TAMPERE UNIVERSITY OF TECHNOLOGY

Loading effects of heavy trucks and autonomous vehicles

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ROADSCANNERS

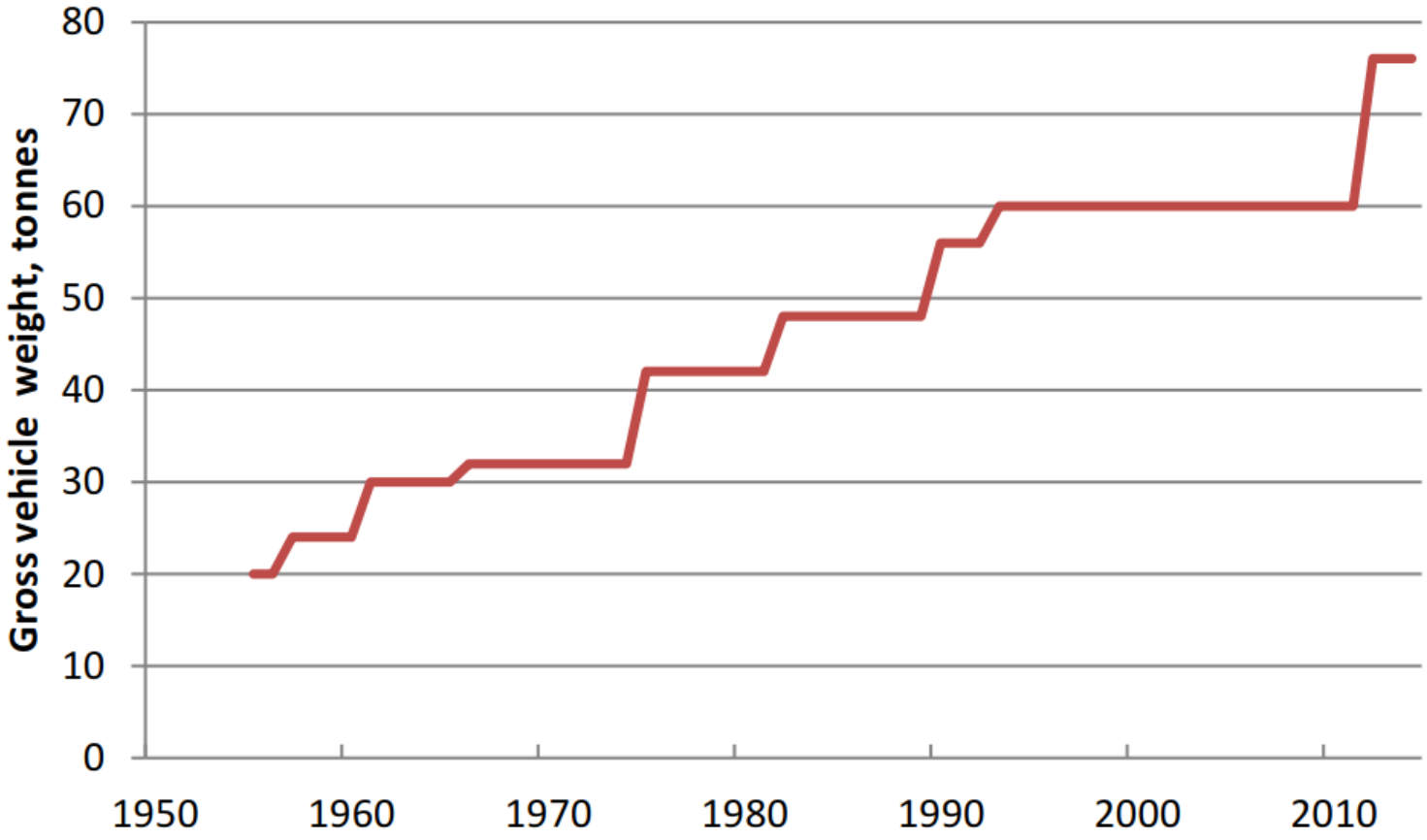
Outline of the presentation

- Background
  - New legislation on (super) heavy trucks
  - Forthcoming introduction of autonomous vehicles
- Concerns with regard to the loading effect of (autonomous) heavy trucks and respective investigations carried out
  - Single tires vs. dual tires
  - Speeding up of road deterioration due to less wheel path wander
  - Pumping effect on soft subgrade soil areas
- Some key results so far

New legislation on super heavy trucks

- New legislation concerning allowable truck masses came into effect in Finland October 1st, 2013:
  - Maximum truck & trailer mass: 600 → 760 kN
  - Maximum double boogie mass: 190 → 210 kN
  - Maximum triple boogie mass: 240 → 270 kN
  - 65% of the trailer mass must be resting on dual tires
- With special permission truck weights even exceeding 1 MN can be allowed on specified transportation routes
- Allowable axle loads were not increased (except for existing trucks for a transition period of four years)
  → more axles in a single truck than before
  → higher load concentration under a group of axles

