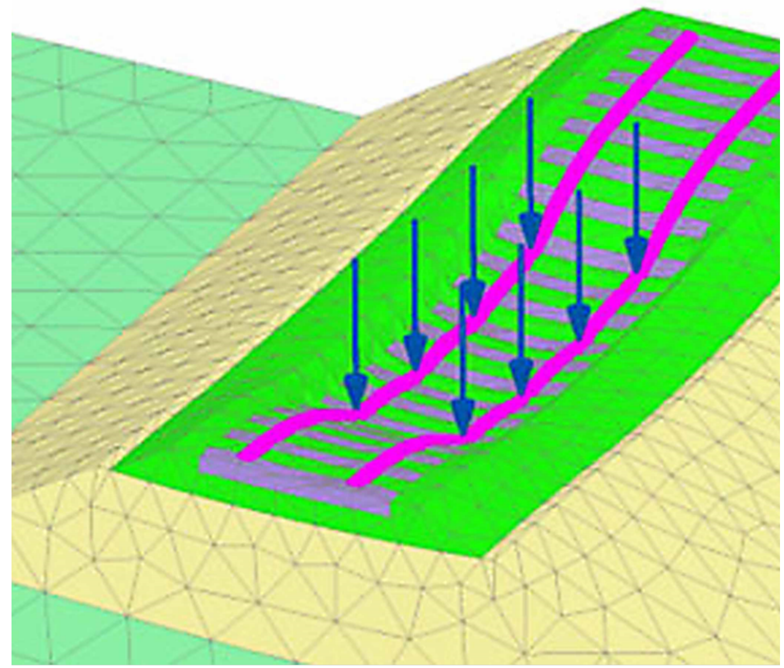
William W. Hay Railroad Engineering Seminar

"Railway Track Structures Research at Tampere University of Technology, Finland"

Pauli Kolisoja

Professor, Department of Civil Engineering



Date: Friday, September 12, 2014

Time: Seminar Begins 12:15

Location: Newmark Lab, Yeh Center, Room 2311
University of Illinois at Urbana-Champaign

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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

NURail Center

Railway Track Structures Research at Tampere University of Technology, Finland

Prof. Pauli Kolisoja

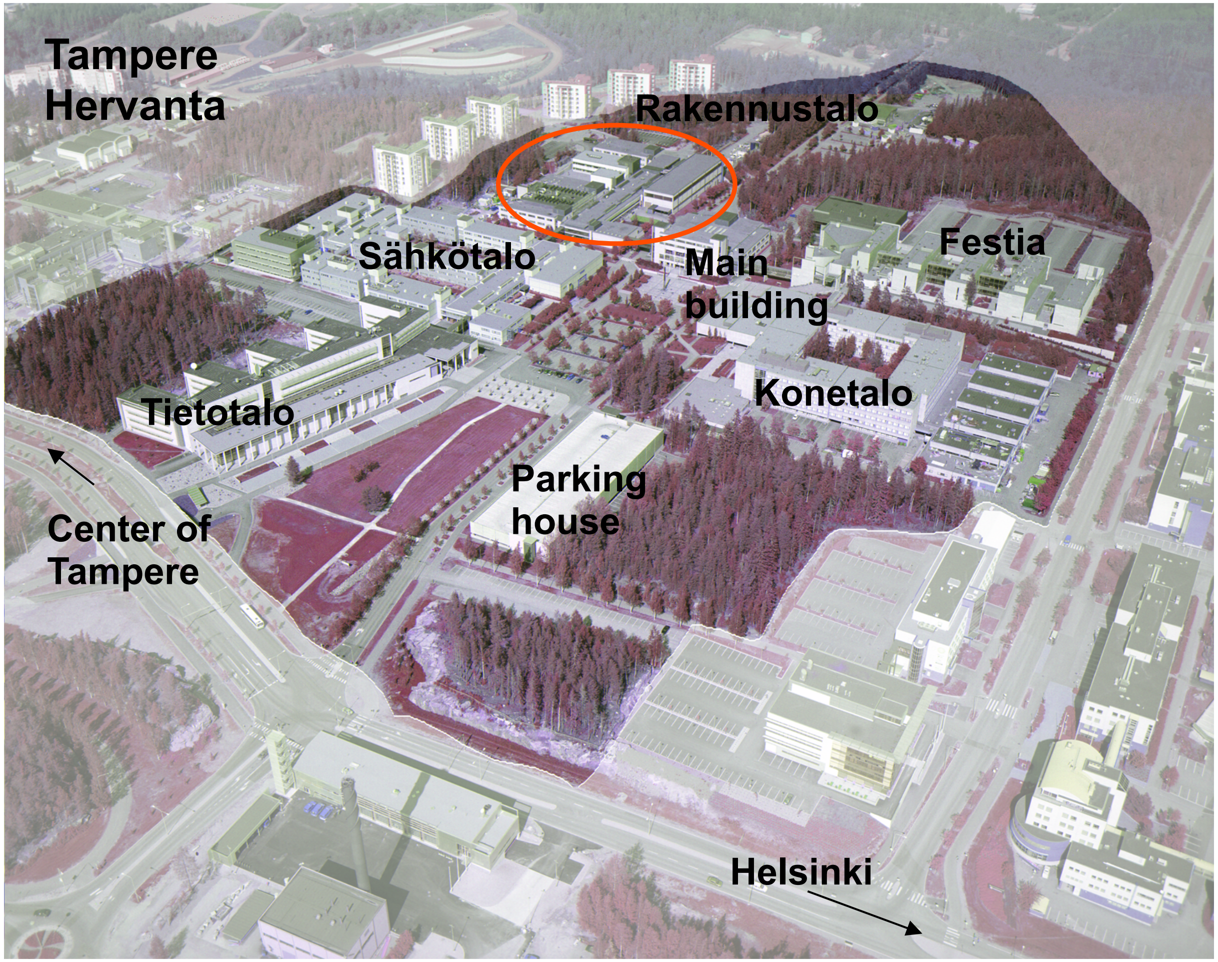
Tampere – a town with 1/4 Million inhabitants in Finland, Northern Europe

TAMPERE UNIVERSITY OF TECHNOLOGY

www.maps.google.fi

A view over Tampere in summer

TUT Campus in Hervanta, Tampere



TUT Department of Civil Engineering

- Part of the Faculty of Business and Built Environment
- Annual student enrollment about 100 new MSc students
- Annual turnover about 8 MEUR
  - 3 MEUR governmental funding
  - 5 MEUR project funding
- About 130 employees (including research assistants) in three operational units:
  - Earth and foundation structures
  - Structural engineering
  - Construction management and economics

www.tut.fi/rak/en

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TUT Earth and Foundation Structures

Dept. of Mechanical Engineering

Dept. of Materials Science

Structural solutions

Design methods

Renovation methods

Material technology

Field monitoring

Laboratory investigations

Foundation engineering

Prof. Tim Länsivaara

- Pile foundations
- Soil structure interaction SSI
- Geotechnical calculations
- Stability, settlement
- GeoFEM
- Bridges and culverts
- Underpinning
- Geotechnical site investi-gation methods
- Foundations systems

Railway structures

Prof. Antti Nurmikolu

- Wheel-rail interaction
- Rails
- Turnouts
- Sleepers
- Superstructure-embankment interact.
- Ballast & subballast
- Embankment deformations
- Frost action
- Life-cycle costs

Earth structures

Prof. Pauli Kolisoja

- Structural design of roads and streets
- Structures of waste disposal sites
- Characterization of fines
- Material technology of earth constructions
- Structures for sports and recreation areas structures
- Use of industrial by-products

Instrumentation and monitoring of earth and foundation structures

Laboratory services

Geotechnical laboratory investigations; acceptability tests for soil and rock materials, asphalt, by-products and bricks

Geotechnical engineering **Engineering geology**

TUT Geotechnical testing laboratory

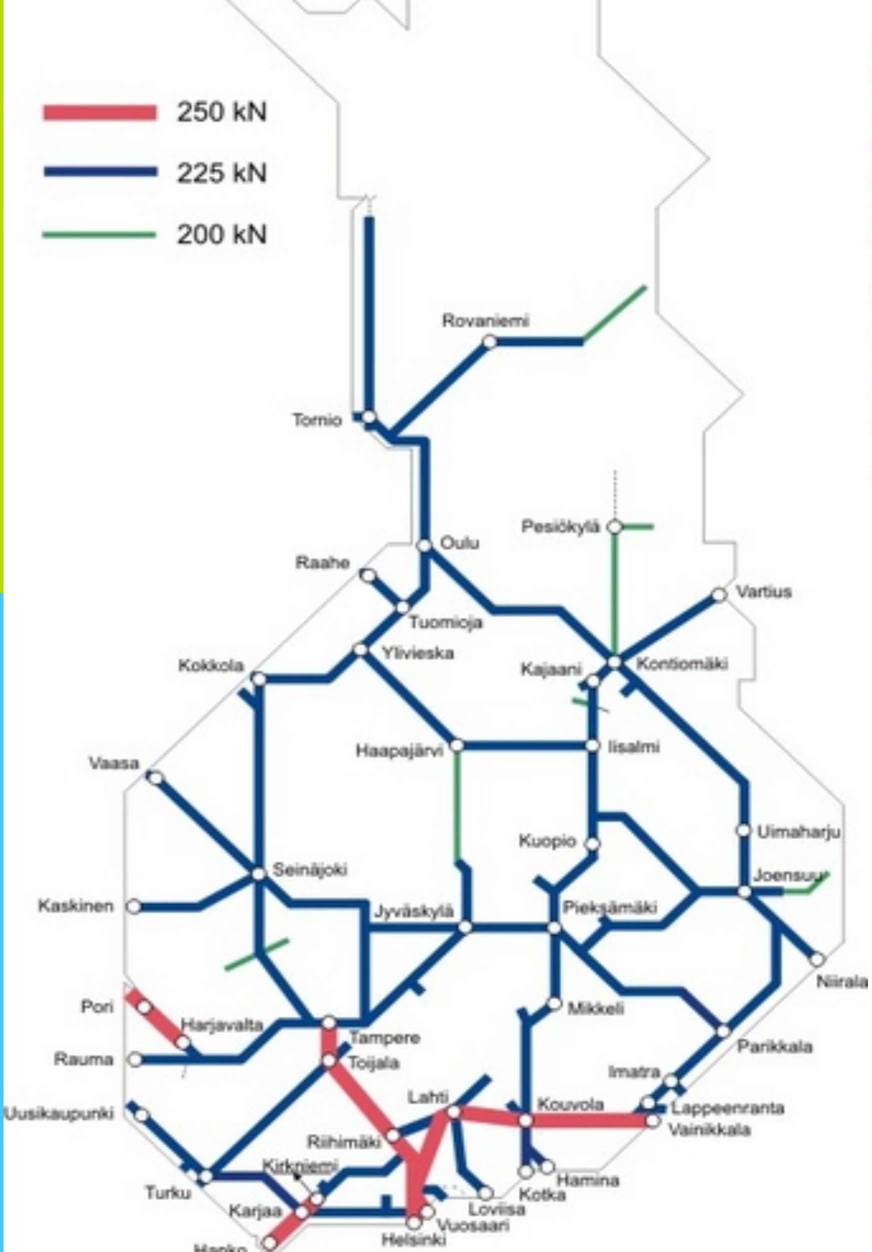
Some of the TUT Large scale testing facilities

