



# ROADEX

Implementing Accessibility



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# Roadex Demonstration Project

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Seminar in Rovaniemi

25th of April 2012



**Rehabilitation of a forest road,  
Timmerleden – design proposals,  
construction and follow up**

[www.roadex.org](http://www.roadex.org)

# The aim of the project

- To develop a design method for rehabilitation of forest roads that optimizes the resources used for a given bearing capacity and quality
- To compare the ROADEX method with the currently available survey- and design technologies concerning environmental impact, cost and quality

# The Swedish demo-project: Rehabilitation of a forest road

- Timmerleden
- Close to Boden in the North of Sweden



# Timmerleden

- Length about 5 km, width 4,5 m finished road
- Width before rehabilitation 4,5-6 m
- Traffic ADT about 25 heavy vehicles
- Some personal cars a day
- Open for traffic around the year
- The road was rehabilitated in 2005 but still there were some weak sections causing problems at spring every year



# Condition July 2010



# Condition July 2010



# Condition July 2010



# The Timmerleden Road

- Rehabilitation design proposals created by
  - Swedish Forest Agency
  - Sveaskog
  - SCA Forest AB
  - Roadscanners according to ROADEX

# Design by Swedish Forest Agency

- Road survey
  - The designer walks along the road
  - Rehabilitation measures are registered section by section
  - All culverts are inspected and photos are taken
  - Equipment
    - Distance measurement wheel
    - Folding rule
    - Camera
    - Sometimes spit and spade for sampling

# Swedish Forest Agency, design proposal

Dimensioning proposals for Timber Road, length 5 km, width 4,5 m; layer thickness in millimeters																				
Swedish Forest Agency																				
Road sections	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	250	250	250	100	100	100	100	100	100	100	250	250	250	250
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	250	250	250	100	100	100	100	100	100	100	100	100	100	100	100	250
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	2050	2100	2150	2200	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	250	250	100	100	100	100	100	100	100	100	100	100	250	250	250	250	250	250	100	100
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	3050	3100	3150	3200	3250	3300	3350	3400	3450	3500	3550	3600	3650	3700	3750	3800	3850	3900	3950	4000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	250	250	100	100	100	250	250	100	100	100	100	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	4050	4100	4150	4200	4250	4300	4350	4400	4450	4500	4550	4600	4650	4700	4750	4800	4850	4900	4950	5000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				

# Design by SCA Forest AB

- Road survey
  - The designer travels along the road with a car equipped with distance meter
  - Rehabilitation measures are registered section by section

# SCA Forest AB, design proposal

Dimensioning proposals for Timber Road, length 5 km, width 4,5 m; layer thickness in millimeters																				
SCA Forest AB																				
Road sections	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	200	200	200	200
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	200	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	2050	2100	2150	2200	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	200	200	100	100	100	100	100	100	100	100	100	200	200	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				
Road sections	3050	3100	3150	3200	3250	3300	3350	3400	3450	3500	3550	3600	3650	3700	3750	3800	3850	3900	3950	4000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	100	200	200	200	200	200	200	200	200	200	200	200	200	200
Sub-base																				
Ditch left																				
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Road sections	4050	4100	4150	4200	4250	4300	4350	4400	4450	4500	4550	4600	4650	4700	4750	4800	4850	4900	4950	5000
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	200	200	200	200	200	200	200	100	100	100	100	100	100	100	100	100	200	200	200	200
Sub-base																				
Ditch left																				
Ditch right																				

# Design by Sveaskog

- Road survey
  - The designer travels along the road with a car equipped with distance meter
  - Rehabilitation measures are registered section by section

# Sveaskog, design proposal

Dimensioning proposals for Timber Road, length 5 km, width 4,5 m; layer thickness in millimeters																				
Sveaskog																				
Road sections	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				
Road sections	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				
Road sections	2050	2100	2150	2200	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
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Road sections	3050	3100	3150	3200	3250	3300	3350	3400	3450	3500	3550	3600	3650	3700	3750	3800	3850	3900	3950	4000
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				
Road sections	4050	4100	4150	4200	4250	4300	4350	4400	4450	4500	4550	4600	4650	4700	4750	4800	4850	4900	4950	5000
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				

# Roadscanners design proposal

## Plan for rehabilitation according to ROADEx Design Method

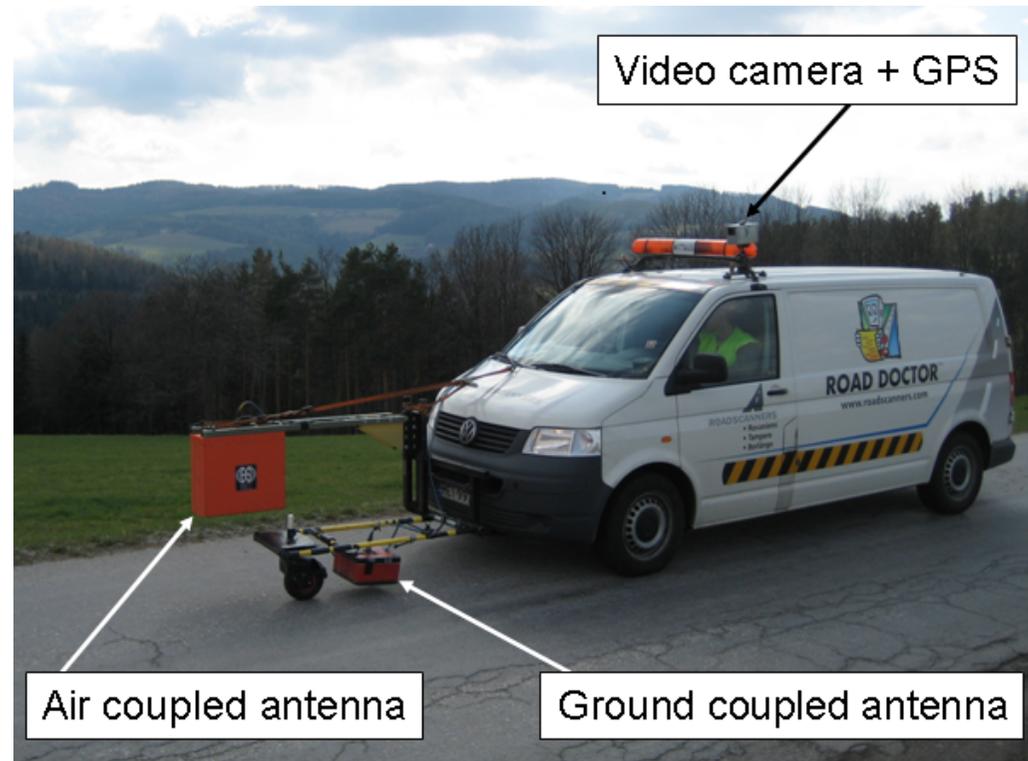
- Step 1 - Collection of data
- Step 2 - Project setup; processing and interpretation of data
- Step 3 - Module calculations for road structure and subgrade soil
- Step 4 - Initial bearing capacity
- Step 5 - New design; Target bearing capacity
- Step 6 - Checking the design with additional data

## Step 1 - Collection of data

- Survey with ground penetration radar (GPR)
- Field survey with video and GPS
- Bearing capacity measurements with falling weight deflectometer
- Sampling (thickness and grading)

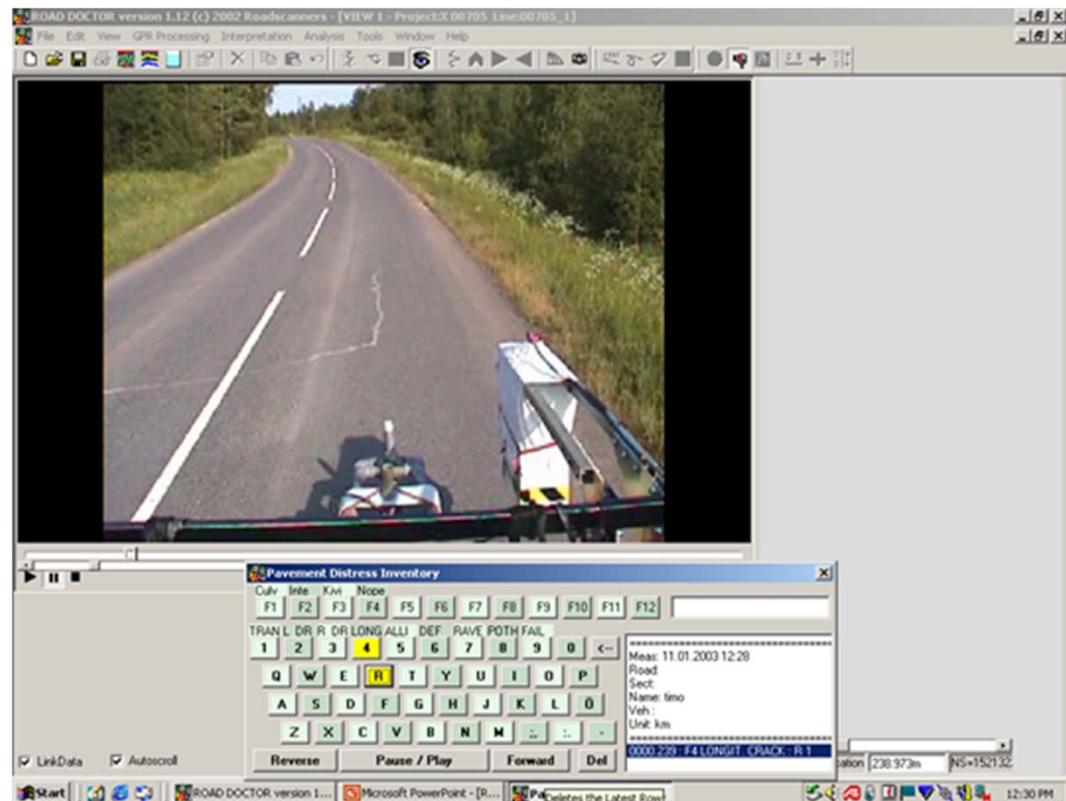
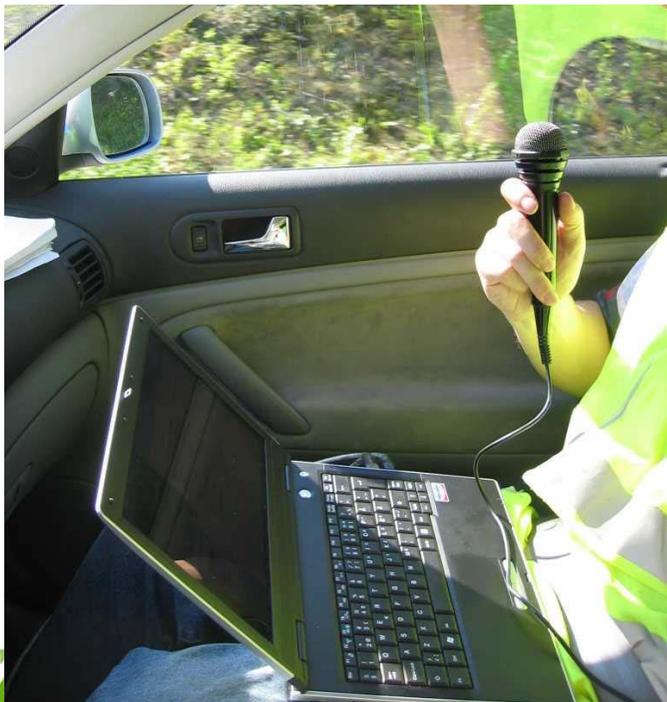
# Measurements with GPR

- Measurement with
  - Ground coupled antenna 200-500 MHz (400)
  - Air coupled antenna 900-2500 MHz (2000)
  - 10 scans/m
  - One measurement line, right wheel path
- Video capture and GPS



# Field survey

- Field survey of
  - Culverts
  - Ditches
- Registration using Road Doctor Cam Link
- Analyses of the digital video using Road Doctor Pro/Designer
  - Road damages
  - Classification of drainage



