NordFoU: Niðurbrot vega – líkanreikningar og mælingar

NordFoU Pavement Performance Modelling

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Overview

The project **NordFoU Pavement Performance Modelling** is a joint Nordic project between Denmark, Iceland, Norway and Sweden.

- The project is divided into two parts:
  - Network level
  - Project level

- The objectives of the project are:
  Develop models and test methods for performance predictions of pavements.

- The project period: 2007 – 2010.

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M-E performance predictions and design

- ***Mechanistically*** **calculate pavement response (i.e., stresses, strains, and deflections) due to:**
    - **Traffic loading**
    - **Environmental conditions**

- **Accumulate *damage* over time**
    - ***Empirically*** **relate damage over time to pavement distresses, e.g.:**
        - **Cracking**
        - **Rutting**
        - **Faulting**
        - **Roughness**

- ***Calibrate*** **(validation) predictions to observed field performance**

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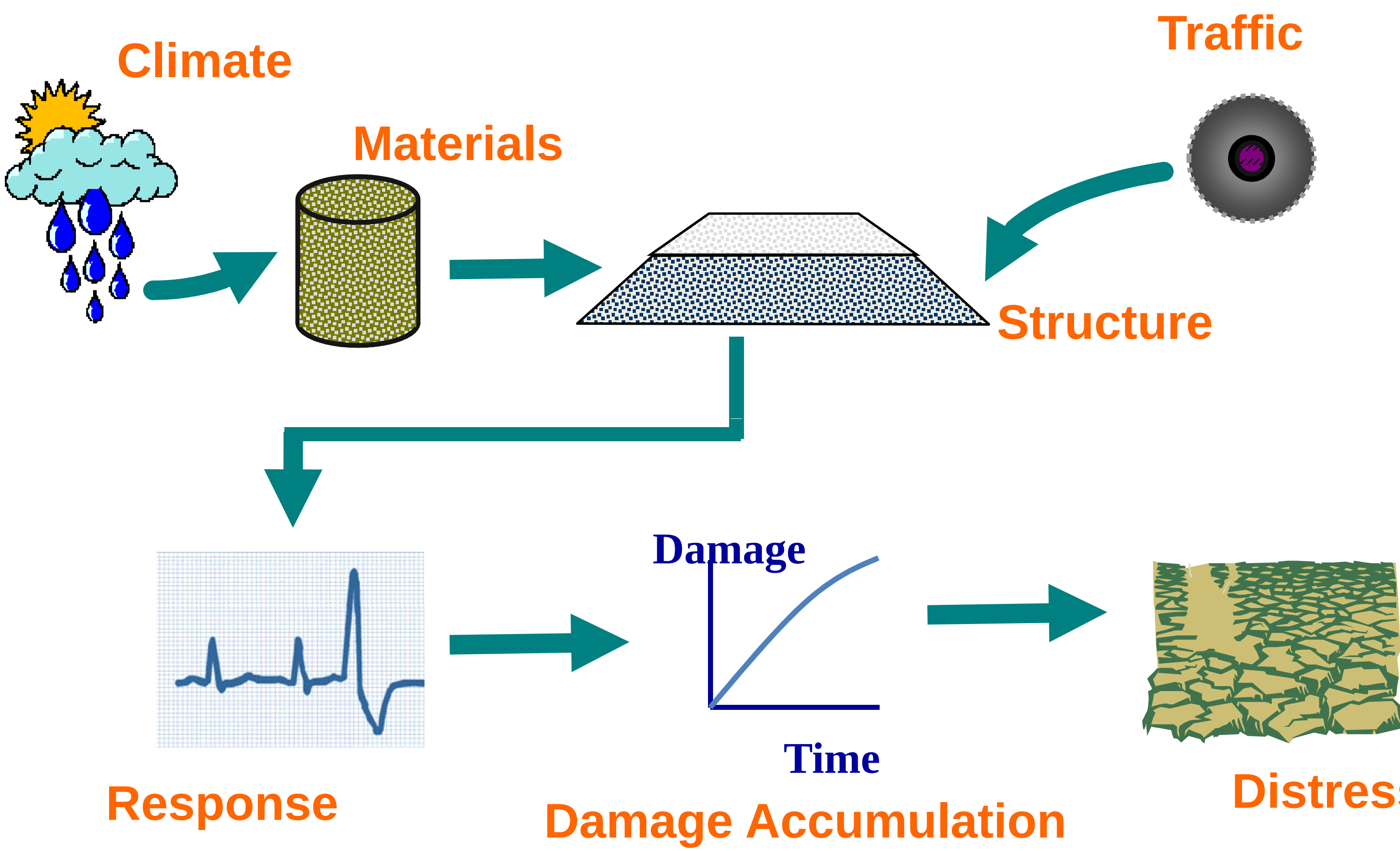
M-E performance predictions of pavements



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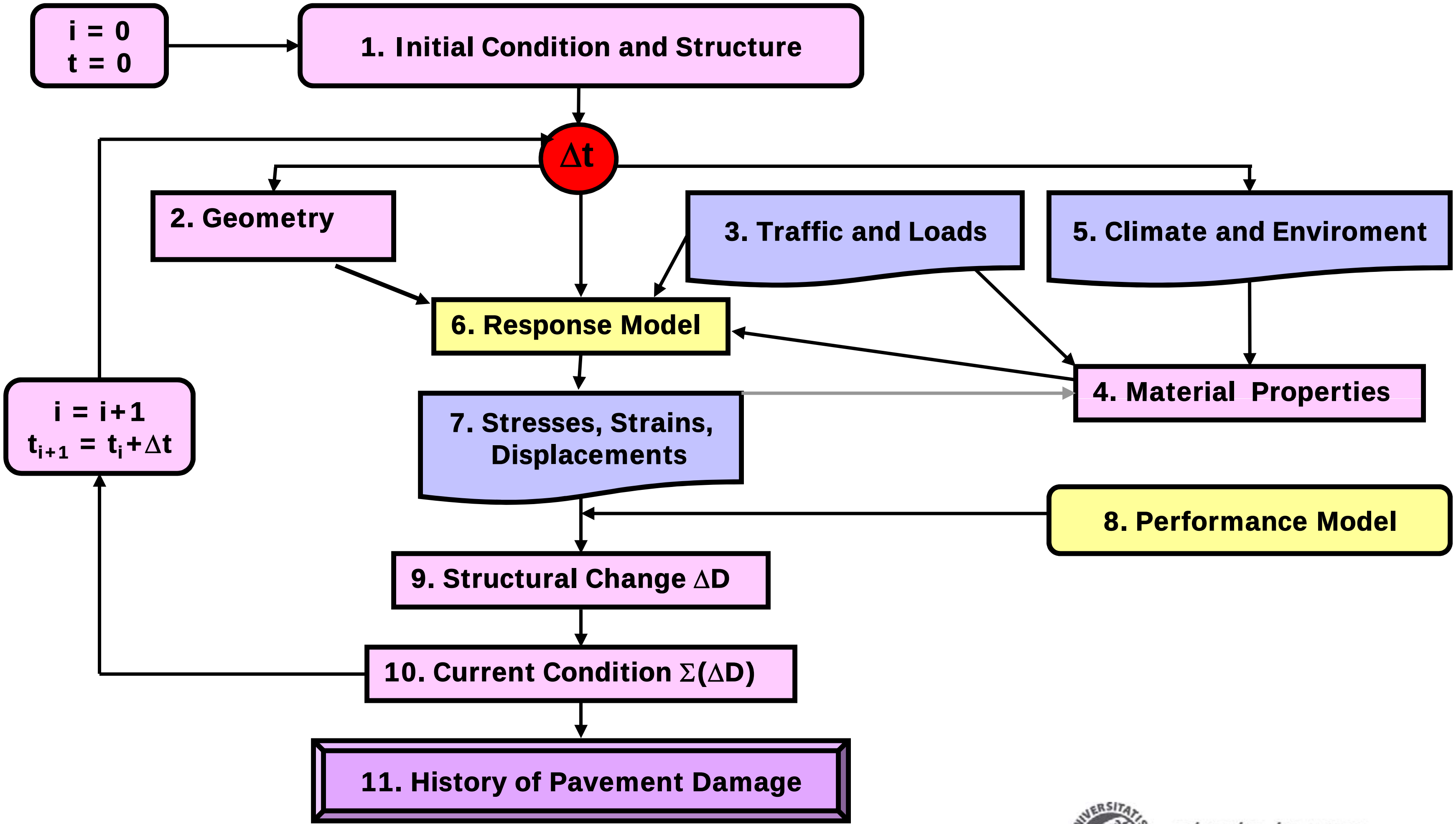
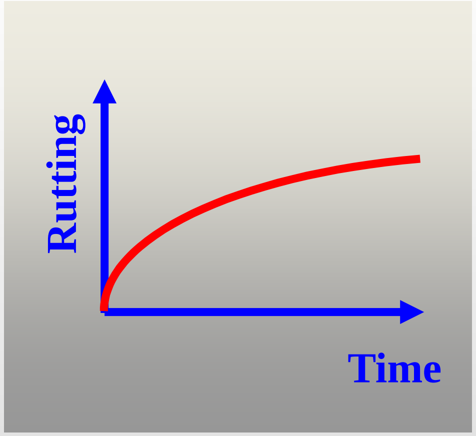
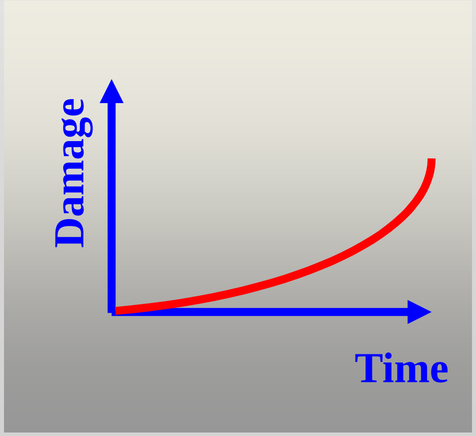
Incremental procedure - Flow diagram