Some basic facts about Finnish rail network

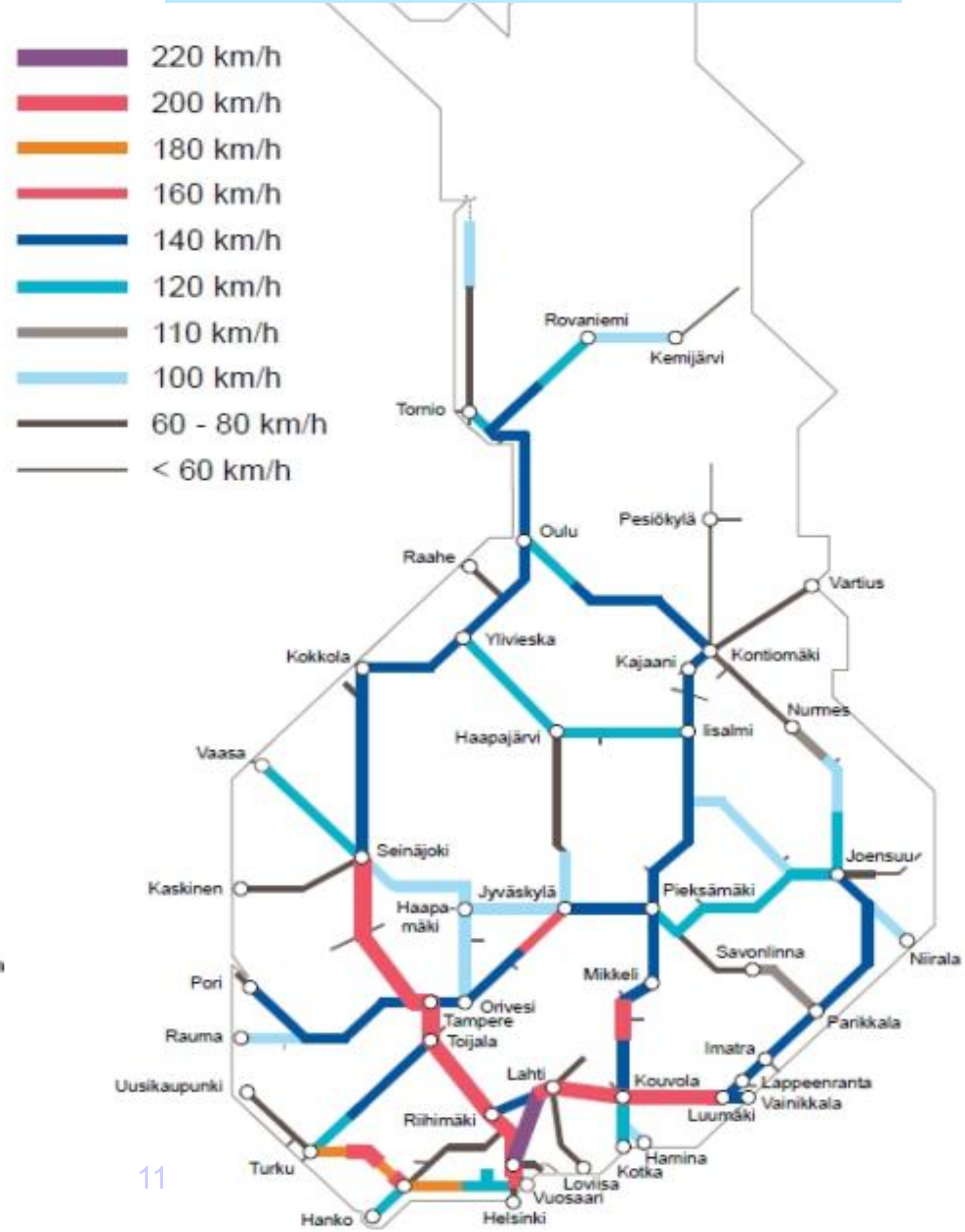
- Total track length including side-tracks: 8 855 km (5506 miles)
- Gauge: 1 524 mm (5 ft)
- Most lines carry mixed (freight & passenger) traffic
- In 90 percent of the network only single line track exists
- On main lines 54 or 60 kg/m rails
- Continuous-welded track on 75 % of the network
- Concrete sleepers on 75 % of the network
- Only 13 % of the network has spike fastenings



Maximum axle load: 22.5-25 tonnes



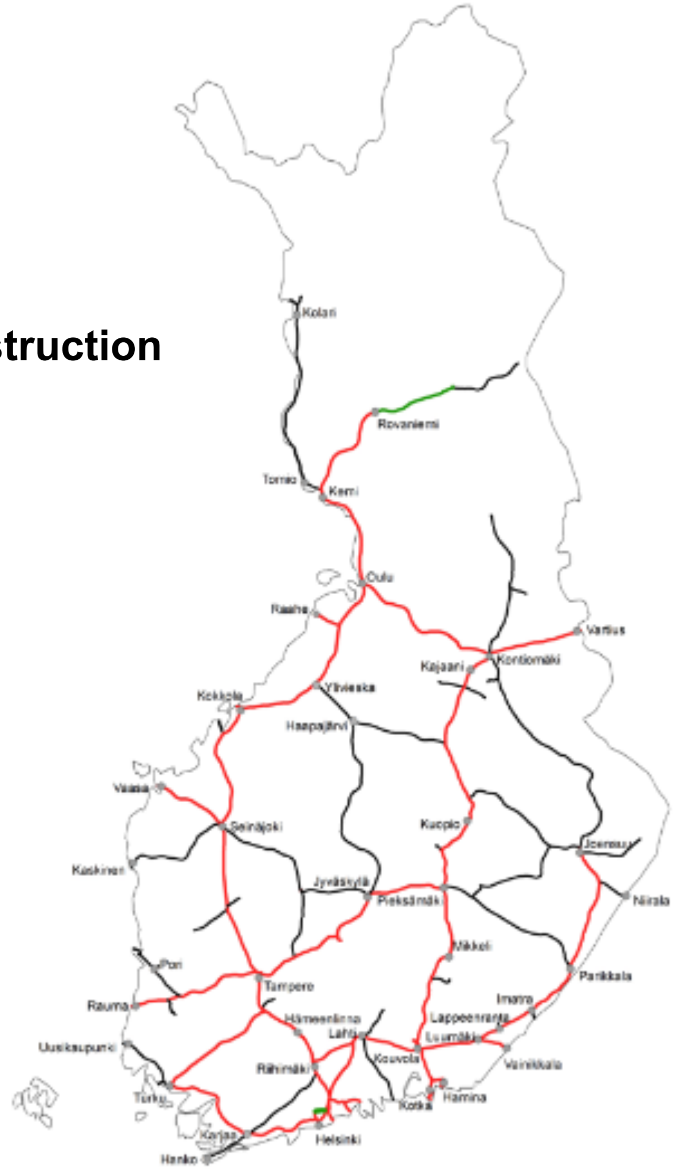
Maximum speed : 80-220 km/h (50-137 mph)



