



ROADEX

Implementing Accessibility



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European Union
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ROADEX
Implementing Accessibility

Roadex Demonstration Project

Svante Johansson, Roadscanners

Seminar in Luleå

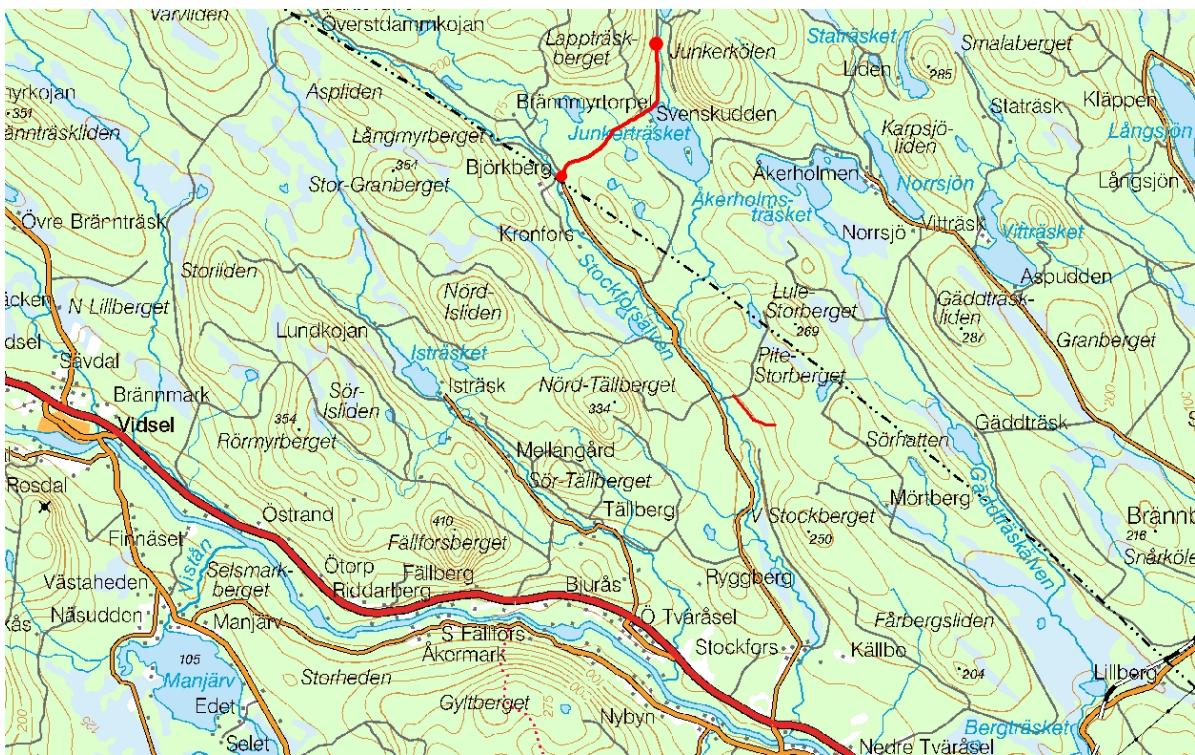
13th of Januari 2011



Rehabilitation of forest roads – proposal for dimensioning method

The Swedish demo-project: Rehabilitation of a forest road

- The Timber Road
- Close to Boden in the north of Sweden



The Timber Road

- Length about 5 km, width 4,5 m finished road
- Traffic ADT about 25 heavy vehicles
- Some personal cars a day
- Open for traffic around the year



Condition July 2010



Condition July 2010



Condition July 2010



The Timber Road

- Design proposals created by
 - Swedish Forest Agency (Skogsstyrelsen)
 - Svea Forest (Sveaskog)
 - SCA Forest AB (SCA Skog AB)
 - Roadscanners

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
 - Road damages
 - Culverts
 - Ditches
- Bearing capacity measurements with falling weight deflectometer
- Sampling (thickness and grading)