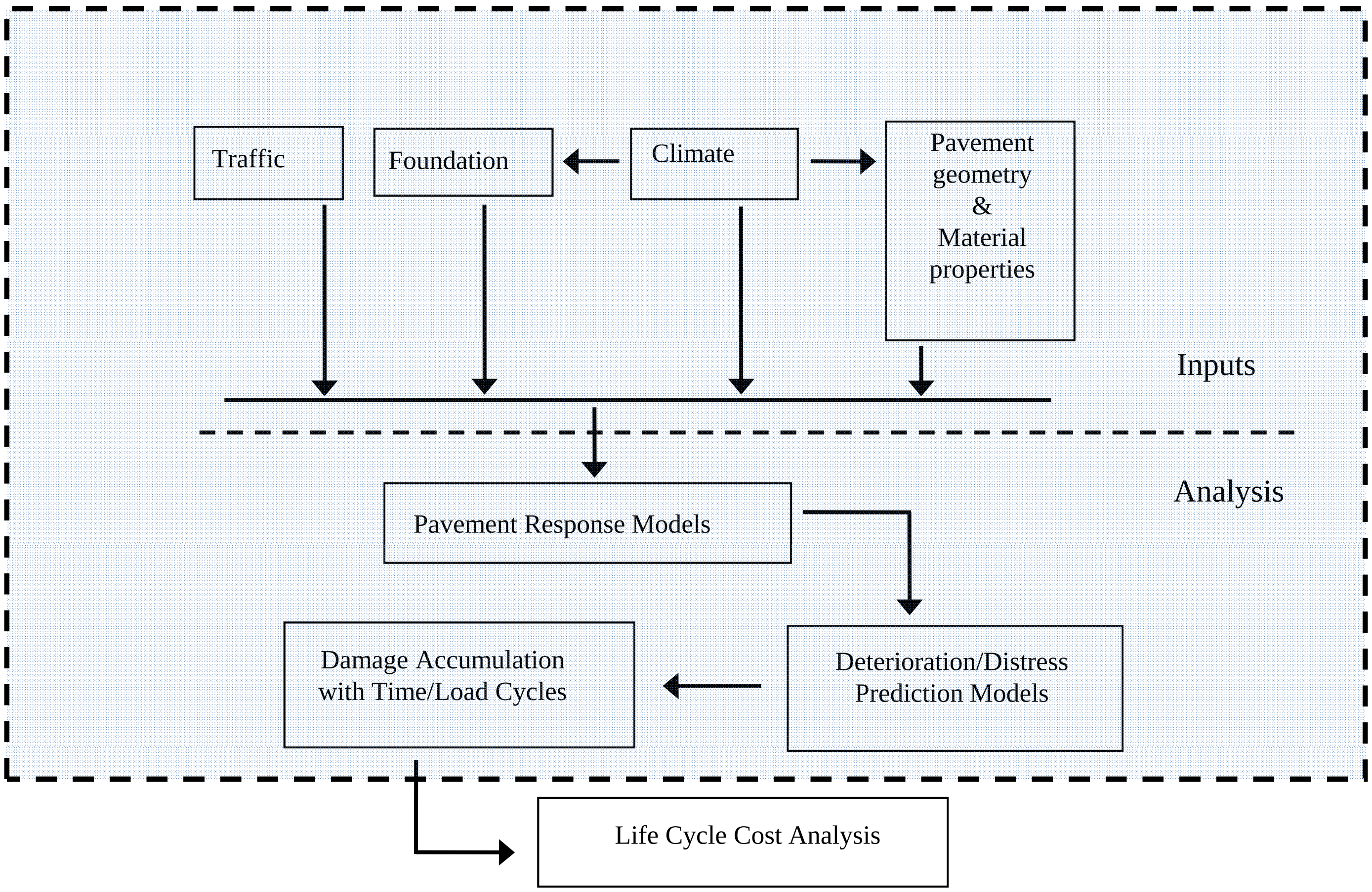


Performance prediction





LCCA


Traffic
Foundation
Climate
Pavement geometry & Material properties
Inputs
Analysis
Pavement Response Models
Deterioration/Distress Prediction Models
Damage Accumulation with Time/Load Cycles
Life Cycle Cost Analysis

Performance modelling - Rutting

Two types of empirical models have been studied (work hardening) to calculate the accumulated permanent deformation:

$$\hat{\delta}_p = \sum_{i=1}^{n}\sum_{j=1}^{m} \hat{\varepsilon}_{p_{ij}} \cdot \Delta z_{ij}$$

- The evaluation of the plastic strain is carried out within a reference framework (laboratory test) giving the model parameters and thereafter scaled to represent the accumulation of plastic strain under the actual field conditions.