Electrified tracks in Finland

Electrified

Under construction



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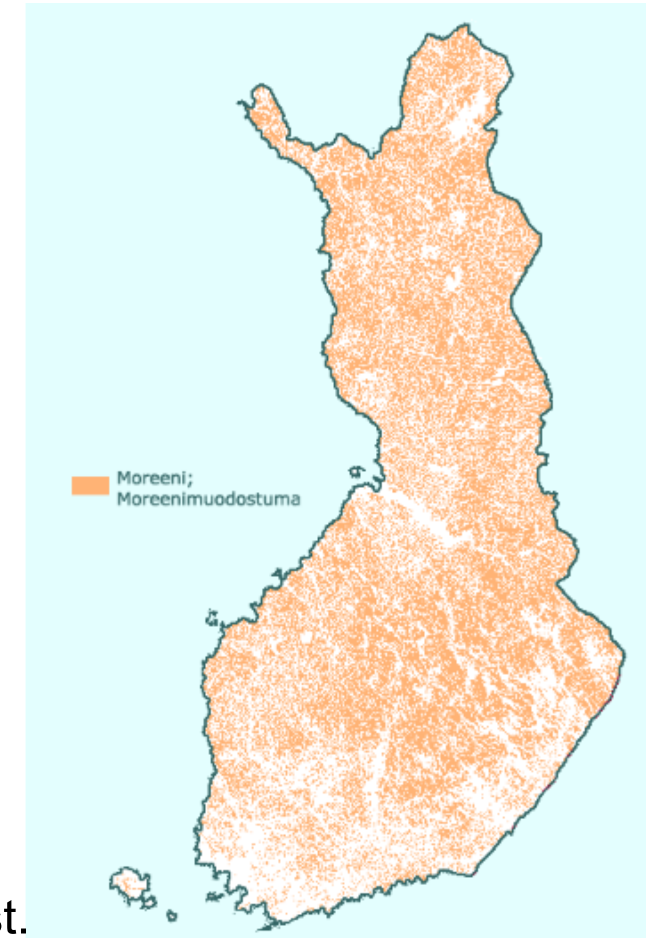
Extent of the latest glaciation over Northern Europe

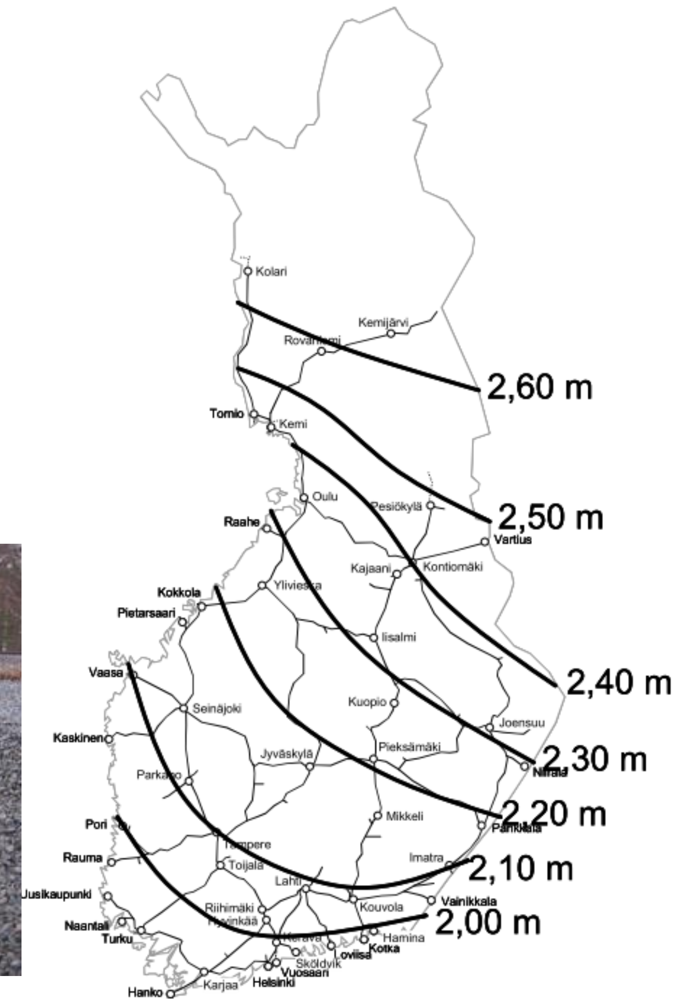


Most of the land area in Finland is moraine – a soil consisting of a wide variety of grain sizes - quite often covered with peat. Soft soils mainly on costal areas in the South and West.

Geotechnical specialities on Finnish railways

- Frost design requires track structure thickness (ballast + subballast) of 2,0-2,6 m
- Materials must be and must stay non-frost-susceptible

- *New tracks:* Huge amount of high quality aggregate is needed

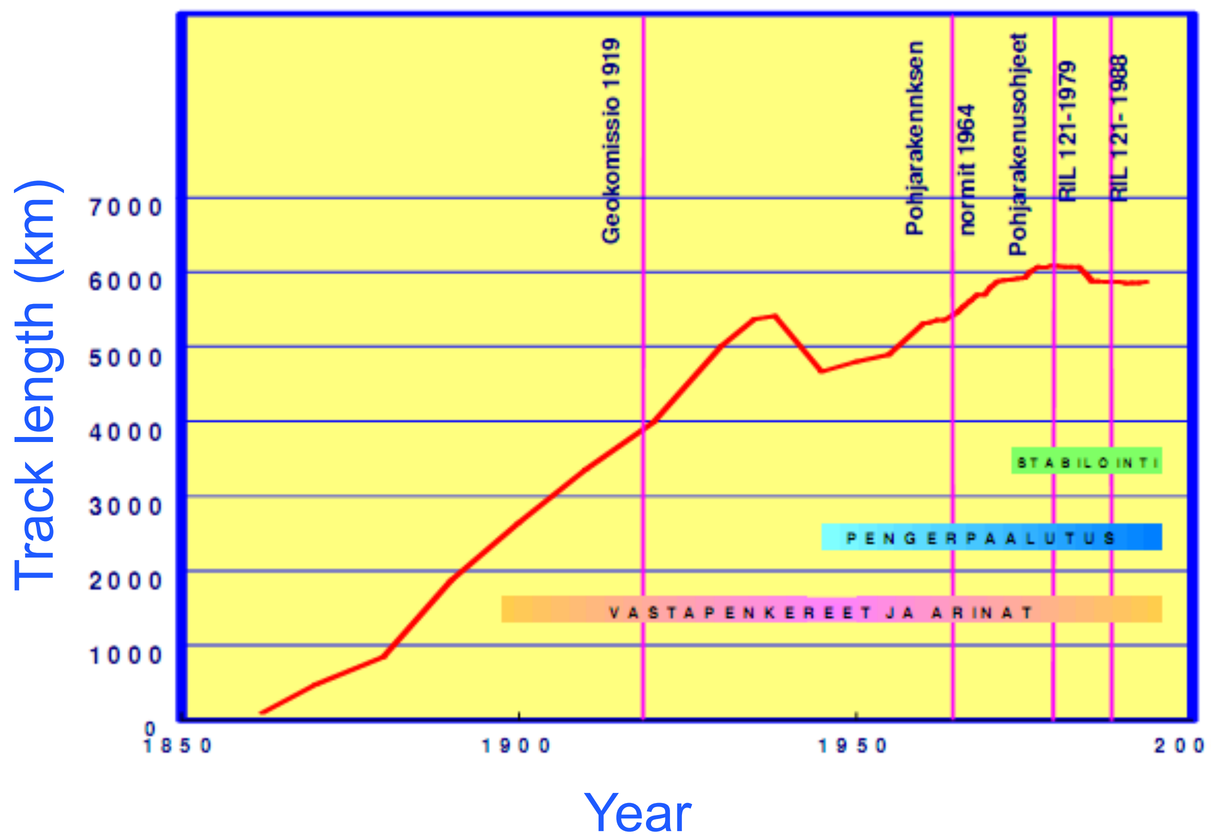


Geotechnical specialities on Finnish railways

- *Existing tracks* have originally been constructed by 1940's

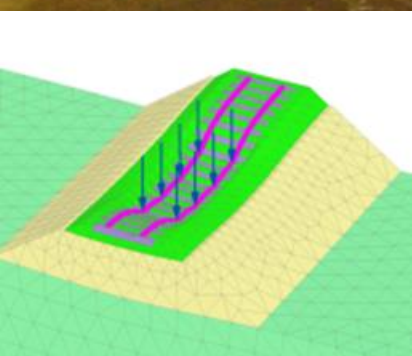
→On existing tracks structural thickness and material quality are typically insufficient for adequate frost protection

→ Large part of the rail network is on soft clay and peat subgrades



Research program *"Life-Cycle Cost Efficient Track II"* at TUT - Ten study areas for 2013-2016 with Finnish Transport Agency




1. **Train-track-interaction:** stresses exerted on track
2. **Rails: degradation mechanisms and life-cycle management**
3. **Switches and crossings:** safety and degradation mechanisms
4. **Sleepers**: superstructure-embankment-interaction, track stability
5. **Ballast: degradation and management of track smoothness**
6. **Frost: frost action mechanism and frost protection** solutions
7. **Embankment: bearing capacity and track smoothness**
8. **Subsoil:** embankment stability management and foundation engineering solutions
9. **Bridges: bearing capacity** calculation and condition assessment
10. **Overall economics: life-cycle cost assessment**