Development of maximum allowed vehicle weight in Finland



Kaakkurivaara, T. (2018)
https://dissertationesforestales.fi/article/9989

A normal heavy truck allowed to operate on the whole Finnish road network

Examples of newly introduced super heavy trucks in Finland

11 axles – 92 tons

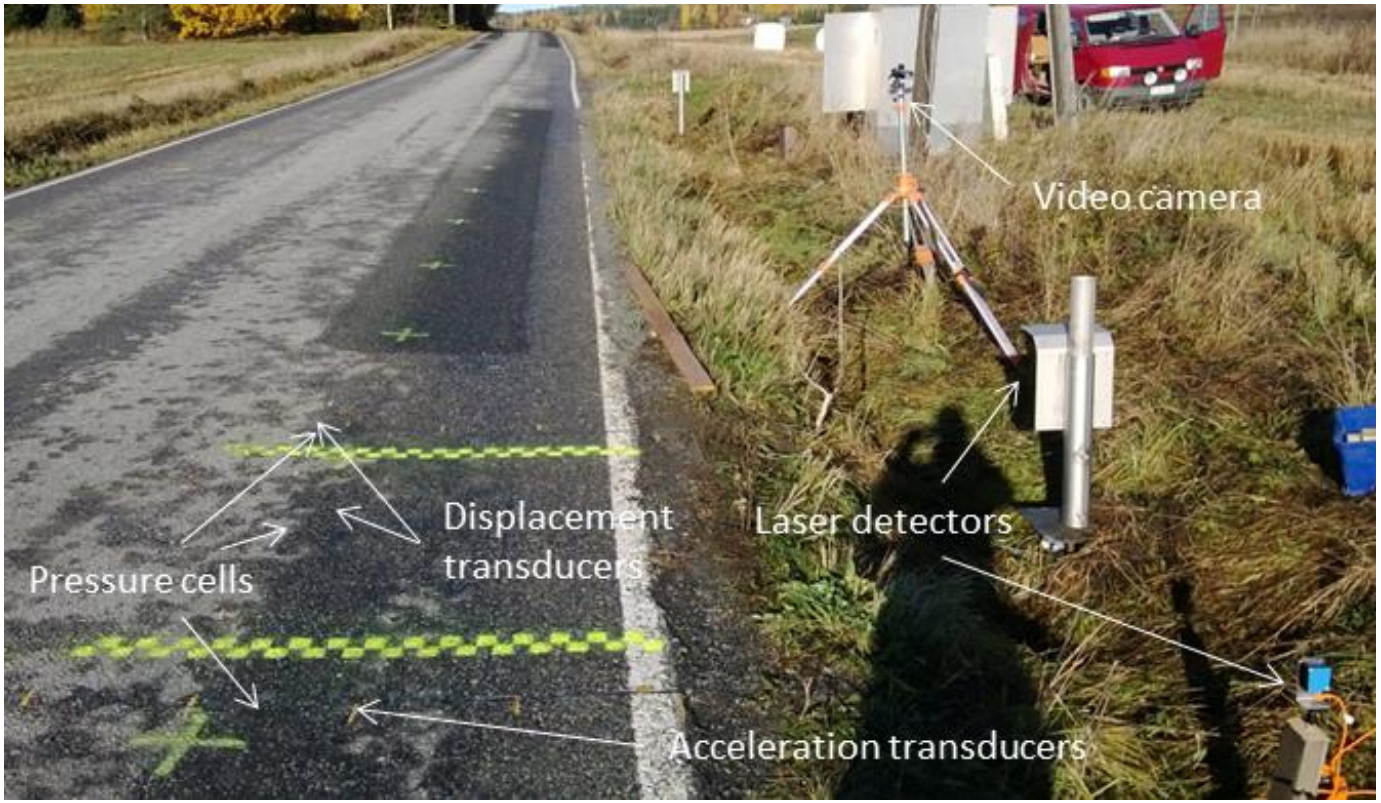
Examples of newly introduced super heavy trucks in Finland

13 axles – 104 tons

Introduction of autonomous vehicles can…

- Markedly decrease the amount of wheel path wander i.e. accumulate the loading effect in road cross section
- Drastically increase the amount of consecutive axles following each other if ‘platoon driving’ is applied

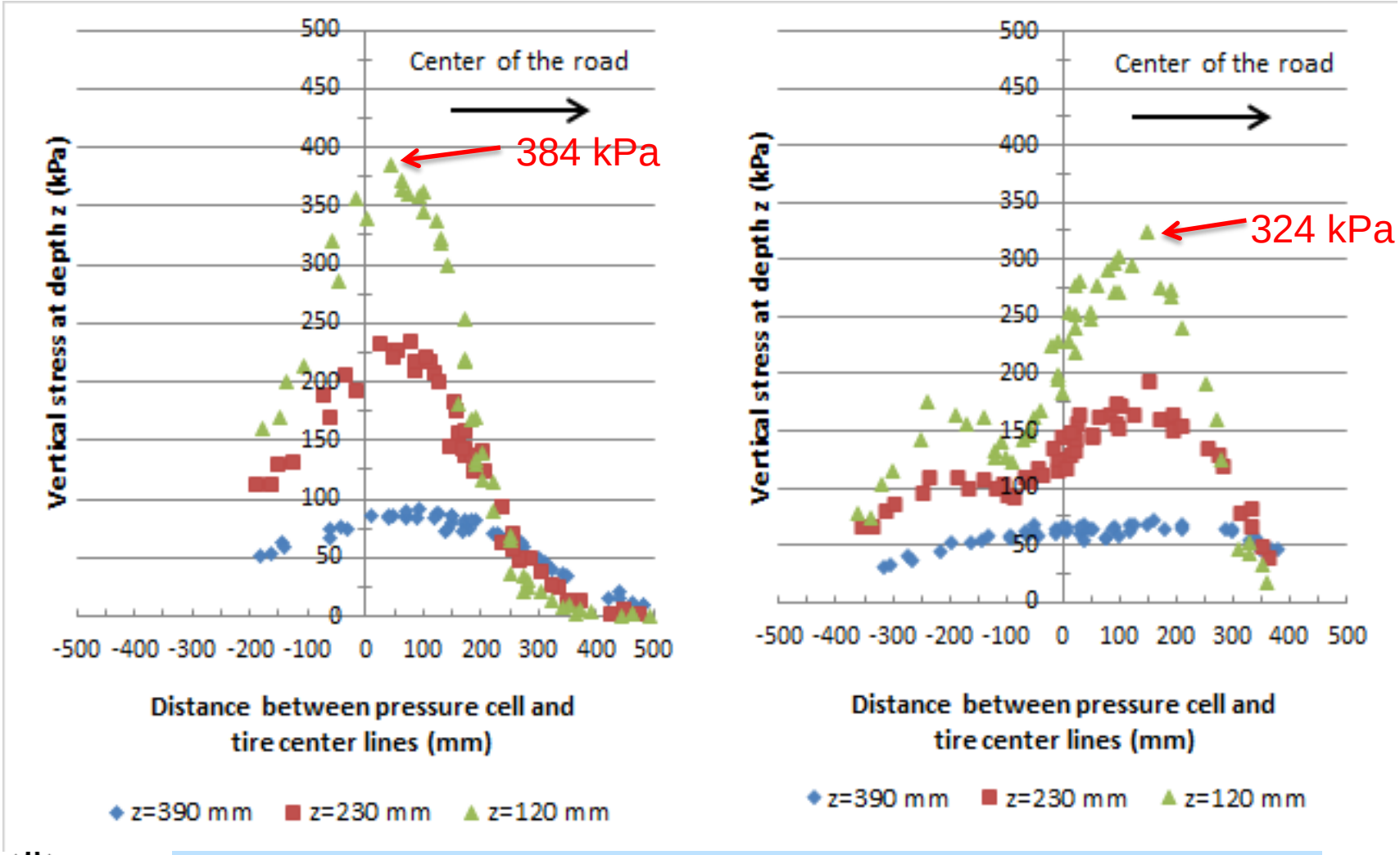
‘65% rule’ - test site for the loading effect of different tire types