- Scaling approaches:

  1) Constant plastic over resilient strain ratio

  2) State of stress with respect to the static failure line

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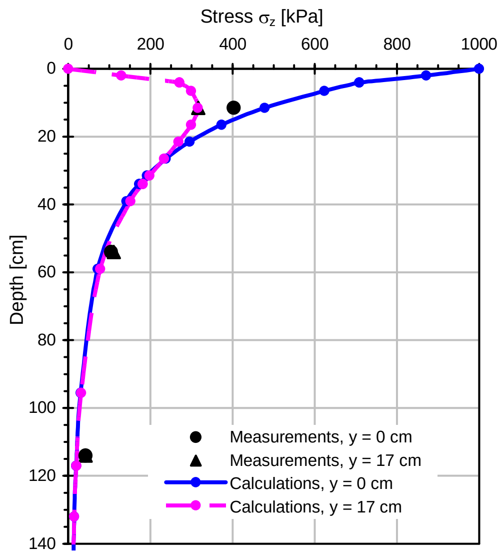
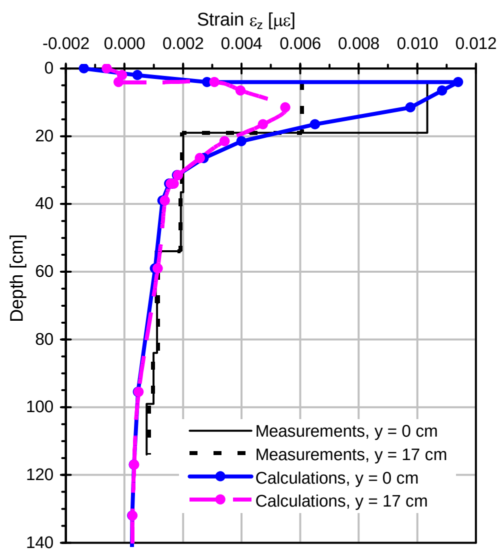
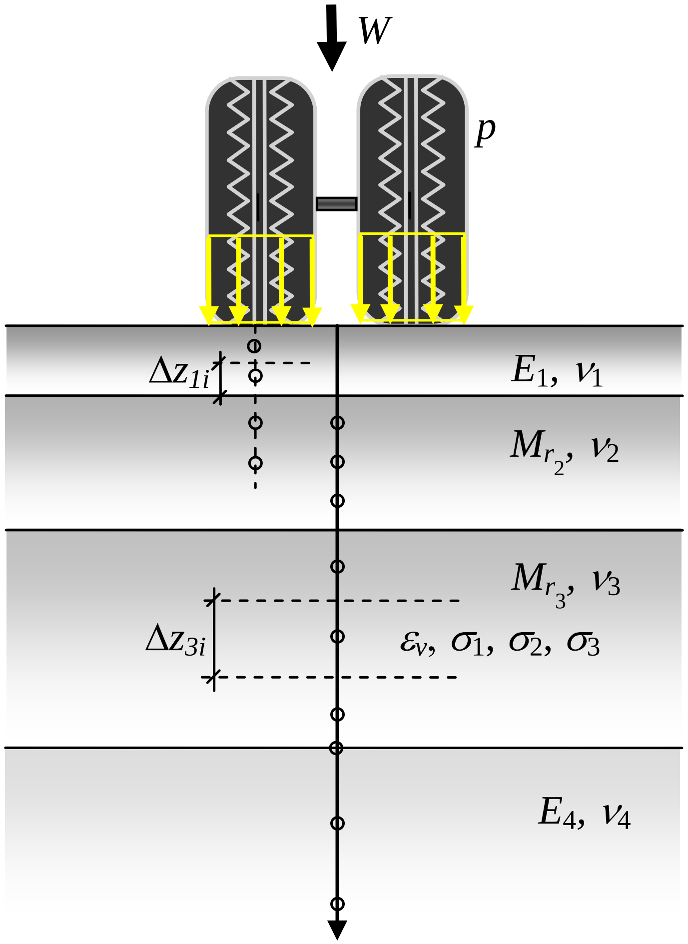
Response modelling

Non-linear elastic modelling of the pavement structure

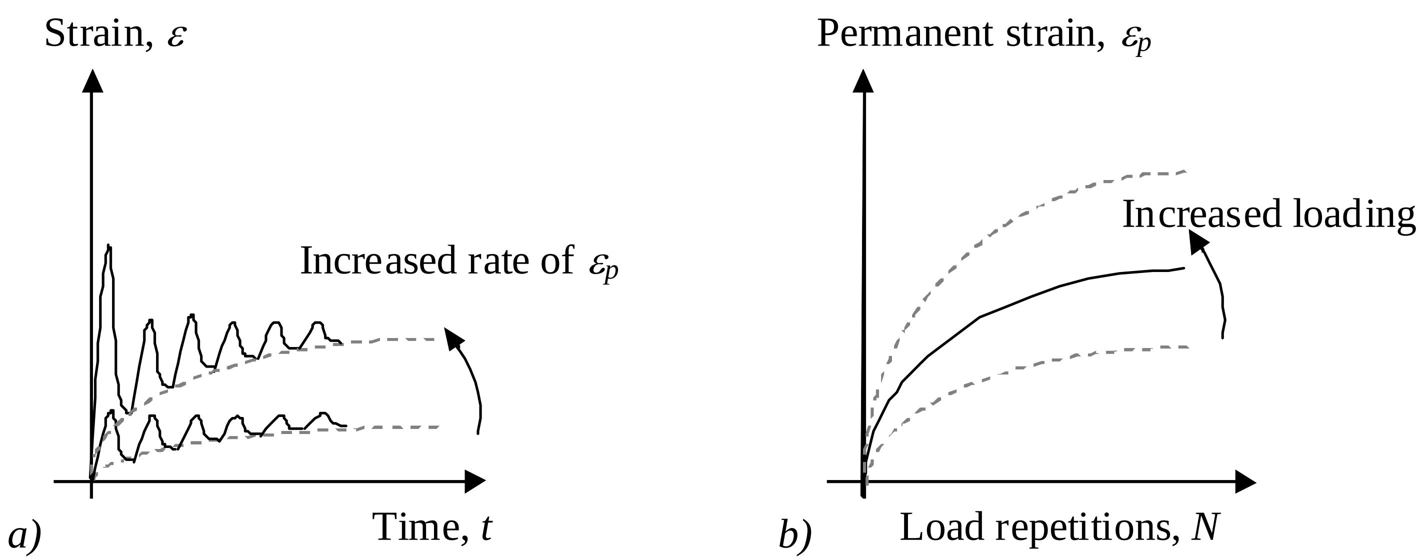






Performance Modelling - Rutting

Constant plastic over resilient strain ratio



1.

$$\frac{\hat{\varepsilon}_p^{field}(N)}{\Delta\varepsilon_r^{field}} = \frac{\hat{\varepsilon}_p^{lab}(N)}{\Delta\varepsilon_r^{lab}}$$

$$\frac{\hat{\varepsilon}_p(N)}{\Delta\varepsilon_r} = \varepsilon_0 \cdot e^{-\left(\frac{\rho}{N}\right)^{\beta}}$$

$$\hat{\varepsilon}_p^{field}(N) = \frac{\varepsilon_0 \cdot e^{-\left(\frac{\rho}{N}\right)^{\beta}}}{\Delta\varepsilon_r^{lab}} \cdot \Delta\varepsilon_r^{field}$$

