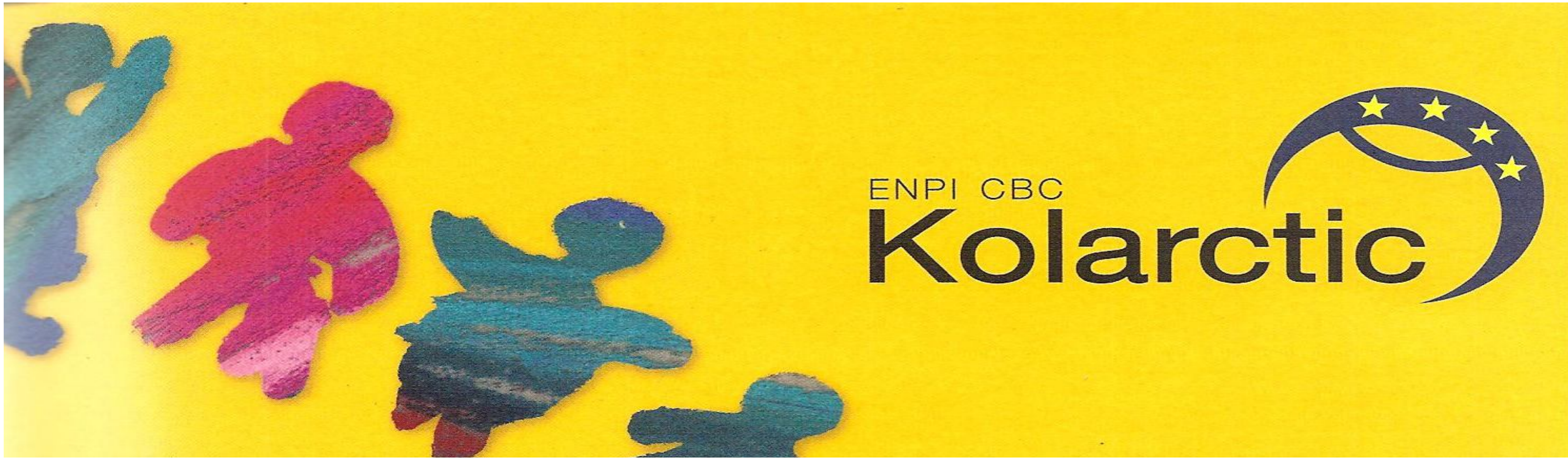

Truck axles, tyre types, tyre pressures and road performance

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Presentation goals

- Understanding the critical stresses and strains in the road structure, and their positions, for failures and/or permanent deformation to develop.

- Understanding what is the effect of following parameters on different parts of road structure and their performance:
  - Axle configurations (axle / axle group weight, distance between axles, number of axles)
  - Tyre type (Super Single vs. Maxi vs. Dual)
  - Tyre pressure (The use of tyre pressure control systems)

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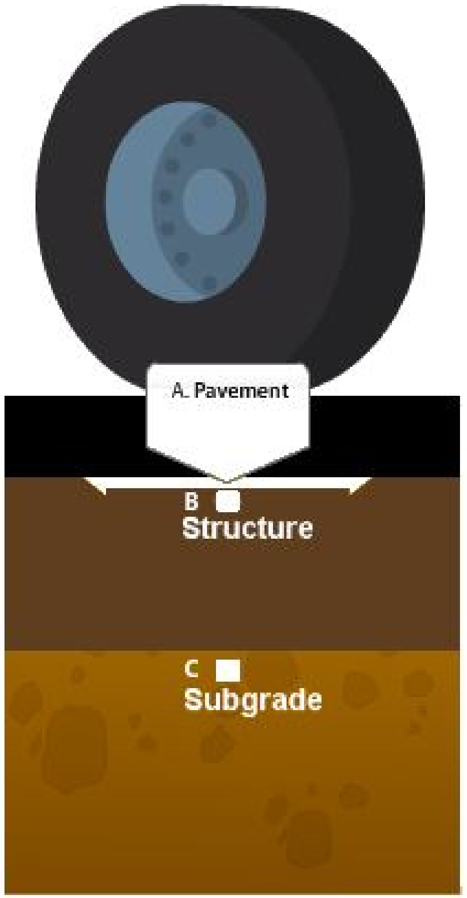
Critical positions in the road structure



Stresses and strains at the following three positions are considered to be the most critical in the road structure for failure / permanent deformation to develop:

A. The horizontal tensile strain at the bottom of the bound layers

→ High values in this position indicate the risk of pavement fatigue.

B. The vertical compressive stress and strain in the upper part of the unbound layers

→ The stresses and strains in this position are the most critical for the development of Mode 1 rutting.

C. The vertical compressive stress and strain on the top of the subgrade

→ The stresses and strains in this position are the most critical for the development of Mode 2 rutting.

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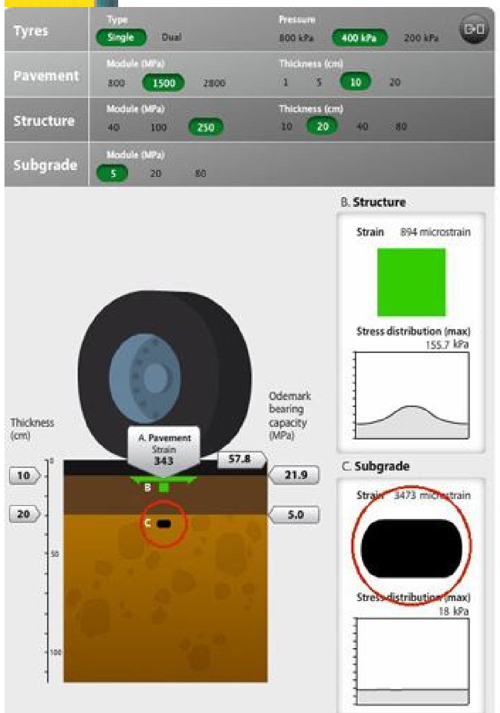
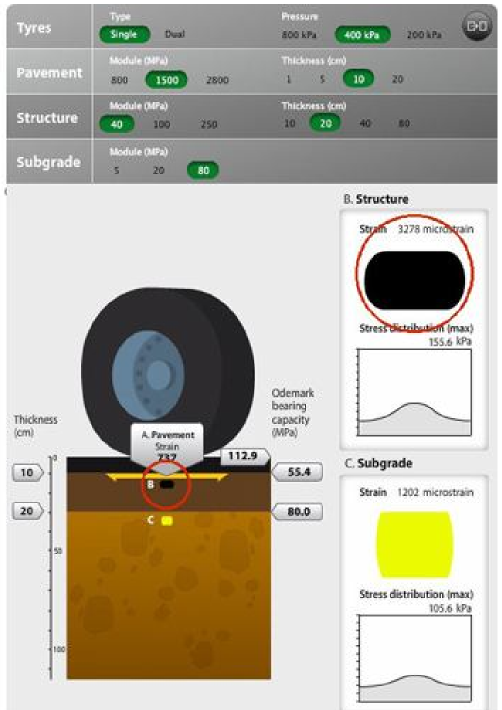
Elastic modulus and bearing capacity

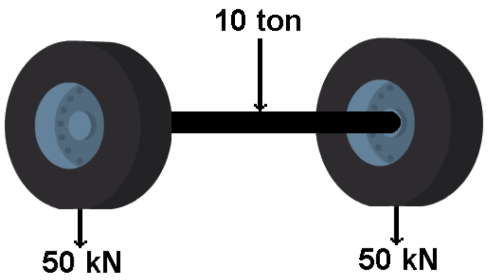
- The elastic modulus describes the stiffness of a material, i.e. its capacity to bear and spread load.
- In an ideal road structure the modulus of the materials in the pavement layers should decrease from top to bottom.
- The bearing capacity at the top of the pavement structure will be determined by the properties of the subgrade and each of the individual structural layers in the road.
- The stresses and strains in every structural layer, and on the subgrade, should be well below their critical limits.
- There are many different ways to achieve the target bearing capacity, but the long term resistance to permanent deformation must also be considered.
- The overall structural quality of a road is defined by its “weakest link” and this can be located in different points of the road structure, or in the subgrade.