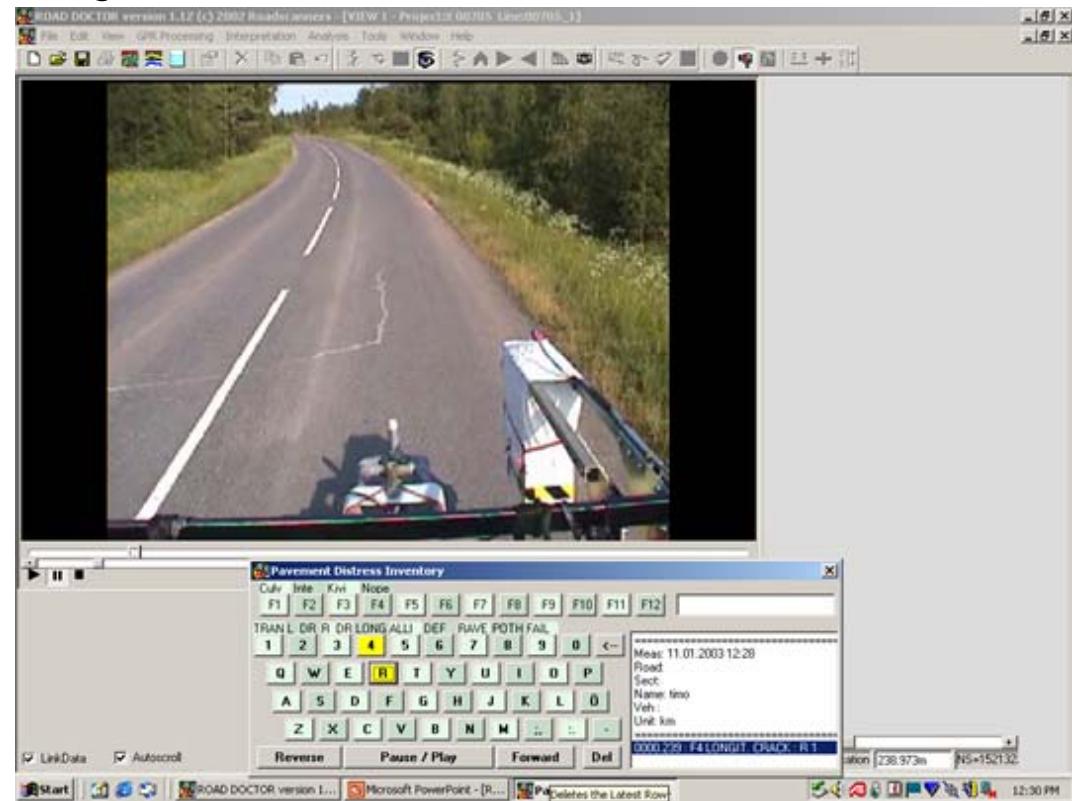
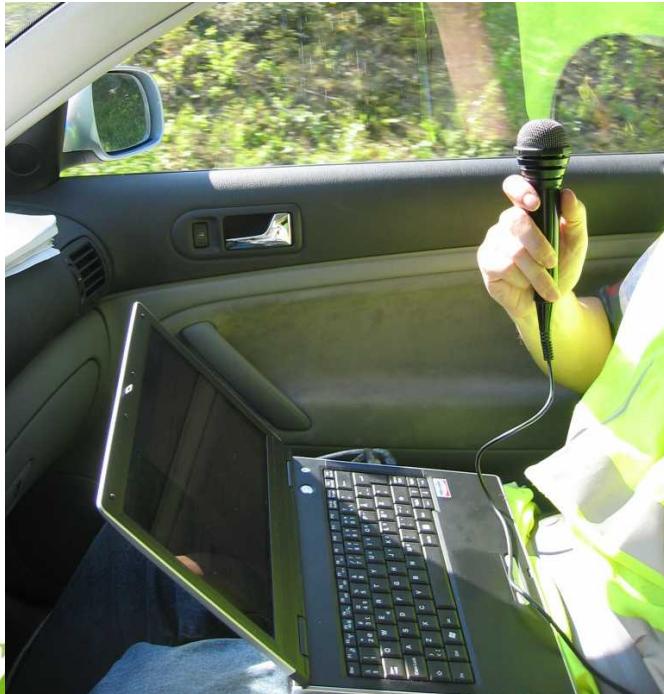
Measurements with GPR

- Measurement with
 - Ground coupled antenna 200-500 MHz
 - Air coupled antenna 900-2500 MHz
 - 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