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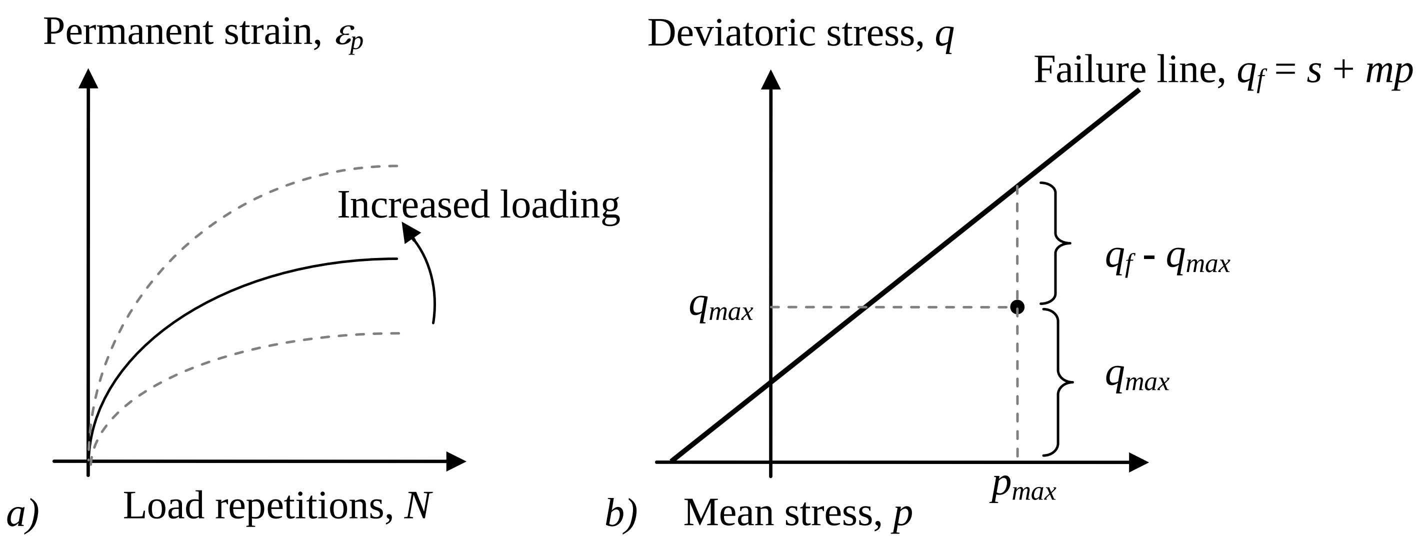
Performance Modelling - Rutting

State of stress scaling

$$\hat{\varepsilon}_p(N) = f(N)\cdot g(p_{\max}, q_{\max})$$



2.

$$\hat{\varepsilon}_p^{field}(N) = \varepsilon_{1p}^{0}\cdot\left[1-\left(\frac{N}{N_0}\right)^{-B}\right]\cdot\left(\frac{L_{\max}}{p_a}\right)^{n}\cdot\frac{1}{\left(m+\frac{s}{p_{\max}}-\frac{q_{\max}}{p_{\max}}\right)}$$

$$L_{\max} = \sqrt{p_{\max}^2 + q_{\max}^2} \qquad m = \frac{6\sin\phi}{3-\sin\phi} \qquad s = \frac{6c\cos\phi}{3-\sin\phi}$$

3.

$$\hat{\varepsilon}_p^{field}(N) = C\cdot N^{b}\cdot\frac{R}{A-R}$$

$$R = \frac{q_{\max}}{q_f} = \frac{q_{\max}}{s+mp_{\max}}$$

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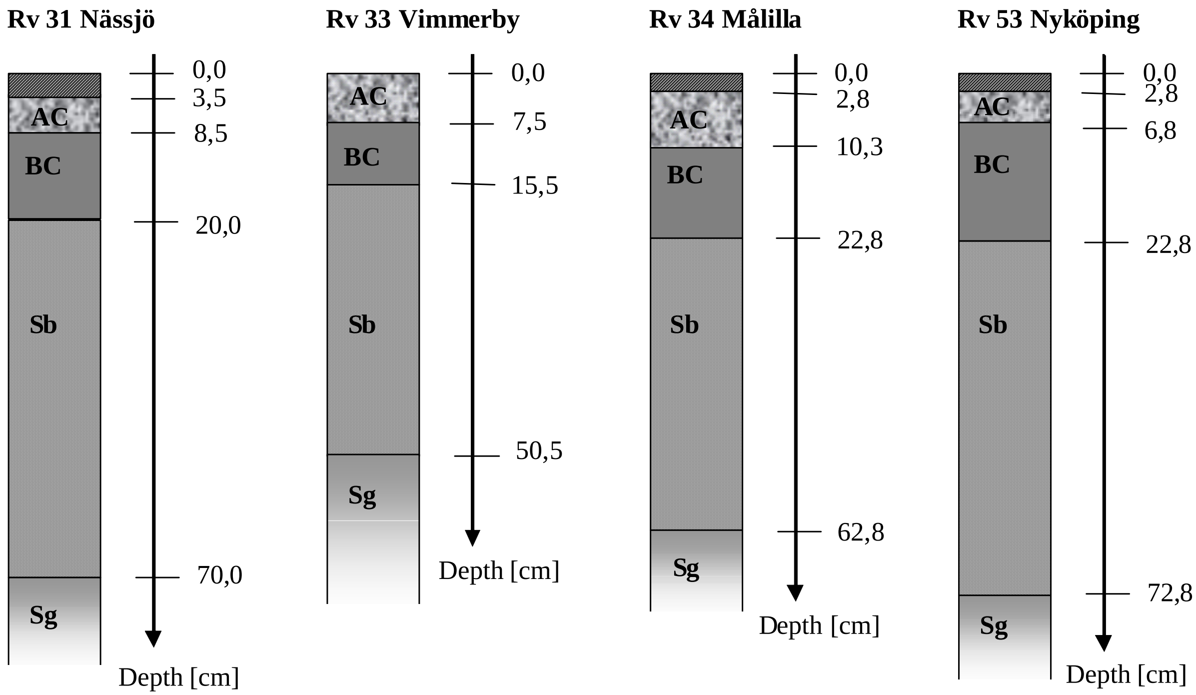
LTPP sections