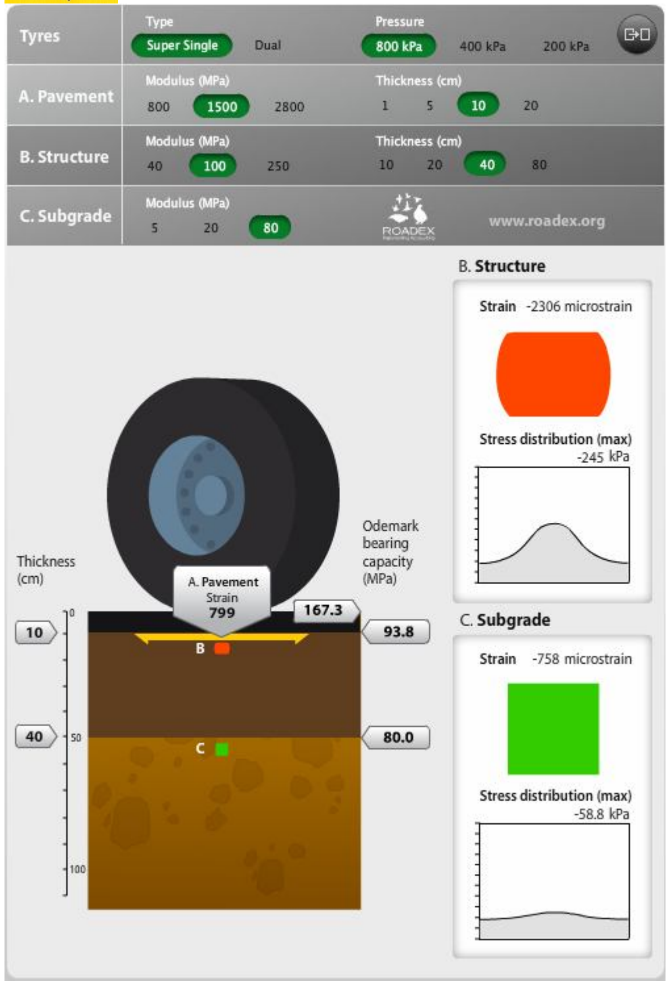




"The ROADEX Pavement Stress and Strain Calculation Demo"

http://www.uleaborg.com/roadex_stress/roadex.html





- The wheel load used in the demo is always the same, a standard wheel load of 50 kN representing a 10 ton axle load.
- The road structure contains three layers: A. the pavement, B. the structure and C. the subgrade
- Options for tyre types: Super Single and Dual
- Tyre pressures: 800 kPa (normal), 400 kPa (lowered) or 200 kPa (very low)
- Bound layer modulus: 800 MPa (poor), 1500 MPa (moderate) or 2800 MPa (good)
- Bound layer thickness: 1 cm (= gravel road), 5 cm, 10 cm or 20 cm
- Unbound structure modulus: 40 MPa (poor), 100 MPa (moderate) or 250 MPa (good)
- Unbound structure thickness: 10 cm, 20 cm, 40 cm or 80 cm
- Subgrade modulus: 5 MPa (weak), 20 MPa (moderate) or 80 MPa (strong)

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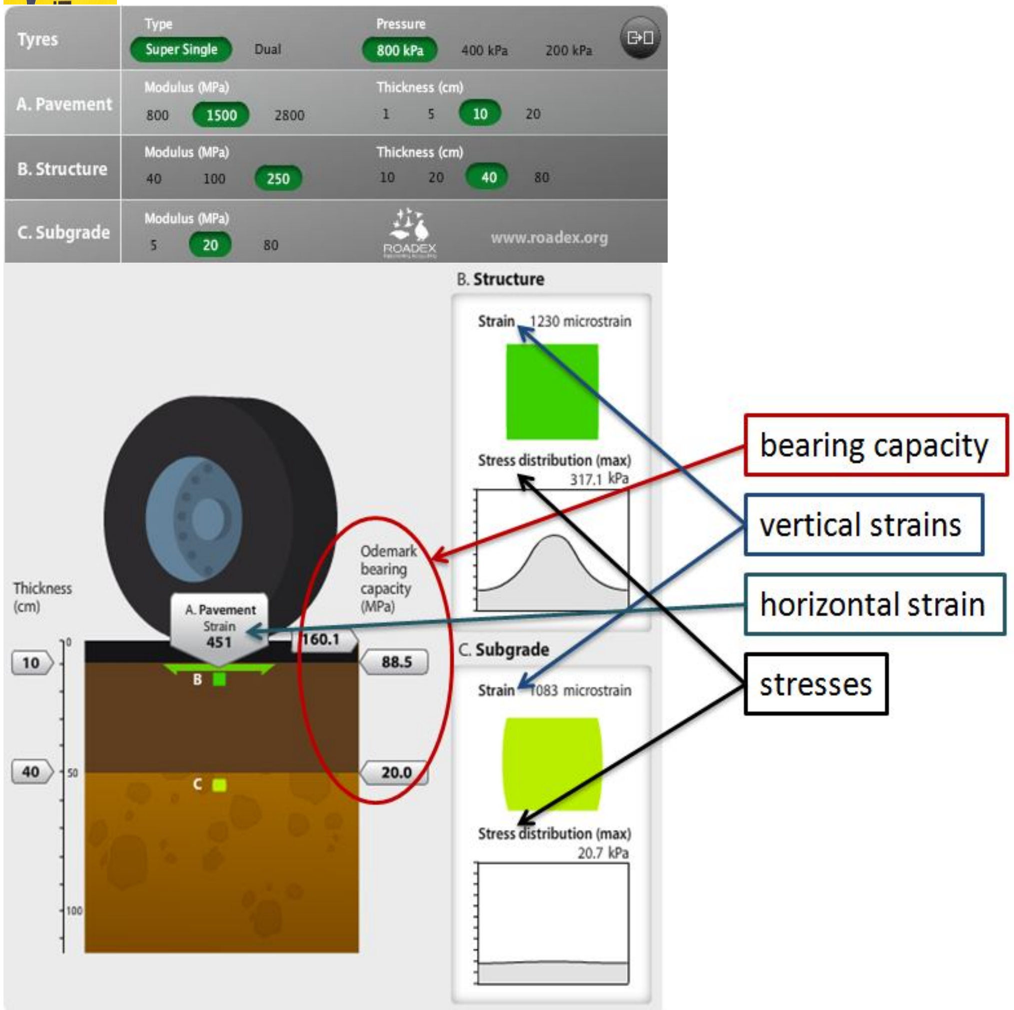
"The ROADEX Pavement Stress and Strain Calculation Demo" - The Results



Green = safe stress and strain level and a very low risk for failure / permanent deformation

Yellow = modest risk

Red = high risk

Black = failure

The weakest layer in the arrangement defines the overall rating of the whole road structure.

The Odemark bearing capacity

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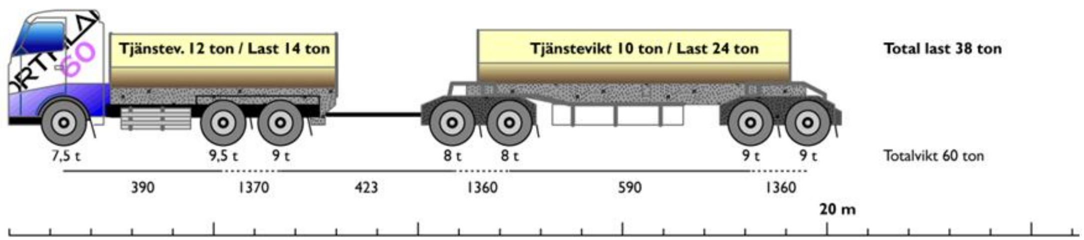
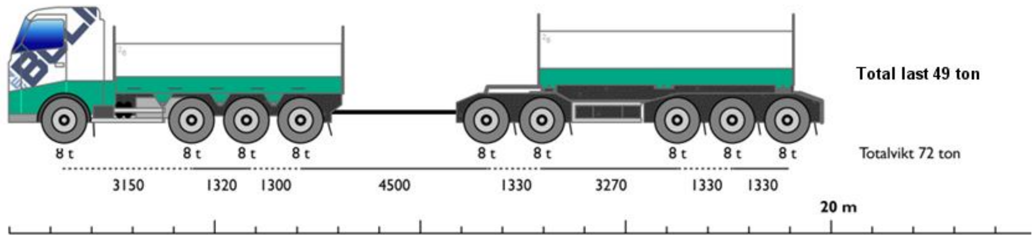
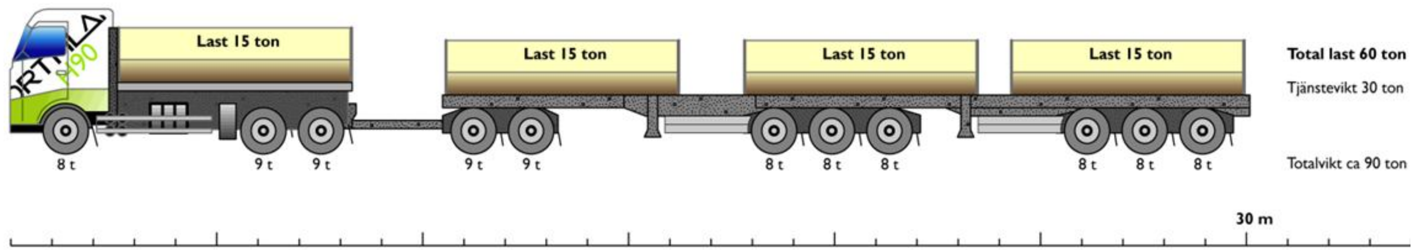
Axles: Calculated truck options in Pajala case, Sweden