FTA wanted to have independent response measurements:

- In the local climatic and road conditions
- With all different currently available truck tire types

Vertical stresses at three depths – single wheel (left) vs dual wheels (right)



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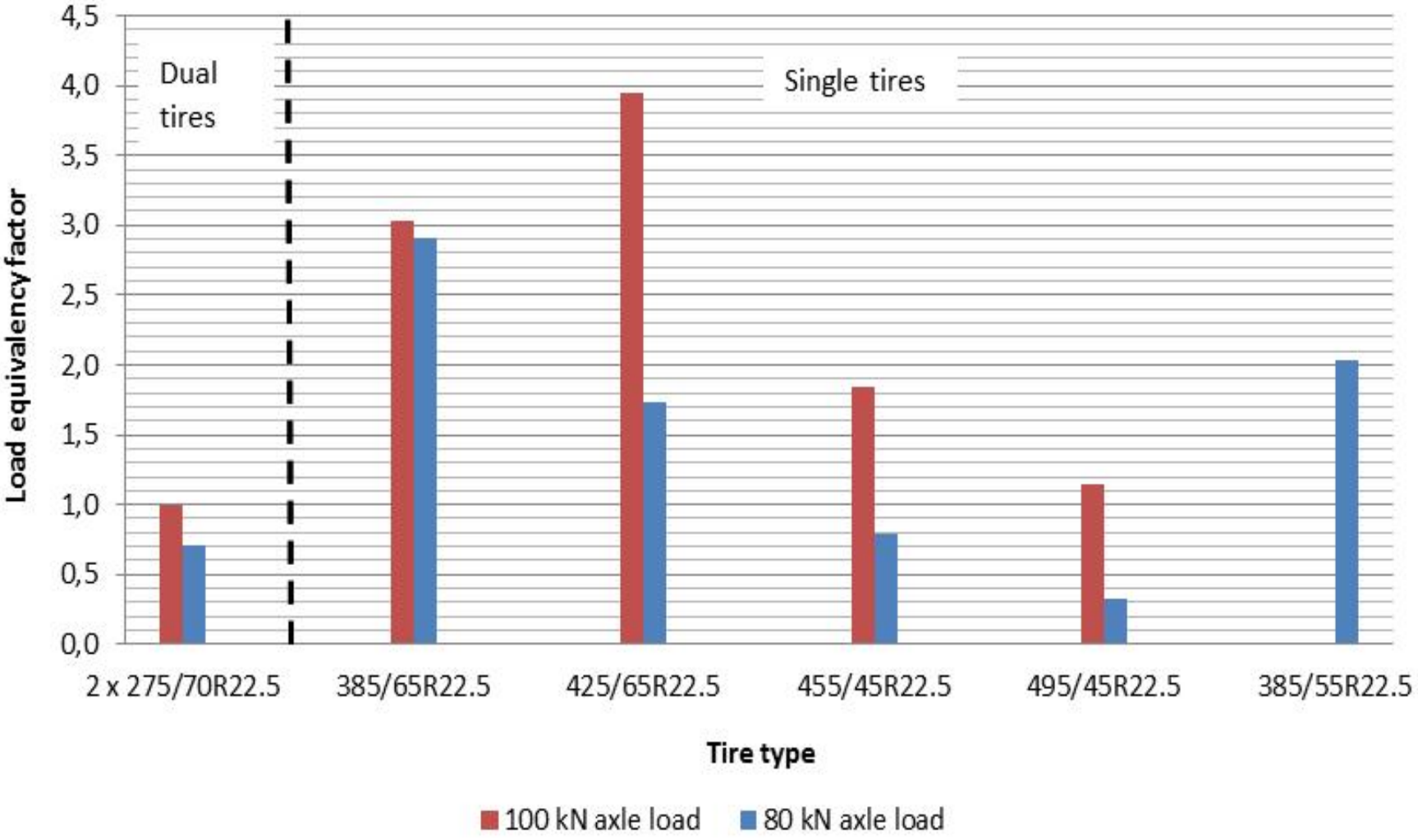
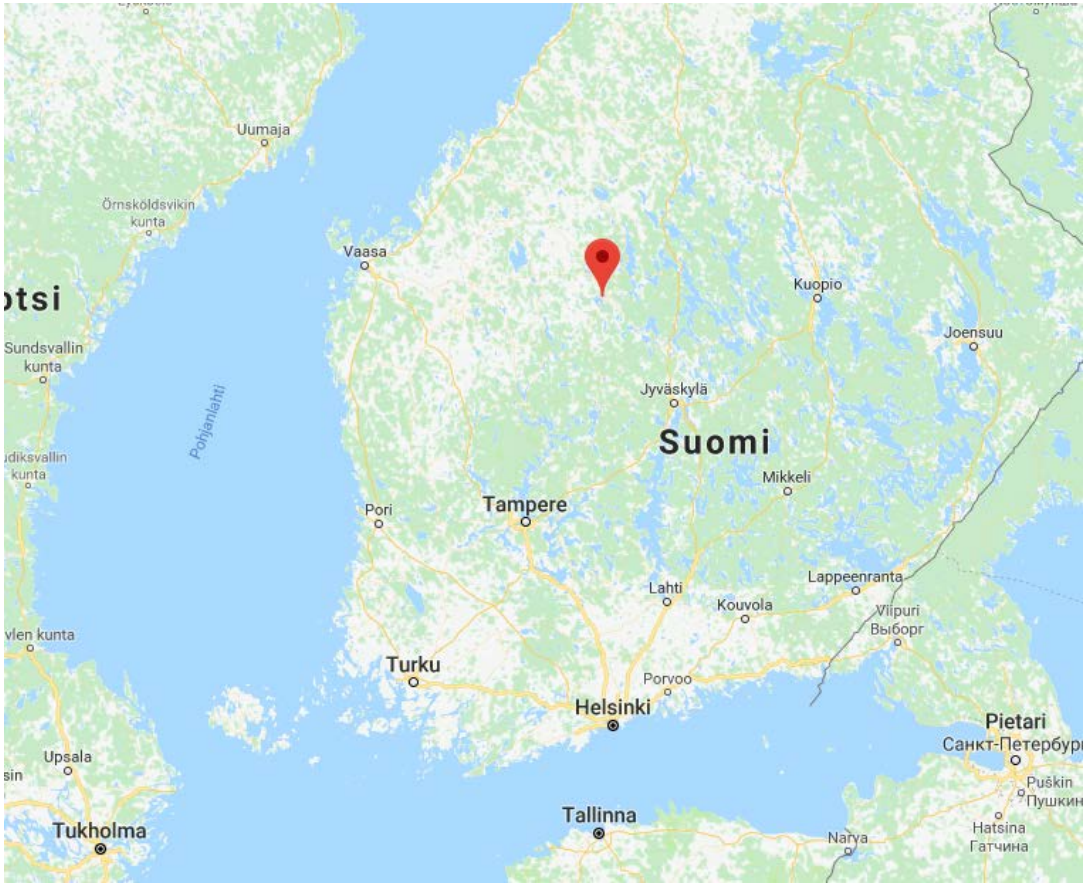
See more details at DOI: 10.3141/2474-20 and 10.3141/2474-21

