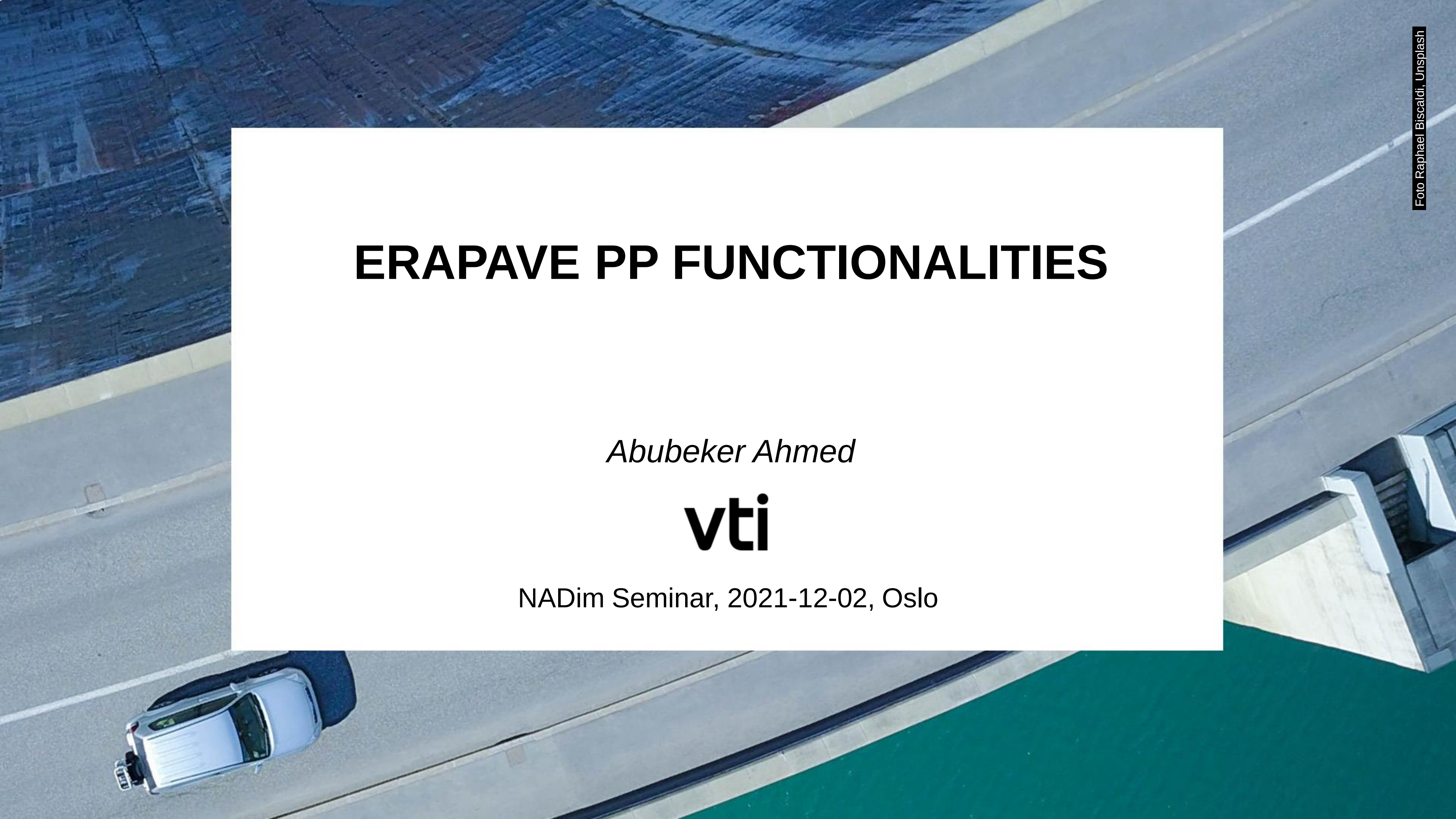


Foto Raphael Biscaldi, Unsplash

ERAPAVE PP FUNCTIONALITIES

Abubeker Ahmed

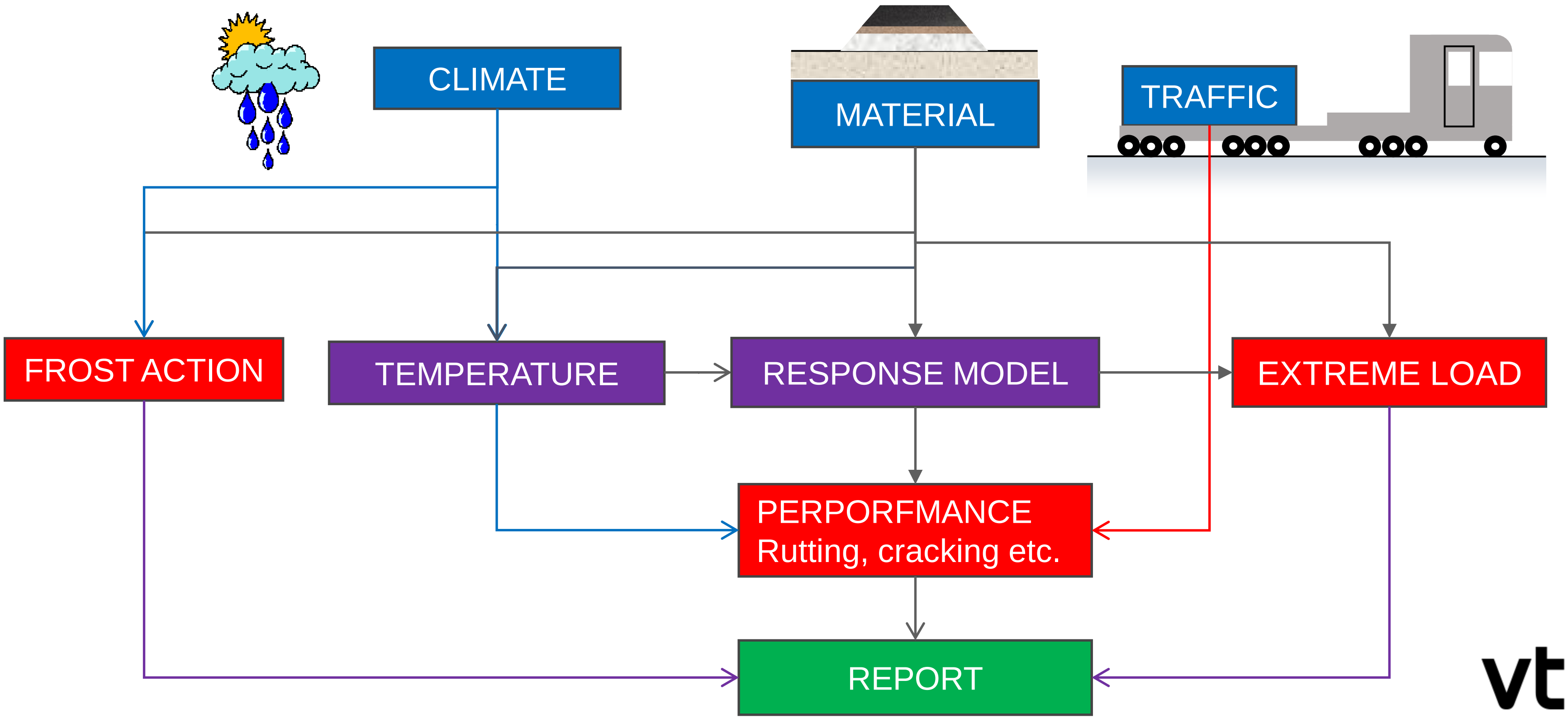
vti

NADim Seminar, 2021-12-02, Oslo

OUTLINE

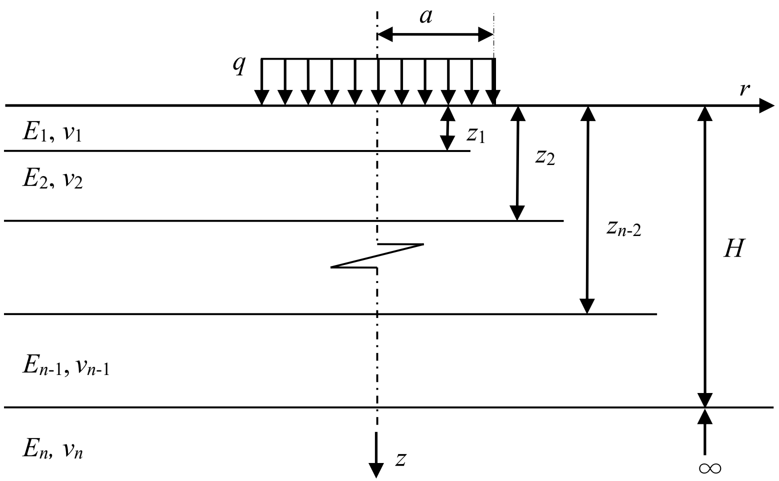
- ERAPave PP components
- Component models
  - Mechanical model
  - Material models
  - Temperature model
  - Performance model
- Report dashboard
- Questions?