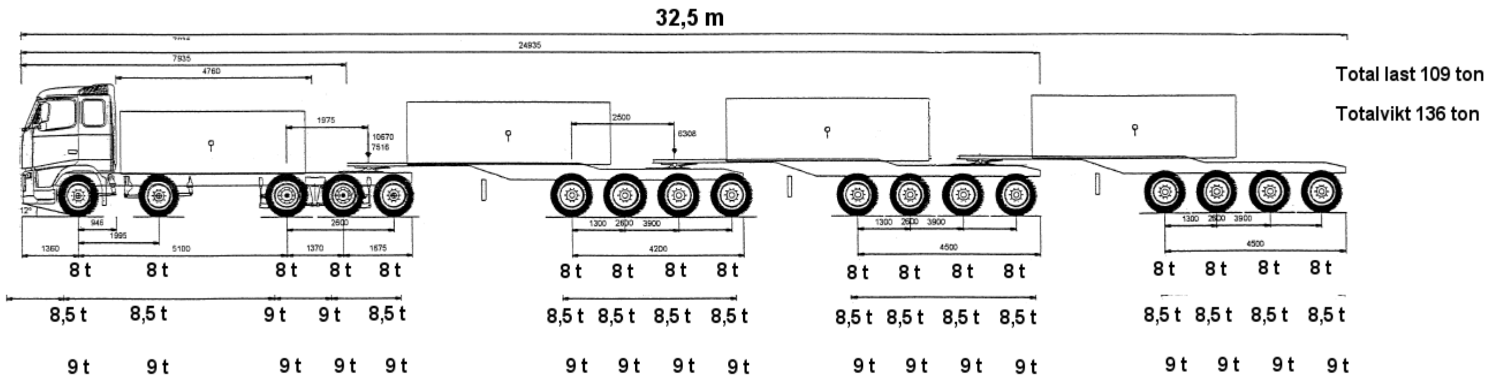
7 axles, 60 ton



9 axles, 72 ton



11 axles,
90 ton



17 axles,
136 ton
145 ton
153 ton

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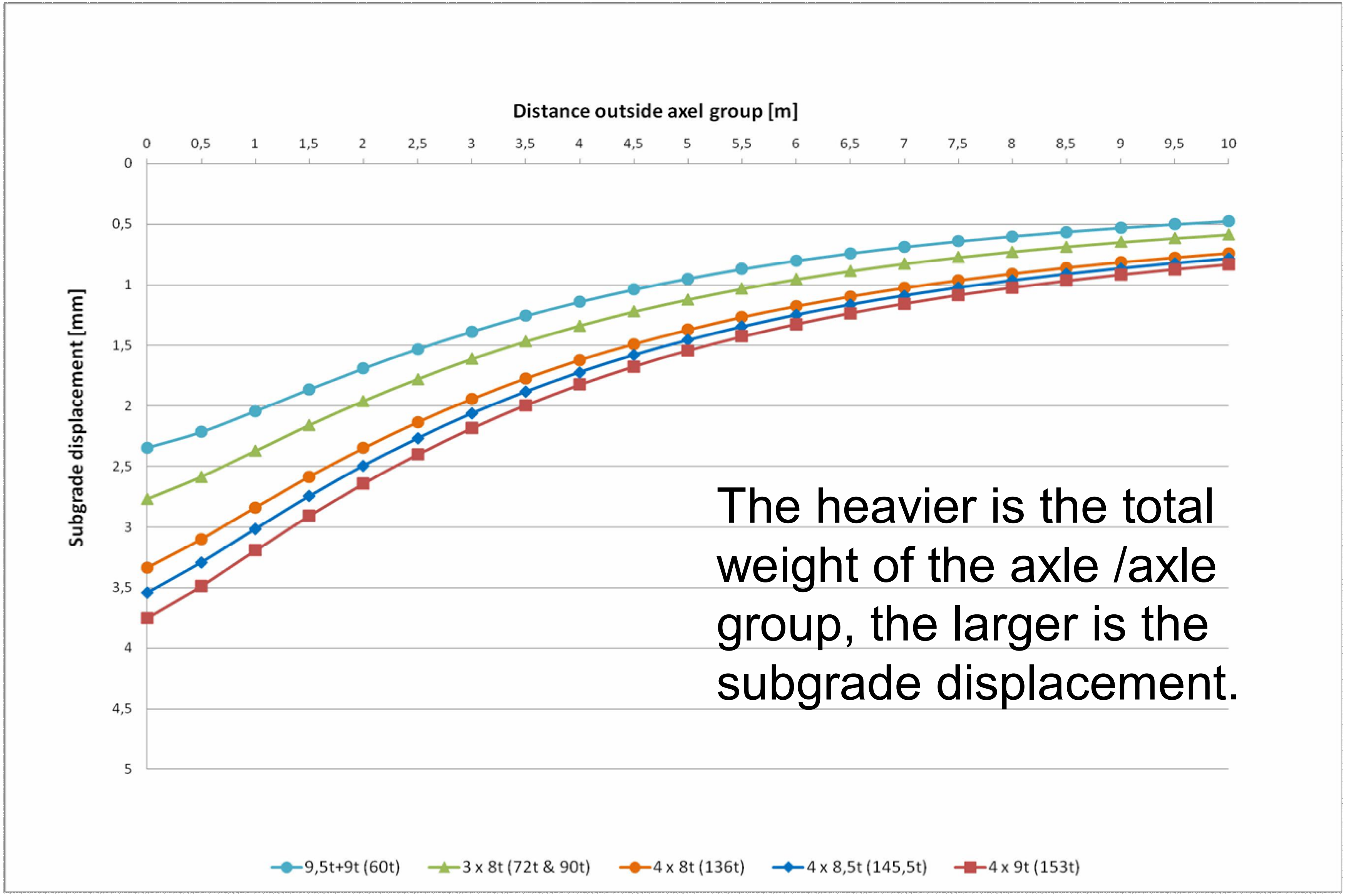
Axles - effect on subgrade:

Weak subgrade displacement induced by the heaviest axle group of each truck option



Axles - effect on subgrade:
Distance between axle groups

The distance between axle groups in the truck should be at least 3 meters.
A distance greater than 3 meters does not have a major effect on the subgrade elastic response under a single axle group. But it does have some effect on the cumulative loading effect of consecutive axle groups.

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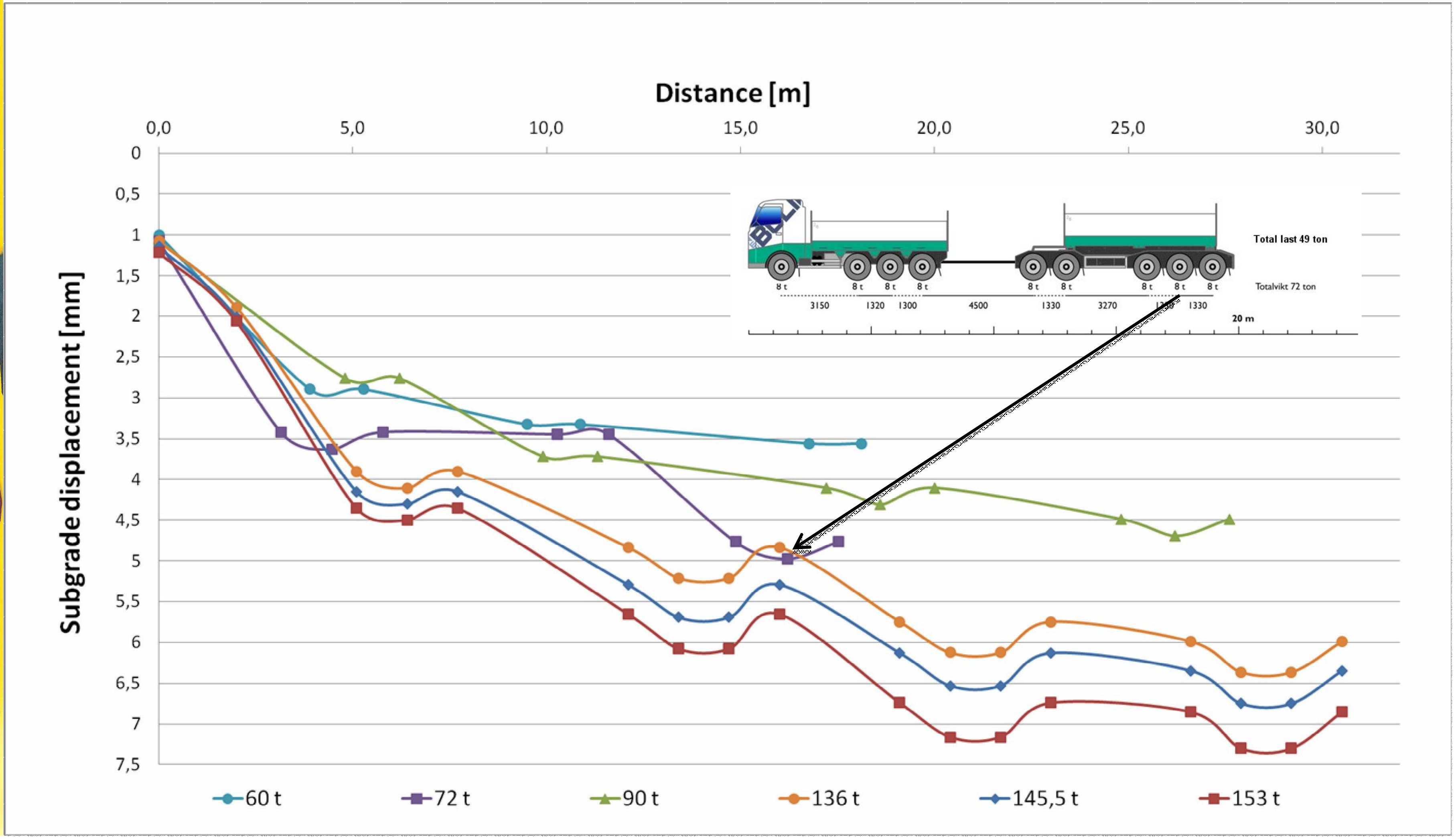
Axles - effect on subgrade:

Cumulative displacement of weak subgrade induced by each truck option

The number of axles is not always critical.