Effect of tire type and axle load on the load equivalency factor

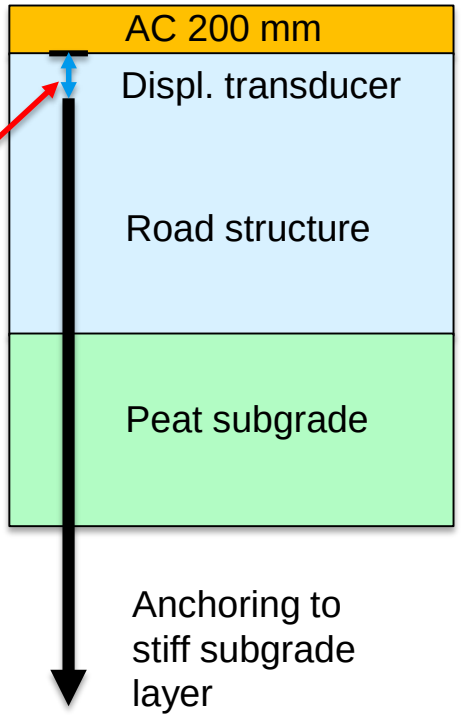


One of the loading test sites for heavy trucks – main road 77 in Karstula

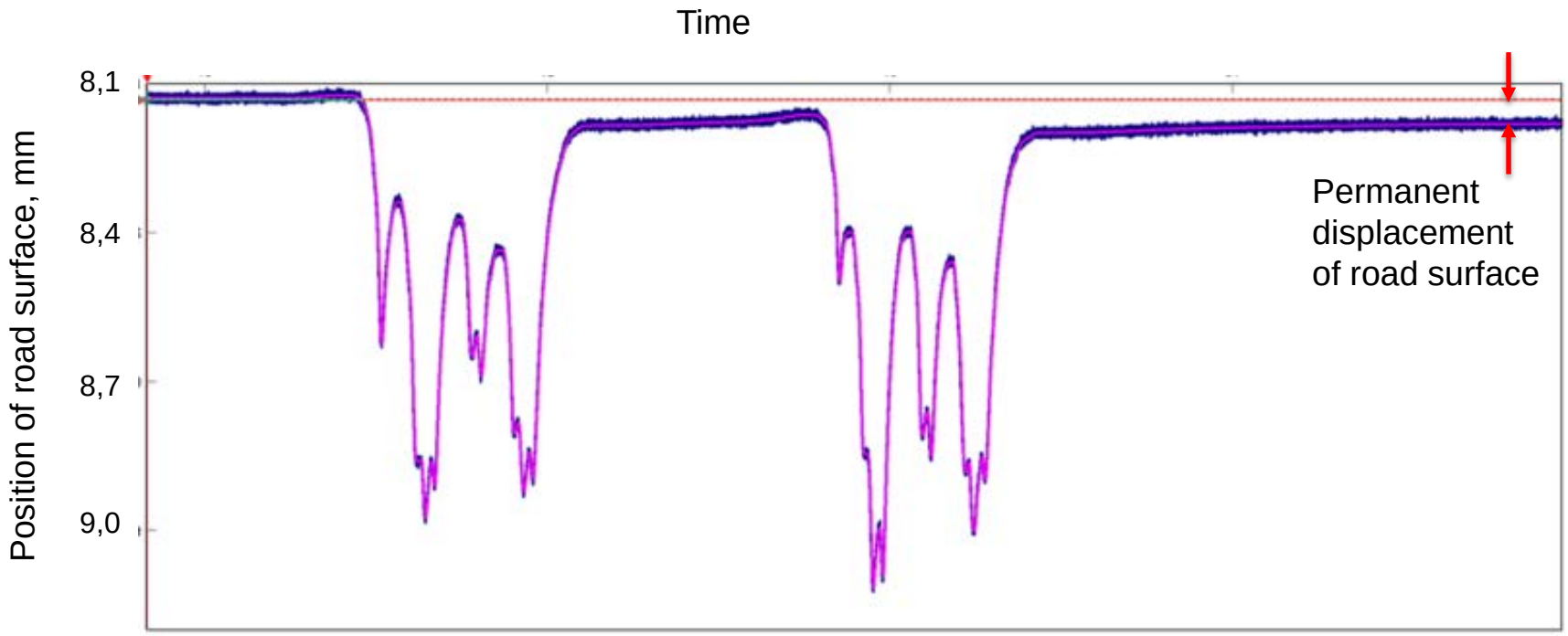


