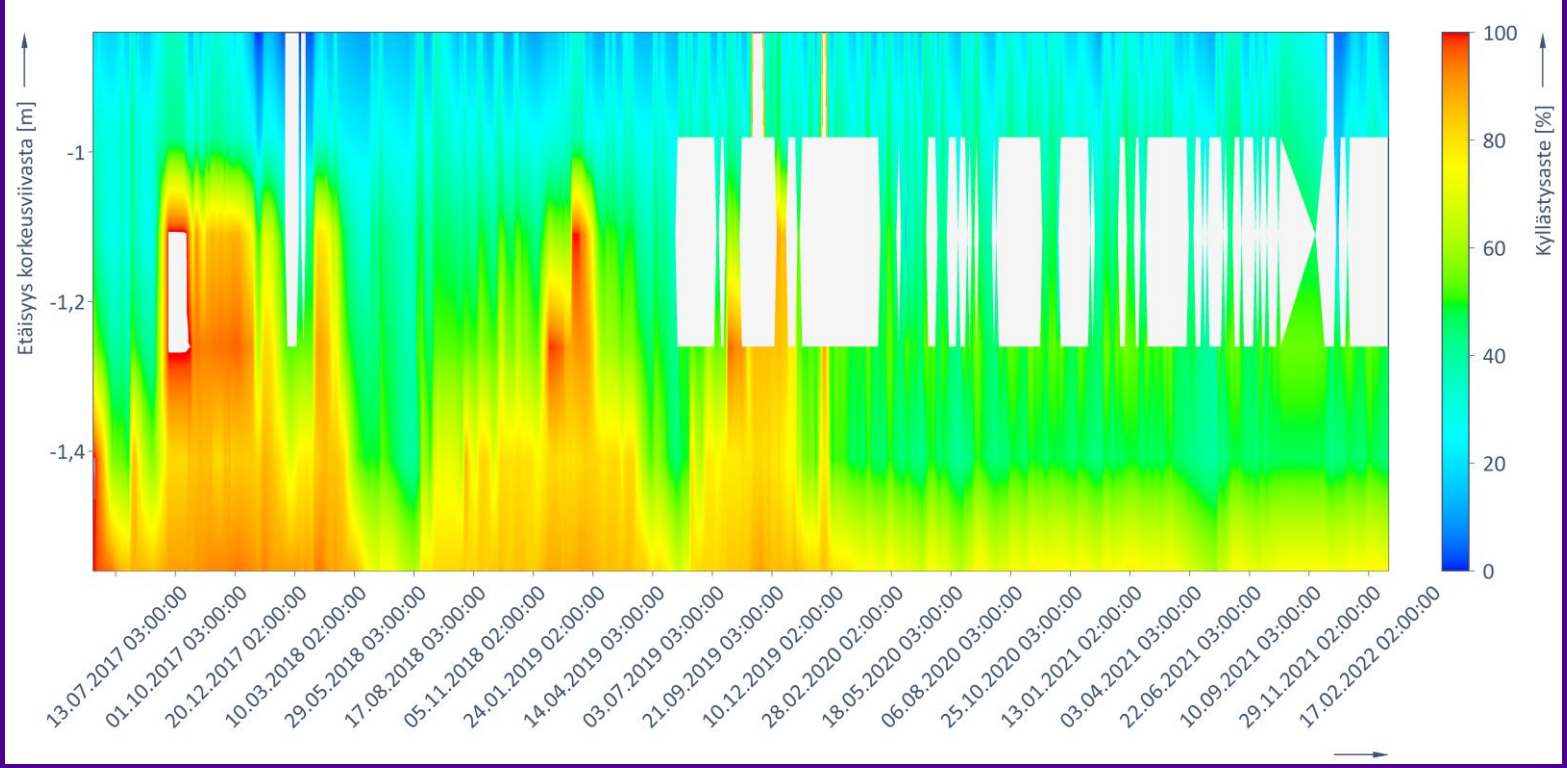
The large scale cyclic triaxial tests at different water contents

- Large scale samples, D=200 mm and h= 400 mm
- Cyclic test were performed at 30 kPa confining pressure, 10 000 pulses per load level at 10 kPa increments starting from 20 kPa and ending to failure
- 5 hz loading frequency was used.
- In the sub-ballast layer, other studies predicted 40 kPa to 80 kPa vertical stress addition.
- In all materials the largest deformations were observed in the most moist samples.
- Differences between the materials and moisture contents were small with passenger traffic axle weights.
- Good quality reference material can work well even in saturated state with high axle loads