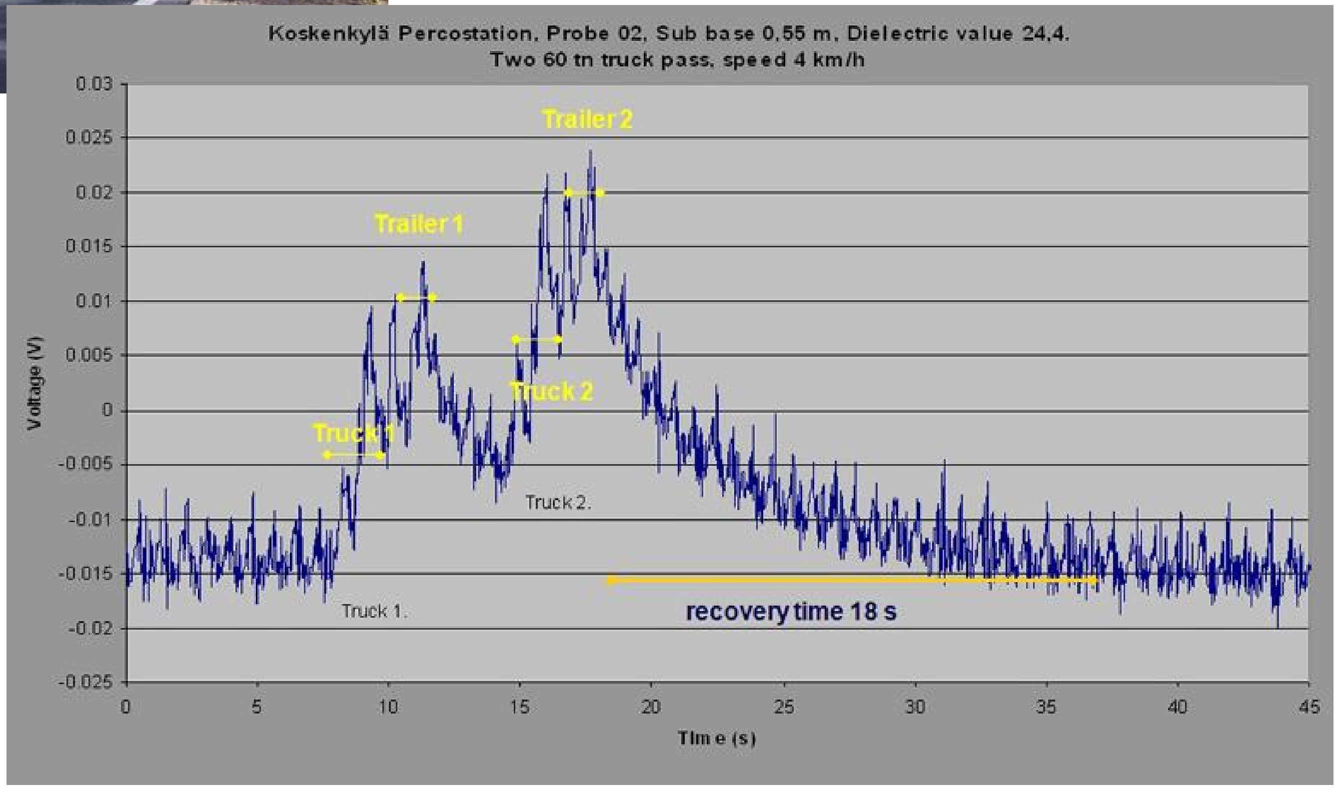


Axles - effect on base / sub-base

Materials of poor quality / with high water content are susceptible to permanent deformation and do not have a totally elastic response under a dynamic wheel load.

These materials do not recover immediately after the load is removed and multiple consecutive axles may cause increasing strain to these types of materials.

Two aggregate truck and trailer combinations passing the Koskenkylä Percostation in Rovaniemi, Finland and their effect on the capacitance changes (dielectric value) in the poor quality sub base at a depth of 0,55 m. The material response follows typical visco elastic behaviour.



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Axles - effect on pavement performance

Evaluation of the **performance of pavement and upper part of the structure** based on the classical "fourth power rule” used in pavement engineering

→ All heavier options are better than the standard 60 ton truck

Truck option & total weight	Axel loads					Truck EKV	Net weight	Truck loads	Load effect	Comparison to 60 ton
	7,5 ton	8 ton	8,5 ton	9 ton	9,5 ton		[ton]			
Standard 60 ton	1	2	0	3	1	3,918	38	131579	515581	1
"Boliden" 72 ton	0	9	0	0	0	3,686	49	102041	376163	0,730
"ETT (En trave till)" 90 ton	0	7	0	4	0	5,492	60	83333	457633	0,888
"Double link" 136 ton	0	17	0	0	0	6,963	109	45872	319413	0,620
"Double link" 145,5 ton	0	0	15	2	0	9,142	118,5	42194	385751	0,748
"Double link" 153 ton	0	0	0	17	0	11,154	126	39683	442607	0,858
Annual transportation (ton) =			5000000							
Stress exponent used in calculations =			4							

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The effect of tyre type

- The different tyre types commonly used on trucks are super single, maxi and dual tyres.

- Generally, the dual tyre is always the most road friendly option, because the contact footprint of the tyre is largest.

- Maxi tyre is not included in the “The ROADEX Pavement Stress and Strain Calculation Demo”, but the effect of super single vs. dual tyre can be compared.

Super Single

Maxi

Dual

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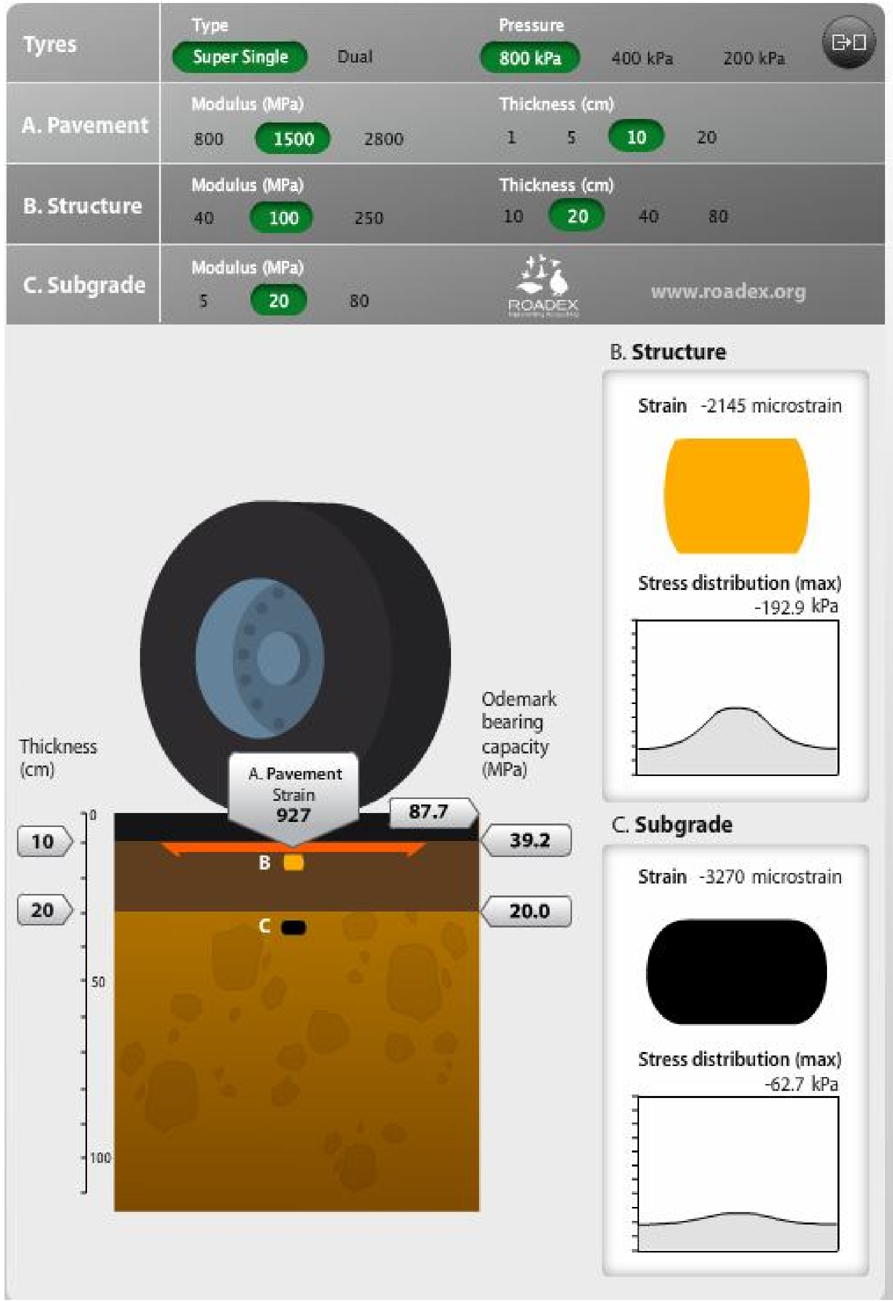
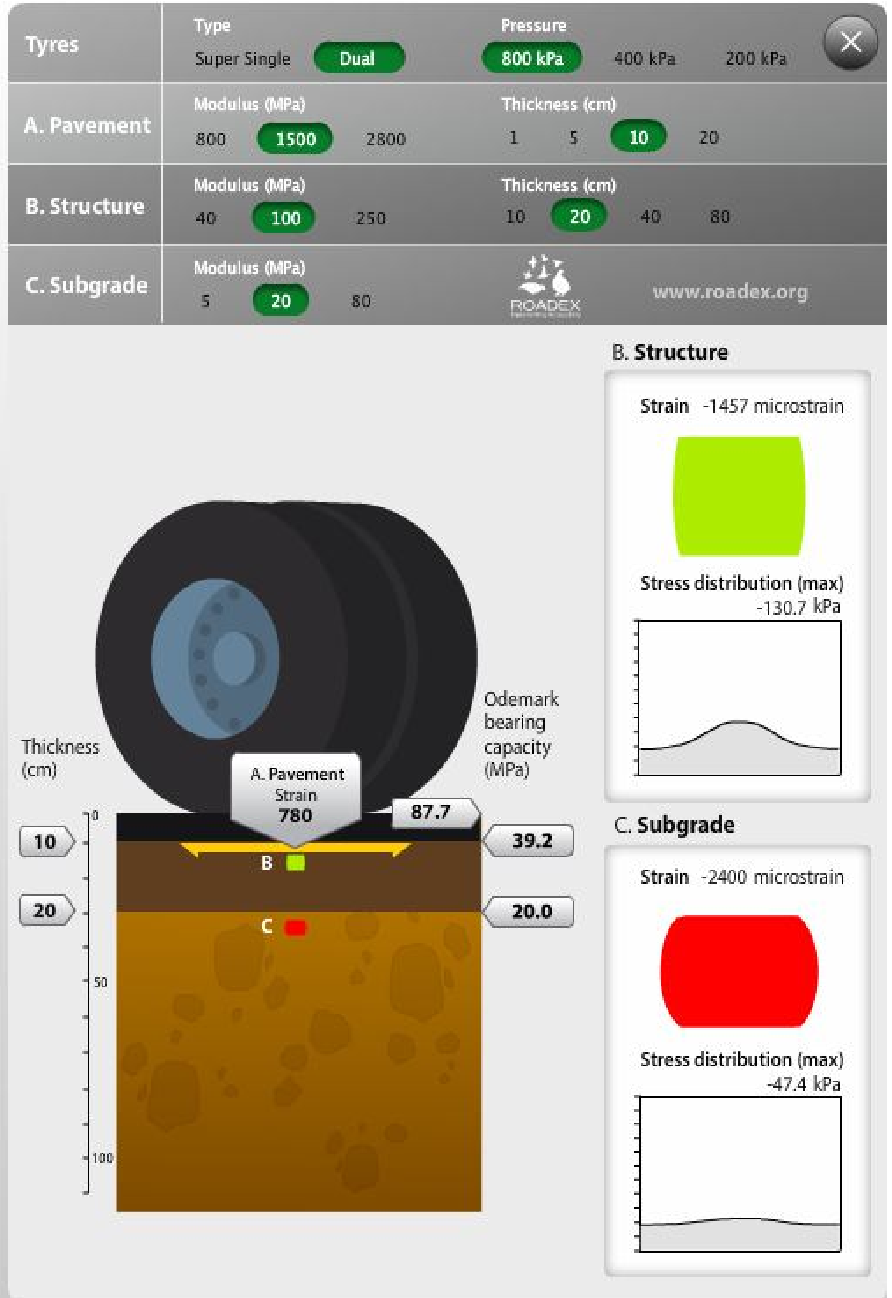
EXAMPLE: Super Single tyre vs. Dual tyre