Railway track research projects at TUT 2009-2012

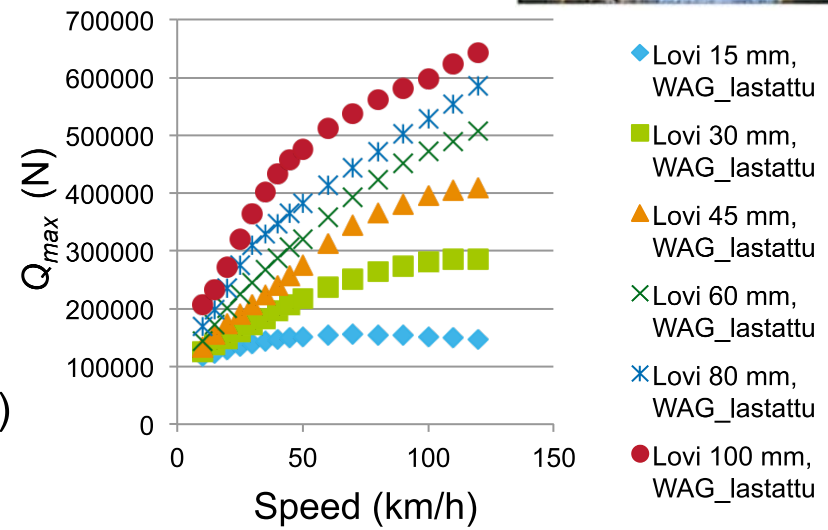
1: Principles of wheel-rail-interaction; traffic loads exerted on track
1: Wheel Impact Load Detector data analysis
2: Rail life-cycle → Rail surface defects
3: Detachment of snow from the rolling stock in rail irregularities (as switches)
3: Operation mechanism of turning assist RAILEX and opening risk of turnout locking due to vibration
4: Degradation mechanisms of concrete sleepers
4: Lateral and longitudinal track resistance
5: Mechanisms and effects of ballast and subballast degradation
5: Utilization of Ground Penetrating Radar and integrated data analysis in track condition assessment
6: Frost and frost susceptibility in railway track
7: The optimization of width and slope of track embankment
7: Compaction and density of subballast
7: Track bearing capacity design
7: The problems on bridge approaches
7: Measurement of vertical track stiffness and utilization of stiffness data
8: Subsoil stability calculation and improvement of stability
8: Development of a monitoring technique for low stability embankments
9: Bearing capacity of bridges ; usage of reliability analysis for capacity assessment
9: Improvement of bridge bearing capacity assessment on steel beam -reinforced concrete bridges
9: Soil-structure-interaction on an integral abutment railway bridge
10: LCC case study on iron ore line: ”For which loads is it economical to improve the track?”
10: Problems in benefit-cost-calculations of railway projects
10: Degradation models and LCC evaluation of track components

See more details at: www.tut.fi/railway

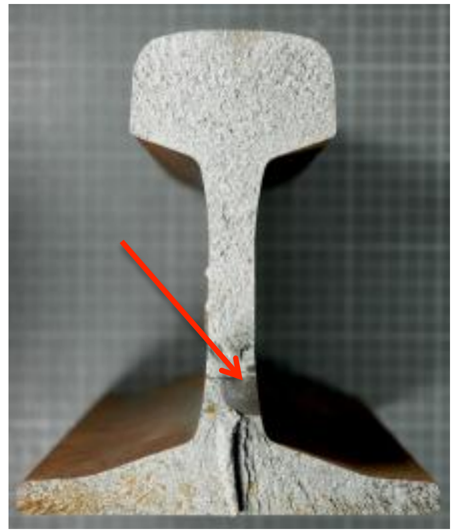
1b: Wheel impact load detector data analysis

- Wheel impact load detectors in test use in 2011 (…→ currently 6 devices installed)

→ Statistical analysis of the data
  - –Comparison of the equipment
  - –Correlation between the flat size and load
  - –Statistical load distributions (static & dynamic)
  - –Role of winter on load levels
  - –Load levels vs. various rolling stock



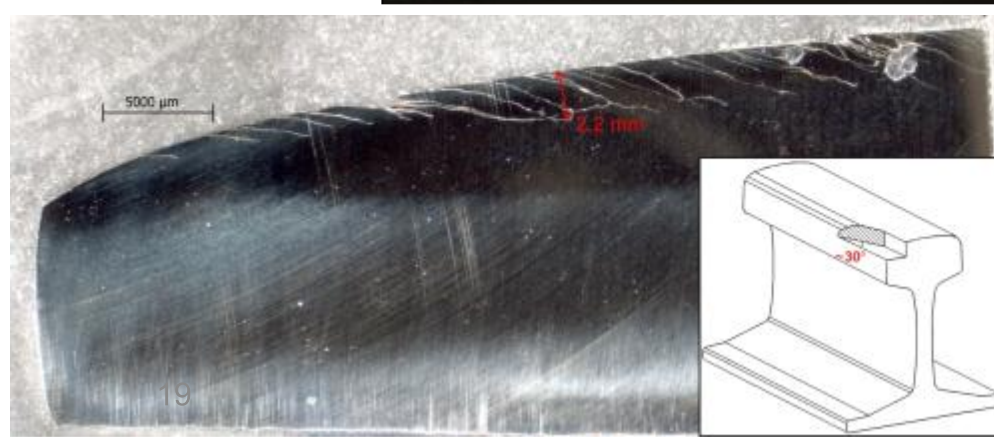
2: Rail life-cycle; especially surface defects



- Review on rail life-cycle
  - Manufacture
  - Installation / construction
  - Stresses
  - Failure mechanisms
  - Inspection methods
  - Maintenance and repair
  - Bases for the end of life-cycle

- Surface defects have been prioritized
  - RCF, Squat
  - Turning and propagation of a crack to rail break can lead to dramatic consequences
  - The growth of cracks and wearing will be monitored on track

→ A model that predicts the rate of deterioration in Finnish conditions?

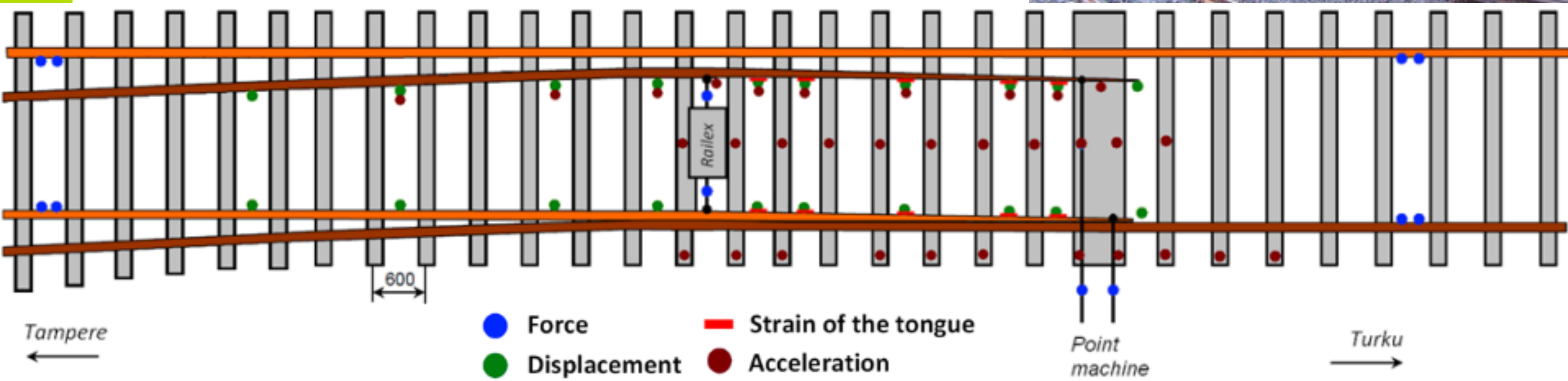


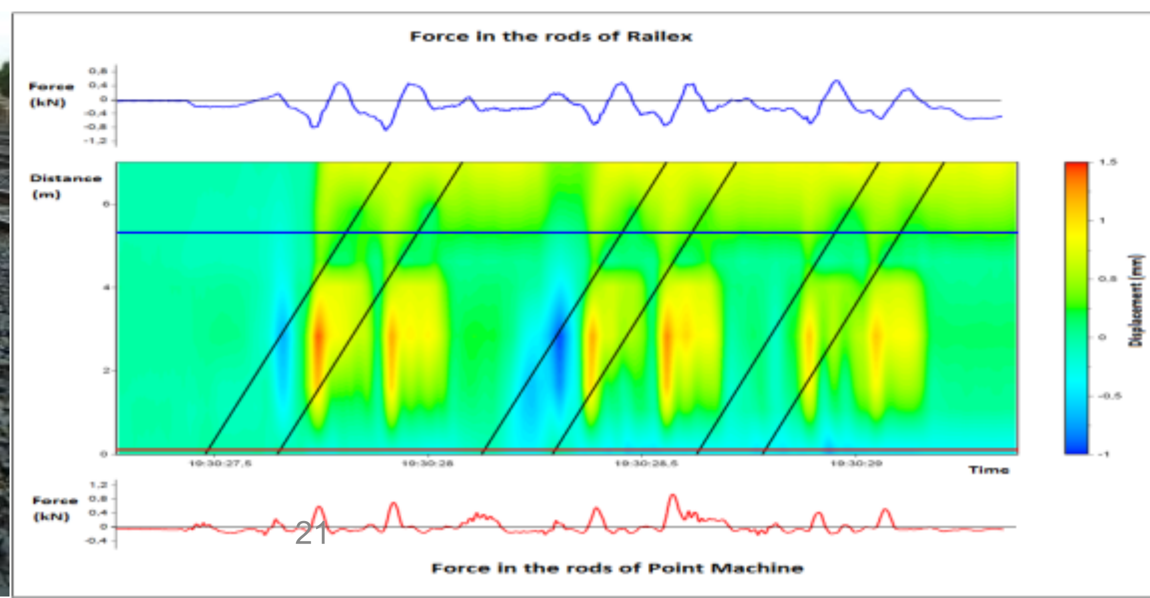
3a: Snow problems of RST and switches

1. Techniques to reduce the accumulation of snow on RST
2. Controlled detaching of snow outside the switch area
3. Winter maintenance techniques of switches