- Thickness of AC layers about 200 mm
- Overall thickness of the road structure about 1,5 m
- Road located on peat subgrade

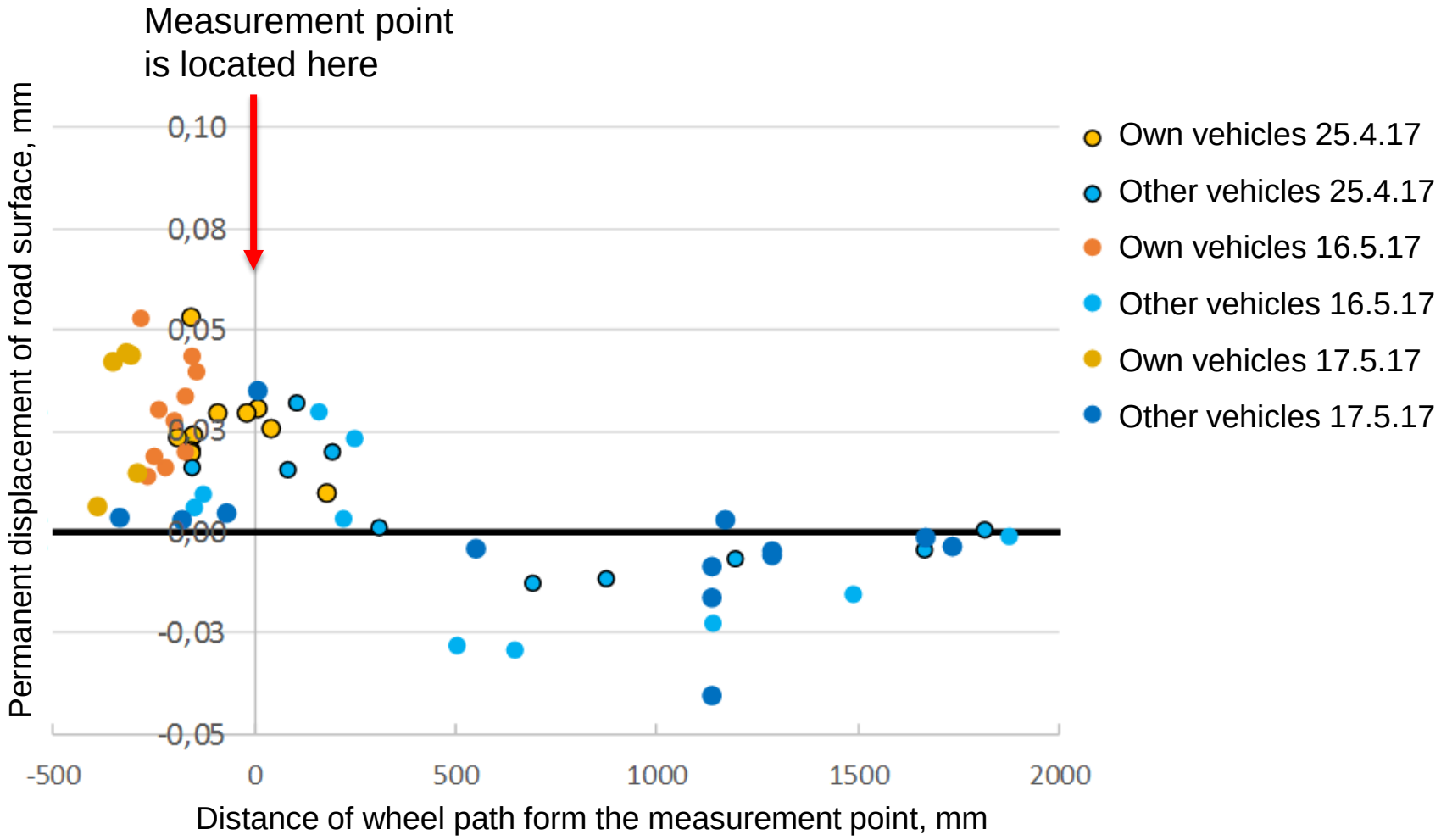
Truck loading tests on road 77 in Karstula