The effect of tyre pressure

• Different tyre pressures effect on the performance of the top part of the structure. Lower tyre pressure can reduce significantly the amount of stress in the pavement and in the top part of unbound road structures and thus reduce the risk for permanent deformation.

• Tyre pressure does not have any significant effect on the stresses on the subgrade level.

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The effect of tyre pressure: case Stynie Wood:
Used gauges and loadings

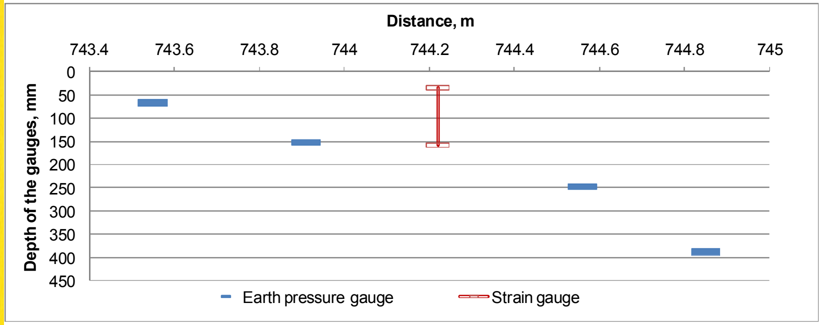
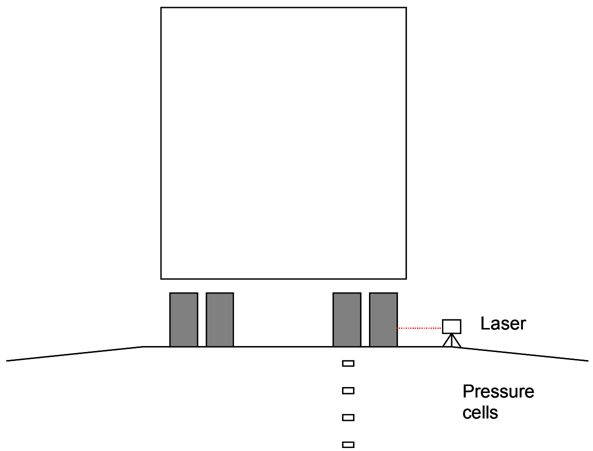


Table 5.1 passing series of truck 1

Time	Load	Tyre pressure	Amount	Wheel side
13:25 – 13:35	Empty	Low	11	R
13:35 – 13:45	Empty	Low	9	L
13:55 – 14:05	Empty	Full	9	L
14:30 - 14:40	Full	Low	12	R
14:45 - 14:55	Full	Quite low	10	R
15:20 – 15:30	Full	Quite high	8	R
15:35 – 15:45	Full	High	4	R
15:55 – 16:10	Full	Low	6	R

Table 5.2. Passing series of truck 2.

Time	Load	Tyre pressure	Amount	Wheel side
17:20 – 17:50	Full	Low	6	R & L
18:00 – 18:15	Full	Quite high	9	R & L



Measurement of driving line

of vehicle over pressure cells

Measuring the contact footprint

of a tyre controlled by TPCS

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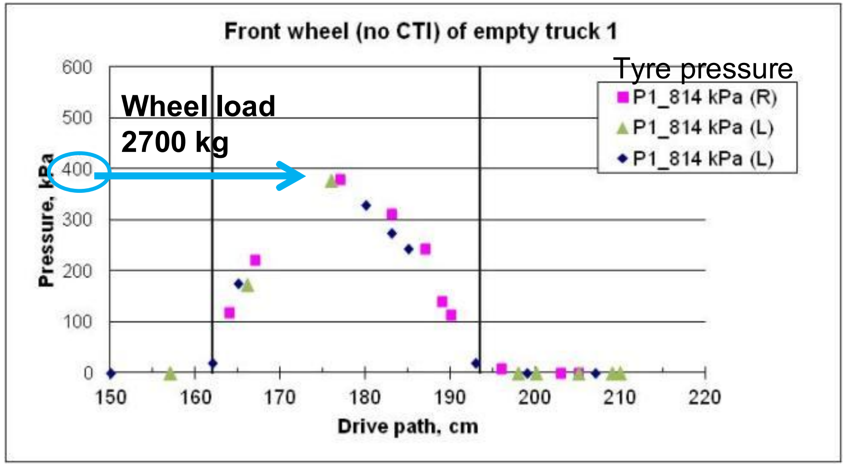
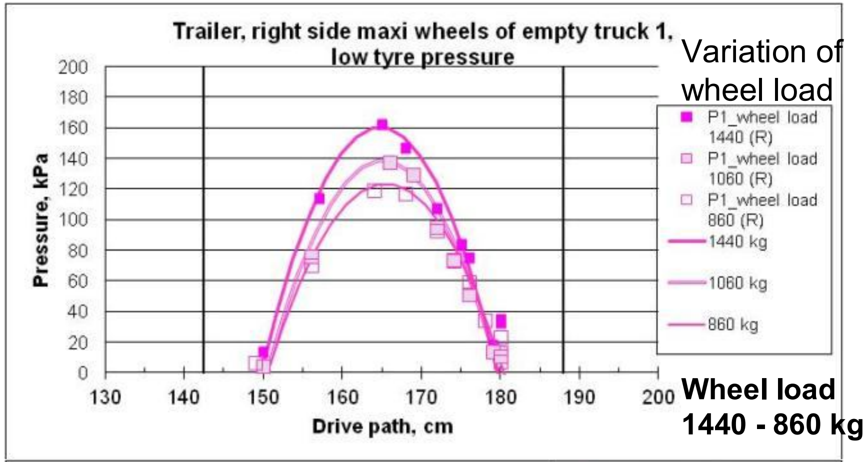
The effect of tyre pressure: case Stynie Wood:

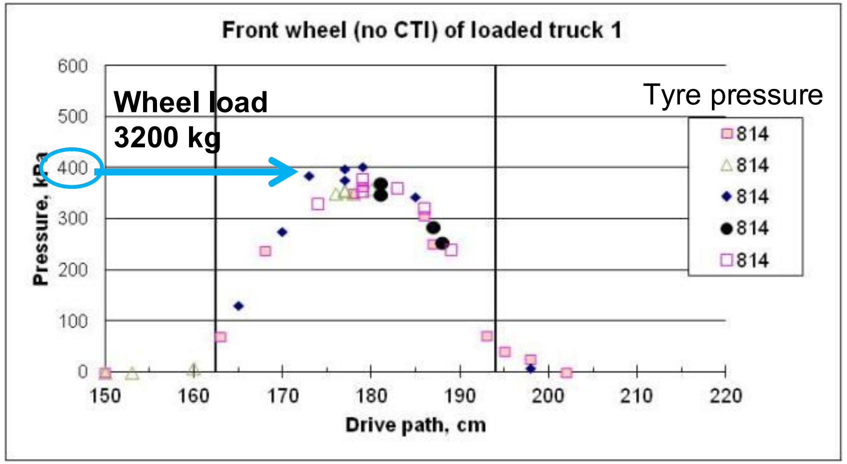
Empty and full truck 1, Pressure cauge at 60 mm (L) = Left side (R) = Right side

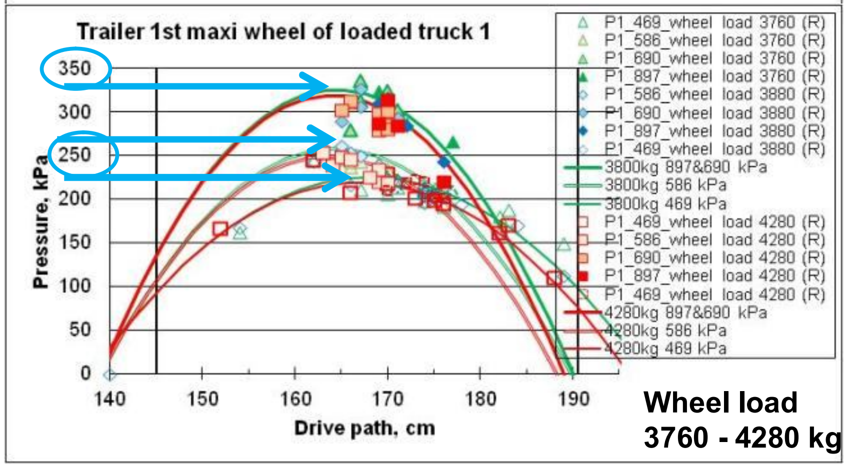
EMPTY





LOADED





Steering wheel: 400 kPa (no CTI and wheel load < 3200 kg

Maxi tyres : <350 kPa with full tyre pressure

Maxi tyres : < 250 kPa with low tyre pressure

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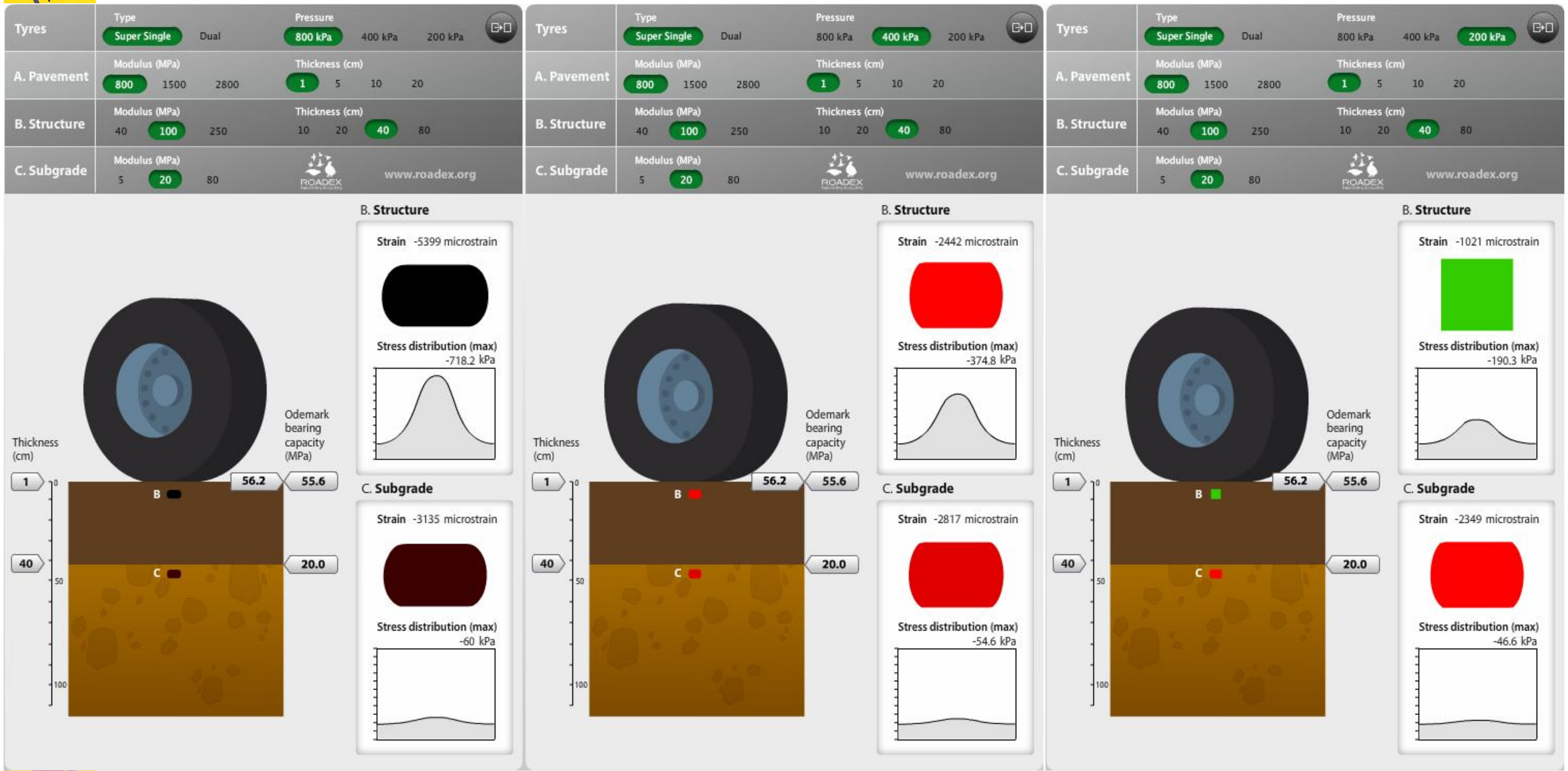
EXAMPLE: The effect of tyre pressure control system (TPCS / CTI)



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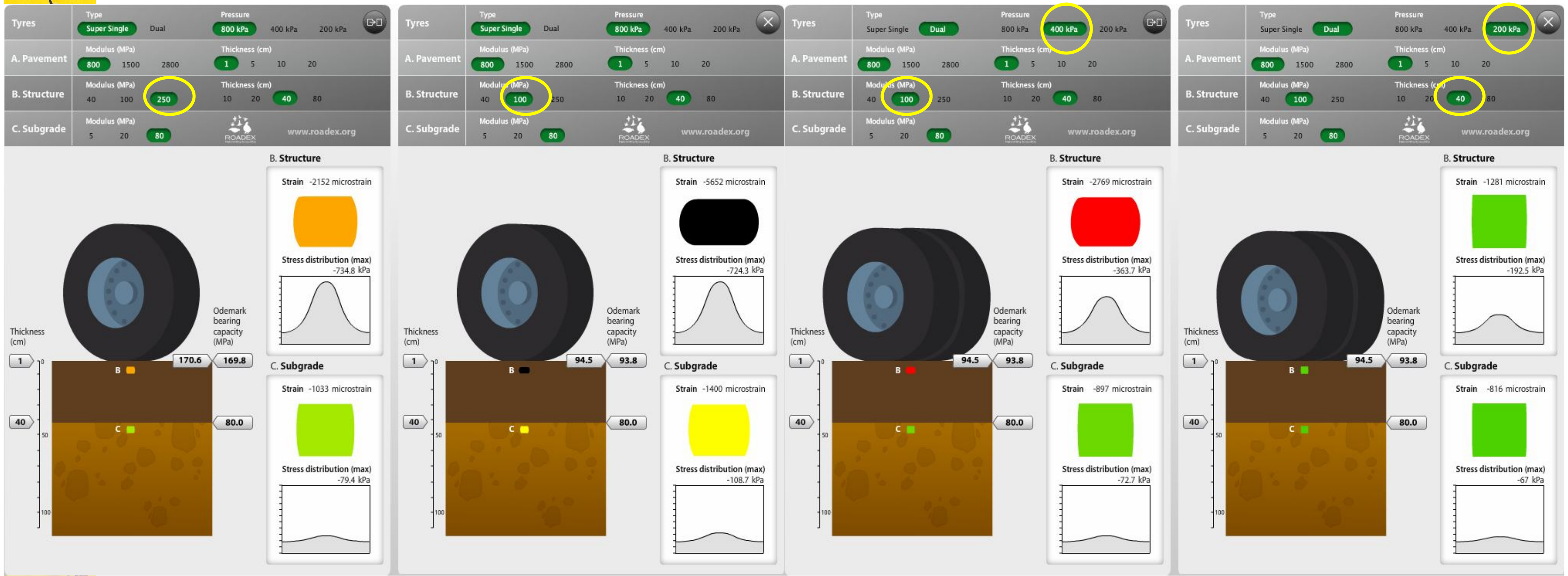
EXAMPLE: Spring thaw weakening, Mode 1 rutting and the effect of CTI