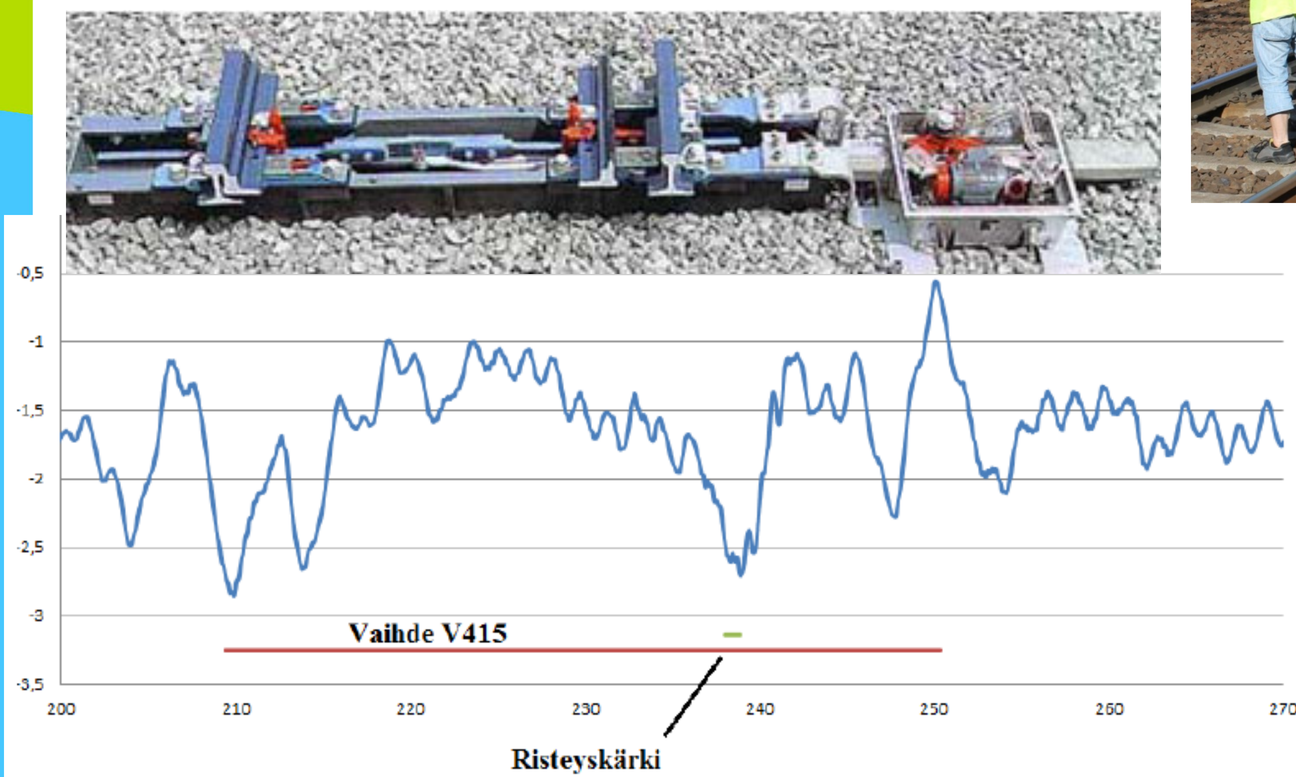

3b: Risk of opening of switch locking due to vibration



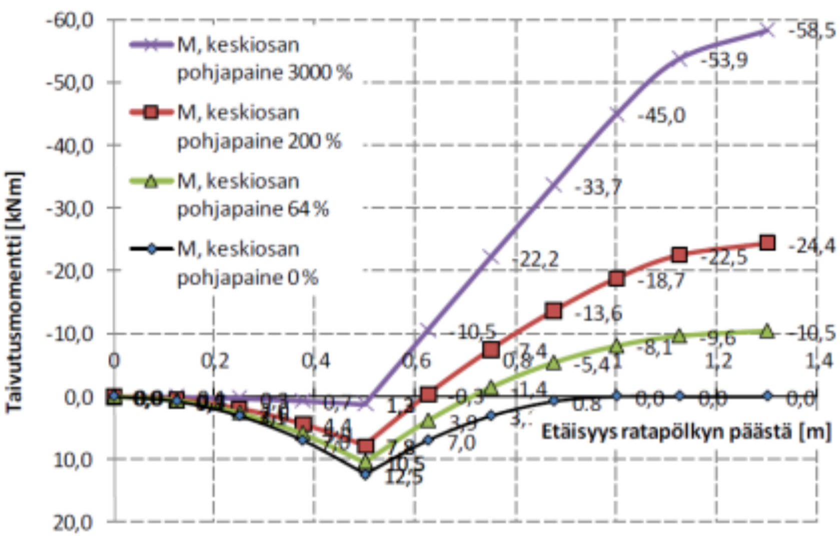


3c: Vertical elasticity in turnouts; problems and their improvements

- Discontinuity → dynamic loading
  - Geometry problems ←→ tamping challenges
  - Rapid wearing of steel component
  - **Design, USP, pad, hollow bearer…**



4a: Life-cycle and degradation mechanisms of concrete sleepers; field, laboratory, calculations



1. Mechanical damage due to traffic loading (taking into account the interaction with embankment and fatigue)
2. Weathering (frost and chemical)

5a: Life-cycle of ballast and subballast materials

Understanding of railway ballast degradation (fouling) mechanism is a starting point in order to improve life cycle economics of ballast

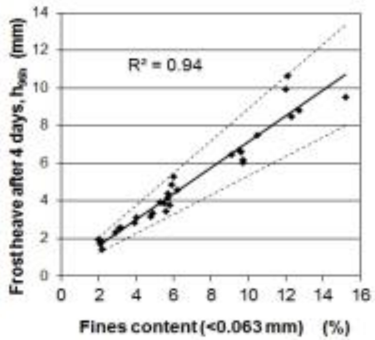
Effects of ballast degradation on:

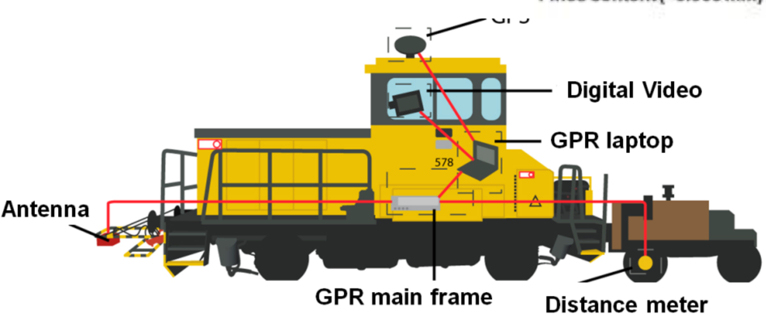
- Frost heave susceptibility
- Deformation behaviour
- Stresses of concrete sleeper
- Track geometry quality
- Water adsorption

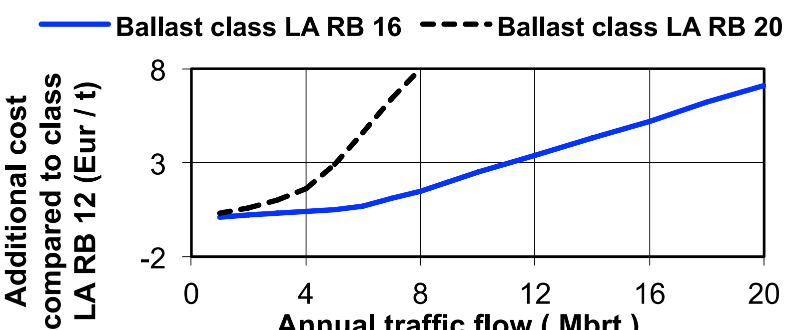
Development of ground penetrating radar to a cost efficient tool for ballast condition assessment (evaluation of the need for ballast cleaning) in collaboration with Roadscanners Oy

Material requirements based on life cycle costs

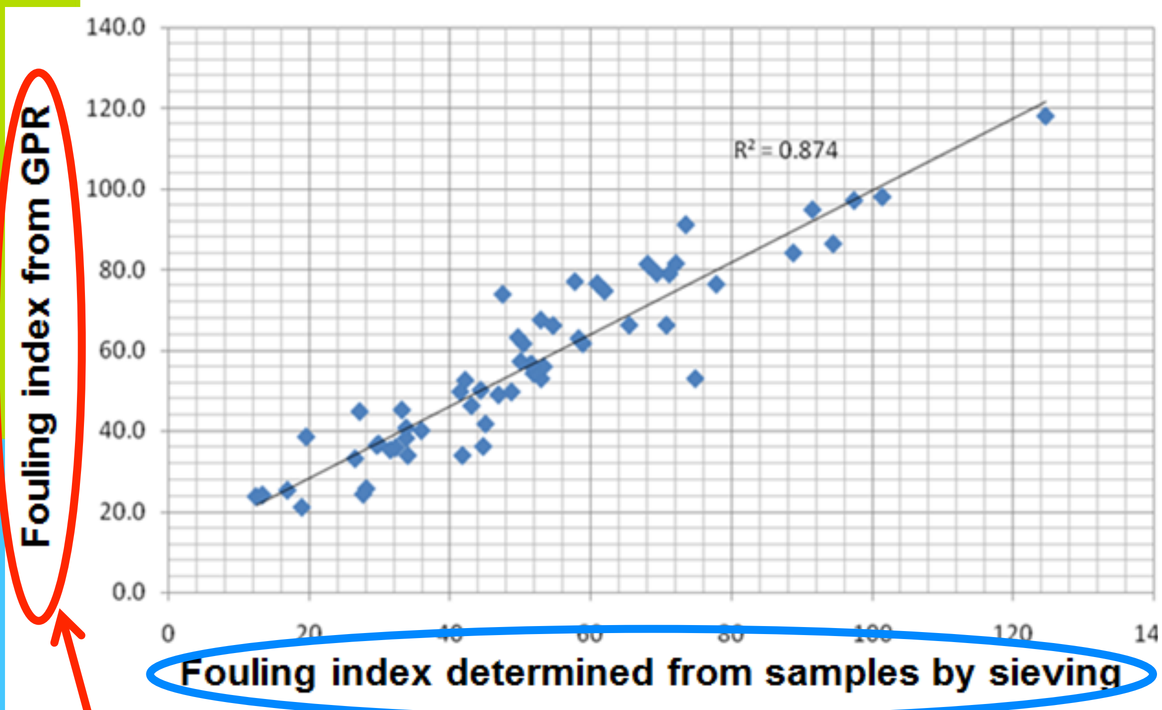
- Subballast: 100 years service life required
- Ballast: selection of ballast grade based on availability of ballast material