ERAPAVE PP COMPONENTS



MECHANICAL MODEL - RESPONSE

- Layered elastic theory is used to estimate stresses ands strains
- Modulus and poisons ratio of each layer are the input parameters
- A circular contact area is assumed for the analysis

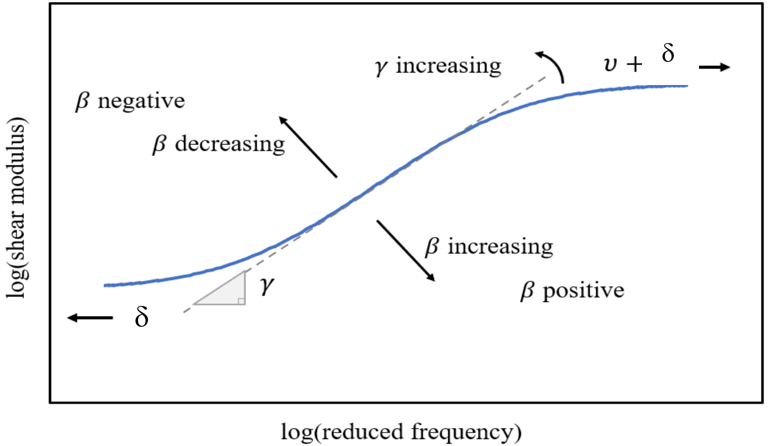


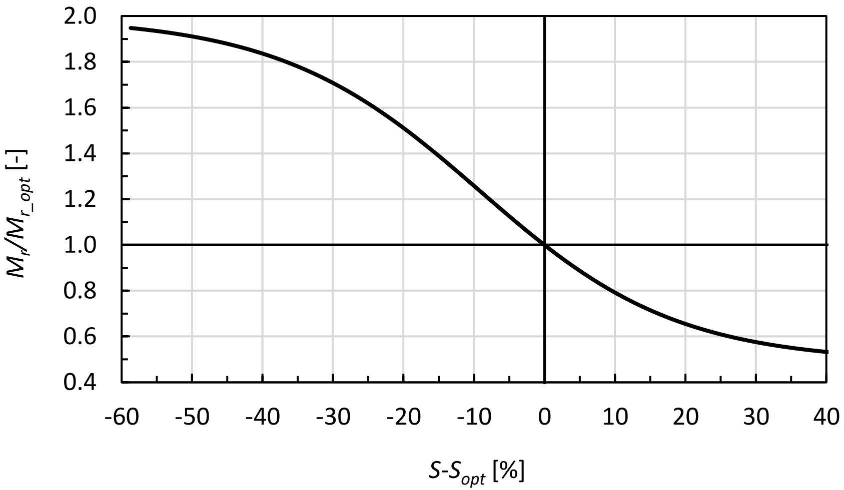
MECHANICAL MODEL - MATERIAL

- Master curve parameters for asphalt mixtures and resilient modulus for UGMs

$$|E_m^*| = \upsilon + \frac{\alpha}{1 + e^{\beta - \gamma \log(f_r)}}$$

$$\log \frac{M_R}{M_{R_{opt}}} = a + \frac{b-a}{1 + \exp\left(\ln \frac{-b}{a} + k_m \left(S - S_{opt} \right) \right)}$$





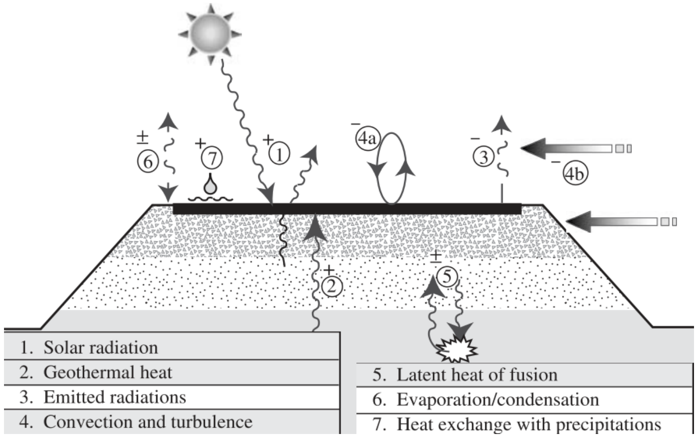
TEMPERATURE MODEL- BACKGROUND

Main heat transfer modes to be considered:

- Conduction/Convection
- Radiation
- Convection

$$\frac{\partial^2 T}{\partial z^2} = \frac{\rho c}{k}\frac{\partial T}{\partial t}$$

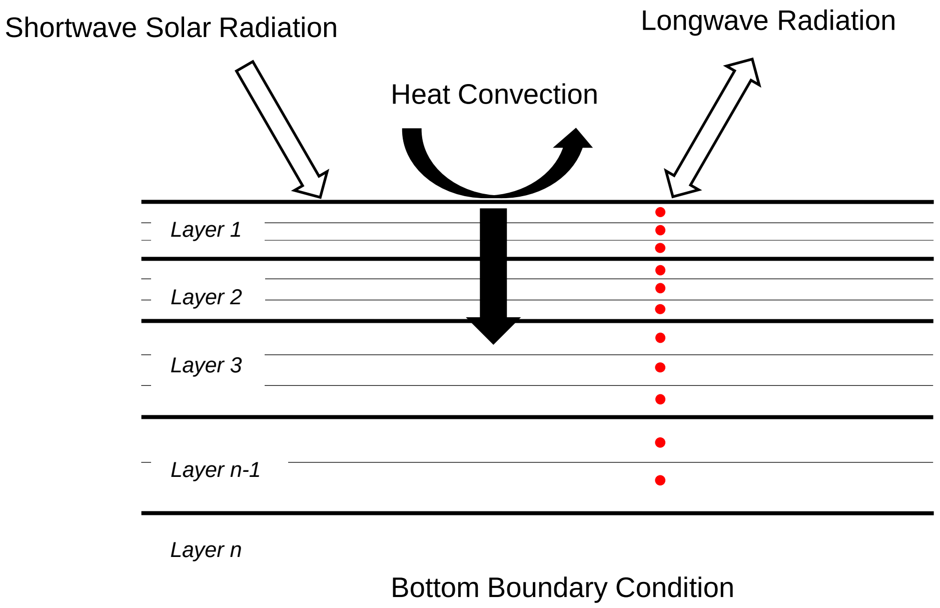
T	Temperature [°C]
z	Depth within the pavement layer [m]
ρ	Dry density of the material [kg/m³]
c	Mass specific heat capacity [J/(K·kg)]
k	Thermal conductivity constant [W/(m·K)]



*Dore & Zubeck (2009)