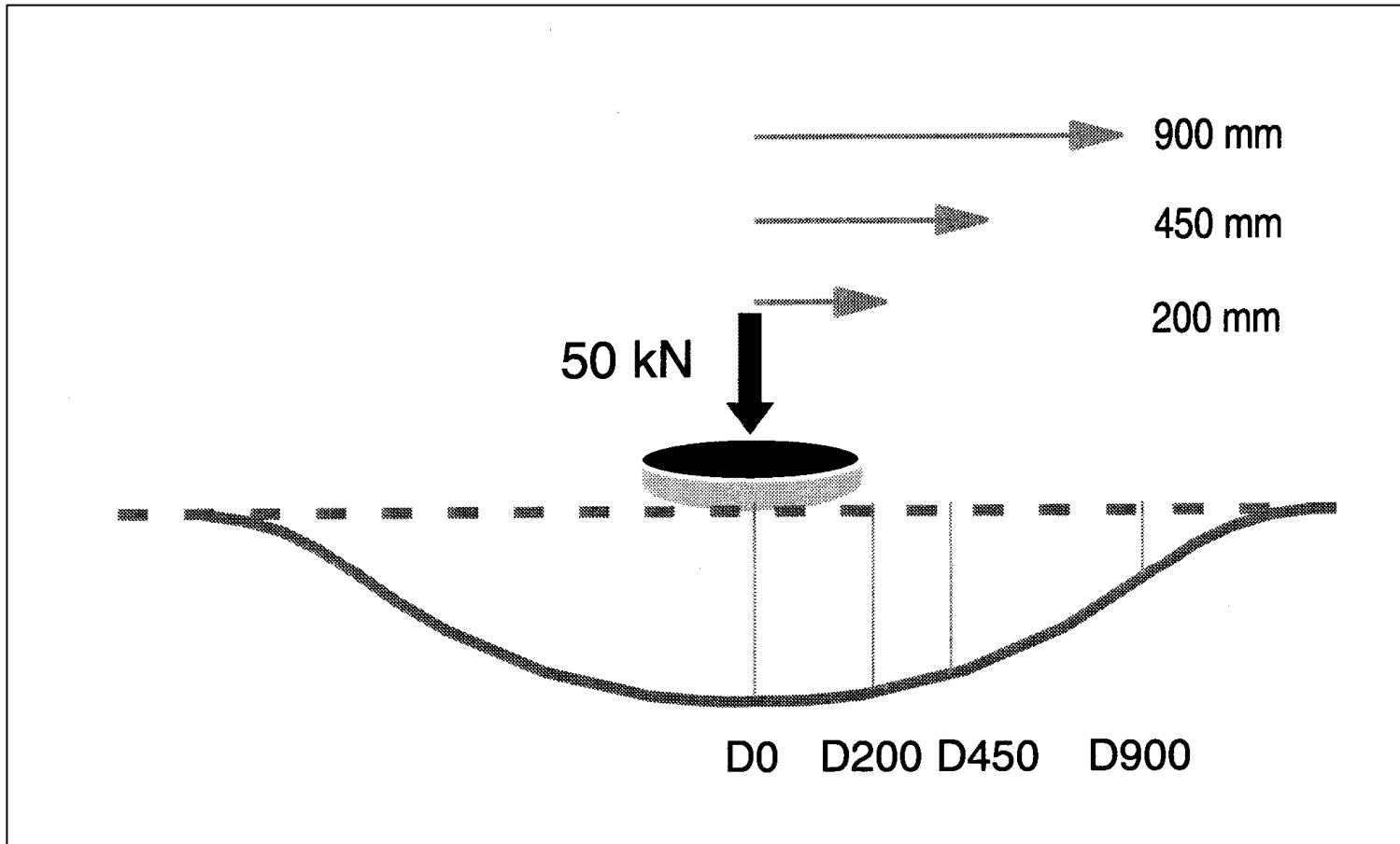
Bearing capacity from Falling Weight (FWD) measurements