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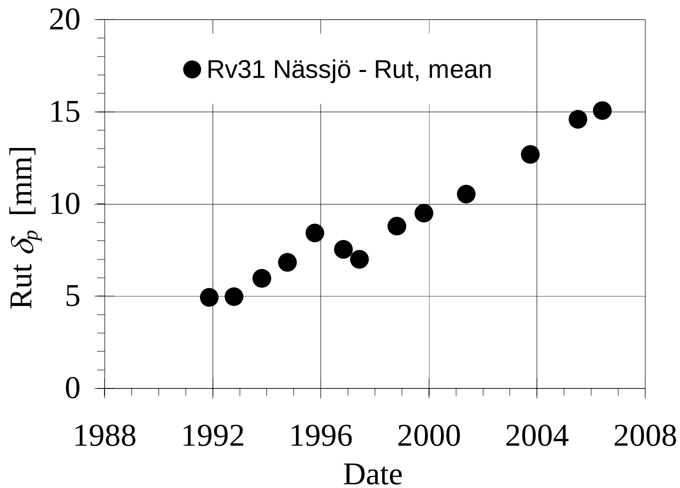
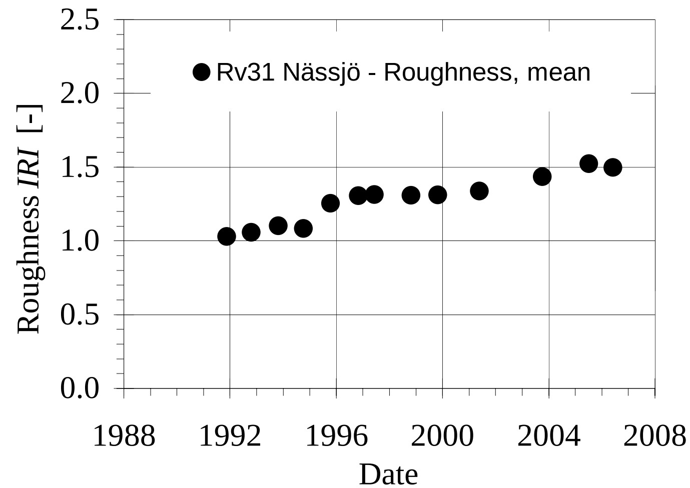
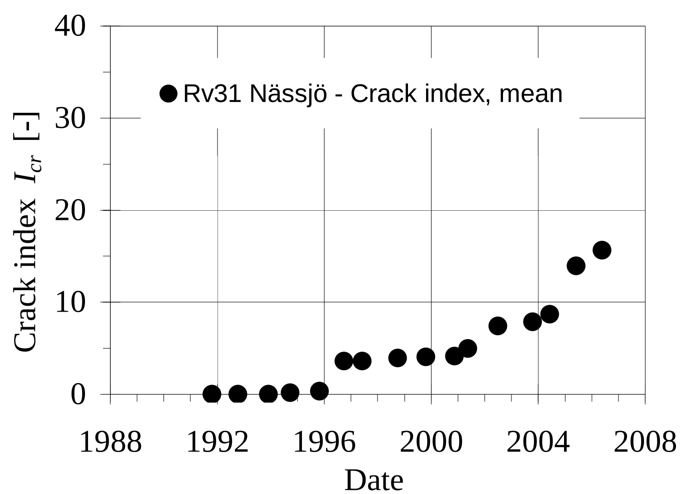
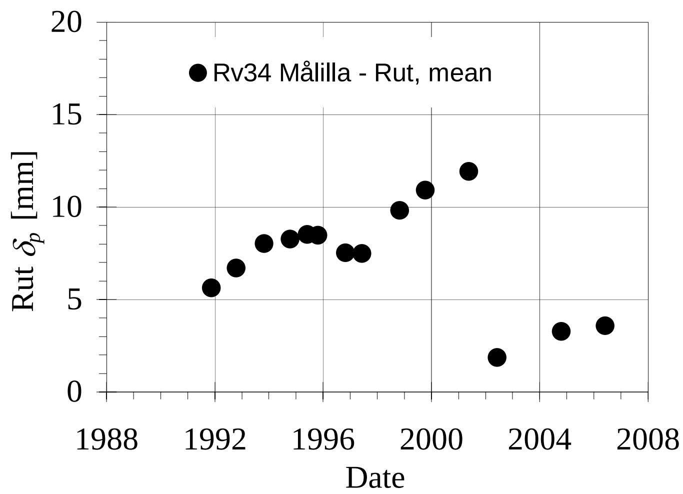
LTPP road Rv31 Nässjö

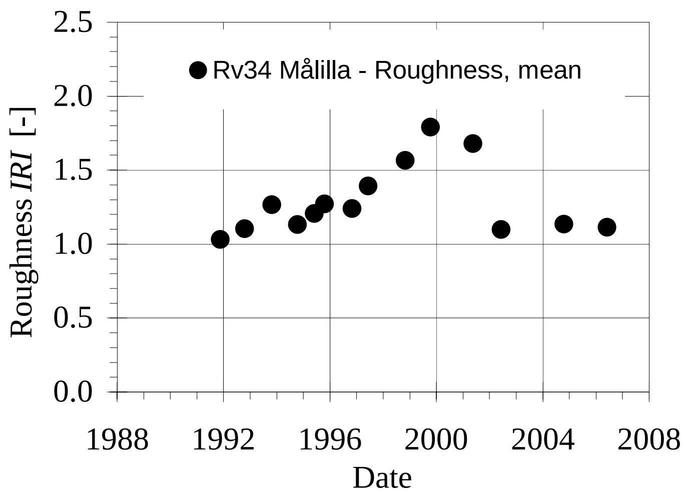


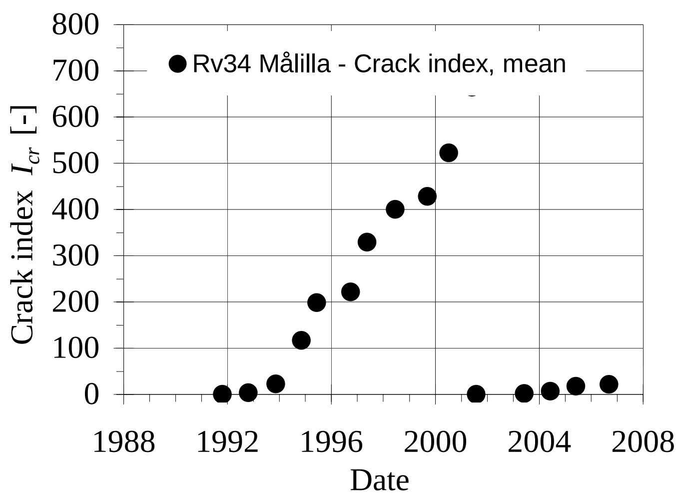




LTPP road Rv34 Målilla







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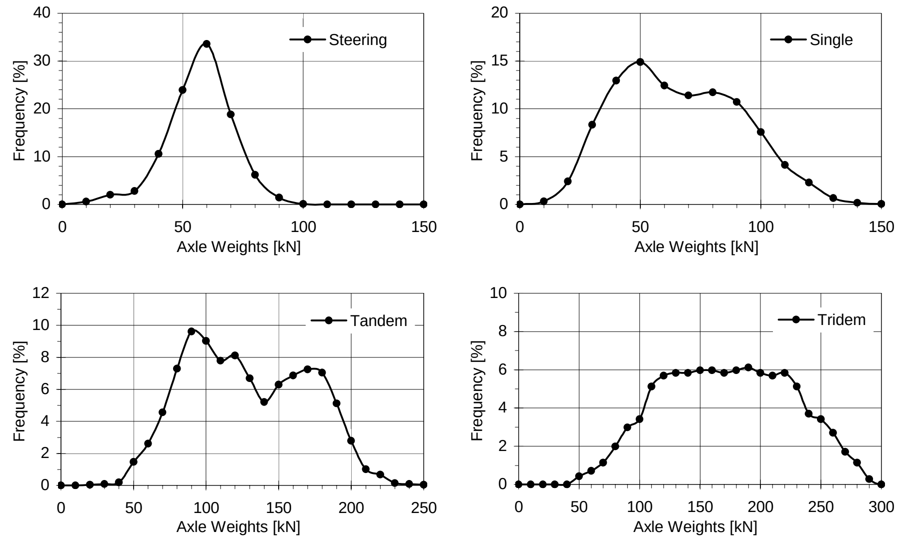
Traffic loading

ALS Forserum 2005



Location	Date of opening for traffic	ESAL´s N_{100} (-)	Av. traffic increase (%)
Rv 31 Nässjö	1988-11-01	182	1.2
Rv 33 Vimmerby	1980-07-01	45	4.6
Rv 34 Målilla	1987-10-13	220	0.4
Rv 53 Nyköping	1987-07-01	50	3.3

$$T_f = \frac{1}{N_{hv}} \cdot \sum_{i=1}^{4} N_i \cdot \sum_{j=1}^{n_j} \left(\frac{W_{ij}}{W_{i_{stand}}} \right)^4 \cdot \frac{f_j^{norm}}{100}$$

$$T_f = 0.99$$

All traffic loading consists of standard axles: Dual wheel single axles with L_A = 100 kN and p = 800 kPa.