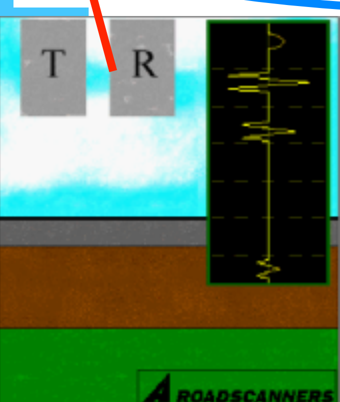


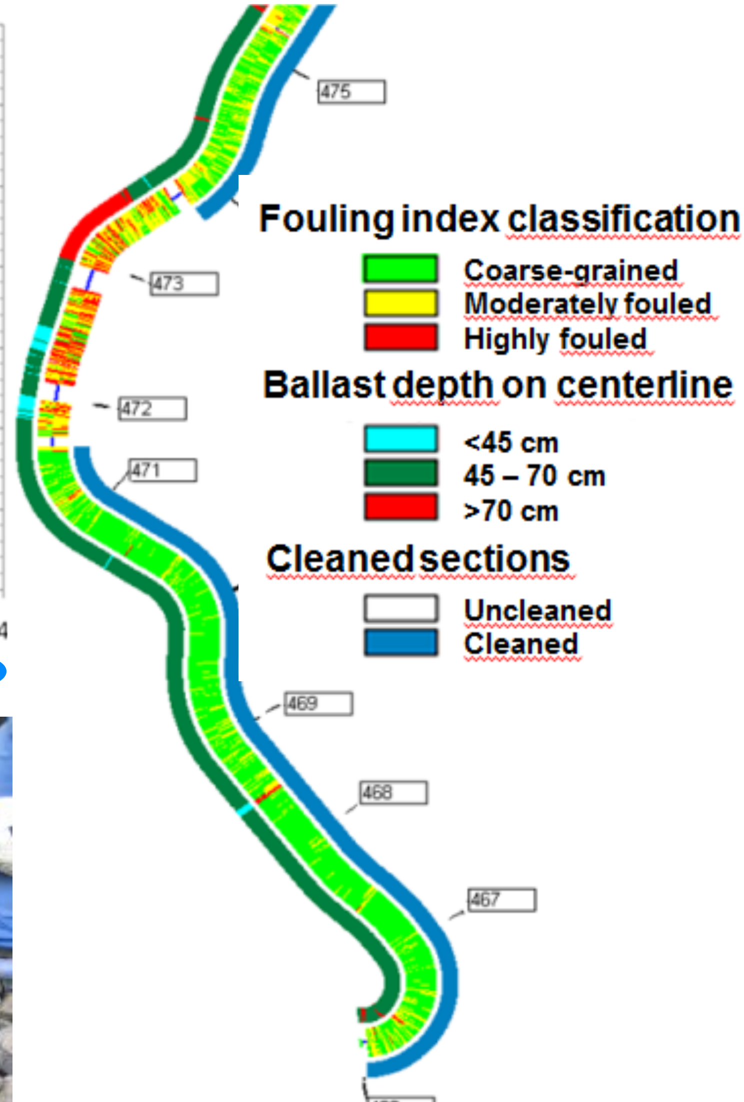




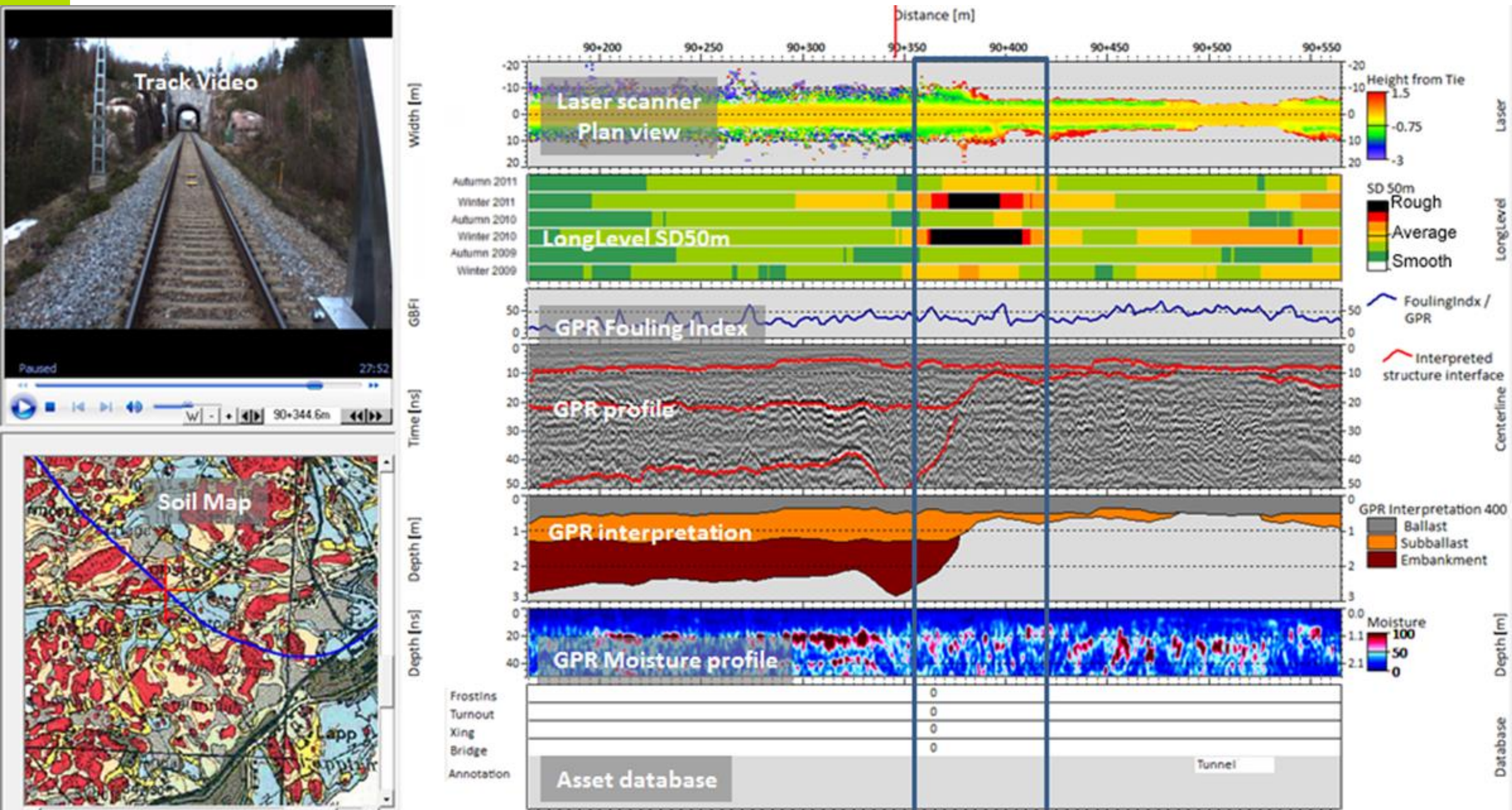
5b: Ground Penetrating Radar in analyzing ballast fouling and structural causes of track geometry deviations & Roadscanners Oy





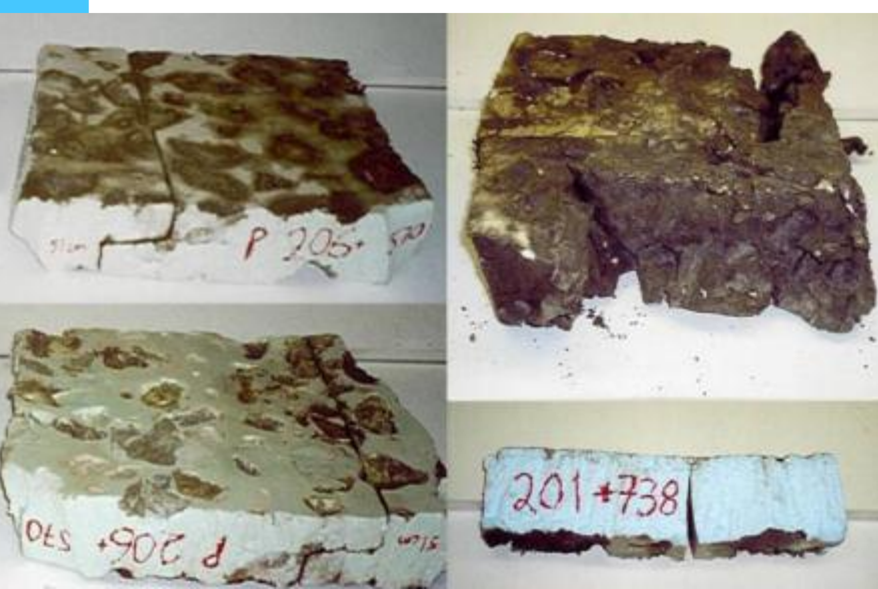


5c: Integration of GPR and track geometry data = key to optimized rehabilitation planning !