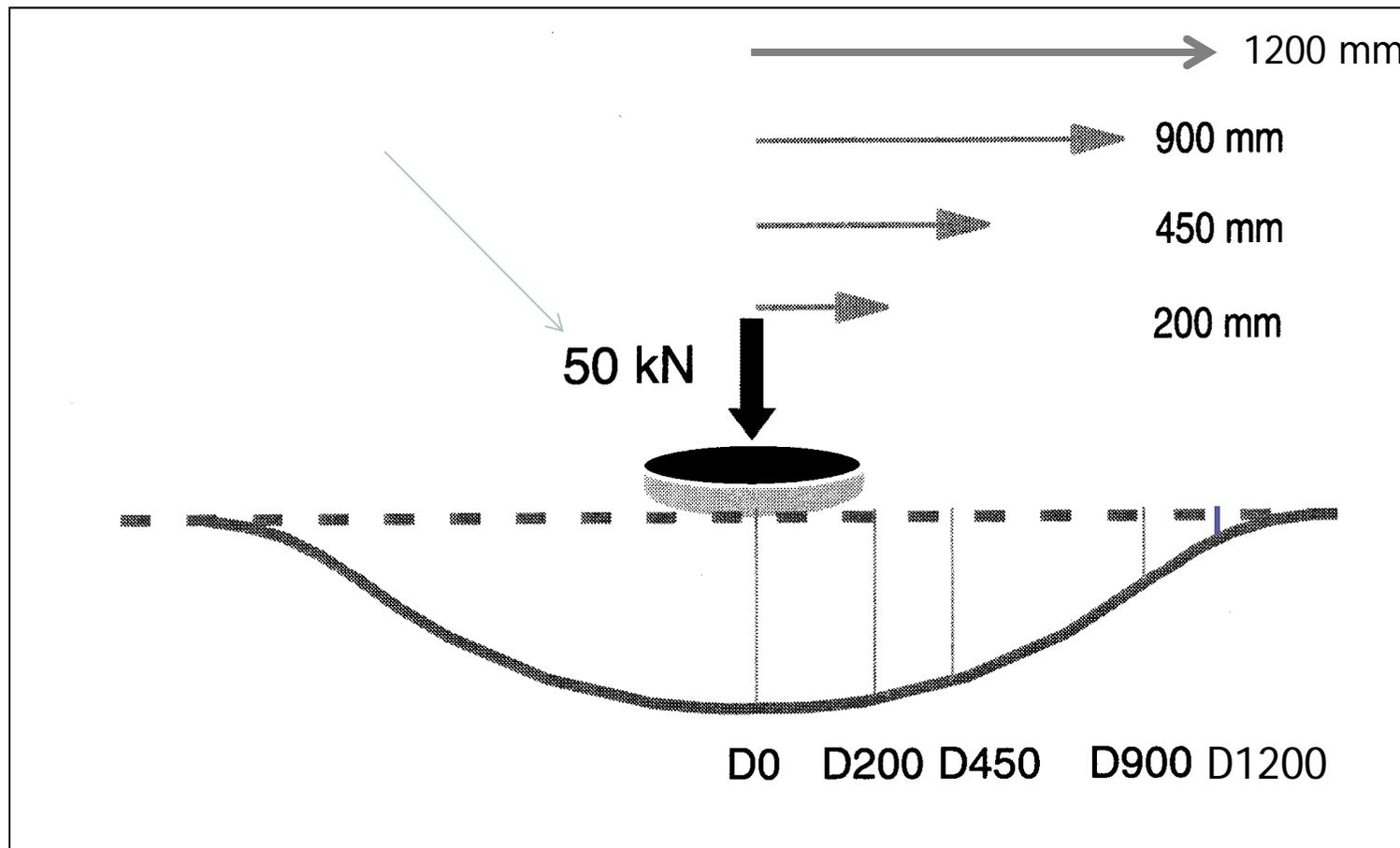
# Bearing capacity from Falling Weight (FWD) measurements

- Measurement with 10-40 measurement points per km road (40 in this project)
- Measurements according to Swedish Transportation Agency's Method Description VVMB 112



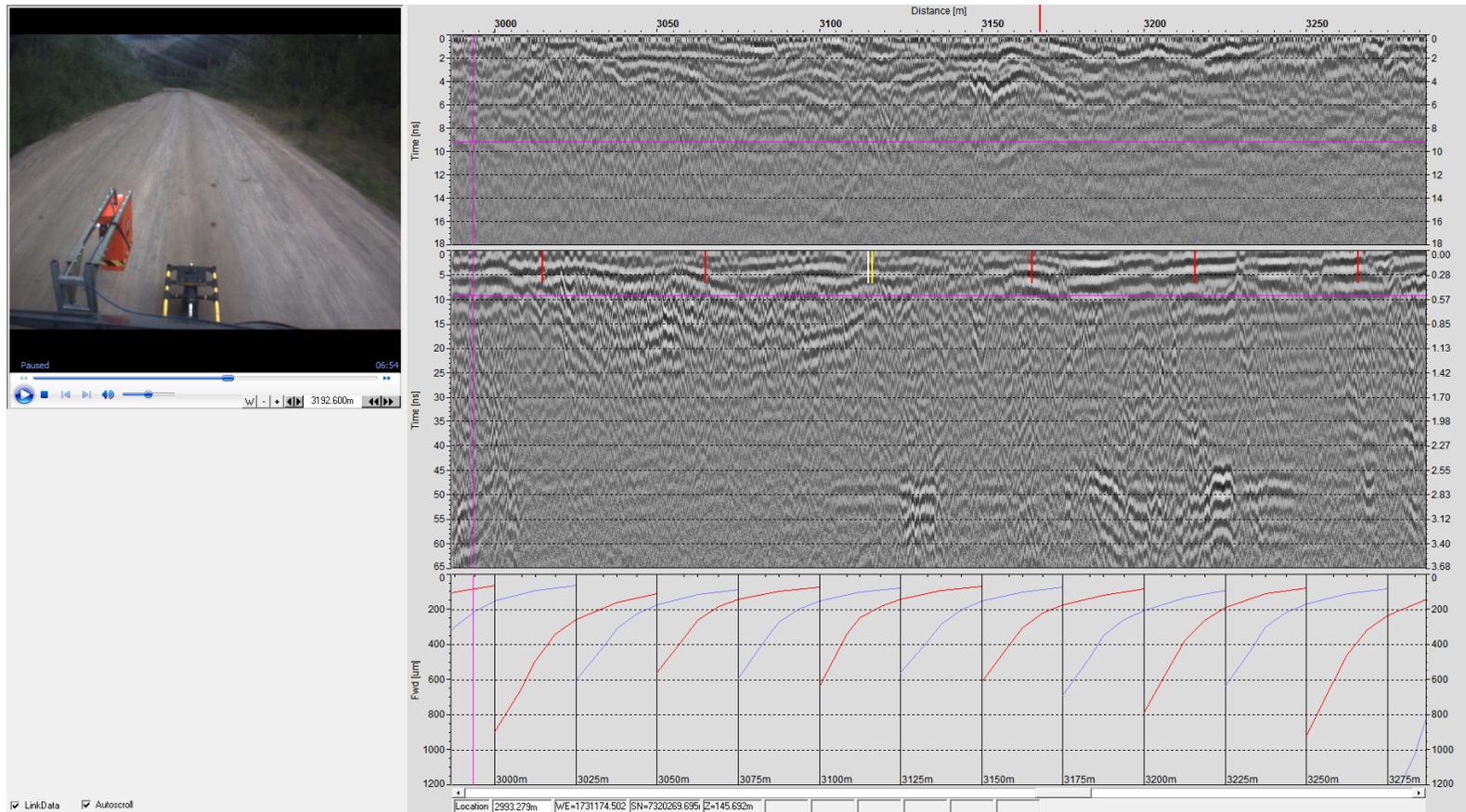
## Deflection basin from FWD-measurements

- Measurement pinciple



## Step 2 - Project setup; processing and interpretation

- Putting in all survey data in the software Road Doctor
- Positioning from GPS or length measurement
- Linking of all survey data
- Preliminary interpretation of layer interfaces
- Selection of sampling points from FWD- and GPR-data



# Sampling

- Layer thickness
- Grading of material from different layers



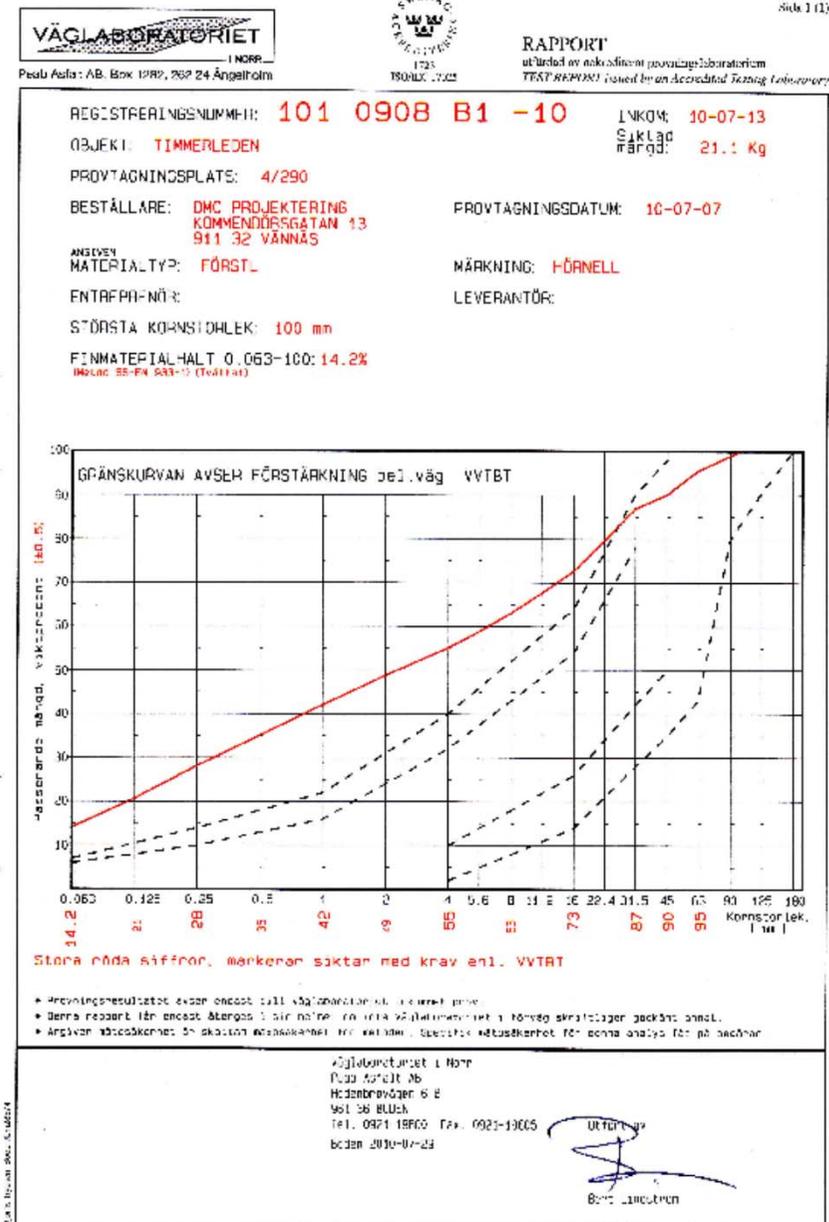
# Results of the sampling from Timmerleden

- Layer thickness, accumulated

- |         |  |  |
|---------|--|--|
| - 1/020 | wearing course and base course<br>subbase<br>subgrade            | = 0-5 cm<br>= 5-57 cm<br>= 57- morain  |
| - 3/650 | wearing course and base course<br>subbase<br>subbase<br>subgrade | = 0-5 cm<br>= 5-27 cm sand+crushed gravel<br>= 27-40 cm stony fine sand<br>= 40- cm silty morain |
| - 4/290 | subbase<br>subbase<br>subbase                                    | = 0-23 crushed gravel<br>= 23-45 stony sand<br>= 45 cm - stony silty sand                        |