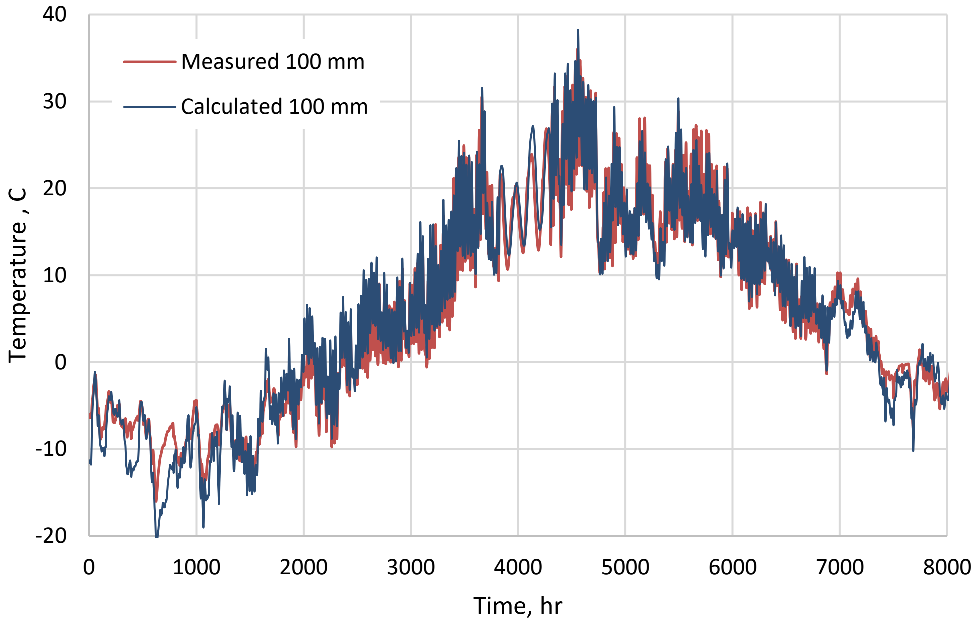
TEMPERATURE MODEL

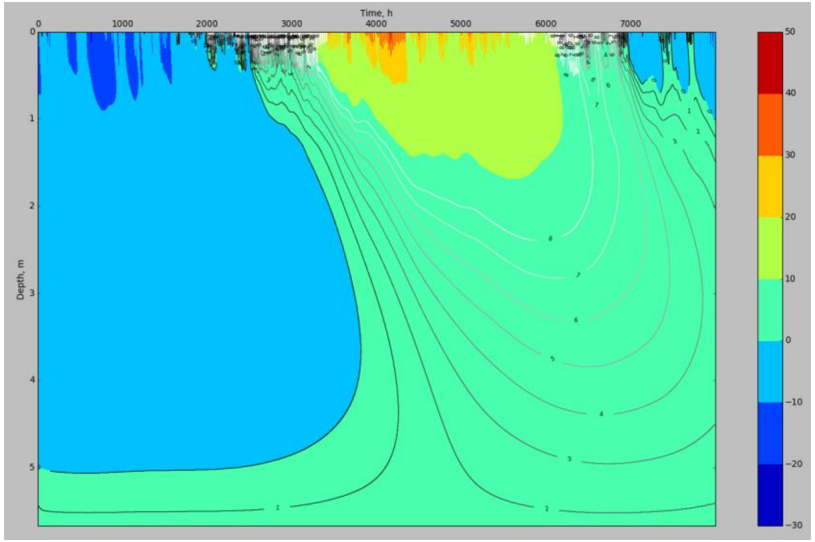
- Finite control volume method (FCVM)
- A numerical approach for solving the heat equation
- Discretization into small control volumes
- Input for analysis
  - Air temperature
  - Wind speed
  - Solar radiation



TEMPERATURE – EXAMPLE

- Test section - Svappavaara





PERFORMANCE MODELS - RUTTING

- Permanent deformation/rutting
  - Asphalt

$$\varepsilon_p(N) = aT^b N^c \varepsilon_r$$

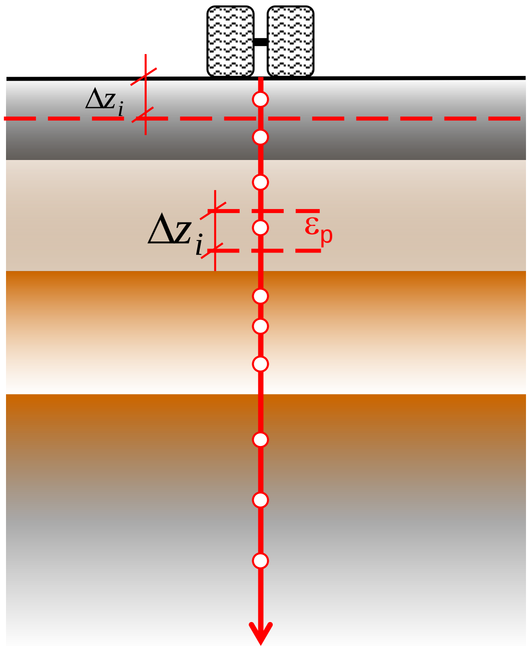
Studded wear tire

$$\varepsilon_{wearing}(N) = \text{VTI model}$$

  - Unbound base/subbase/subgrade

$$\varepsilon_p = aN^{b(\varepsilon_r)}\varepsilon_r$$

T	Temperature [°C]
S	Degree of saturation
ε_r	Elastic strain [m/m]
N	Number of load cycles
a, b, c	Model parameters

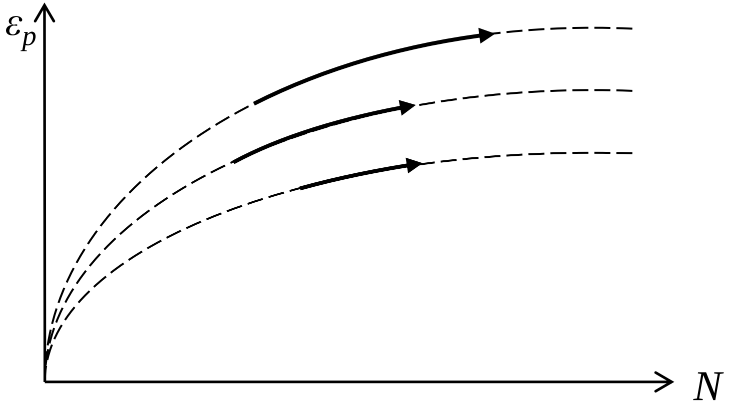


vti

PERFORMANCE MODELS - RUTTING

- Permanent deformation/rutting
  - Asphalt

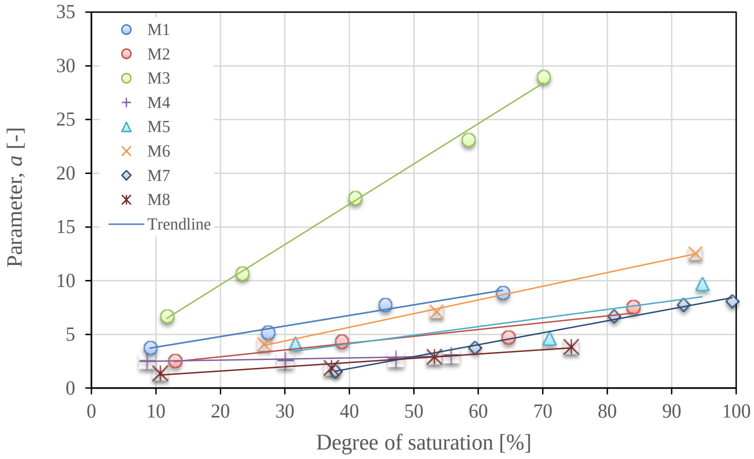
$$\varepsilon_p(N) = aT^bN^c\varepsilon_r$$



  - Unbound base/subbase/subgrade

$$\varepsilon_p = aN^{b(\varepsilon_r)}\varepsilon_r$$

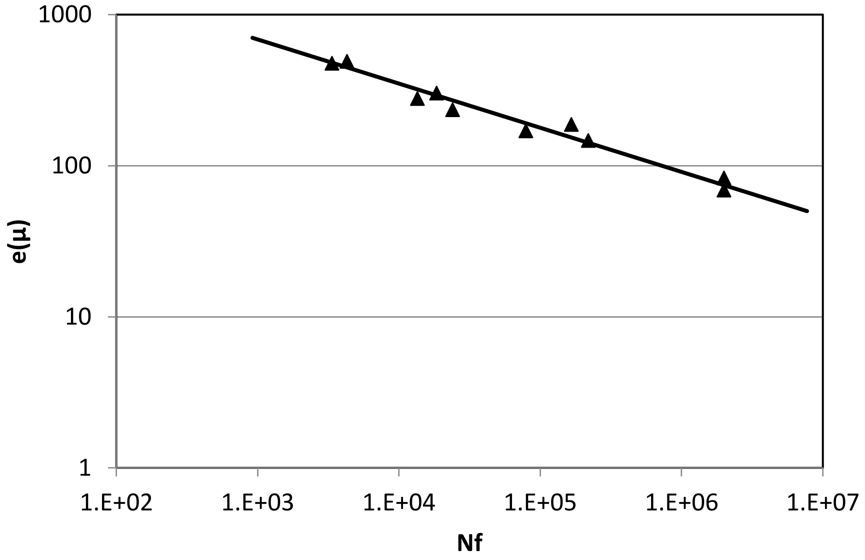
T	Temperature [°C]
S	Degree of saturation
ε_r	Elastic strain [m/m]
N	Number of load cycles
a, b, c	Model parameters

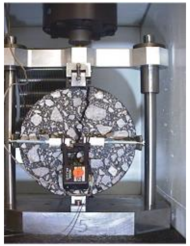


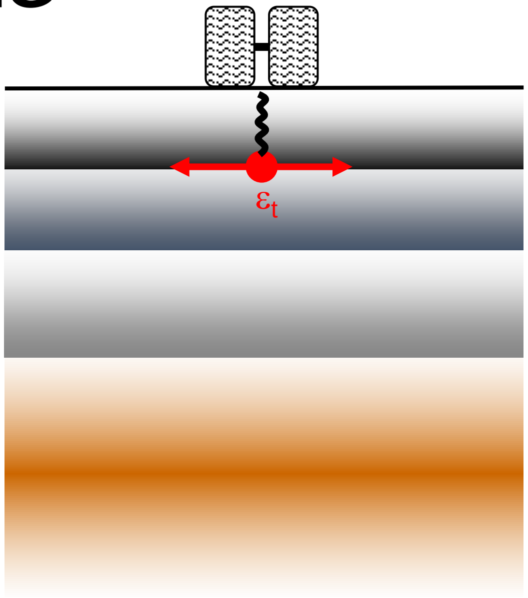
PERFORMANCE MODELS – CRACKING

- Fatigue cracking – bottom-up fatigue cracking
  - Asphalt

$$N_f = k_1 {\varepsilon_t}^{-k_2} E^{-k_3}$$







ε_t	Elastic strain [m/m]
k_1, k_2, k_3	Model parameters
N_f	Number of cycles to failure due to fatigue