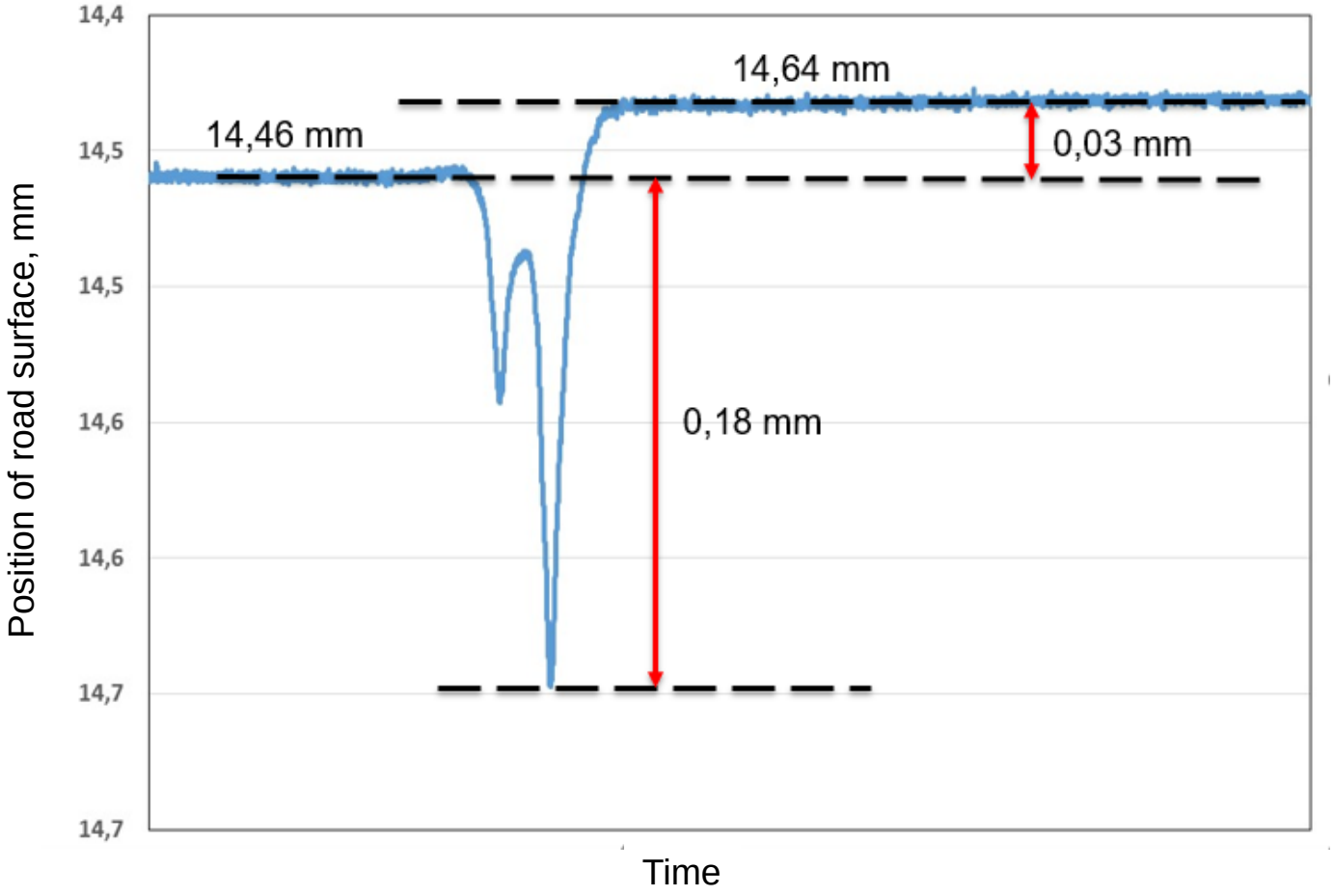
Road surface deflection while two 9-axle (76 ton) trucks are passing over the site