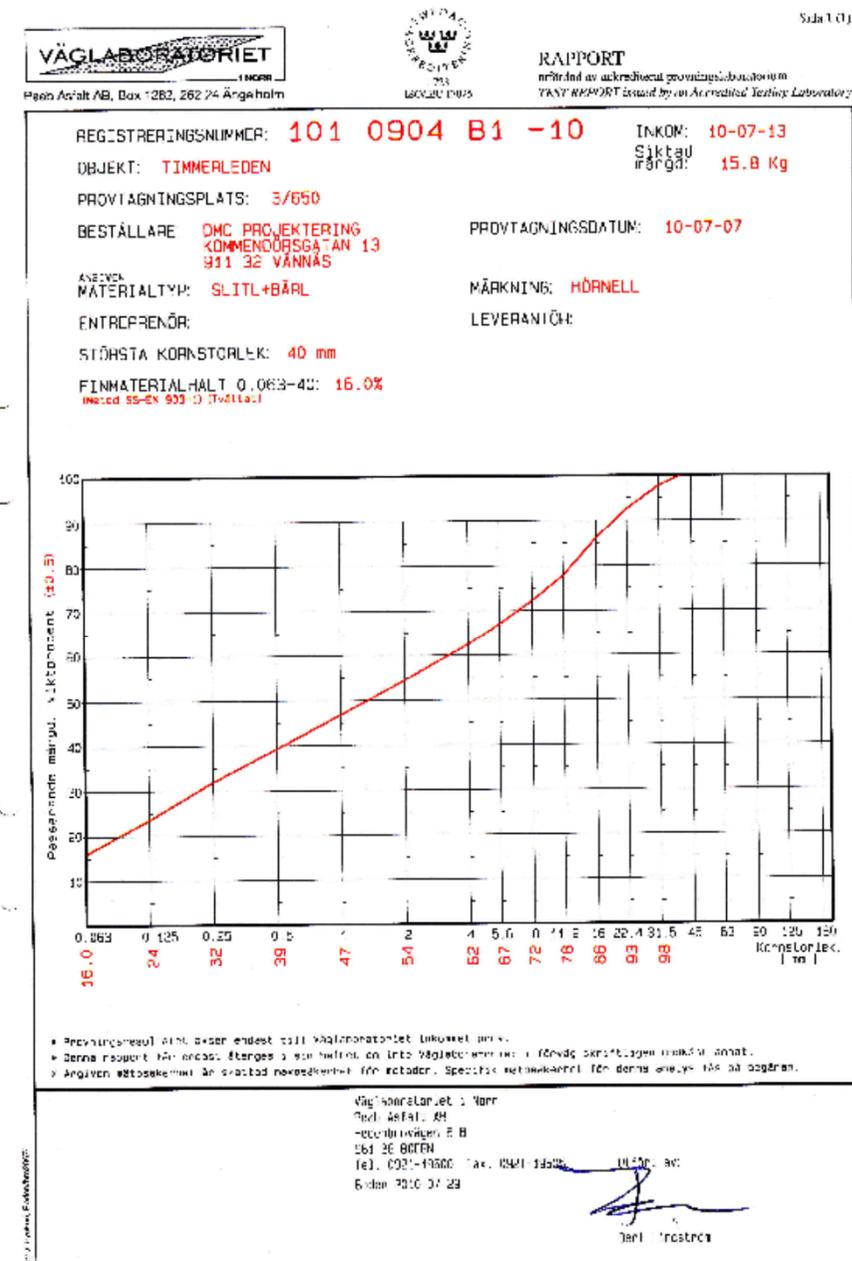
# Results from sampling

- Grading
  - Subbase



# Results from sampling

- Grading
  - Base course and wearing course mixed

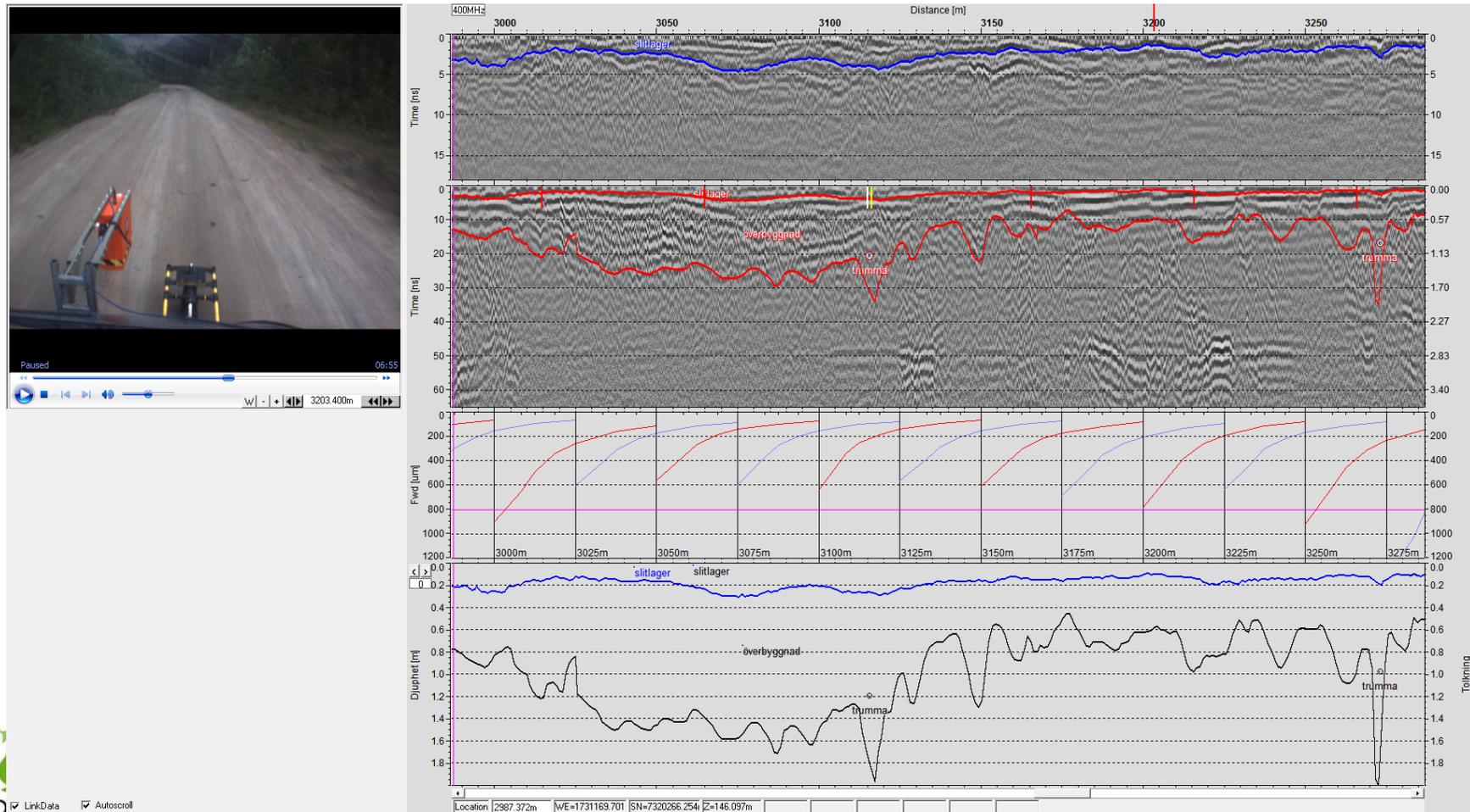


# Analyses of data

- Analyses of data in Road Doctor
  - Interpreted layer interfaces in the road structure
    - Bottom of wearing course
    - Bottom of structure
    - Sometimes bottom of base course
  - Risk for deformation based on FWD-data
    - Subgrade modules
    - BCI and SCI
  - Grading

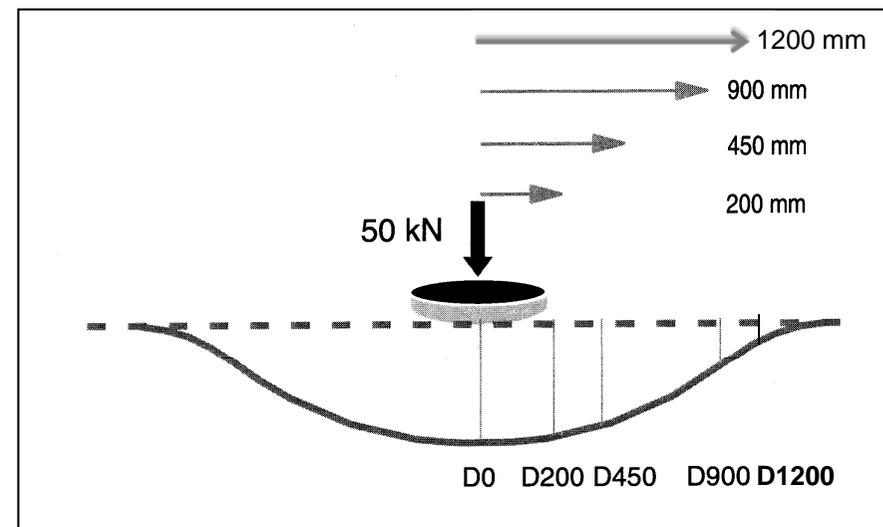
# Interpretation of layer thickness

- Checking against reference samples



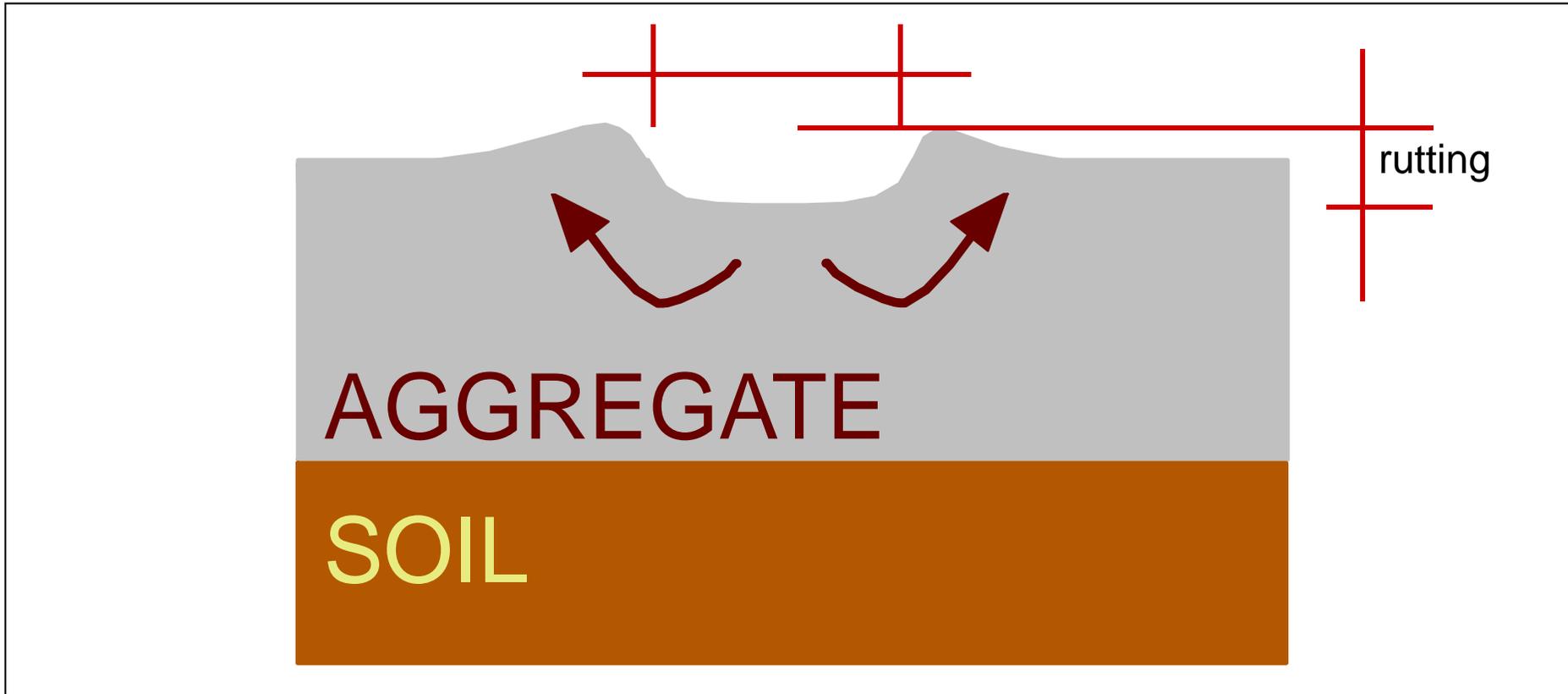
## Calculated from the results of the FWD-measurement Deformation risk