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



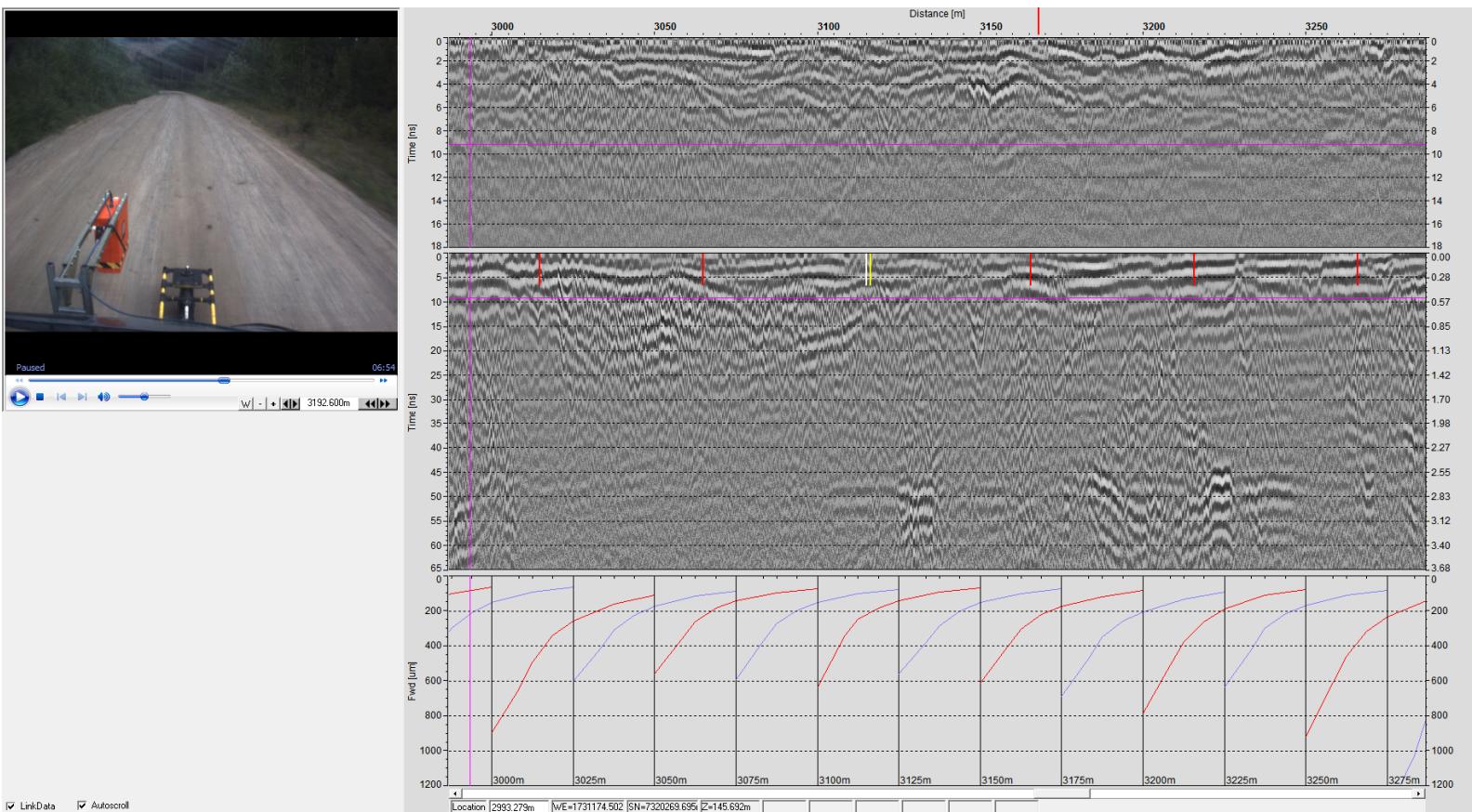
Deflection basin from FWD-measurements

- Measurement principle



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



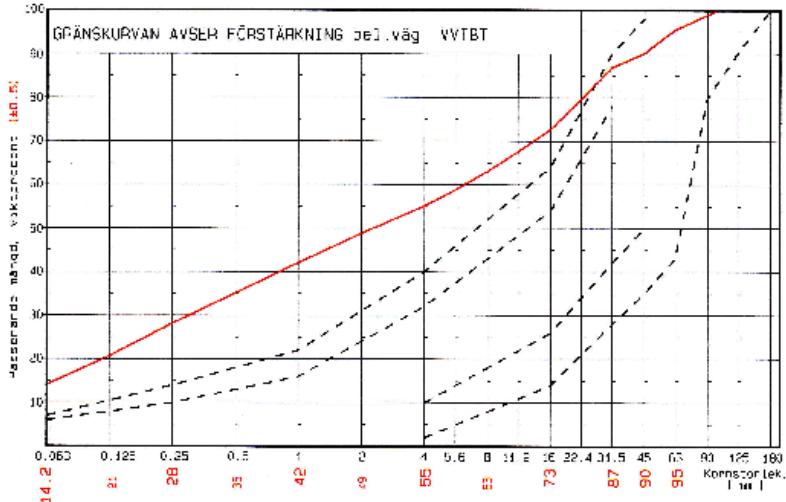
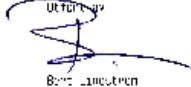
Results from sampling on the Timber Road