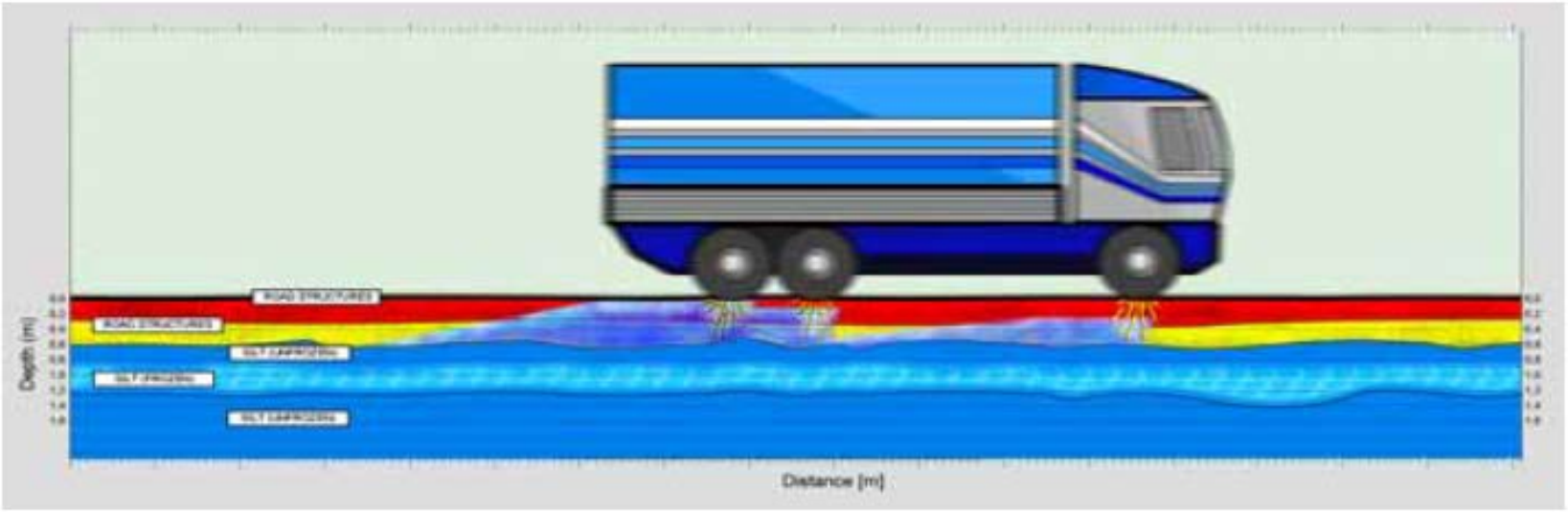
Permanent displacements of road surface in relation to the position of wheel path



Plastic rebound of the road surface due to a vehicle passing nearby



Principal mechanism of water pumping into the road structure

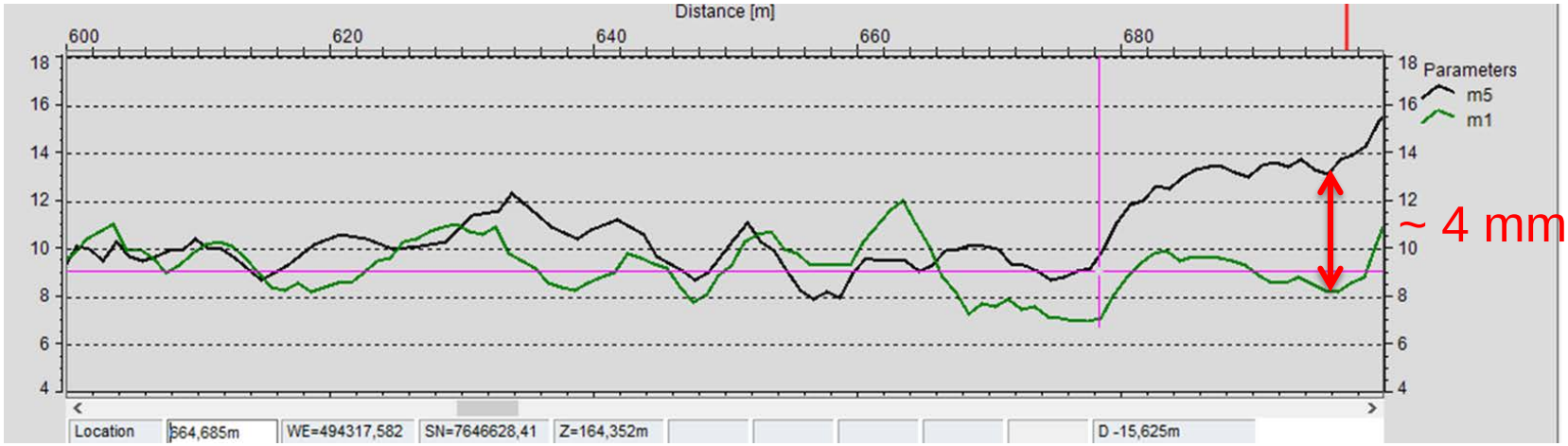


- A passing over axle load is inducing excess pore water pressure in soft water-saturated subgrade soil
- Water is pushed upwards into the road structure
- Successive axles are accumulating the phenomenon