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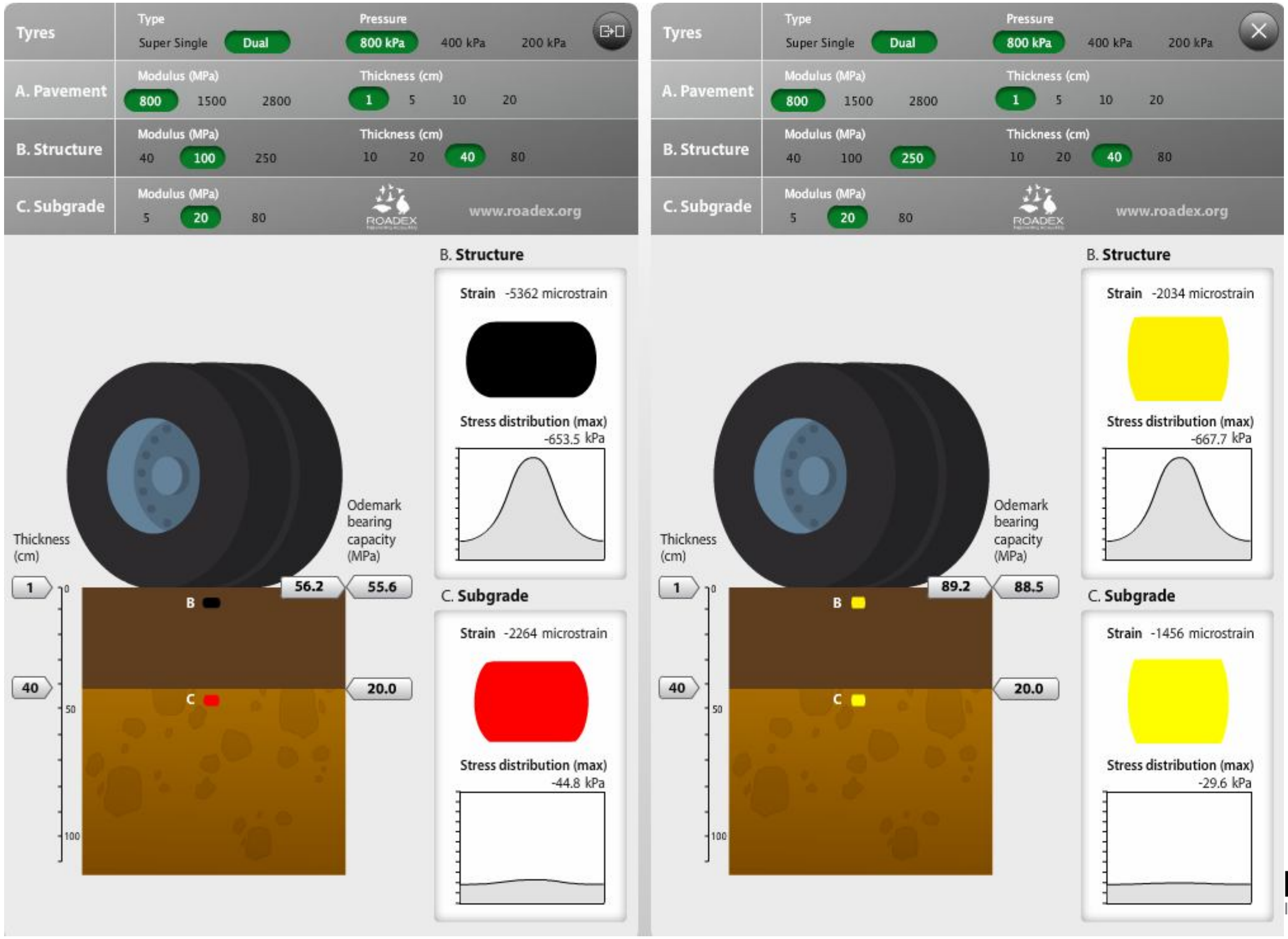
EXAMPLE: Structure against Mode 1 rutting, 1/2

- Improve the quality of the aggregate in the road structure:
  In this case the modulus of road structures has been increased from 100 MPa to 250 MPa. This can be done, for example, by mixing ballast into the structure.



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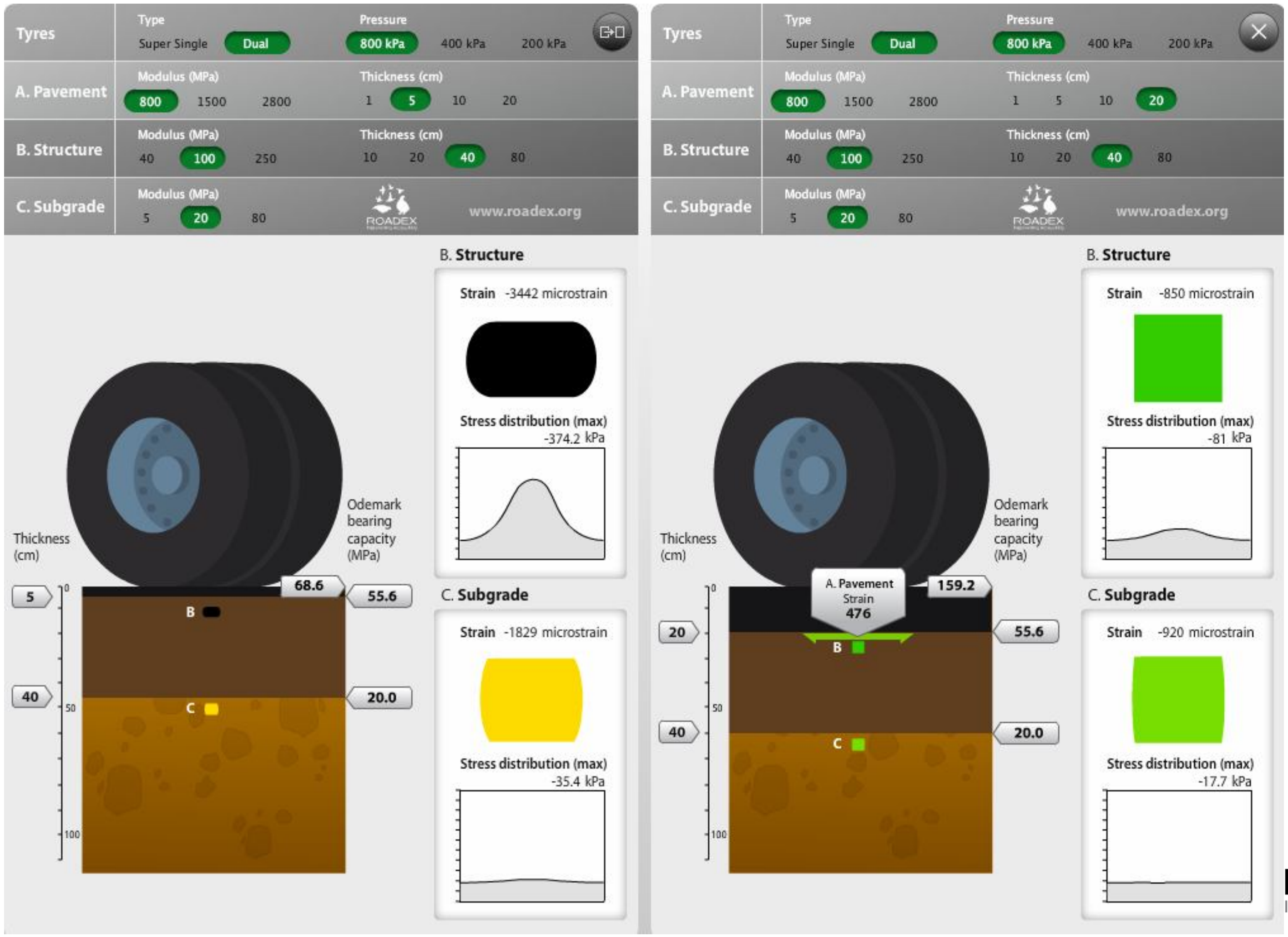
EXAMPLE: Structure against Mode 1 rutting, 2/2

- Reduce the stresses imposed by the tyre, by covering the structure with better material, ie with better aggregate or asphalt:

    In this case a soft bitumen layer, with low modulus value (800 MPa), has been increased in thickness from 50 mm to 200 mm.