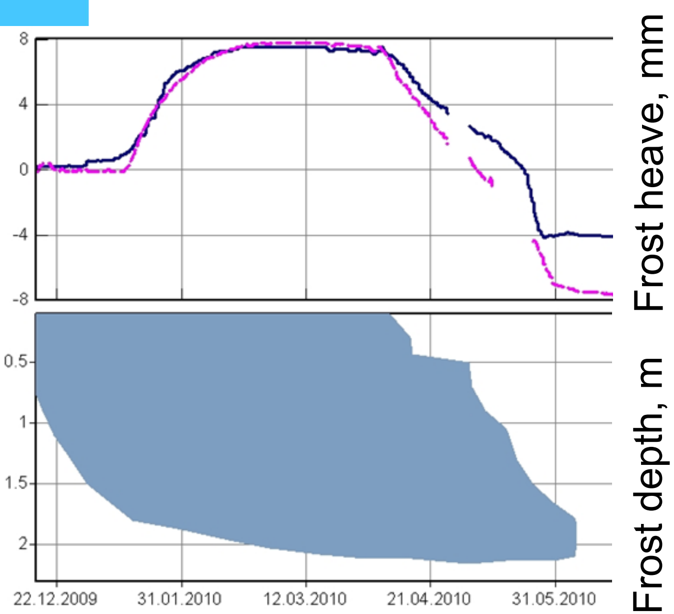


Protection against freezing of subsoil <u>on existing tracks</u>

- On existing tracks frost insulation boards are utilized
- Long-term durability of XPS-boards is sufficient



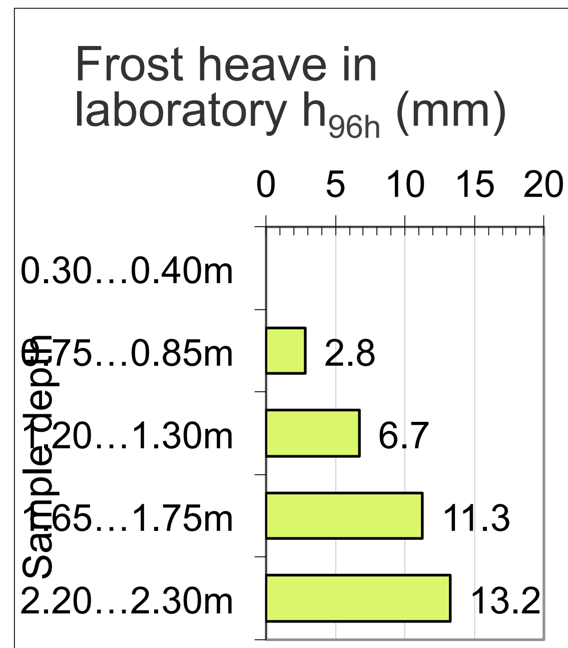
6: Frost and frost susceptibility in railway track



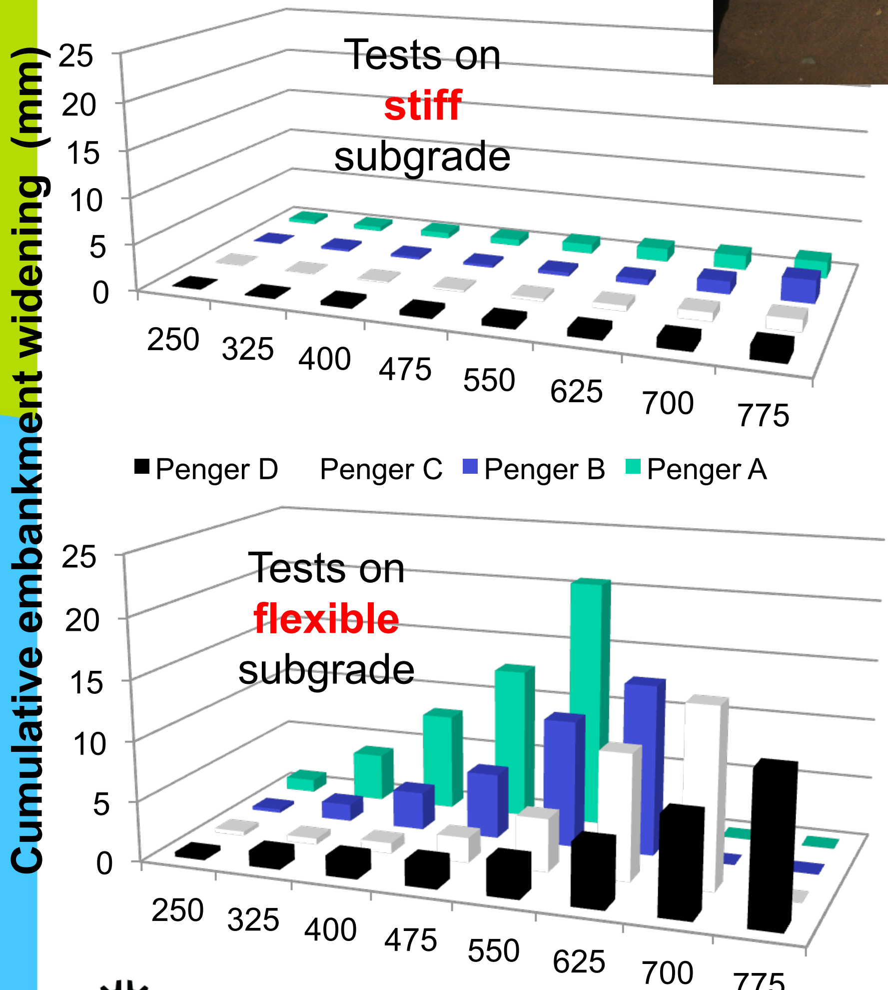
Analyzing the correlation

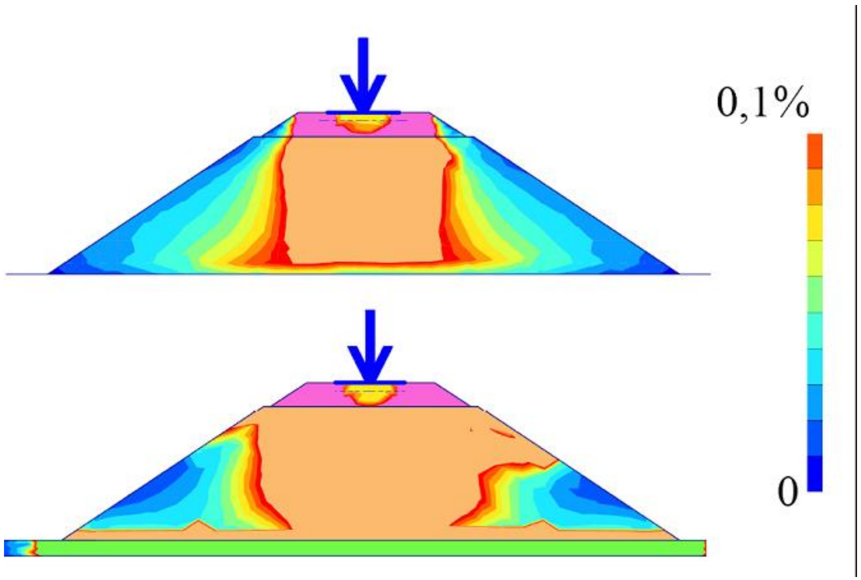
… → … → …

→ Ability to compare the costs of repair to the operational benefits gained



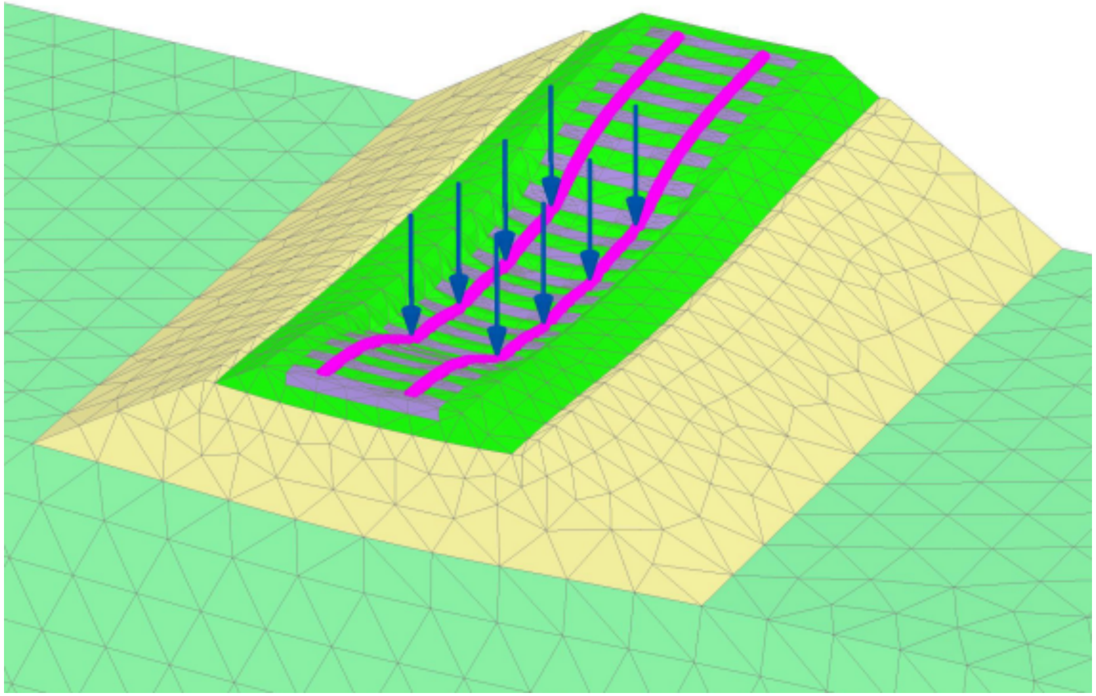
7a: The width and slope of track embankments