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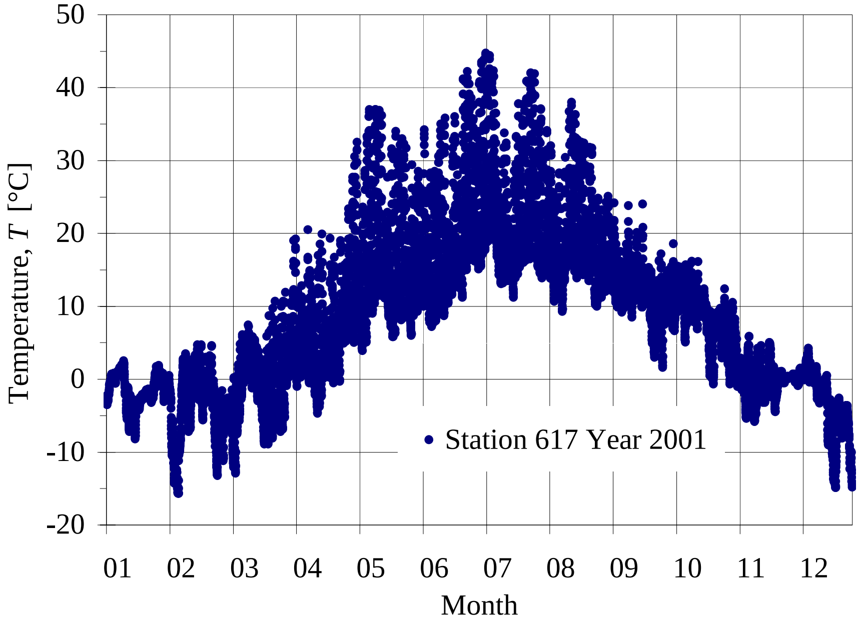
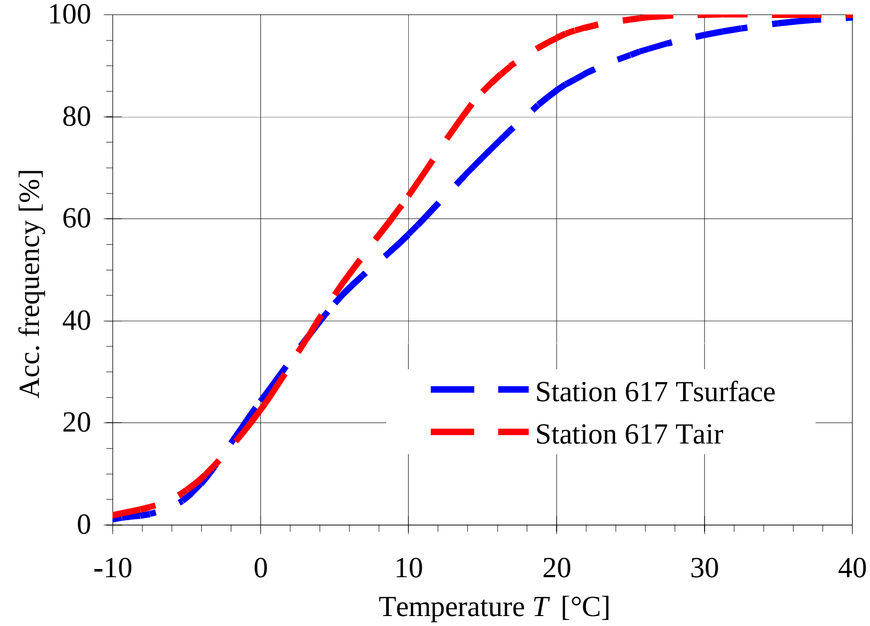
Climate data

Station 617: Nässjö



Average temperature for 2001 - 2008



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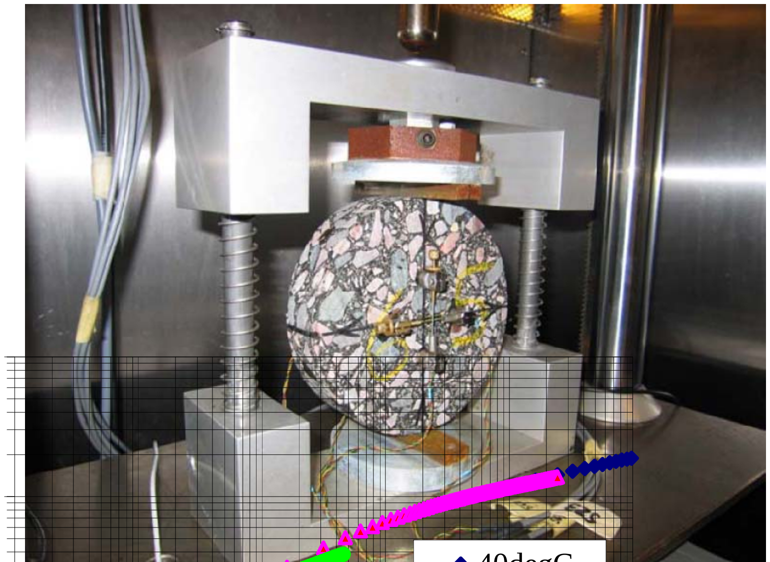
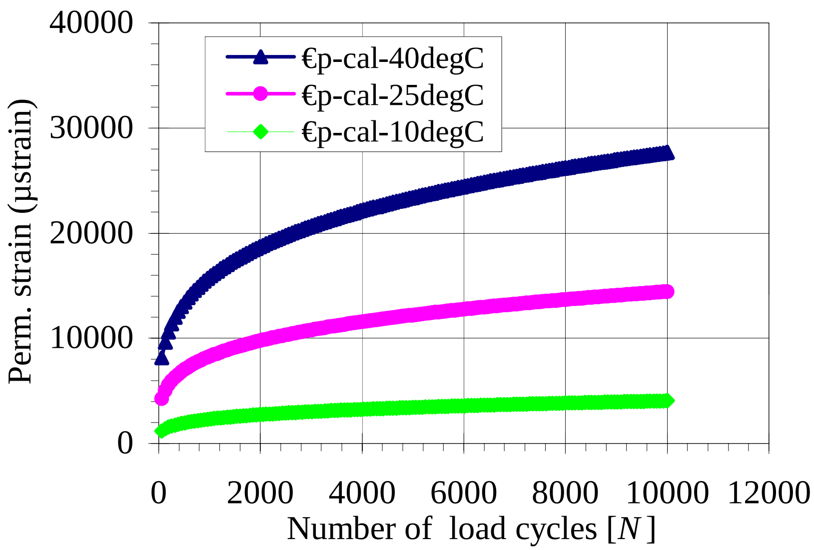
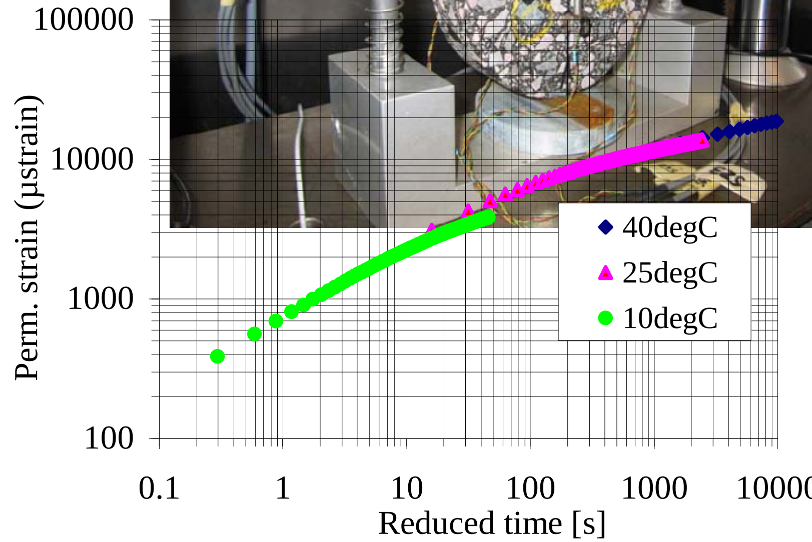
Material parameters: AC

$$\hat{\varepsilon}_p^{field}(N) = \frac{a_1}{\Delta\varepsilon_r^{lab}} \cdot T^{a_2} \cdot N^{a_3} \cdot \Delta\varepsilon_r^{field} = a_1^* \cdot T^{a_2} \cdot N^{a_3} \cdot \Delta\varepsilon_r^{field}$$