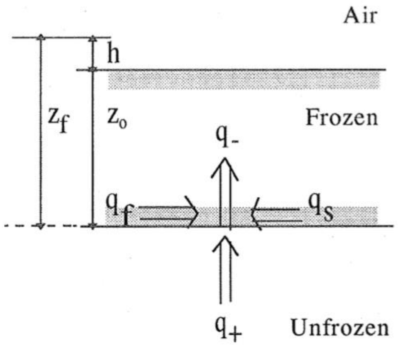
vti

PERFORMANCE MODELS - FROST

- Frost heave - SSR model

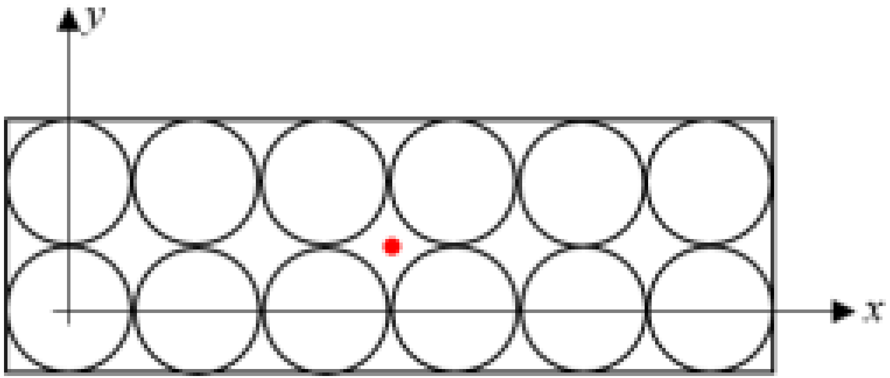
$$k_f \nabla T_- = L \frac{\Delta z_0}{\Delta t} + k_t \nabla T_+ + L_w SP \nabla T_-$$

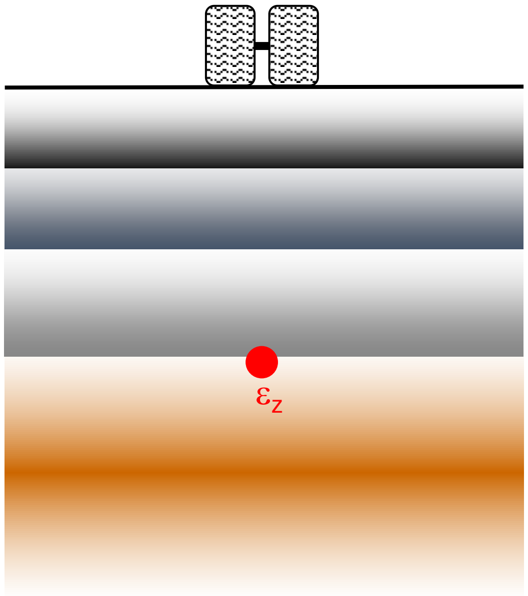
Stefan (1889) — Skaven Haug (1971) — Konrad & Morgenstern (1981)



- Conductivity - frozen and unfrozen
- Particle and bulk – density
- Segregation Potential, SP

PERFORMANCE MODELS - EXTREME LOADING



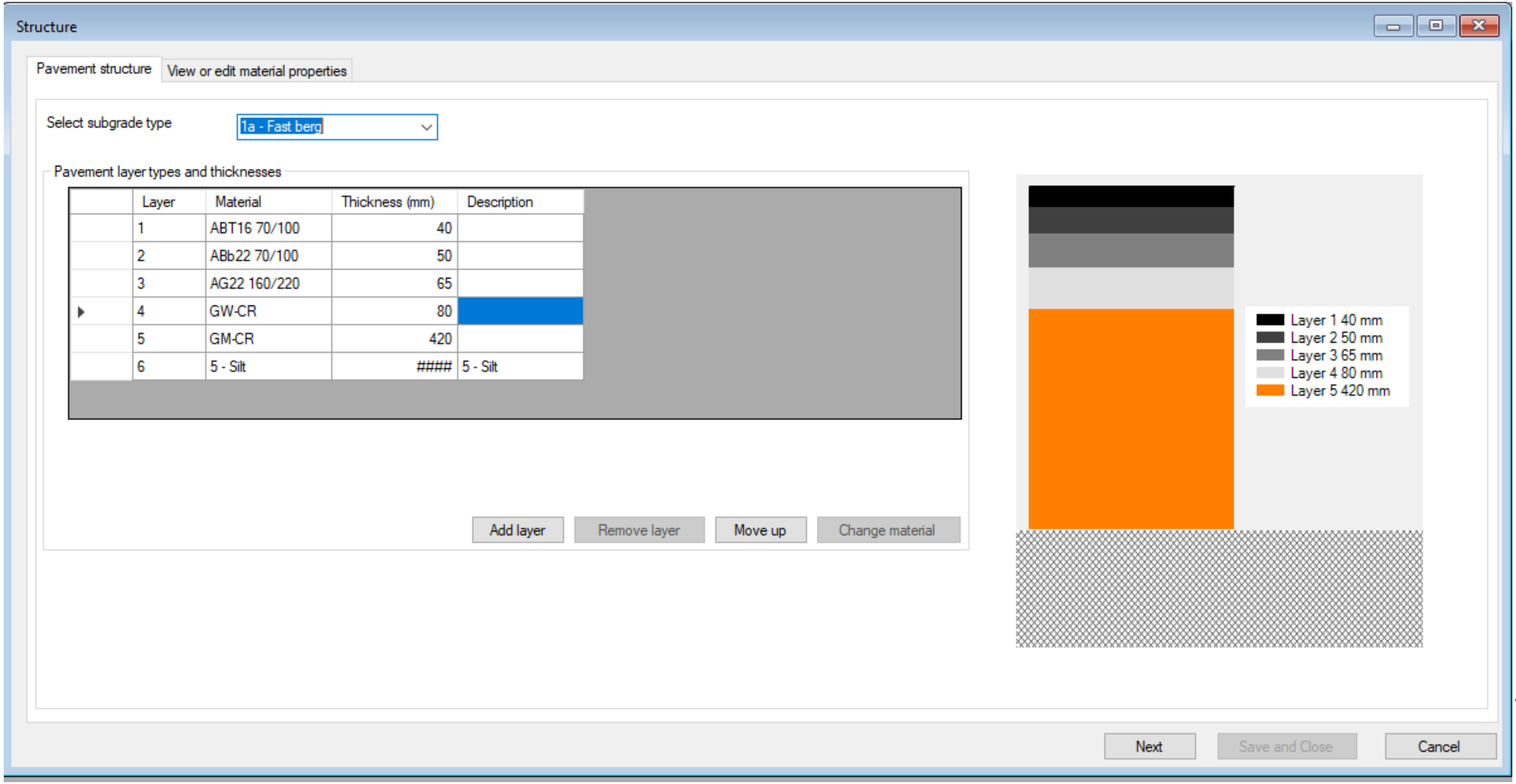


vti

ERAPAVE PP - LAYOUT

- Define Pavement
- Define Traffic
- Define Climate
- Control for frost action
- Control for extreme loading
- Long term performance – rutting
- Long term performance – fatigue