- Layer thickness, accumulated
 - 1/020 wearing course and base course = 0-5 cm
 subbase = 5-57 cm
 subgrade = 57- morain
 - 3/650 wearing course and base course = 0-5 cm
 subbase = 5-27 cm sand+crushed gravel
 subbase = 27-40 cm stony fine sand
 subgrade = 40- cm silty morain
 - 4/290 subbase = 0-23 crushed gravel
 subbase = 23-45 stony sand
 subbase = 45 cm - stony silty sand

Results from sampling

- Grading
 - subbase

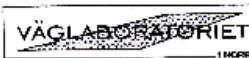
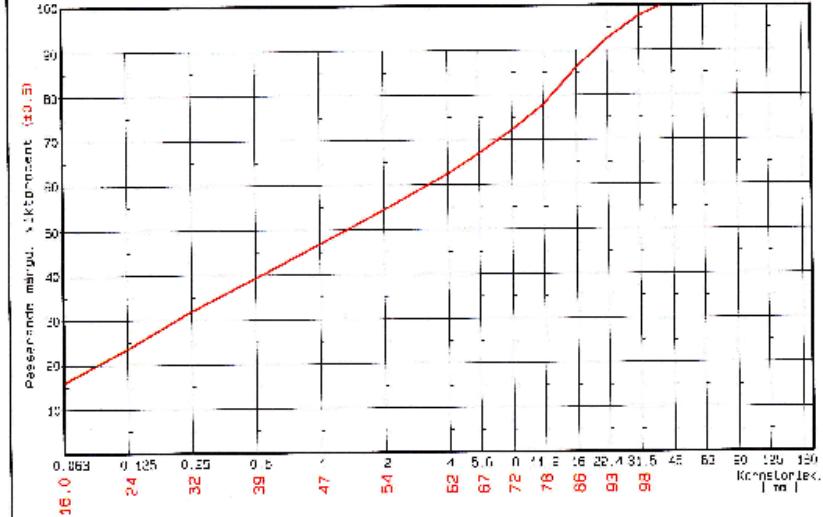
Sida 1 (1)

 VÄGLABORATORIET <small>I NORR</small> Postadress: AB Box 1992, 262 24 Ängelholm  1735 T8010X 7702	<p style="text-align: right;">RAPPORT</p> <p>Utlärd av tekniskt utvärderat provtagningslaboratorium TEST REPORT Issued by an Accredited Testing Laboratory</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%; padding: 5px;"> REGISTRERINGSNUMMER: 101 0908 B1 -10 OBJEKT: TIMMERLEDEN PROVTAGNINGSSPLATTE: 4/290 BESTÄLLARE: DMC PROJEKTERING KOMMENDÖRSGATAN 13 911 32 VÄNNÄS <small>ANGIVEN</small> MATERIALTYP: FÖRSL ENTAFERFÖR NÖ: STÖRSTA KÖRNSTDÖHLER: 100 mm FINMATERIALHALT 0.063-100: 14.2% <small>(Metac 88-EN 883-10 (Tillatt))</small> </td> <td style="width: 40%; padding: 5px; text-align: right;"> LINJOM: 10-07-13 Cirkeld: Färgad: 21.1 Kg PROVTAGNINGSDATUM: 10-07-07 MÄRKNING: HÖRNELL LEVERANTÖR: </td> </tr> </table>  <p style="text-align: center;">GRÄNSKURVAN AVSER FÖRSTRÄKNING del.väg VVTBT</p> <p style="text-align: center;">Stora röda siffror, markerar siktat med krav enl. VVTBT</p> <p style="text-align: center;">• Provtagningsresultatet visar endast svit väglabotoriet att acceptera provet. • Denne rapport lär endast återges i sitt nuvarande tillstånd och är ej skrivelserihet i Nörvég skriftilagrar godkänt annat. • Angiven körsökmätning är skötten körsökmätning från det last. Specifika körsökmätning för detta analys kan ej härställas.</p> <p style="text-align: right;">Vägslabotoriet i Norr Postfack 1992 Hödenbrevsgatan 6 E 262 26 Ängelholm Tel. 0421-18600 Fax. 0421-19005 Datum 2010-07-23</p> <p style="text-align: right;">Utturare  Björn Ljungström</p>	REGISTRERINGSNUMMER: 101 0908 B1 -10 OBJEKT: TIMMERLEDEN PROVTAGNINGSSPLATTE: 4/290 BESTÄLLARE: DMC PROJEKTERING KOMMENDÖRSGATAN 13 911 32 VÄNNÄS <small>ANGIVEN</small> MATERIALTYP: FÖRSL ENTAFERFÖR NÖ: STÖRSTA KÖRNSTDÖHLER: 100 mm FINMATERIALHALT 0.063-100: 14.2% <small>(Metac 88-EN 883-10 (Tillatt))</small>	LINJOM: 10-07-13 Cirkeld: Färgad: 21.1 Kg PROVTAGNINGSDATUM: 10-07-07 MÄRKNING: HÖRNELL LEVERANTÖR:
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Results from sampling