- Analyses of unsatisfactory bearing capacity
  - SCI = Surface Curvature Index, a measure of the stiffness in the upper part of the road structure
  - SCI = D0 - D200
  
  - BCI = Base Curvature Index, a measure of the stiffness in the lower part of the road structure
  - BCI = D900 - D1200



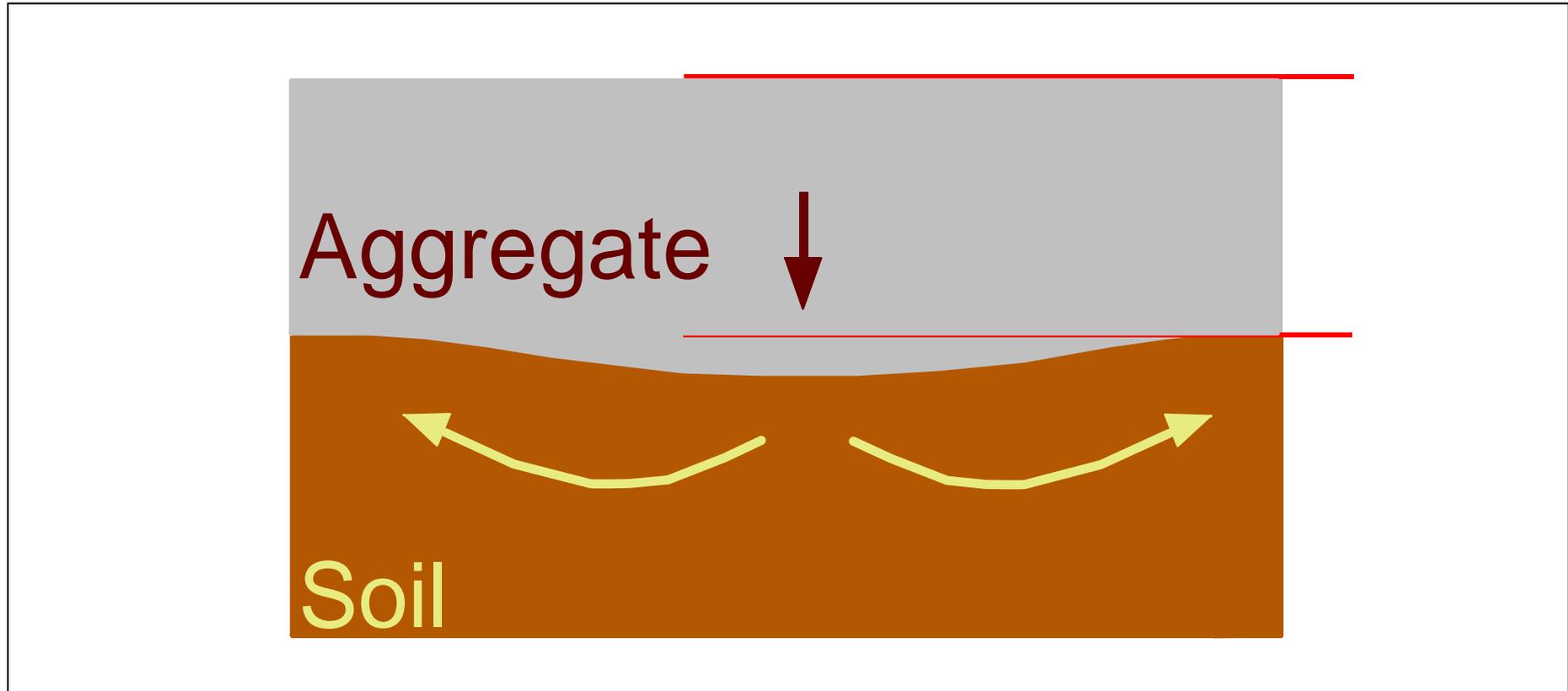


## RUTTING MODE 1 – NEAR SURFACE SHEAR





## RUTTING MODE 2 – DEEPER SHEAR



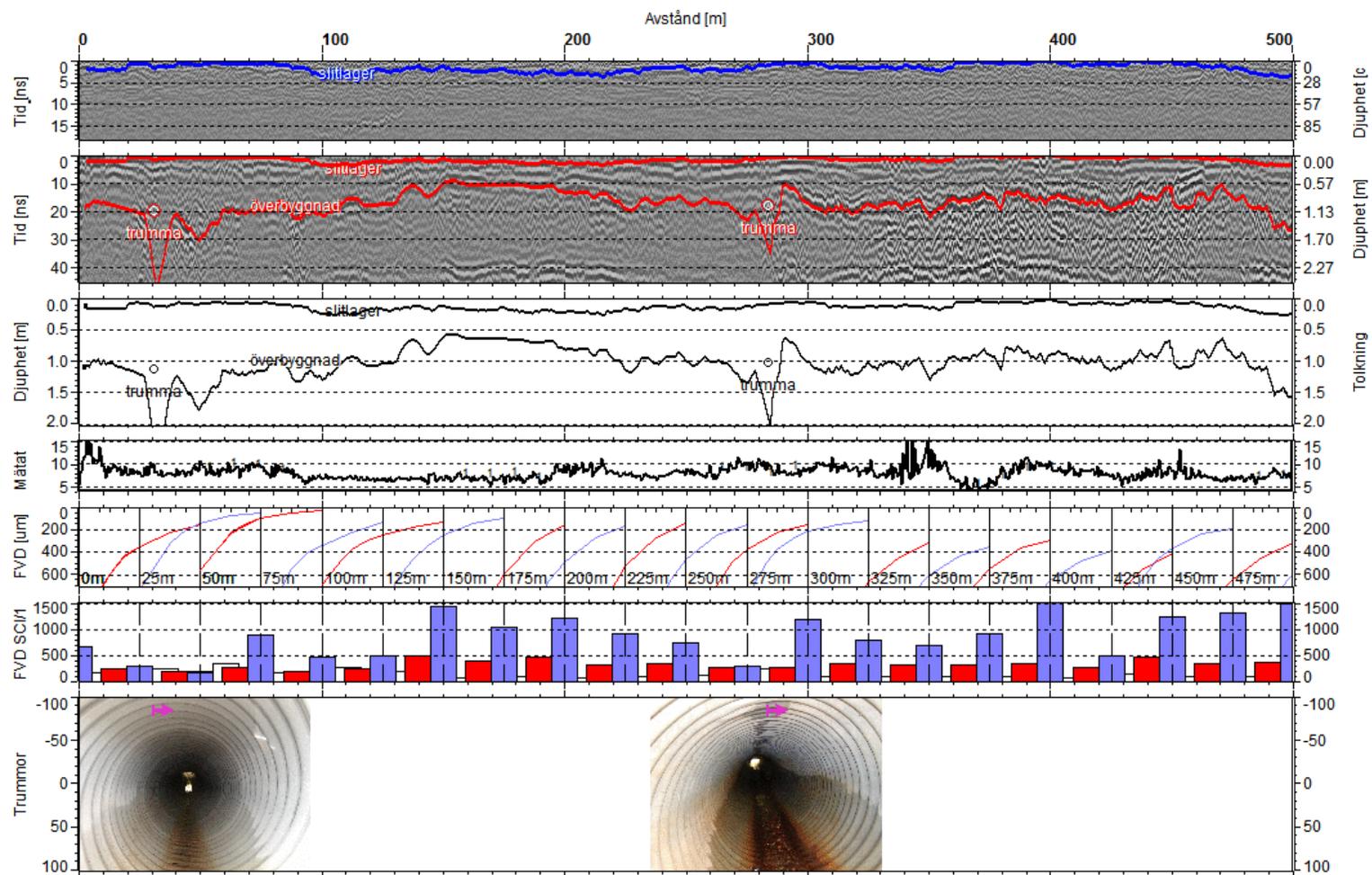


## MODE 2 – DEEPER SHEAR



# Data from field surveys in Road Doctor

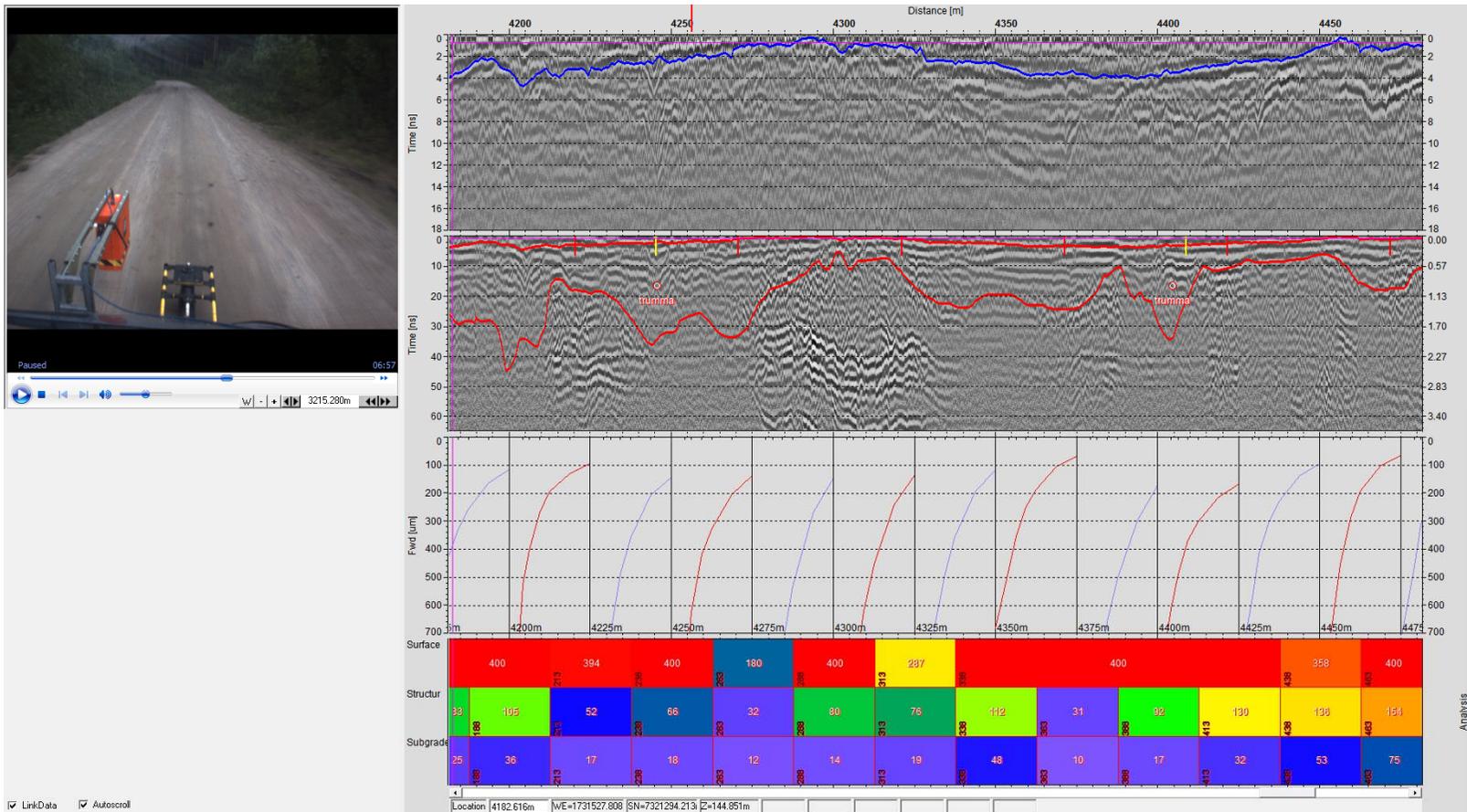
Initial - Timmerleden



Roadscanners 2010

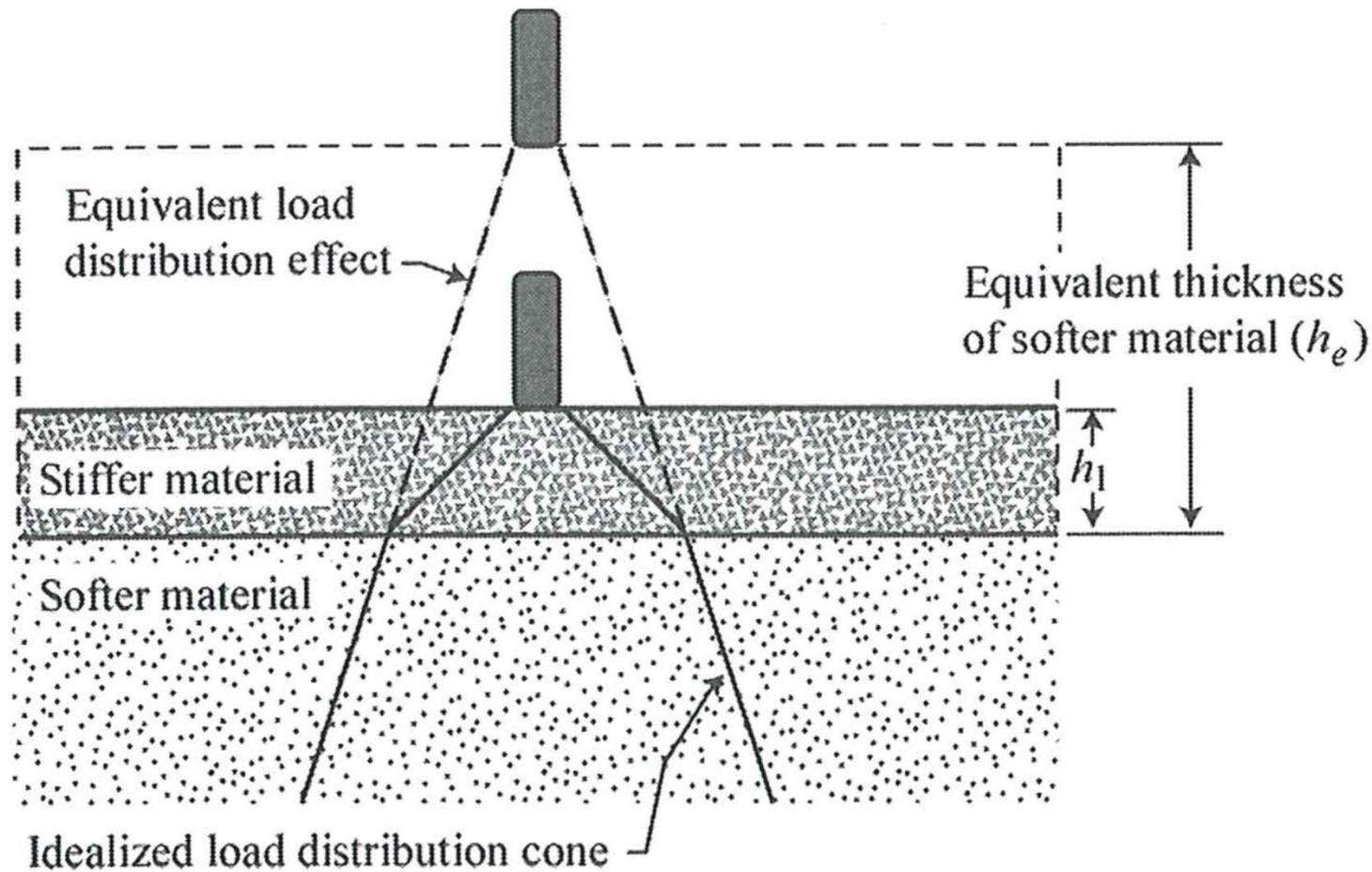
# Step 3 - Module calculations for the road structure and the subgrade soil

- Calculation of E-modules using Road Doctor's forward calculation function from FWD-results