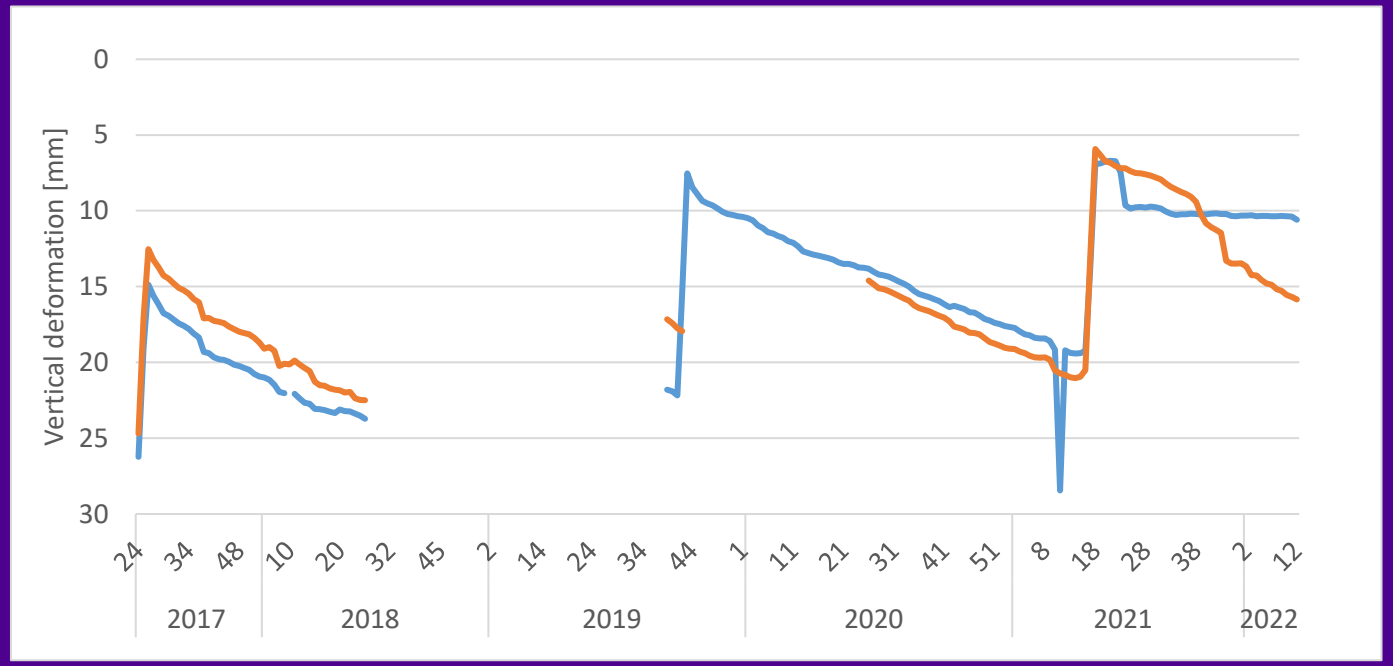
Water contents on the field, example of km44

- Before the drainage improvement: lot of high seasonal water contents
- After drainage in the start of 2020: no more saturated states!



Deformation measurements, km44

- How the drainage improvement affected to vertical deformations?
- Unfortunately the deformation rate is still high.
  - -> Deformations are mainly caused by other factors (in this case subsoil consolidation)



Conclusion

- The cyclic loading strength decreased in all materials samples near the saturated zone.
- Great differences between different material samples were observed:
  - The most uniform and small grained km137 material has the poorest strength.
  - The reference sample had the best strength properties and can work even in the saturated state.
- Axle weight plays an important role:
  - Even poor materials can work adequately if the traffic consist of passenger trains and water level is not on the top of the sub-ballast layer
  - With heavier traffic, good materials can work well even with higher water contents.
- In Finland, the role of sub-ballast deformation is probably quite small (in the line). Transitions zones are different because of high amplitude dynamic loadings.
- Based on the laboratory tests, it is likely that sites with unevenness problems are multi-problematic and the measurable benefits by improving drainage alone may be small, unless the track sub-ballast layer is nearly fully saturated and the axle loads are high.

Thanks!

Km44 measurement station a couple of years ago…