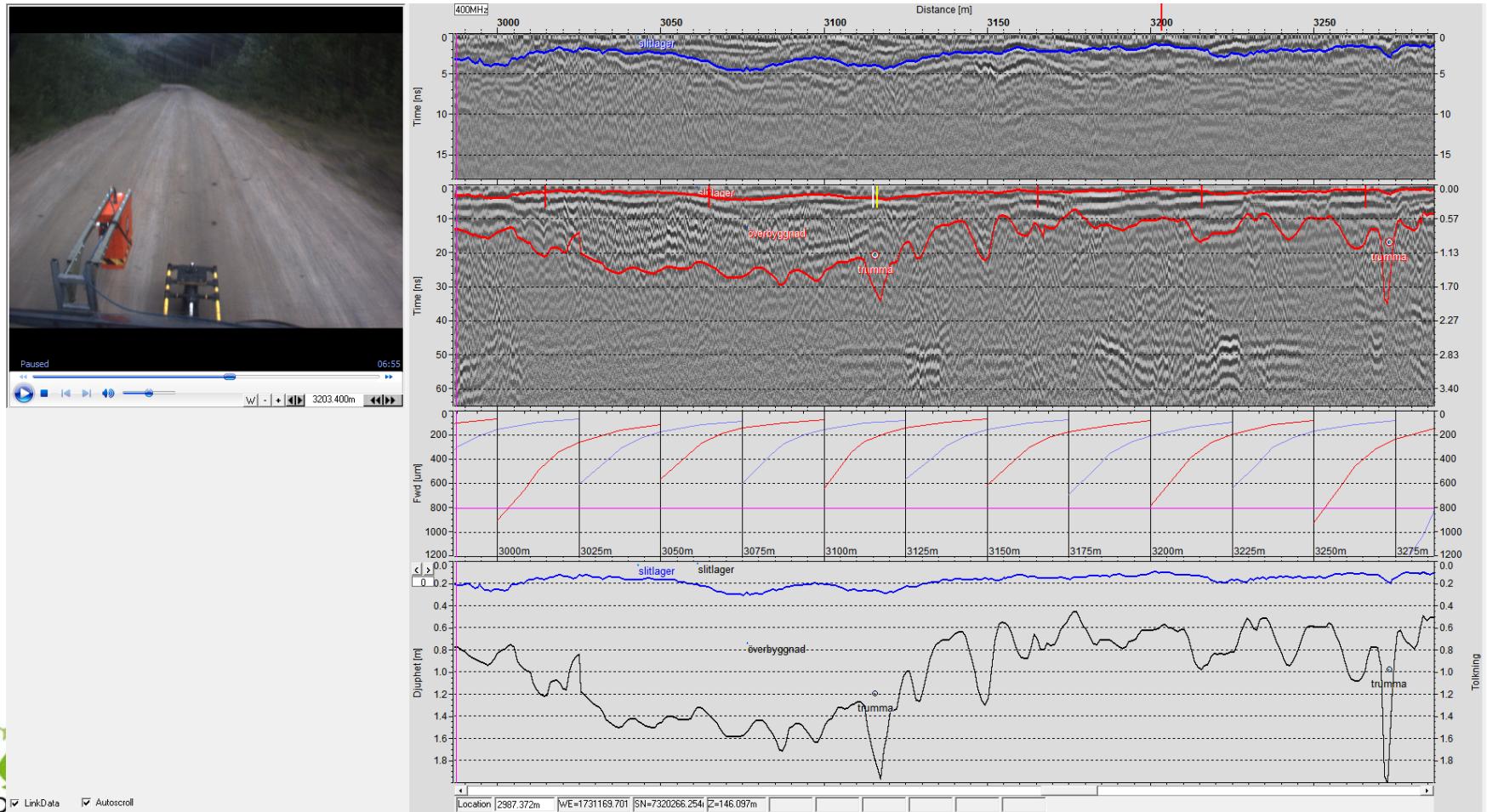
- Grading
 - Base course

Sida 1/1

 VÄGLABORATORIET INCPA Poco Asalt AB, Box 12B2, 262 24 Ängelholm Leverans 10/07/2013	 Leverans 10/07/2013	RAPPORT <small>utgiven av akkrediterat provningslaboratorium TANT REPORT issued by an Accredited Testing Laboratory</small>
		REGISTRERINGSNUMMER: 101 0904 B1 -10 INKOM: 10-07-13 OBJEKT: TIMMERLEDEN Siktat: 15.8 Kg PROVTAGNINGSPLATS: 3/650 BESTÄLLARE: DMC PROJEKTERING KOMMENDORGATAN 13 911 32 VÄNNÄS ANSEHEN: MATERIALTYP: SLITL+BÄRL MÄRKNING: HÖRNELL ENTREPRENÖR: LEVERANCIÖH: STÖRSTA KORNSTÖRLEK: 40 mm FINNMATERIALHALT 0,063-40: 16.0% <small>enligt SS-EN 933-10 (Vattad)</small>
 <p>The graph plots 'Procentvärde mar.yt.' (Percentage value) on the y-axis (0-100) against 'Kornstorlek [mm]' (Particle size [mm]) on the x-axis (0.063-120). A red curve represents the measured data, which follows a standard normal distribution curve.</p>		
<small>* Provresultatet visar att den endast till kravspecifikationen uppmättes pris. * Denne rapporten härmed ges å vissa delar en liten vägslaburk med fördig skriftbogen tillstånd annat. * Angiven effektkonstant är exaktad nedanför i de sista siffrorna från detta svaras tills på begäran.</small>		
Vägslaburket i Horn Post kod 410 00 Tel: 031-49600 Fax: 031-33650 E-post: post@vägslab.se  Jeri Frostrom		

Interpretation of layer thickness

- Checking against reference samples

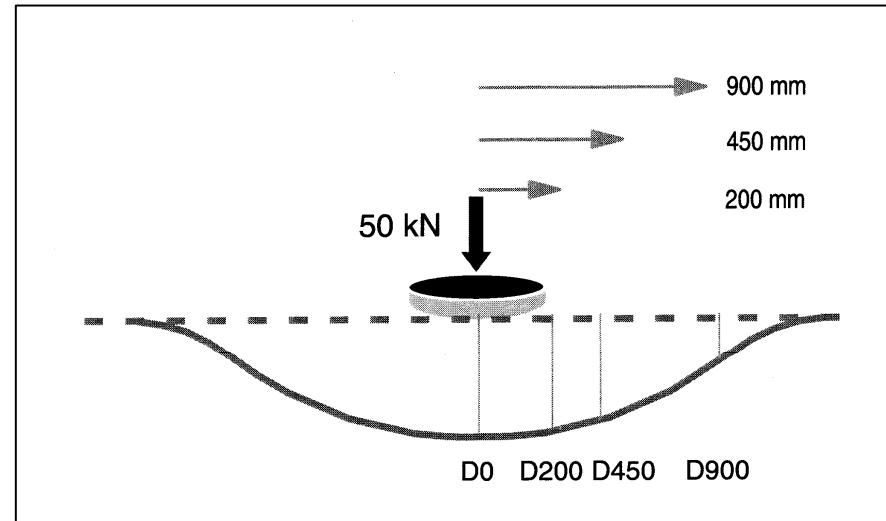


Analyses of data

- 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
 - Subgrade modules
 - From FWD-data, BCI and SCI
 - Grading