- Adjustment of homogenous sections based on GPR-data and video



# Step 4 - initial bearing capacity

- *Principle for Odemark's dimensioning.*



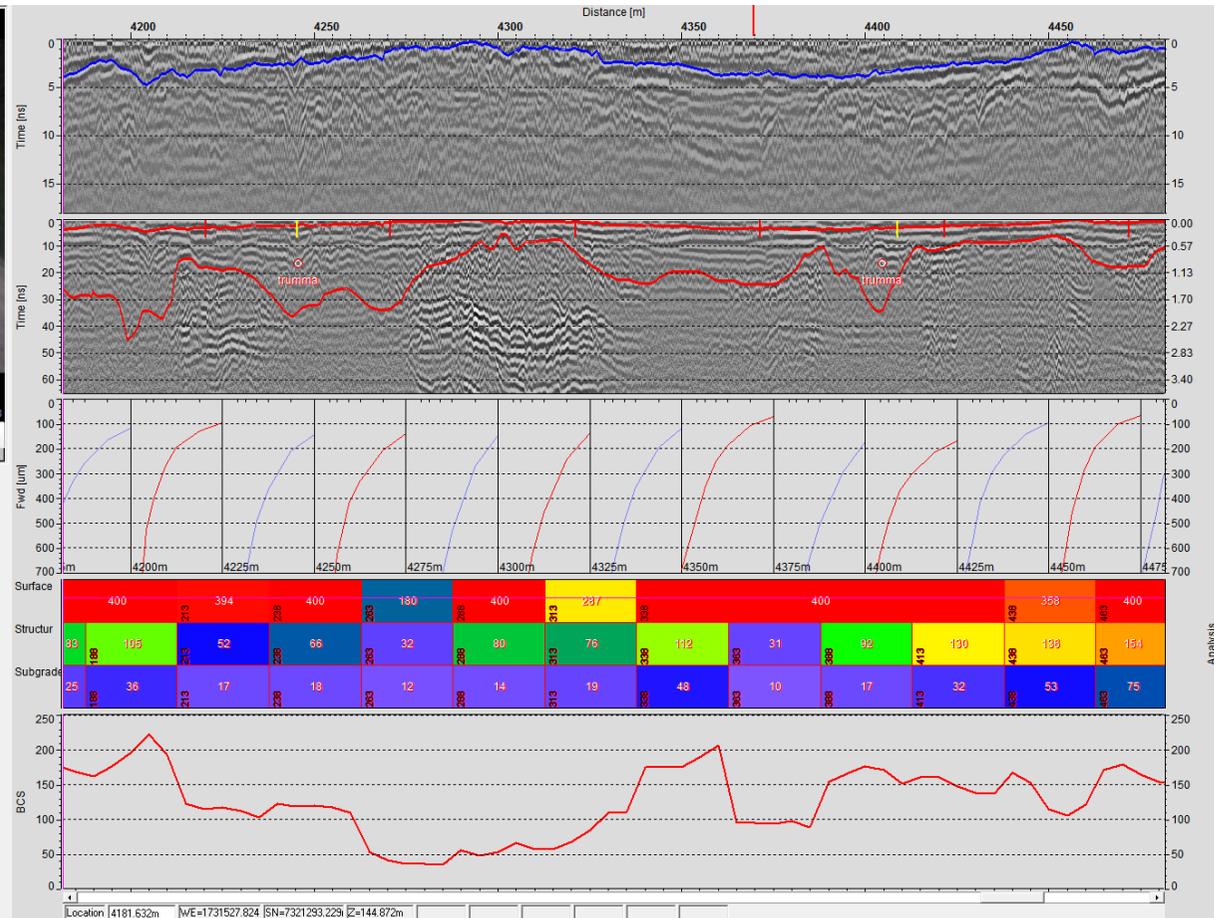
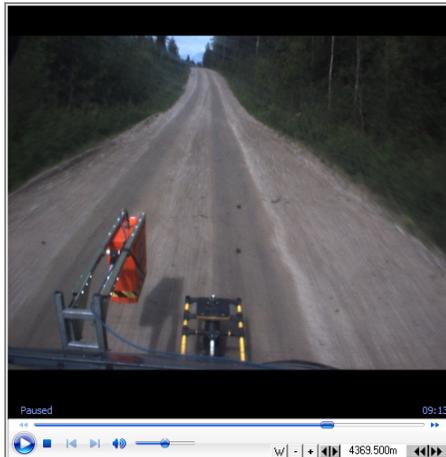
# Step 4 - initial bearing capacity

- Odemark's formula.
  - where
  - $E_p$  = bearing capacity on top of the layer being dimensioned [MPa]
  - $E_A$  = bearing capacity beneath the layer being dimensioned [MPa]
  - $E$  = elastic modulus of the layer being dimensioned [MPa]
  - $h$  = thickness of the layer being dimensioned [m]

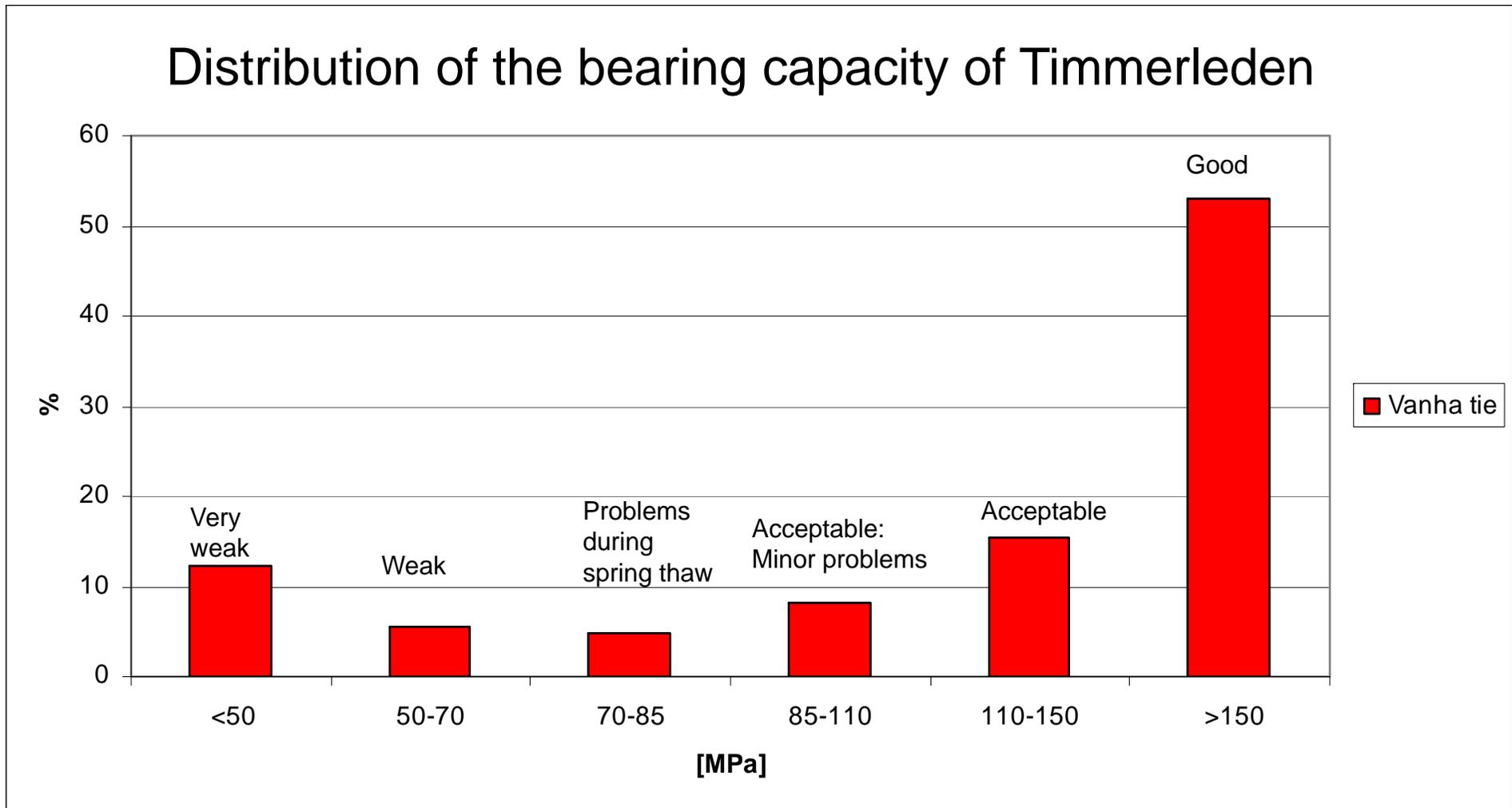
$$E_p = \frac{E_A}{\left(1 - \frac{1}{\sqrt{1 + 0,81 \times \left(\frac{h}{0,15}\right)^2}}\right) \frac{E_A}{E} + \frac{1}{\sqrt{1 + 0.81 \times \left(\frac{h}{0,15}\right)^2 \left(\frac{E}{E_A}\right)^{\frac{2}{3}}}}}$$