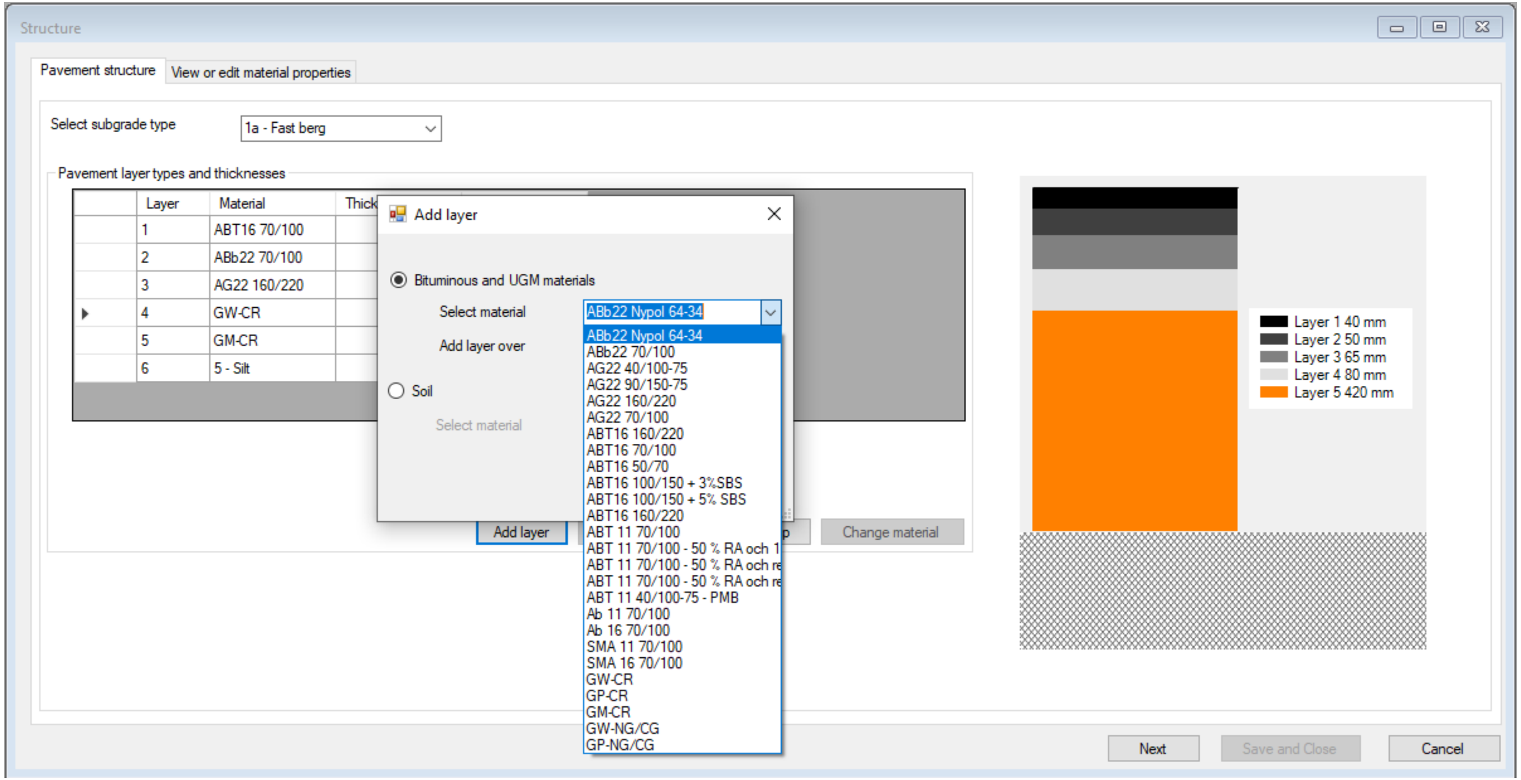
PROGRAM LAYOUT - STRUCTURE



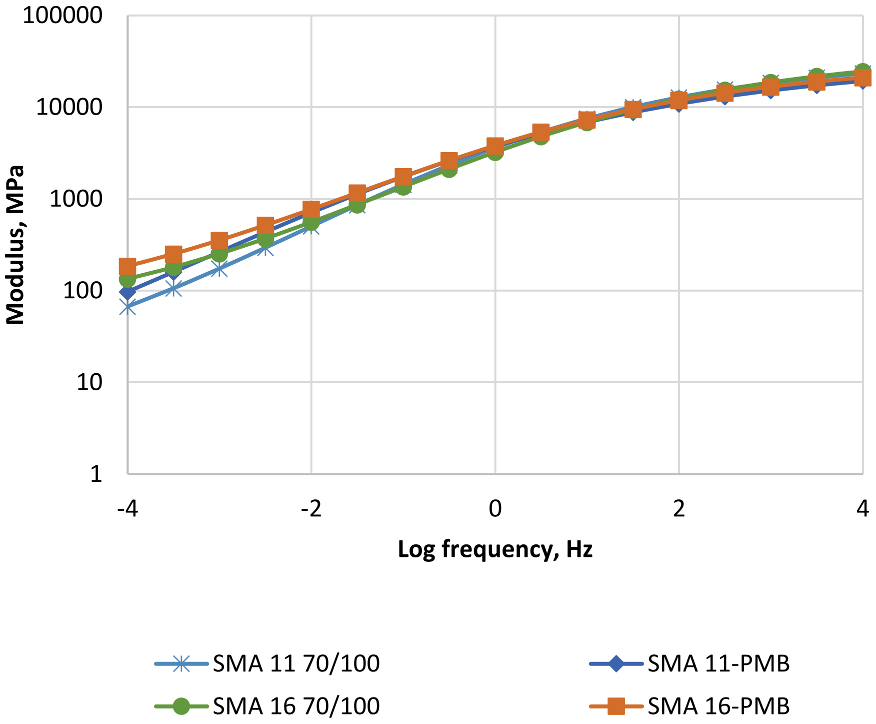
vti

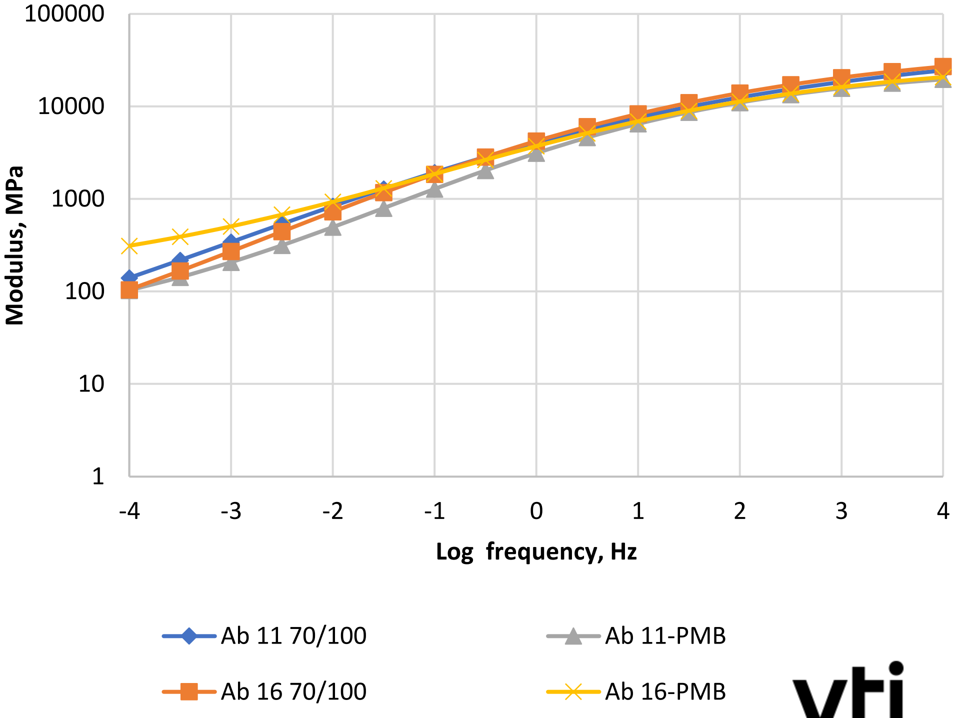
PROGRAM LAYOUT - DATABASE

- Material database



NTNU/VTI DATA

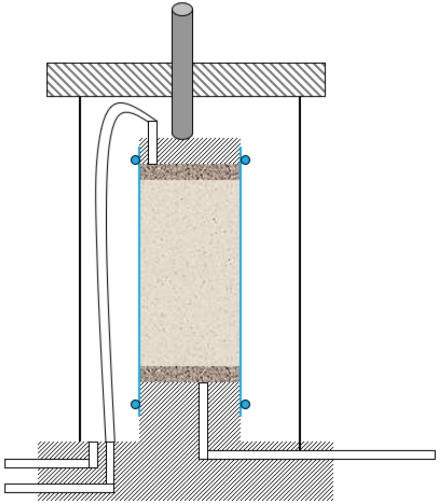


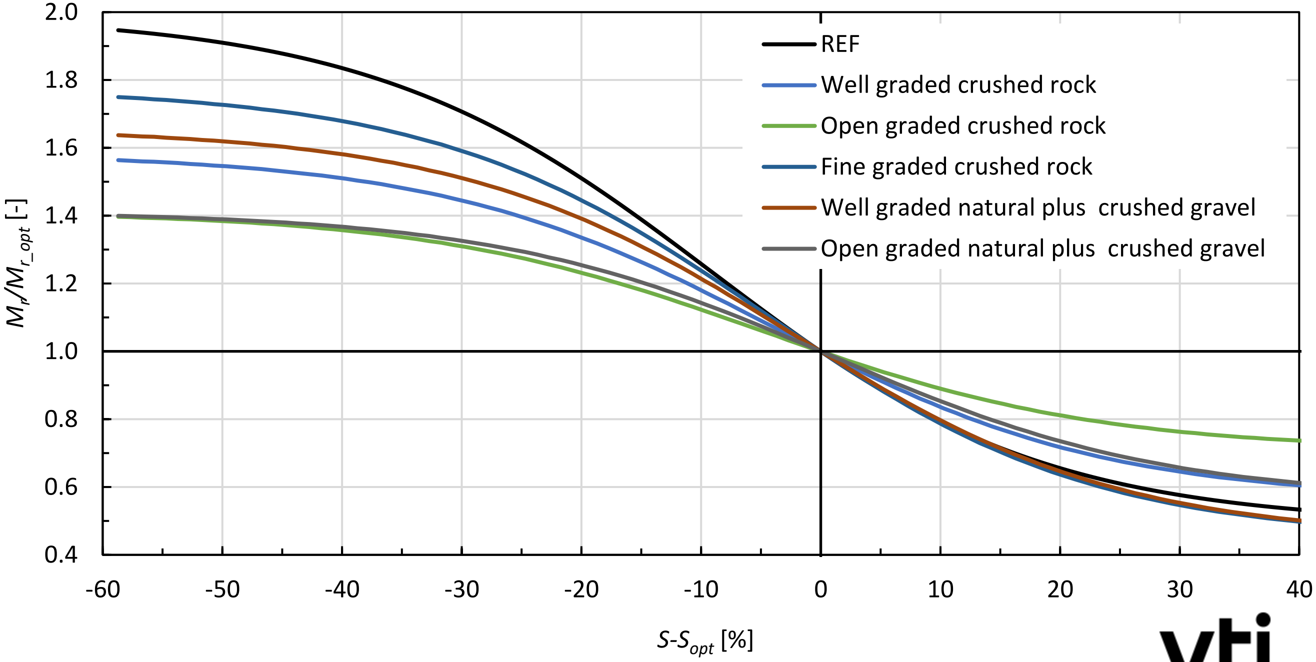


vti