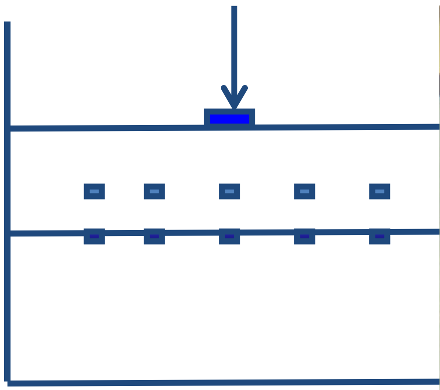


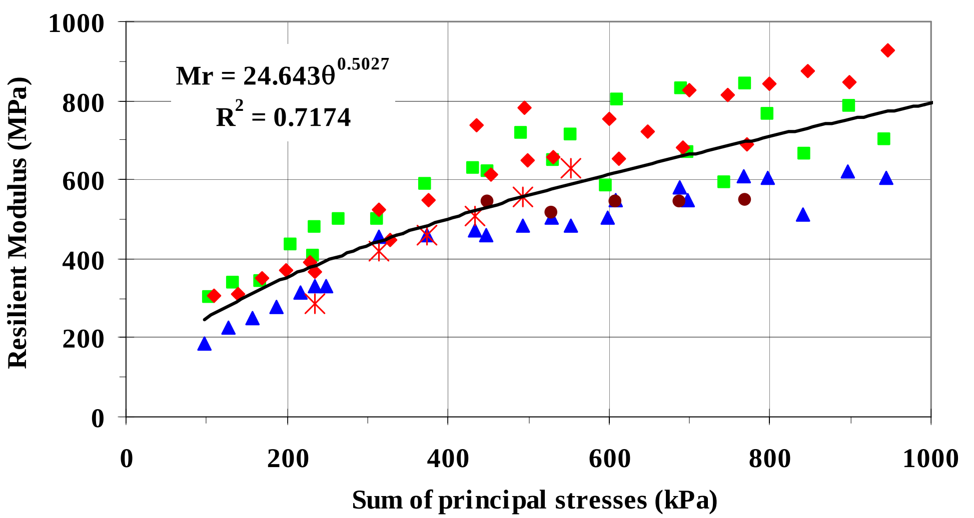


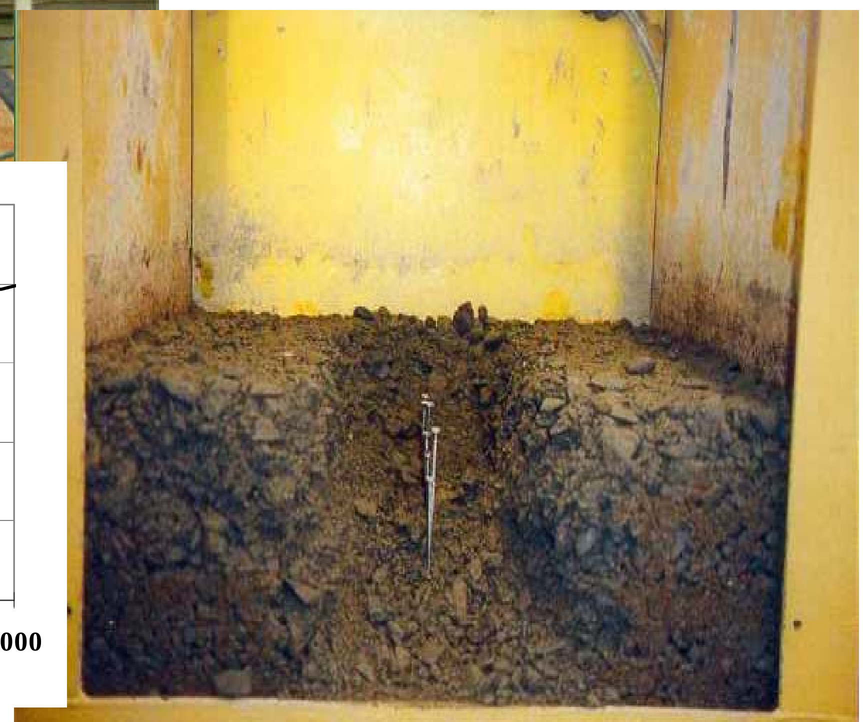


E_{Tref} [MPa]	ν [-]	b [-]	a_1^* [-]	a_2 [-]	a_3 [-]
6,500	0.35	0.065	0.17	1.85	0.27