# Step 4 - initial bearing capacity

- Calculated initial bearing capacity according to Odemark
  - Using forward calculated modules from FWD-measurements
  - Using thickness interpreted from GPR-data

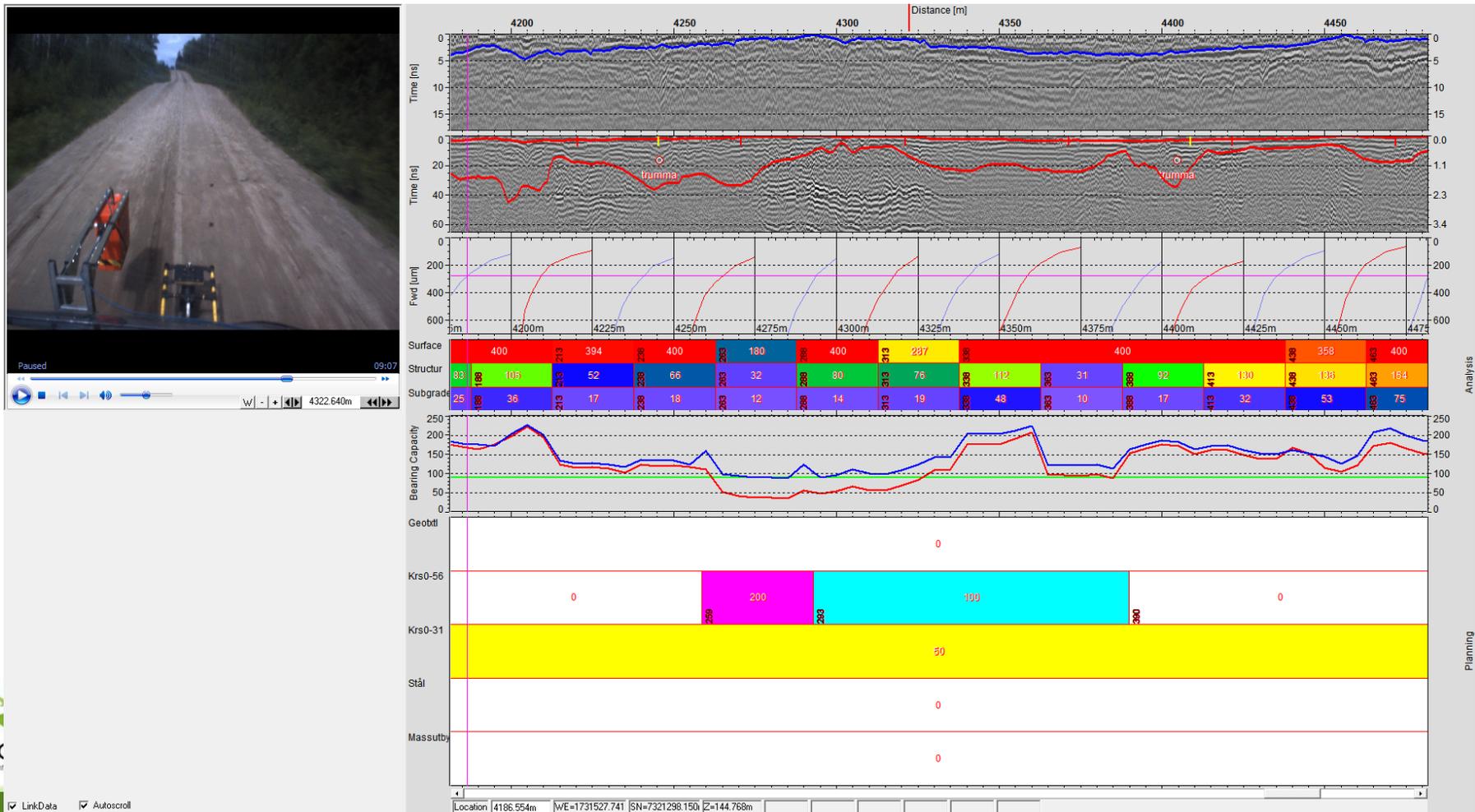


# Distribution of the Odemark bearing capacity



# Step 5 - Design of new structure; target bearing capacity according to Odemark, 90 MPa

- Target bearing capacity and new layers included





## Step 6 - Check of the design proposal with additional data

- Weaknesses in the proposed design model
  - Bedrock close to the road surface
    - Will influence the initial bearing capacity - too high value
      - Can result in too weak strengthening measure
      - Can be checked against the "strain" - value( $E_a$ )
      - At high "strain" -value, increase the thickness
  - On peat subgrade
    - The target bearing capacity can result in too strong strengthening measure
      - Can give risk for settlements
      - Lower target bearing capacities should be considered on peat subgrade



# Roadscanners, design proposal

Dimensioning proposals for Timber Road, length 5 km, width 4,5 m; layer thickness in millimeters

## Roadscanners

Road sections	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100	100	100	100	100	100	200	200	200	200	200	100	100	100	200	250	250	250	250	250

### Sub-base

### Steel reinforcement

### Ditch left

### Ditch right

Road sections	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000
Wearing course	150	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	250				200	200	200	200	200	100								100	100	100

### Sub-base

### Steel reinforcement

### Ditch left

### Ditch right

Road sections	2050	2100	2150	2200	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100							100			100	100	100	200	200	200	200			

### Sub-base

### Steel reinforcement

### Ditch left

### Ditch right

Road sections	3050	3100	3150	3200	3250	3300	3350	3400	3450	3500	3550	3600	3650	3700	3750	3800	3850	3900	3950	4000
Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base						100				100	100	200	100	200	100	200	200	200	100	100

### Sub-base

### Steel reinforcement

### Ditch left

### Ditch right

Road sections	4050	4100	4150	4200	4250	4300	4350	4400	4450	4500	4550	4600	4650	4700	4750	4800	4850	4900	4950	5000
Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100	100	100			200	100	100				200	200							

### Sub-base

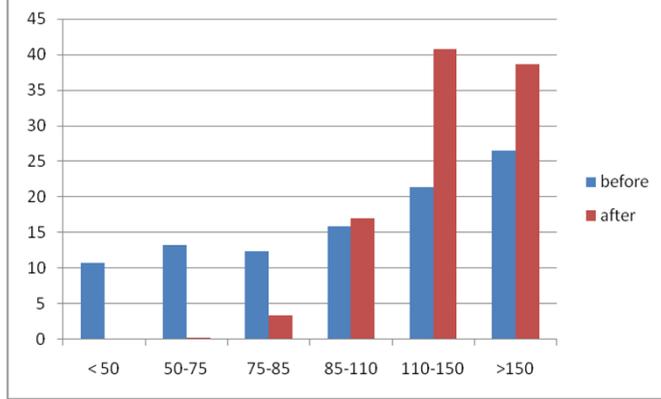
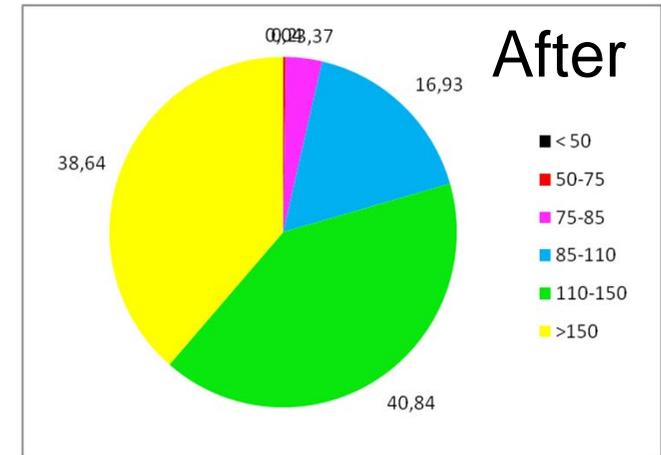
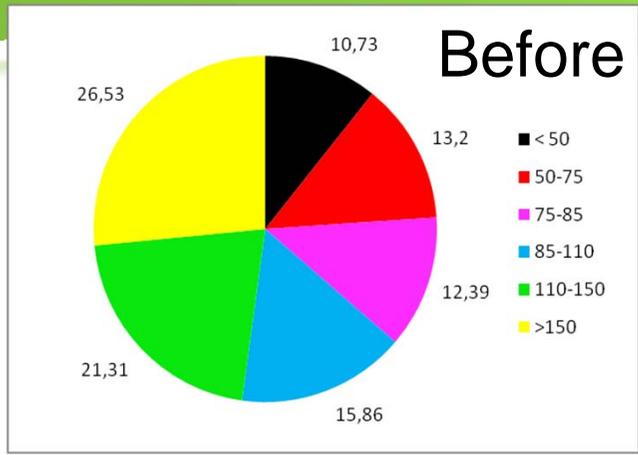
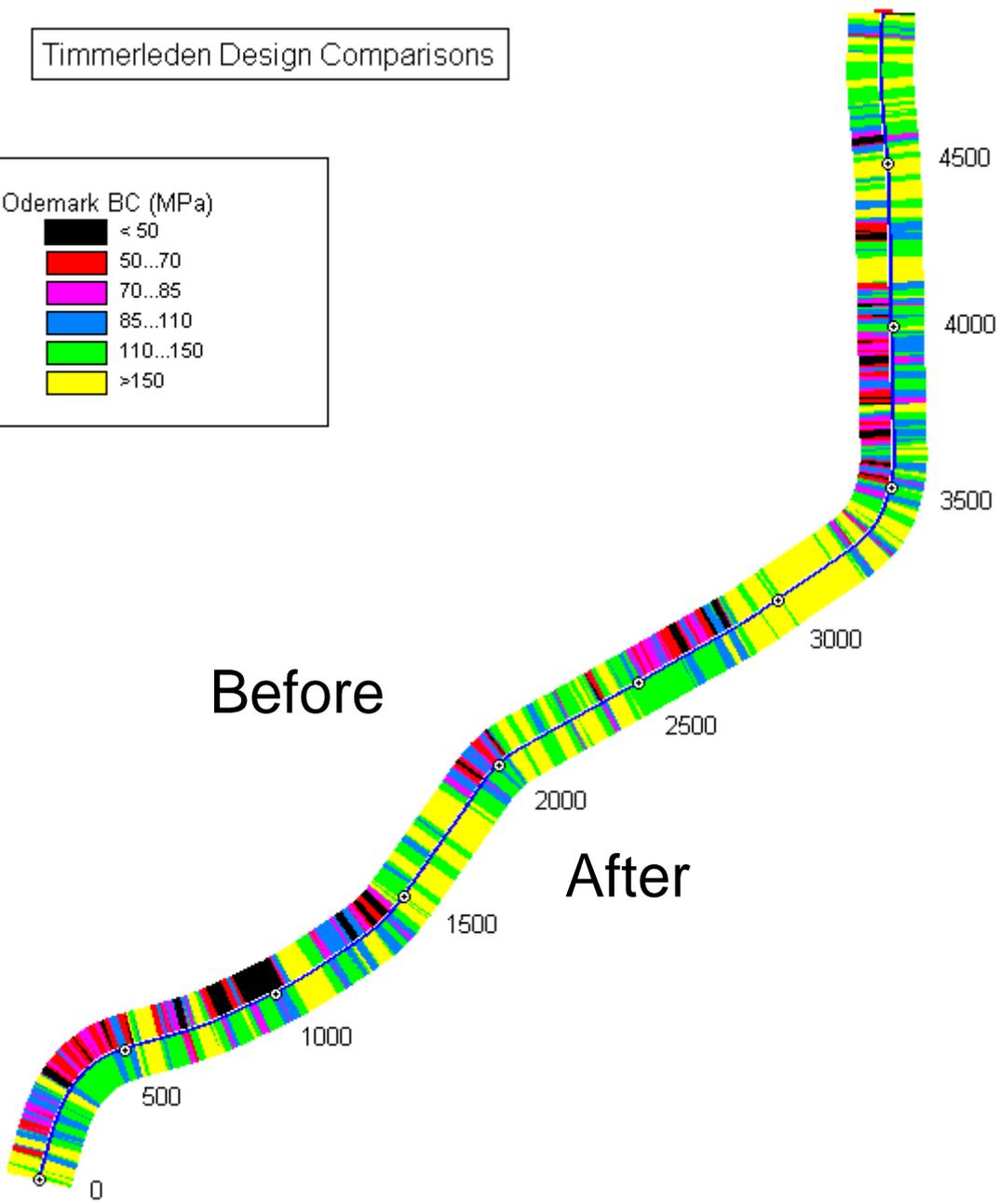
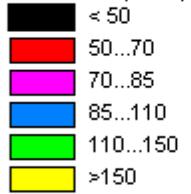
### Steel reinforcement