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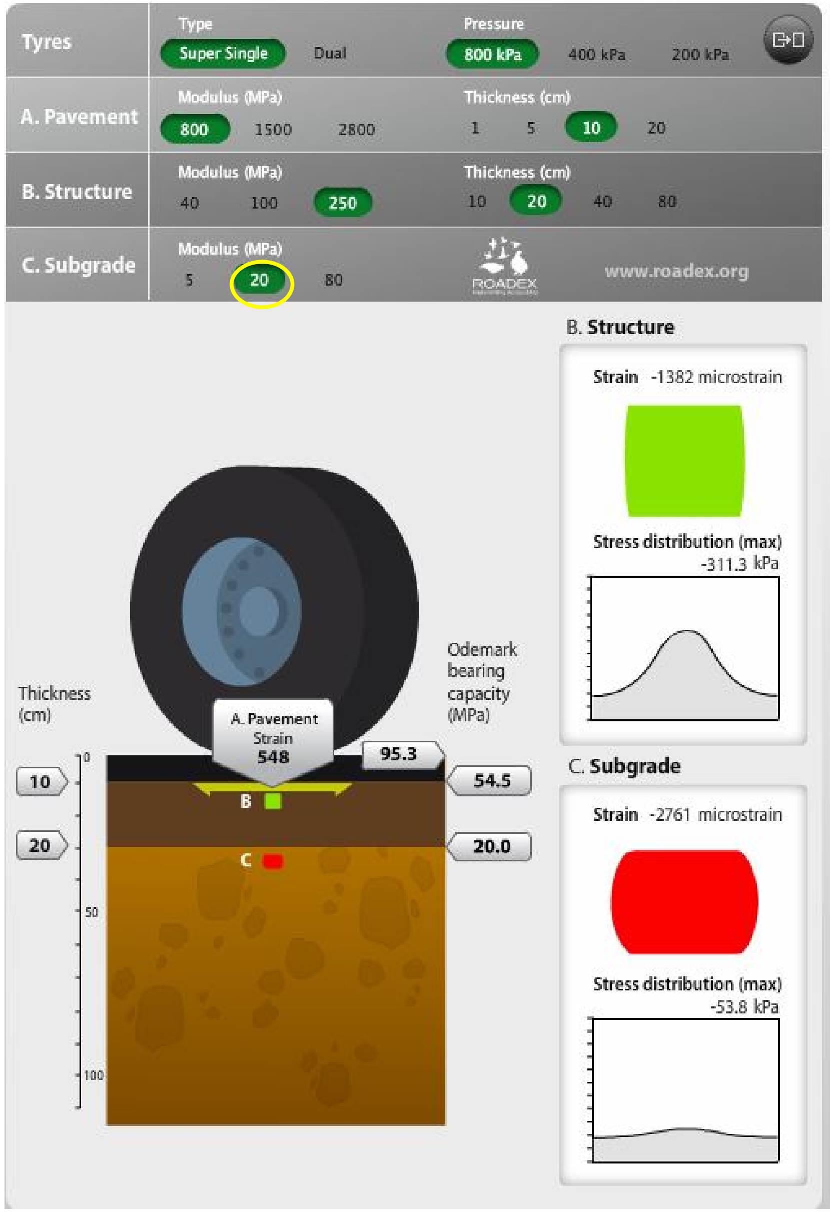
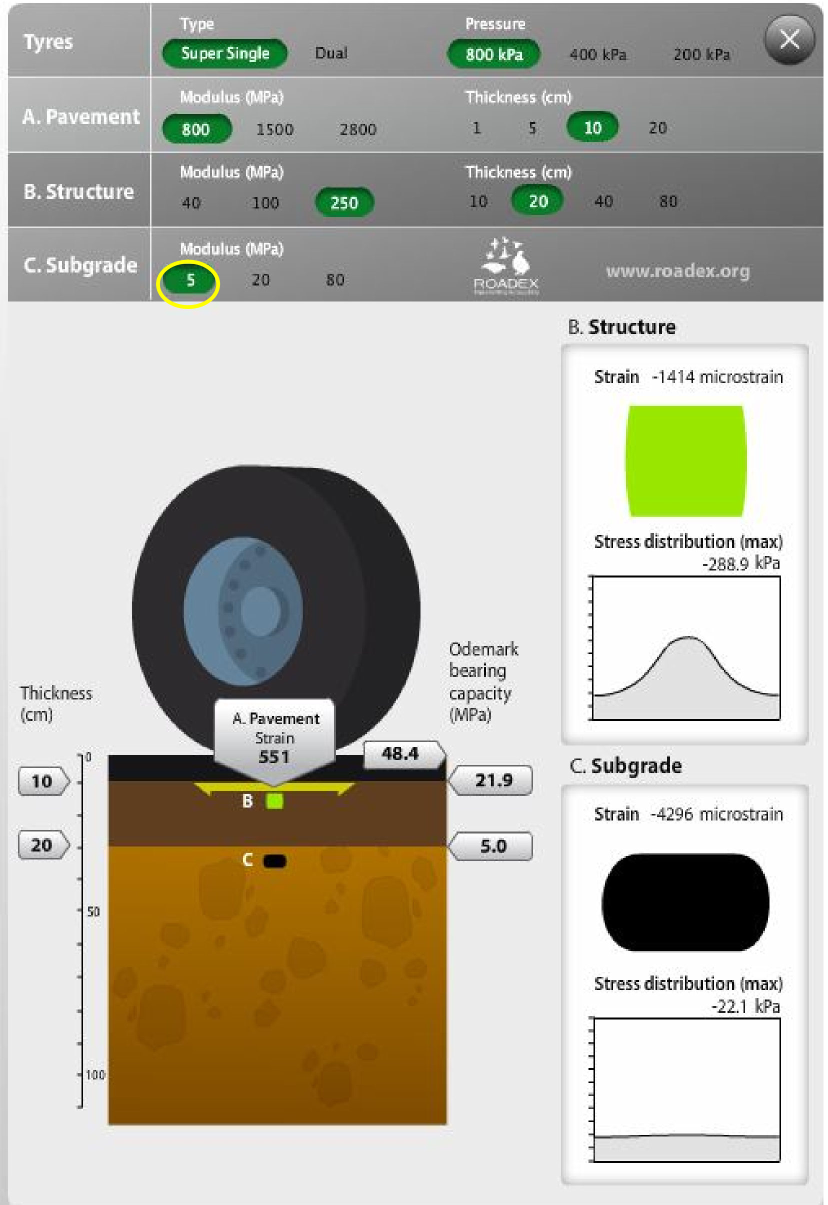
EXAMPLE: Spring thaw weakening, Mode 2 rutting





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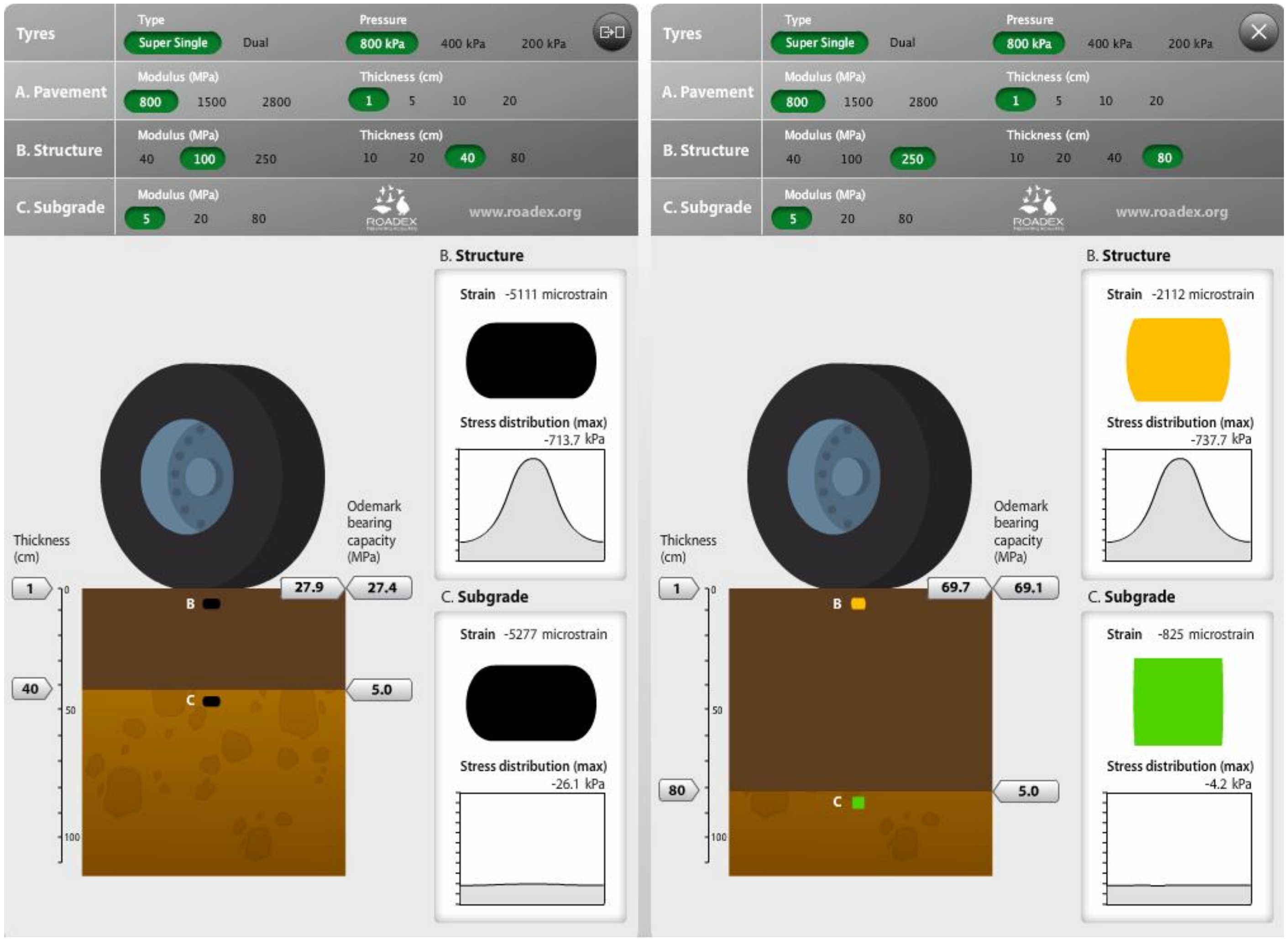
EXAMPLE: Structure against Mode 2 rutting

• The key issue in preventing Mode 2 rutting from happening is to reduce the intensity of stresses transmitted to the subgrade from the road surface. This can be achieved by increasing the thickness of the structural layers.



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EXAMPLE: The effect of thicker bound layer

- In this case, there is already 10 cm thick bound layers, so CTI does not anymore have a major effect. The subgrade is also very weak. Increasing the thickness of bound layers to 20 cm reduces the stresses in all positions.