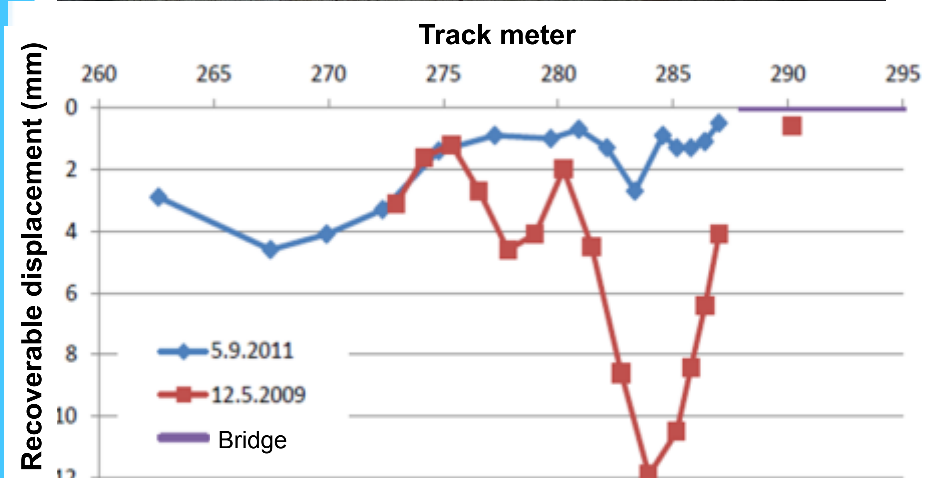
Embankment width (m)		Measured recoverable vertical displacement of sleeper under Sr2 loco
Straight	Curve	
6.0	6.4 (1	<0.6mm
6.2	6.6 (1	0.6…0.8mm
6.4	6.8 (1	0.8…1.0mm
6.6	7.0 (1	1.0…1.2mm
6.8	7.2 (1	>1.2mm

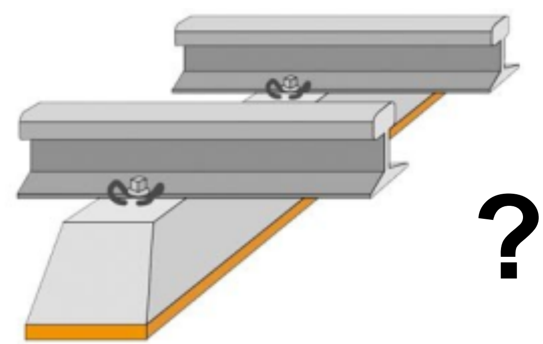
7c: Load carrying capacity design of a track



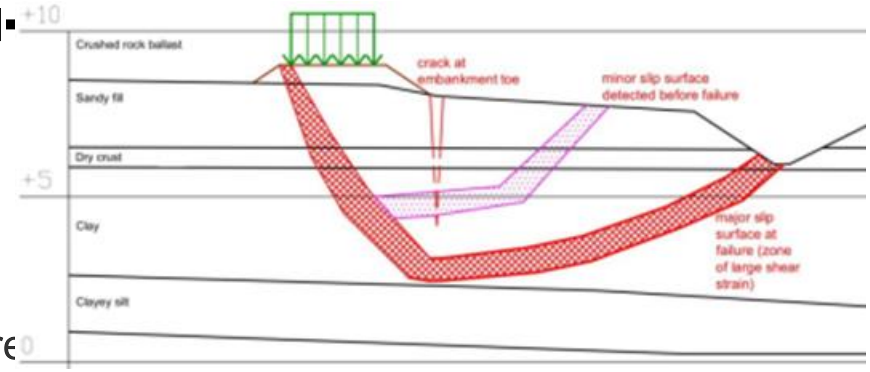
- Whole track 3D-model enables evaluation of mutual interaction of various structural components of track (for example: certain change in subsoil stiffness → magnitude of the change in rail stresses)
- Ultimate goal: Incorporation of modelled stresses and fatigue models → ”technical life-cycle design” !!

7d: Measurement of vertical track stiffness and utilization of stiffness data



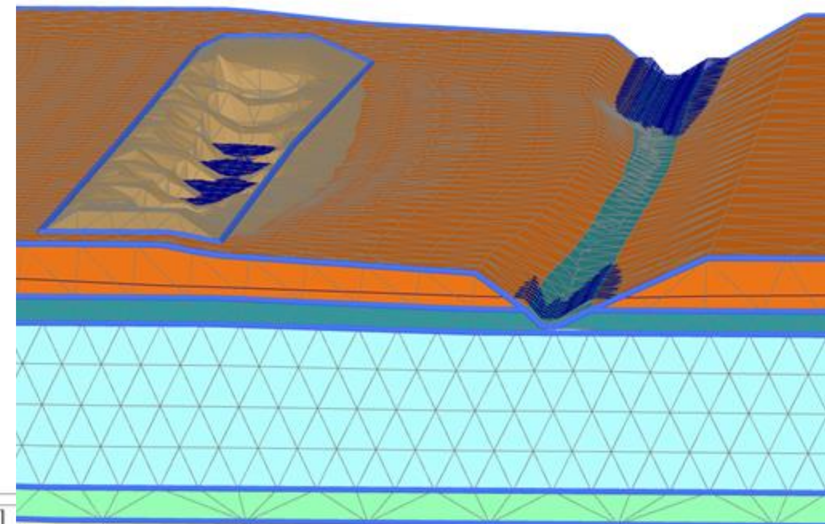


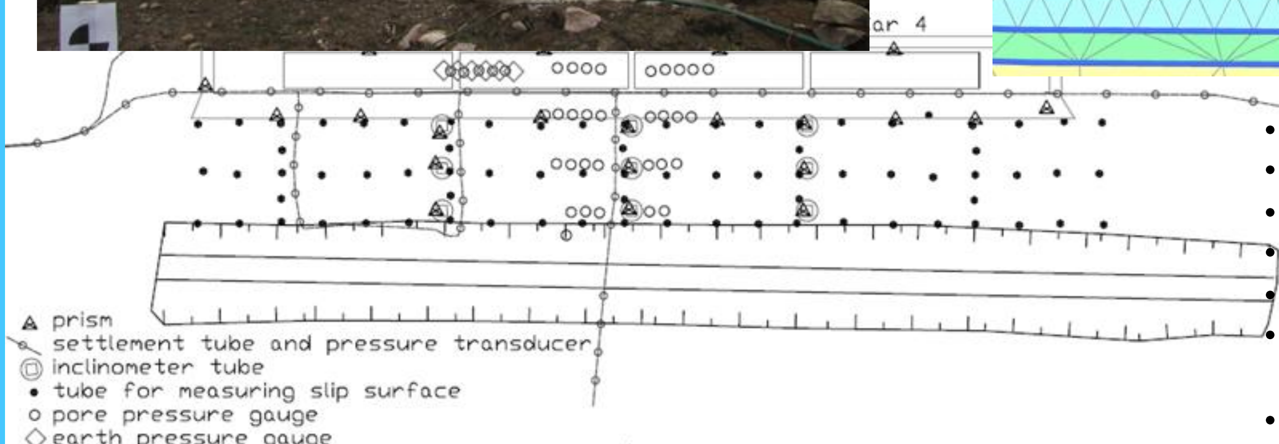
8a: Subsoil stability calculation methods and stability improvement



- A large part of the Finnish railway network is situated on very soft soils (clay, peat)

→Accurate stability calculations and monitoring are vital for embankments on soft soils in order to design a safe track economically





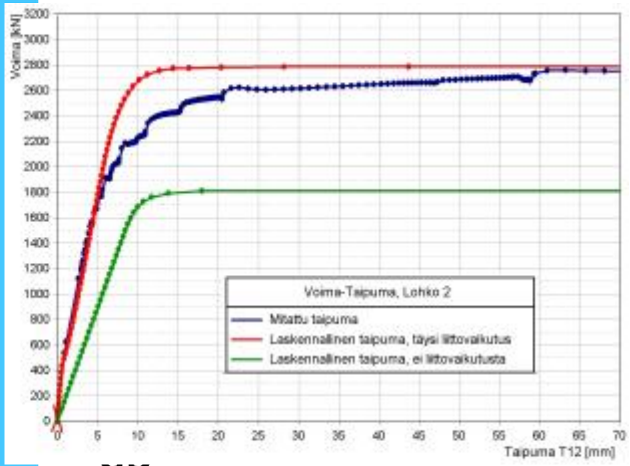
- 37 pore pressure gauges
- 9 automatic inclinometers
- 3 settlement tube (tot. 50 transd.)
- 2 total stations, 27 prisms
- 5 earth pressure gauges
- weighting of containers with strain gauges
- 76 slip surface detection tubes

Video: http://www.youtube.com/watch?v=ISES3Wh-3PE

9b: Bridges; improvement of bearing capacity evaluation of filler beam bridges

- Failure load testing (3171 ja 2762 kN) of two filler beam bridge decks
- Safety factor for 25 t axle load about 4…5!

→ Filler beam bridge decks can generally be considered as composite structure



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9c: Soil-structure-interaction on an integral abutment railway bridge

- Longitudinal force was caused by dragging four heavily loaded wagons (with brakes on) on the bridge by wire rope attached to heavy wagons further on rails.
- Earth pressure measured on different levels of the abutment

International research assessment of TUT Civil engineering in 2011

Assessment results:

• Scientific quality	4
• Scientific impact	3
• Societal impact	5
• Research environment	4
• Future potential	5

Assessment scale:

Outstanding International Level (5),
Very Good International Level (4),
Good International Level (3),
Fair International Level (2),
Poor International Level (1),

Cutting edge research areas:

- Railway structures (www.tut.fi/railway)
- Building physics
- Foundation engineering structures
- Renovation of buildings

TUT 50 years in 2015