### Ditch left

### Ditch right

Timmerleden Design Comparisons

Odemark BC (MPa)



# Comparison of design proposals 0 - 1000 m

Dimensioning proposals for Timber road, length 5 km, width 4,5 m; layer thickness in millimeters

COMPANY      Road sections  
 50   100   150   200   250   300   350   400   450   500   550   600   650   700   750   800   850   900   950   1000

**Swedish Forest Agency**

Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	250	250	250	100	100	100	100	100	100	100	250	250	250	250
Sub-base																				
Ditch left																				
Ditch right																				

**Swedish Cellulosa AB, SCA**

Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	200	200	200	200
Sub-base																				
Ditch left																				
Ditch right																				

**Svea Forest (Sveaskog)**

Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				

**Roadscanners**

Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100	100	100	100	100	100	200	200	200	200	200	100	100	100	200	250	250	250	250	250
Sub-base																				
Ditch left																				
Ditch right																				

# Comparison of design proposals 1 000-2 000 m

Dimensioning proposals for Timber road, length 5 km, width 4,5 m; layer thickness in millimeters

COMPANY 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000

**Swedish Forest Agency**

Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	250	250	250	100	100	100	100	100	100	100	100	100	100	100	100	250
Sub-base																				
Ditch left																				
Ditch right																				

**Swedish Cellulosa AB, SCA**

Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	200	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				

**Svea Forest (Sveaskog)**

Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				

**Roadscanners**

Wearing course	150	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	250				200	200	200	200	200	100								100	100	100
Sub-base																				
Steel reinforcement							10	10												
Ditch left																				
Ditch right																				

# Comparison of design proposals 2 000-3 000 m

Dimensioning proposals for Timber road, length 5 km, width 4,5 m; layer thickness in millimeters

COMPANY	Road sections																			
	2050	2100	2150	2200	2250	2300	2350	2400	2450	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000
<b>Swedish Forest Agency</b>																				
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	250	250	100	100	100	100	100	100	100	100	100	100	250	250	250	250	250	250	100	100
Sub-base																				
Ditch left																				
Ditch right																				
<b>Swedish Cellulosa AB, SCA</b>																				
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Base course	100	100	100	200	200	100	100	100	100	100	100	100	100	100	200	200	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				
<b>Svea Forest (Sveaskog)</b>																				
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				
<b>Roadscanners</b>																				
Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100							100				100	100	100	200	200	200	200		
Sub-base																				
Ditch left																				
Ditch right																				

# Comparison of design proposals 3 000-4 000 m

Dimensioning proposals for Timber road, length 5 km, width 4,5 m; layer thickness in millimeters

	Road sections																			
COMPANY	3050	3100	3150	3200	3250	3300	3350	3400	3450	3500	3550	3600	3650	3700	3750	3800	3850	3900	3950	4000
<b>Swedish Forest Agency</b>																				
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	250	250	100	100	100	250	250	100	100	100	100	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				
<b>Swedish Cellulosa AB, SCA</b>																				
Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Base course	100	100	100	100	100	100	100	200	200	200	200	200	200	200	200	200	200	200	200	200
Sub-base																				
Ditch left																				
Ditch right																				
<b>Svea Forest (Sveaskog)</b>																				
Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				
<b>Roadscanners</b>																				
Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base						100				100	100	200	100	200	100	200	200	200	100	100
Sub-base																				
Ditch left																				
Ditch right																				

# Comparison of design proposals 4 000-5 000 m

Dimensioning proposals for Timber road, length 5 km, width 4,5 m; layer thickness in millimeters

Road sections

**COMPANY** 4050 4100 4150 4200 4250 4300 4350 4400 4450 4500 4550 4600 4650 4700 4750 4800 4850 4900 4950 5000

**Swedish Forest Agency**

Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Road base	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sub-base																				
Ditch left																				
Ditch right																				

**Swedisc Cellulosa AB, SCA**

Wearing course	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Base course	200	200	200	200	200	200	200	100	100	100	100	100	100	100	100	100	200	200	200	200
Sub-base																				
Ditch left																				
Ditch right																				

**Svea Forest (Sveaskog)**

Wearing course	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Road base	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sub-base	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Ditch left																				
Ditch right																				

**Roadscanners**

Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100	100	100			200	100	100			200	200								
Sub-base																				
Ditch left																				
Ditch right																				

# Comparison of design proposals

## Use of aggregate

Company	Wearing course	Road base	Sub-base	Sum aggregate	Ditching
	M3	M3	M3	M3	M
Swedish Forest Agency	1750	3363	0	5113	0
SCA Forest AB	1750	3338	0	5088	60
Sveaskog	1500	1500	3750	6750	0
Roadscanners	1250	2276	0	3526	10000

# Comparison of design proposals

## Environmental aspects, emission of CO<sub>2</sub>

- Skogsstyrelsen, 5113 m<sup>3</sup>, => 28 480 kg CO<sub>2</sub>
- SCA Skog AB, 5088 m<sup>3</sup>, => 29 360 kg CO<sub>2</sub>
- Sveaskog AB, 6750 m<sup>3</sup>, => 37 600 kg CO<sub>2</sub>
- Roadscanners, 3526 m<sup>3</sup>, => 19 640 kg CO<sub>2</sub>.

# Comparison of design proposals

## Cost comparison

Company	Skogsstyrelsen	SCA	Sveaskog	Roadscanners
<b>Aggregate complete on the road 10 €M3</b>	51 130	50 880	67 500	35 260
<b>Steel net reinforcement 4 €M2</b>	-	-	-	1 840
<b>Grading?</b>	?	?	?	?
<b>Ditching?</b>	?	?	?	?
<b>Field survey, analyses &amp; design</b>	500	250	250	8 500
<b>Environmental costs, 0,15 €/kg</b>	4 272	4 404	5 640	2 946
<b>Total costs</b>	55 902	55 534	73 390	48 546
<b>Costs, €M forest road</b>	11,18	11,06	14,63	9,71
	115 %	114 %	151 %	100%

# Decision from the client about the design proposals

- It was decided to use the Roadex proposal for the rehabilitation

# Construction

- In August 2011 the rehabilitation was done using the Roadex proposal
- Post signs showed the design thicknesses



# Construction

- Aggregate was a rock aggregate crushed locally and delivered by trucks



# Construction

- The road was shaped with a grader and then the new aggregate was levelled with a grader



# Construction

- Per was successful to convince the forest company to use a roller



# Aggregate consumption

- A little less than planned

Aggregate type	Planned M <sup>3</sup>	Consumed M <sup>3</sup>	Difference
Base course	2276	2286	+ 10
Wearing course	1250	1176	- 74
Total	3526	3462	- 64

# Economy

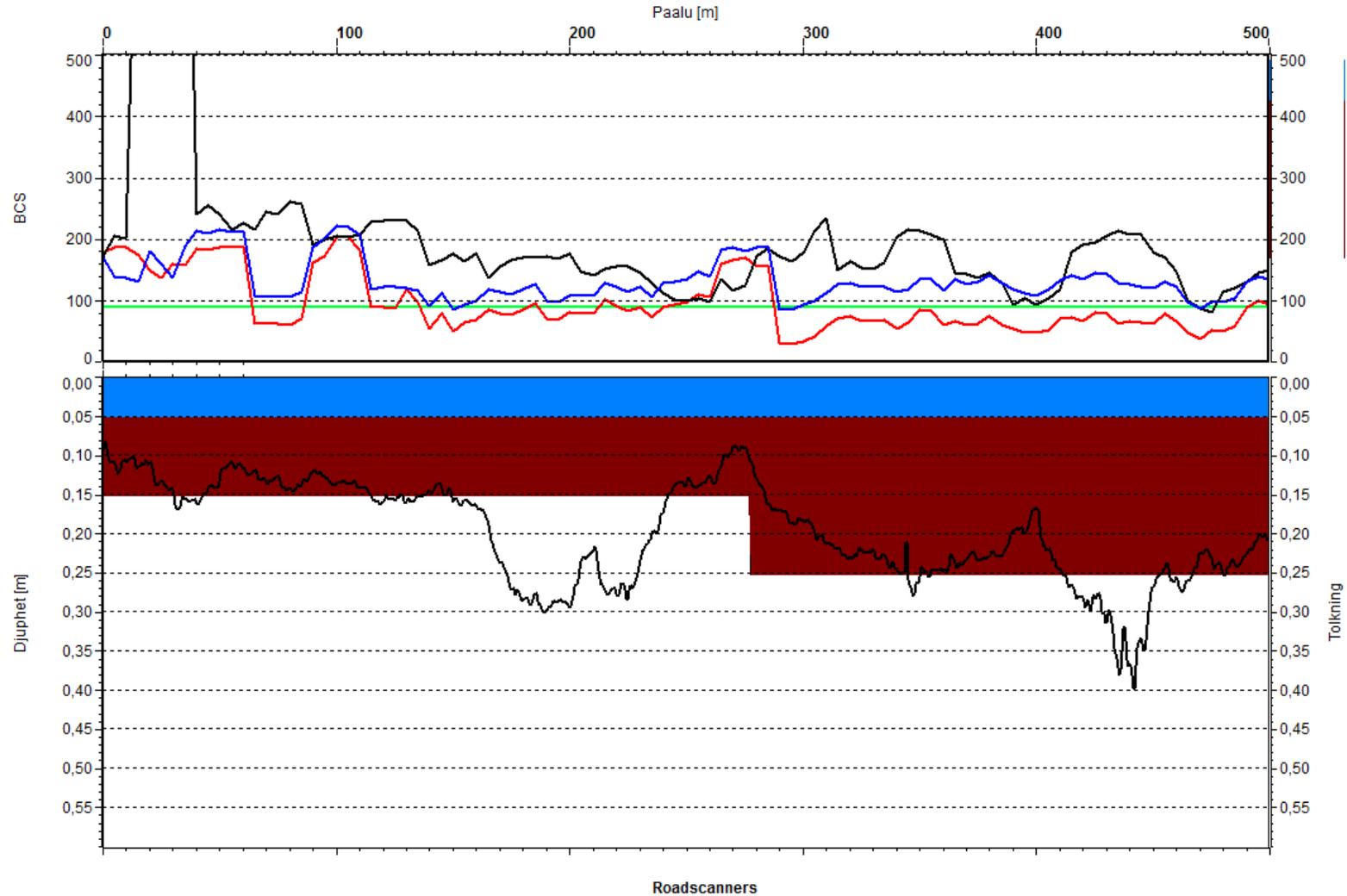
- The final cost for the rehabilitation made according to Roadex
  - about 535 000 SEK, about 60 000 € =
    - Including exchange of 5 culverts = 100 000 SEK
    - No ditch cleaning was performed
    - No steel net was used
    - Compaction with roller 600 € (0,12 €/m)
  - Means ab 50 000 €/5 000 m = 10 € per m
    - A bit more expensive than estimated (9,71 €/m) as a crushed rock aggregate was used instead of a crushed moraine which also increased transportation costs