DATABASE - UGMS

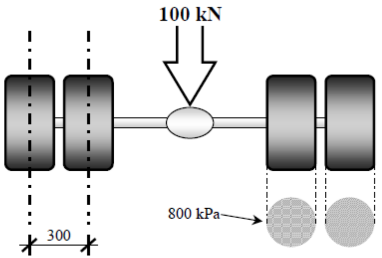
- UGM – Resilient modulus



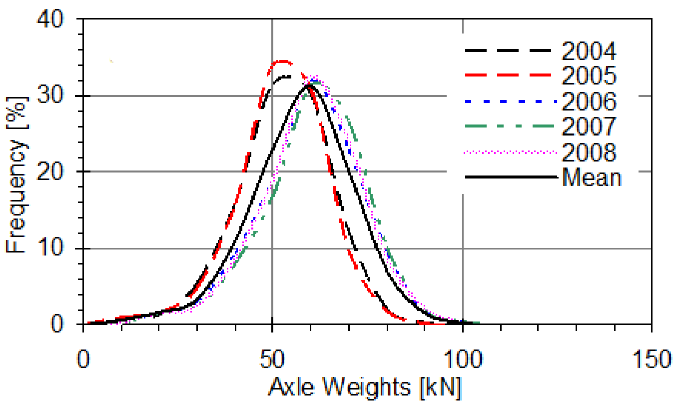


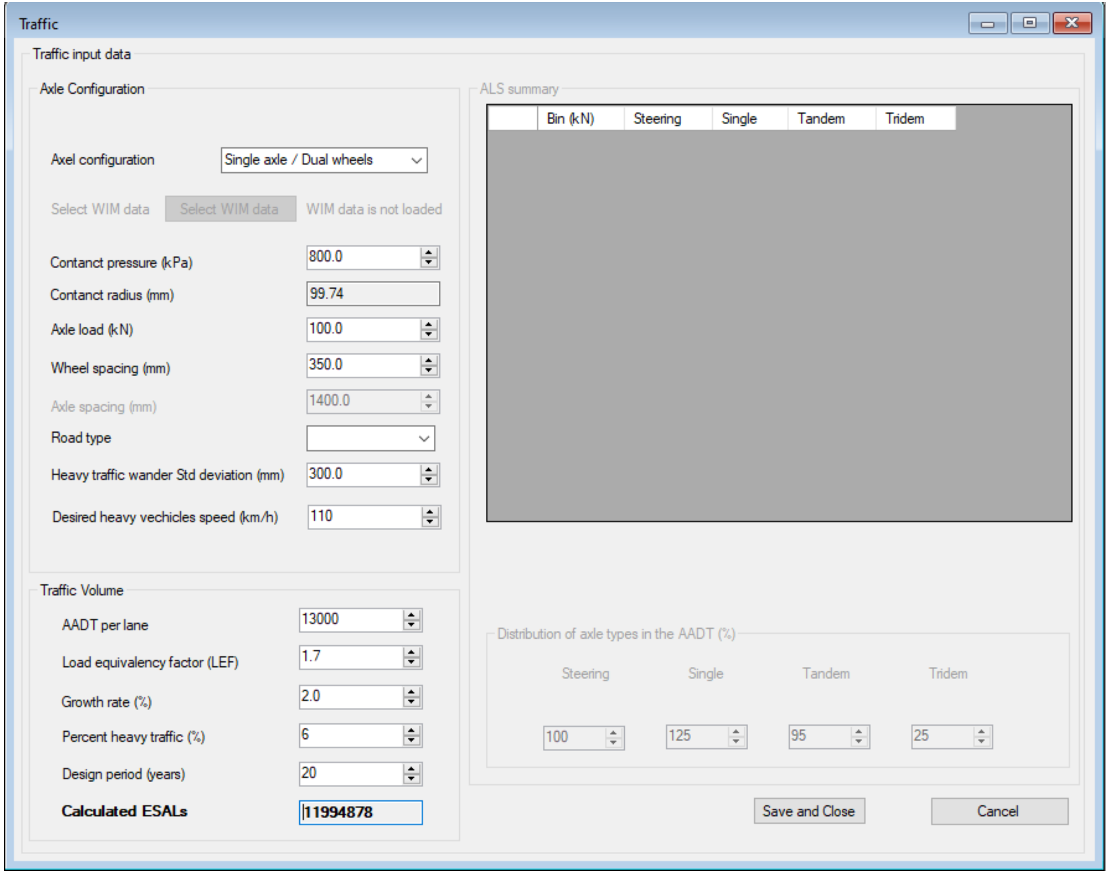
PROGRAM LAYOUT – TRAFFIC

- ESAL



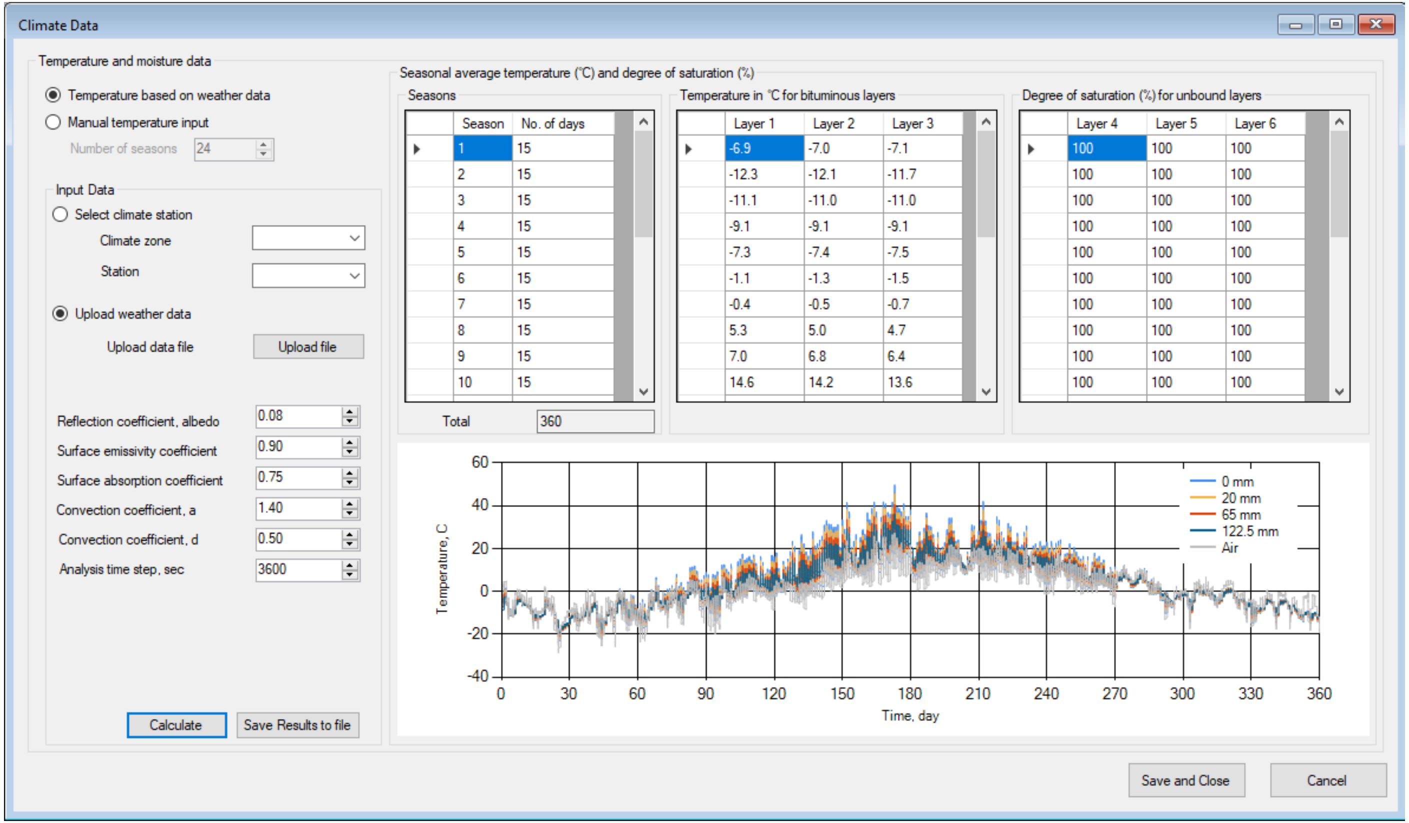
- WIM



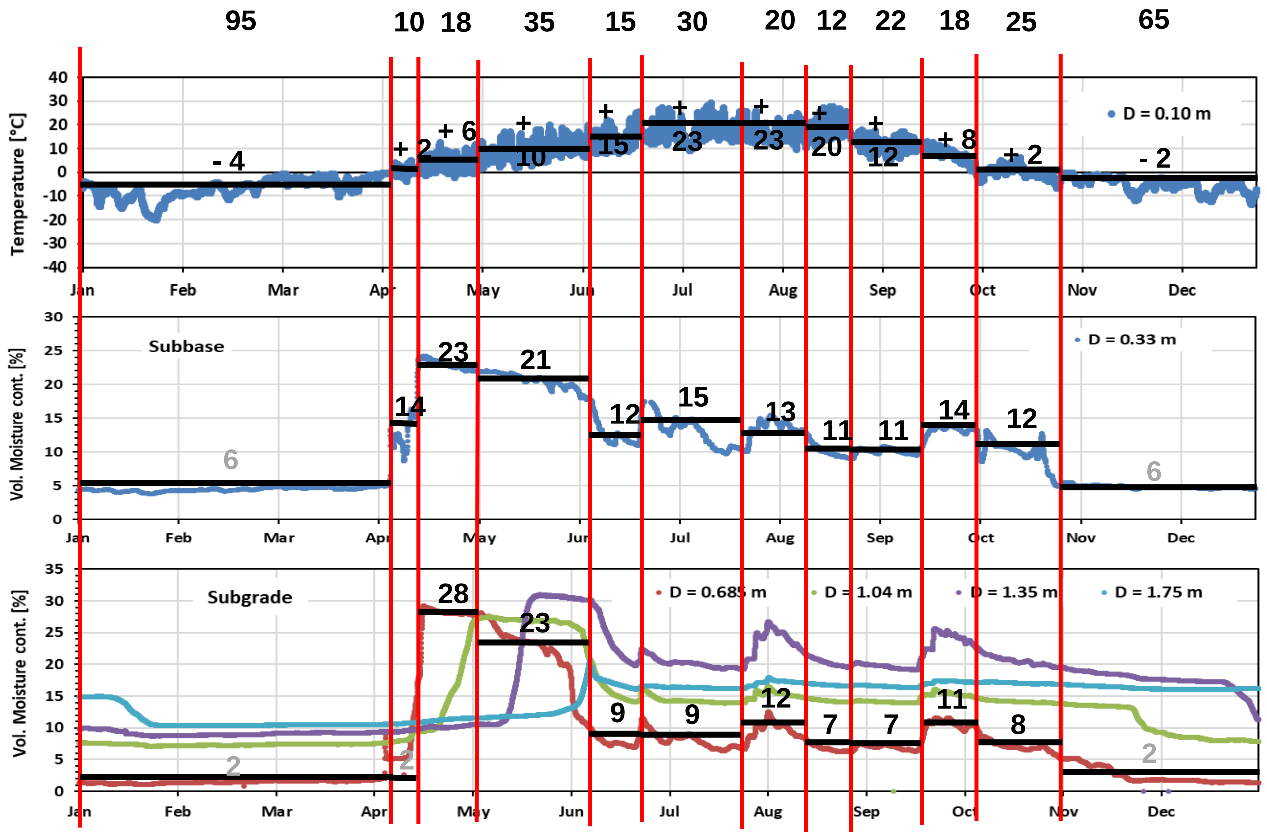