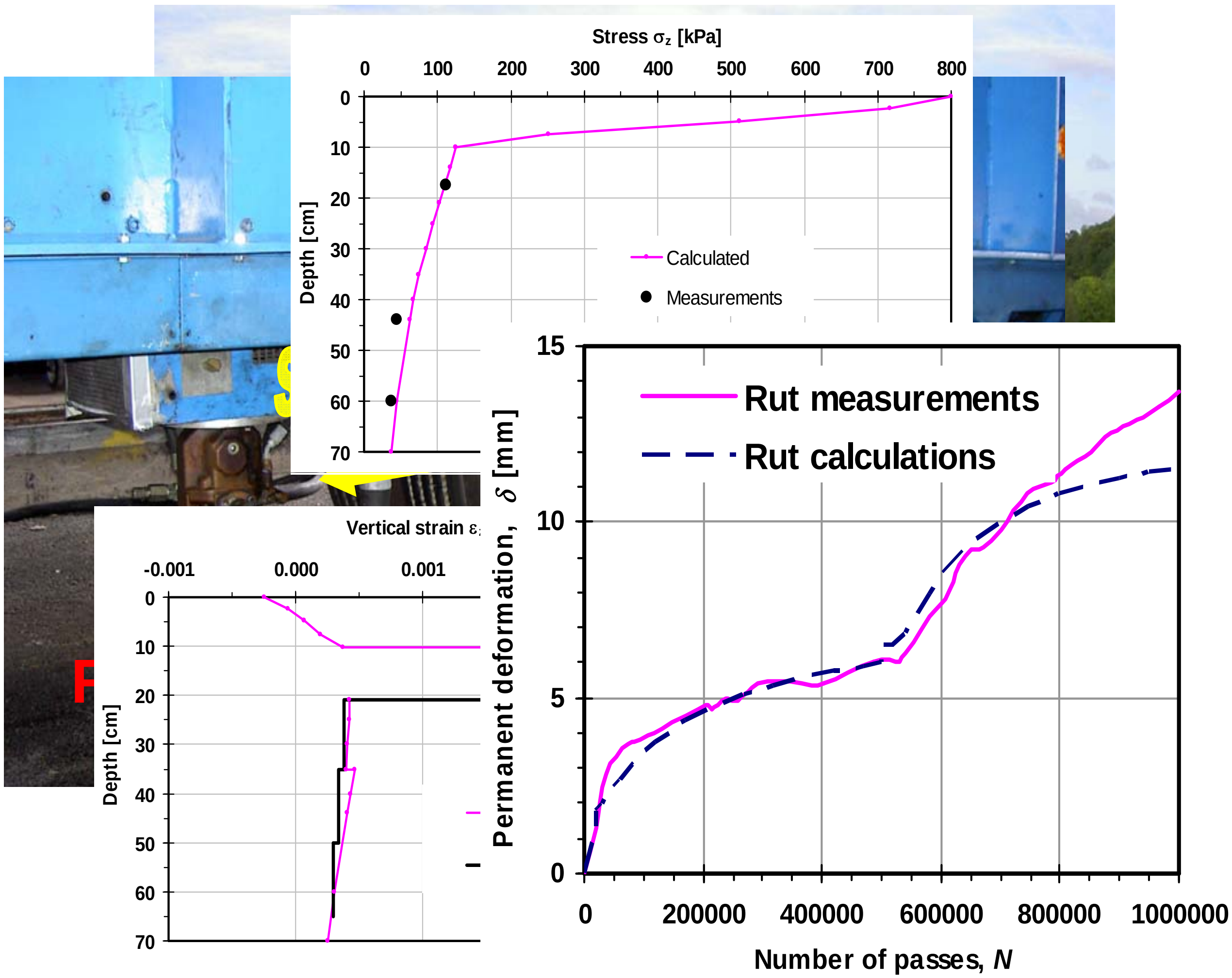
Material parameters: UGM

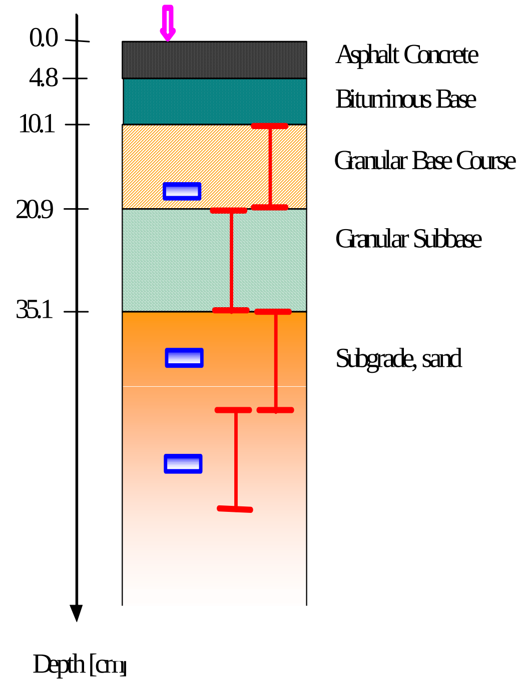






Material parameters: Subgrades





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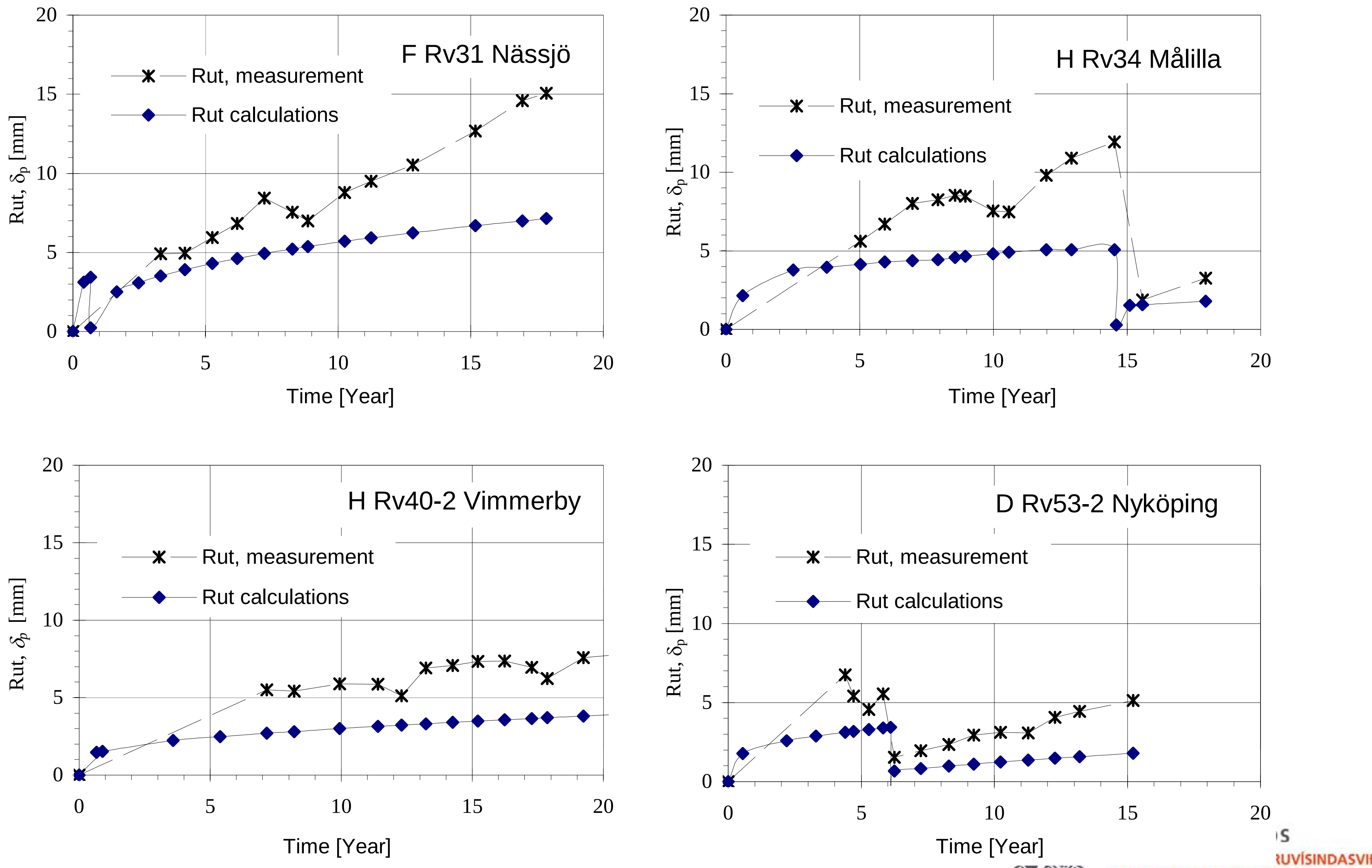
Rutting prediction – comparison with LTPP data



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Conclusions

Performance prediction has been carried out for four LTPP test road section in southern Sweden using a two-step M-E approach.

The major findings from this study were:

- The M-E approach proposed here can predict the rutting development of typical Swedish roads.
- The simple performance models used here seems to predict adequately the expected permanent deformation of the structures for at least of a time period of 8 - 10 years.
- Performance calculations for longer periods need to be adjusted to include changes in material properties due to ageing of material as well as changes in the structural integrity of the pavement (cracking).
- As studded tyres are frequently used in the Nordic countries wear due to studs should be added to the total rut to improve the prediction of the total rut.
- The material behaviour dependency on the climate needs to be better represented in the predictions.

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