# Follow up

- Measurement was done with GPR to be sure the right measure was in the right place
- Measurement was done with FWD to measure estimated bearing capacity was achieved
- A calculation was done

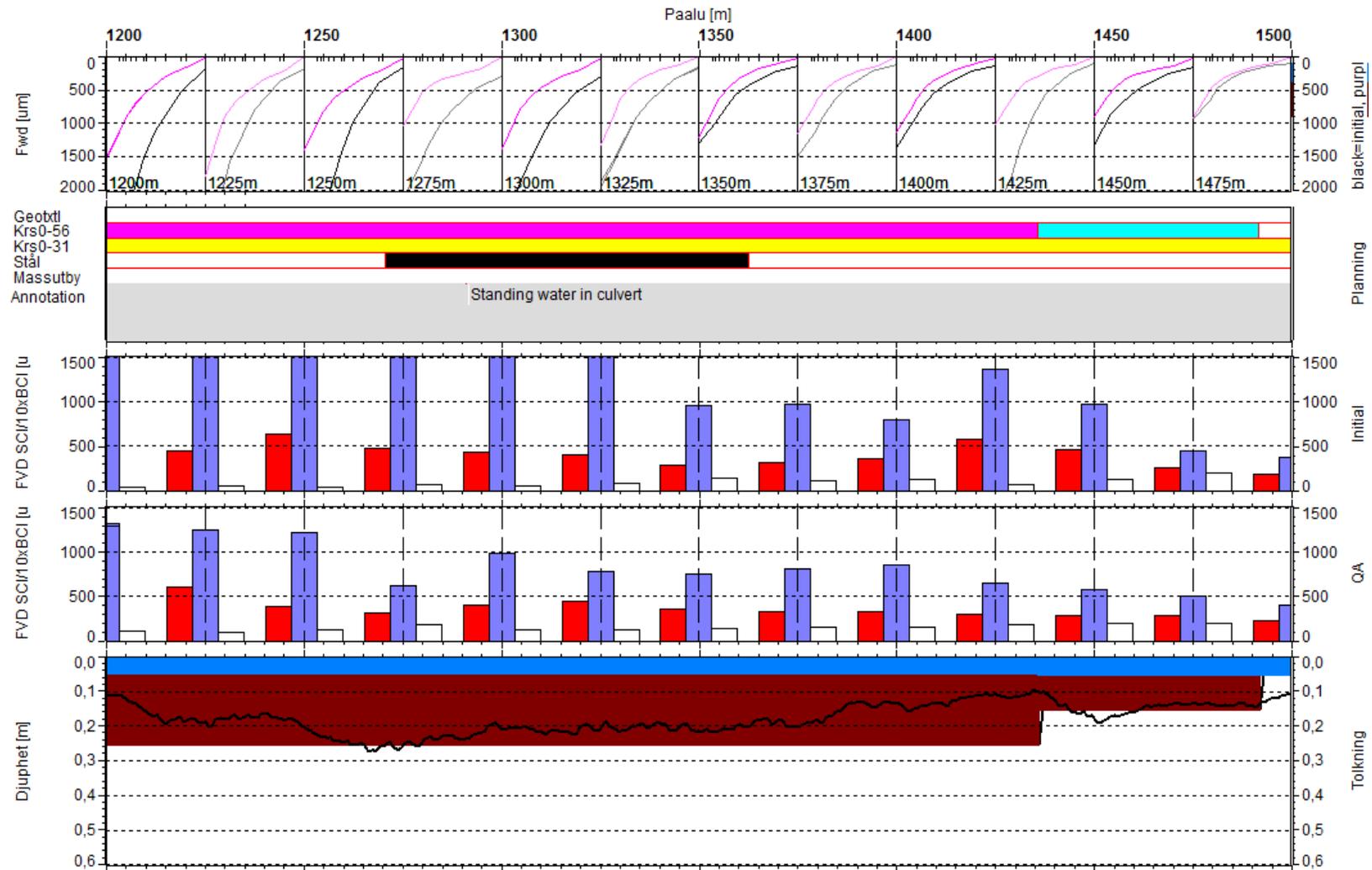
# Quality control

Timmerleden, bearing capacities comparison



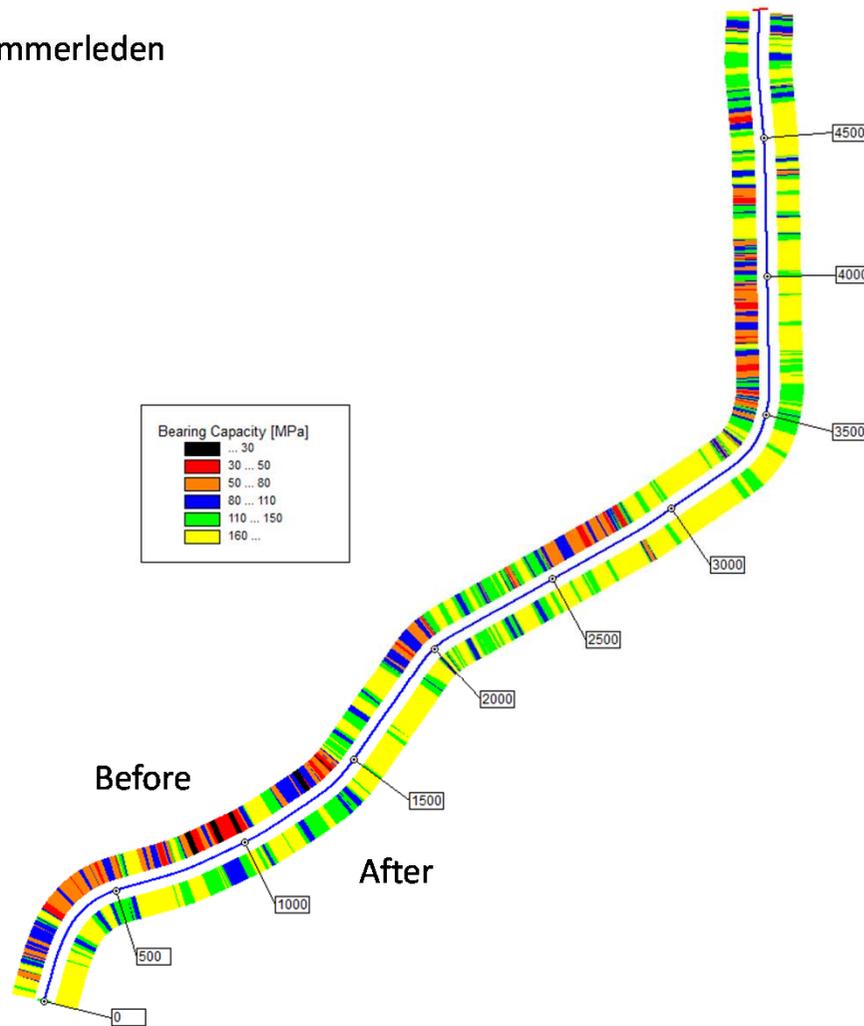
# Quality control

## Timmerleden



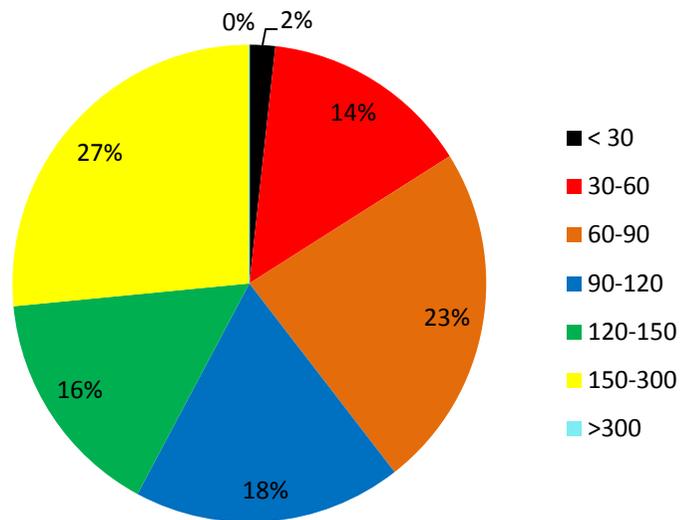
# Bearing capacity before and after rehabilitation

Timmerleden

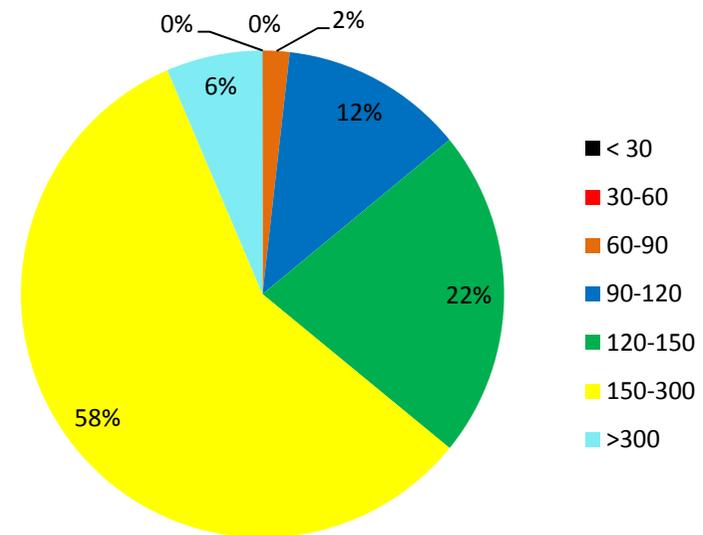


# Timmerleden

## Initial bearing capacity distribution (%)



## Bearing capacity distribution after construction (%)



# Road condition October 2011



# Road condition October 2011



# Performance and life length

- As the the strengthening design by ROADEX is based on objectively measured data and calculated with a well-known method to a reasonable target strain level it can be regarded as an optimized design.
- The early deterioration places should then arise where the partners design is thinner than Roadscanners

# Conclusions

- By using careful field surveys and analytical design based on the survey results the total costs can be reduced with 15-50 %.
- In bigger projects or a couple of smaller project in the same area the survey- and design costs will be reduced and the savings will increase
- It also saves natural resources and emission of CO<sub>2</sub>

# Conclusions

- Analytical design based on surveyed road condition data can provide many advantages:
  - Decisions on design thicknesses can be objectively based on measured data
  - Over dimensioning can be avoided
  - Previous years of experience in the method is not required
  - The finished rehabilitation can be checked objectively
  - Comparisons can be made between projects and choice of measures

# Lessons learned

- A careful road condition survey and rehabilitation design will always give a cheaper and safer rehabilitated road

*Thanks for your attention!*



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