PROGRAM LAYOUT-CLIMATE

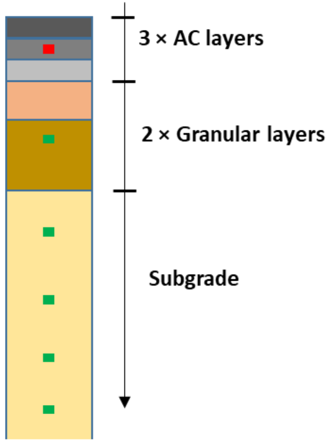
- Air temperature
- Wind speed
- Solar radiation
- Deg. of saturation



PROGRAM LAYOUT- MANUAL INPUT



= 365 days



$$e = \frac{G_s \gamma_w}{\gamma_{dry}} - 1$$

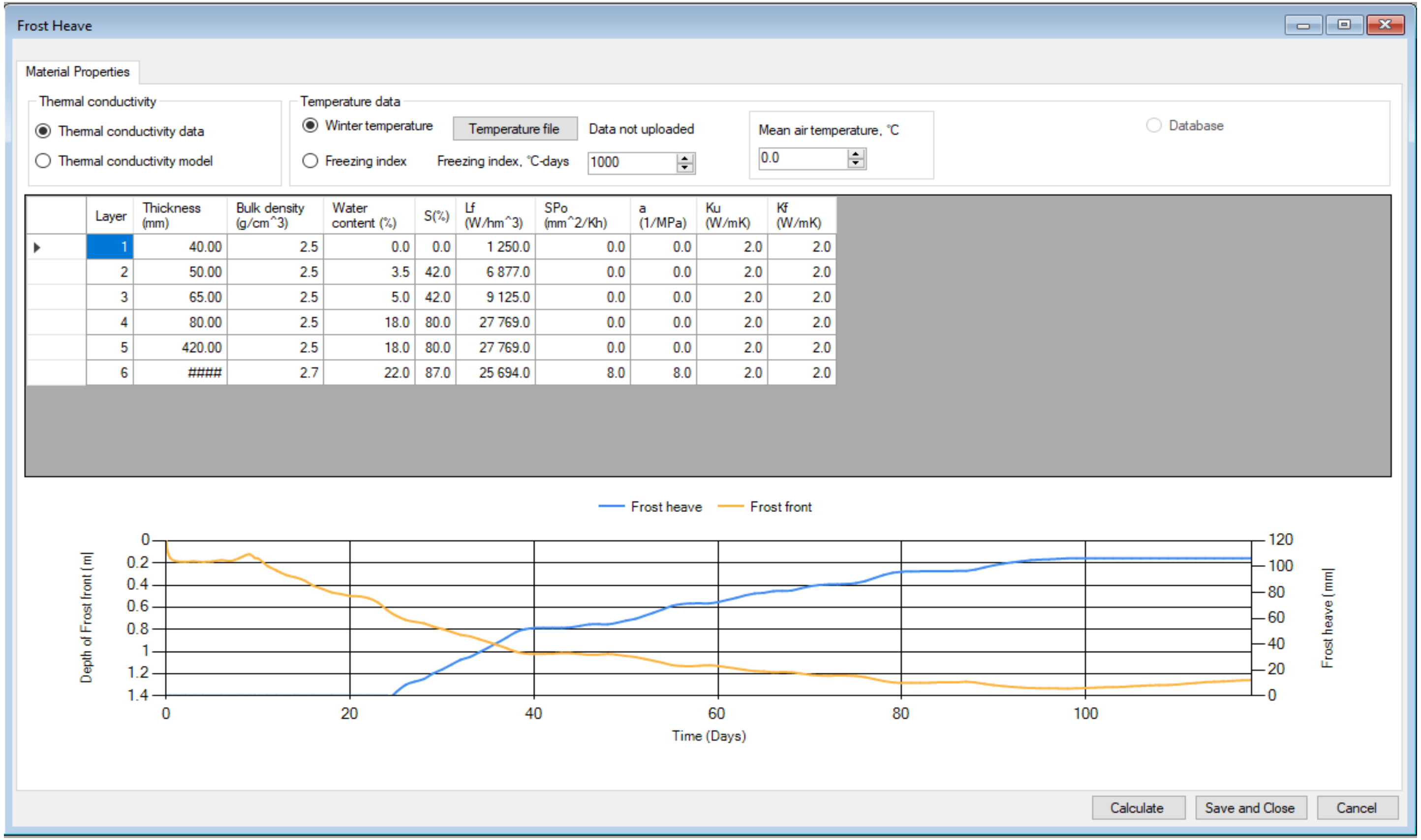
$$w = \frac{\gamma_w}{\gamma_{dry}} \theta_{vol}$$