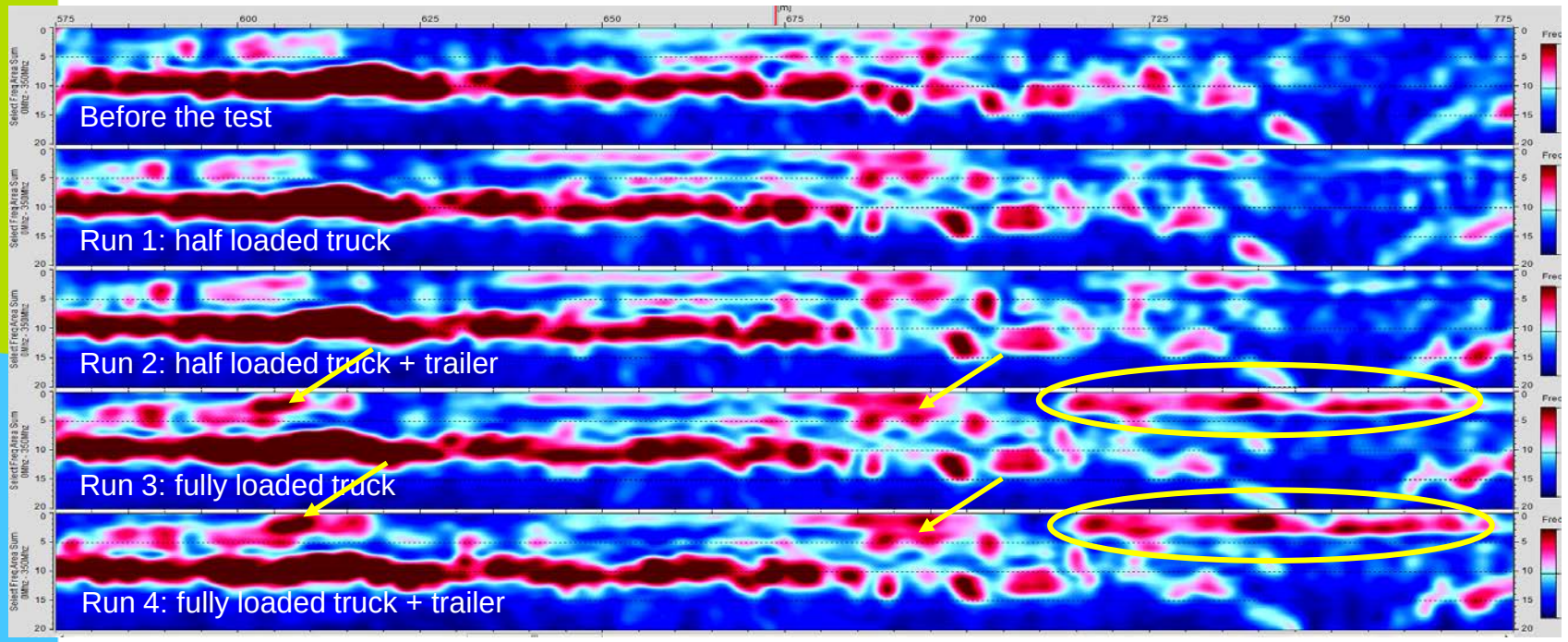
Pumping effect test site in Inari in the autumn 2015 (www.google.fi/maps)

Rut development after 5 partially loaded and 2 fully loaded truck overpasses

- Thickness of AC layer at the Inari test site was about 80 mm and the total thickness of road structure about 0.6 m
- Ground water level near to ground surface
- Rut development rate of the order of 1 mm/overpass was observed on a road section resting on top of peat subgrade

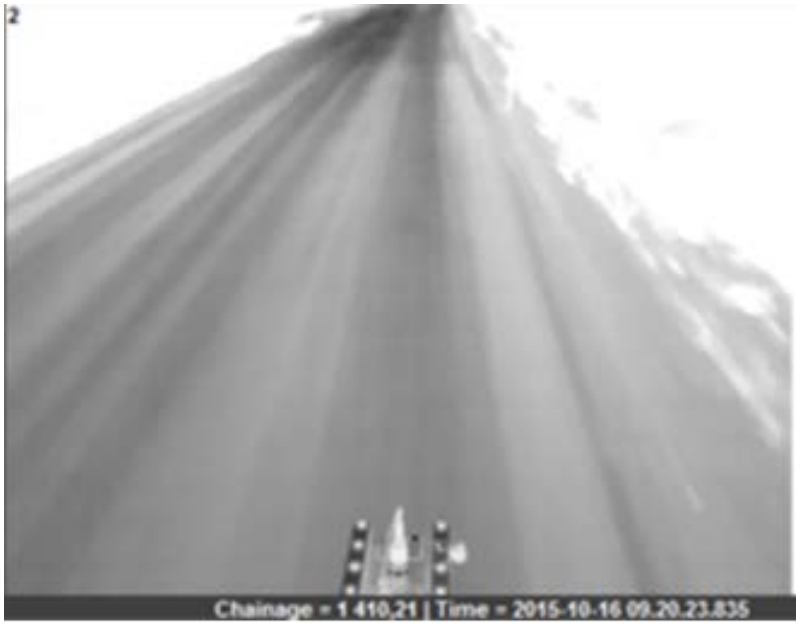


Ground Penetrating Radar signal attenuation analysis of the test site



GRP analysis performed by Roadscanners Ltd indicate the amount of water in the road structure by red color

Thermal images of the road surface before and at the end of loading tests



Before

After

Conclusions

- Damaging effect of (old generation) single wheels is several times higher than that of dual wheels
  → '65% rule' is definitely appropriate
- Variation of vehicle wheel paths is critical for limiting the rut development rate even on high quality main roads
  → Introduction of autonomous heavy vehicles is potentially risking the condition of our road infrastructure
  → Technically is should be possible to avoid this risk by enforcing the use of controlled wheel path variation
- Increasing the number of consecutive axles due to heavier trucks or introduction of platoon driving increases the risk for pumping effect and consequent rapid road deterioration on wet/soft subgrade soil areas

Hard working people behind the results

Nuutti Vuorimies, project manager
(nuutti.vuorimies@tut.fi)
- Laboratory testing and analysis
- Conduction of in-situ loading tests

Antti Kalliainen (PhD student)
(antti.kalliainen@tut.fi)
- Mechanical modelling of pavement structures

A number of other people have been assisting in different project phases:
Ville Liiv, Jonna Rossi, Antti Akkanen, Altti Kurki, Marko Happo, Tero Porkka…

Close collaboration with Roadscanners Ltd during the whole project.

Questions, comments?