$$S = \frac{w G_S}{e}$$

PROGRAM LAYOUT – FROST HEAVE

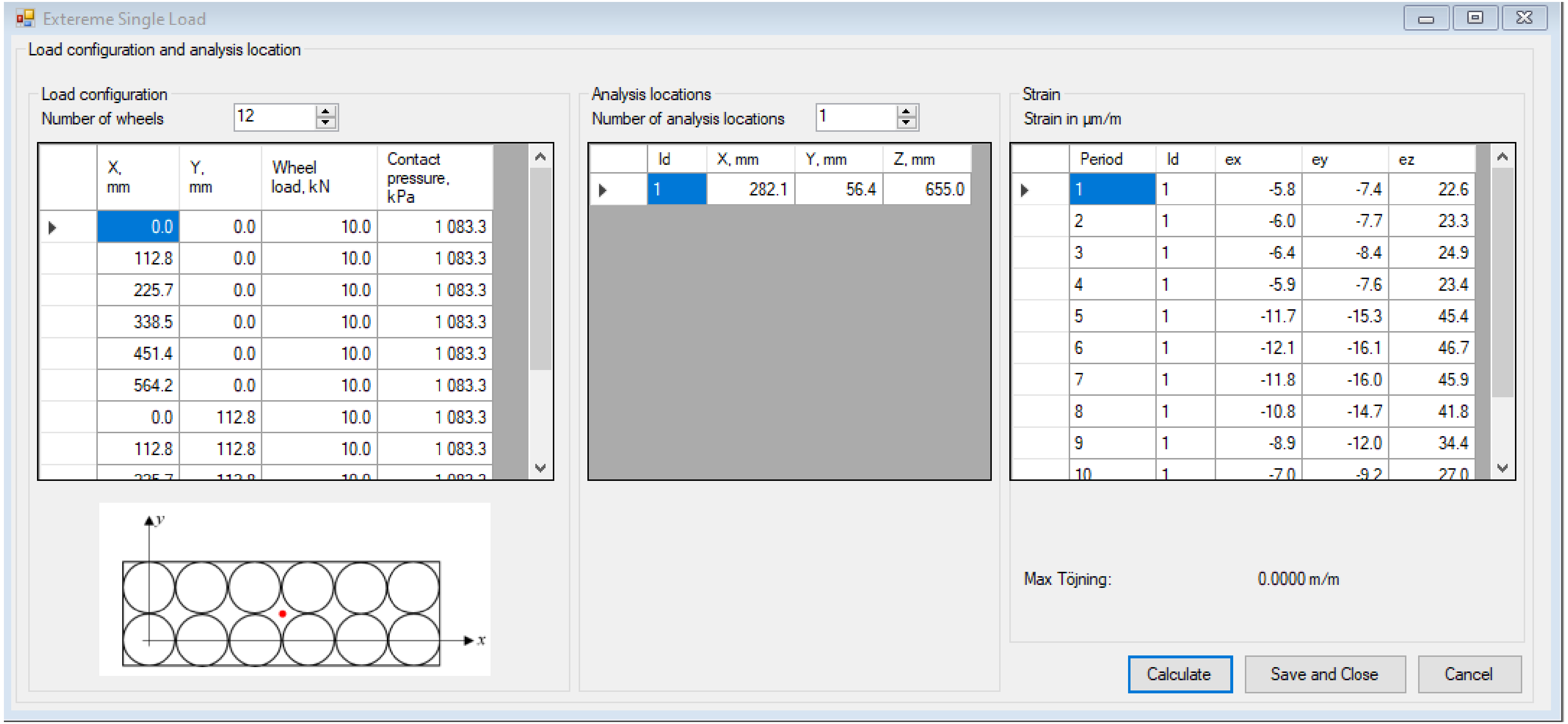
Inputs

- Winter temp.
- Freezing index



Layer	Thickness (mm)	Bulk density (g/cm^3)	Water content (%)	S(%)	Lf (W/hm^3)	SPo (mm^2/Kh)	a (1/MPa)	Ku (W/mK)	Kf (W/mK)
1	40.00	2.5	0.0	0.0	1 250.0	0.0	0.0	2.0	2.0
2	50.00	2.5	3.5	42.0	6 877.0	0.0	0.0	2.0	2.0
3	65.00	2.5	5.0	42.0	9 125.0	0.0	0.0	2.0	2.0
4	80.00	2.5	18.0	80.0	27 769.0	0.0	0.0	2.0	2.0
5	420.00	2.5	18.0	80.0	27 769.0	0.0	0.0	2.0	2.0
6	####	2.7	22.0	87.0	25 694.0	8.0	8.0	2.0	2.0

PROGRAM LAYOUT – EXTREME LOADING



vti

PROGRAM LAYOUT – RUTTING/FATIGUE

Rutting

Permanent deformation models and parameters

Permanent deformation models

Model 1 (MEPDG)

$$\varepsilon_p = aT^b N^c \varepsilon_r$$

Model 2 (Tseng and Lytton, 1981)

$$\varepsilon_p = a e^{-\left(\frac{b}{N}\right)^c} \varepsilon_r$$

Model 3 (Rahman et al. 2021)

$$\varepsilon_p = (a(S) + b) N^{c(\varepsilon_r)} \varepsilon_r$$

a, b, c = Material constants
ε_r = Elastic resilient strain
T = Temperature (°C)
N = Number of load cycles

Model parameters

Layer	Material	Model	a	b	c
1	Bound	Model 1	0.03	1.85	0.27
2	Bound	Model 1	0.03	1.85	0.27
3	Bound	Model 1	0.03	1.85	0.27
4	Unbou...	Model 3	0.00	5	250
5	Unbou...	Model 3	0.00	5	250
6	Unbou...	Model 3	0.00	10	250

Maximum permitted design total rutting, mm: 13.0

Save and Close | Save and Close | Cancel

Fatigue

Fatigue cracking model parameters

Tensile strain at the bottom of layer: 3

f1: 15.40
f2: 3.90
f3: 0.00

$$\log(N_f) = f_1 - f_2 \log(\varepsilon_{bt}) - f_3 \log(E)$$

N_f = Number of load cycles until failure
f_1, f_2, f_3 = Material constants, f_1 also includes laboratory to field shift factor
ε_{bt} = Tensile strain at the bottom of asphalt (µm/m)
E = Stiffness modulus (MPa)

Save and Close | Cancel

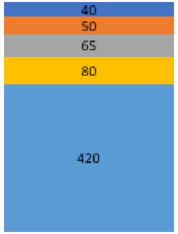
vti

REPORT

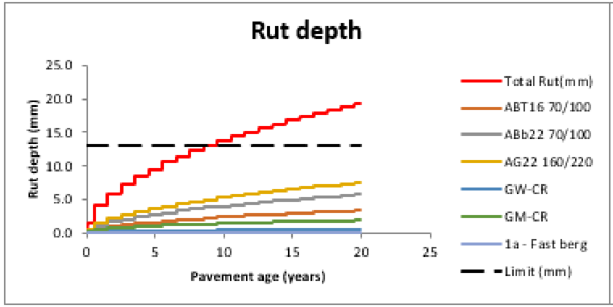
Summary

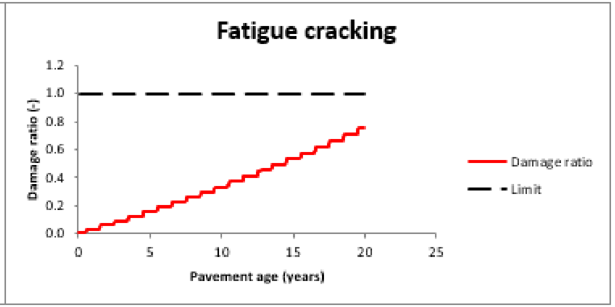
- Input data
- Predicted damages
  - rutting and wear
  - fatigue
  - frost

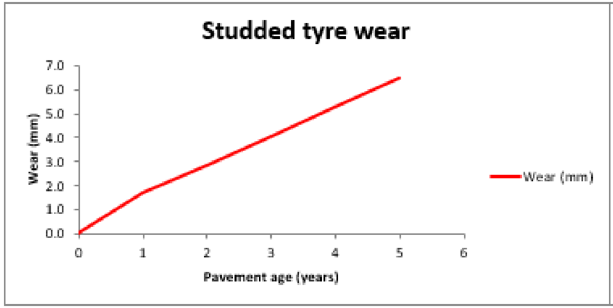
Road Section TEST
Date 2021-11-30

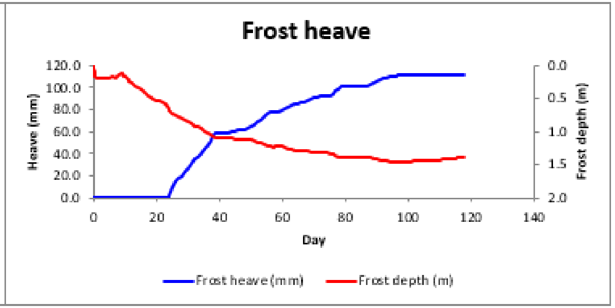


Layer	Rutting (mm)
ABT16 70/100	3.4
ABb22 70/100	5.8
AG22 160/220	7.6
GW-CR	0.7
GM-CR	1.9
1a - Fast berg	0.0
Total rutting	19.4
Studded tyre Wear	6.4
Fatigue life	0.7
Frost heave	111.5
Frost depth	1.4









FUTURE WORK

- Update the material database
- Database of weather stations/data
- Improve user interface
- Calibration/Validation of the component models

Thank you for your attention!