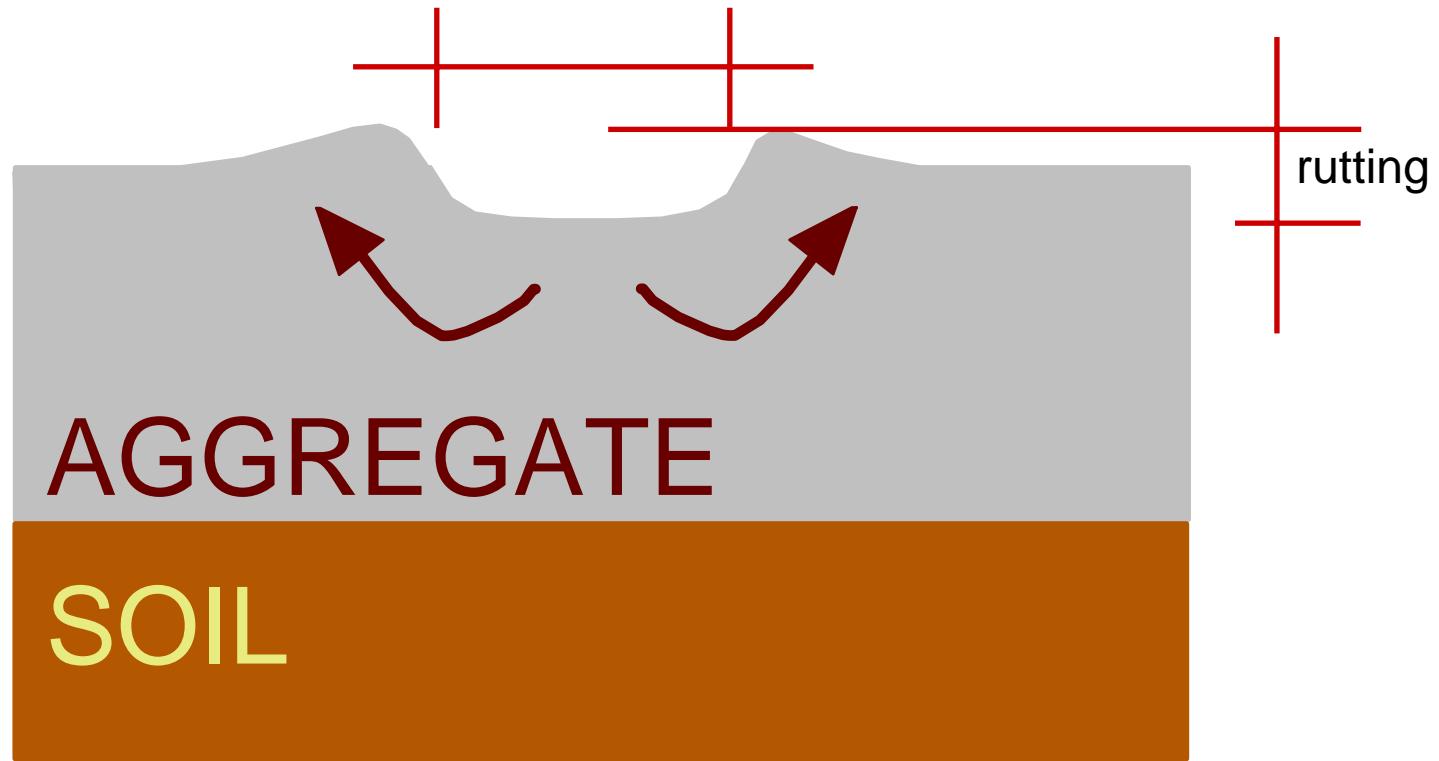
Calculated from the results of the FWD-measurement Klassification of the bearing capacity of gravel roads

- Analyses of unsatisfactory bearing capacity
 - SCI = Surface Curvature Index, a measure of the stiffness in the upper part of the road structure
 - SCI = $D_0 - D_{200}$
 - BCI = Base Curvature Index, a measure of the stiffness in the lower part of the road structure
 - BCI = $D_{900} - D_{1200}$



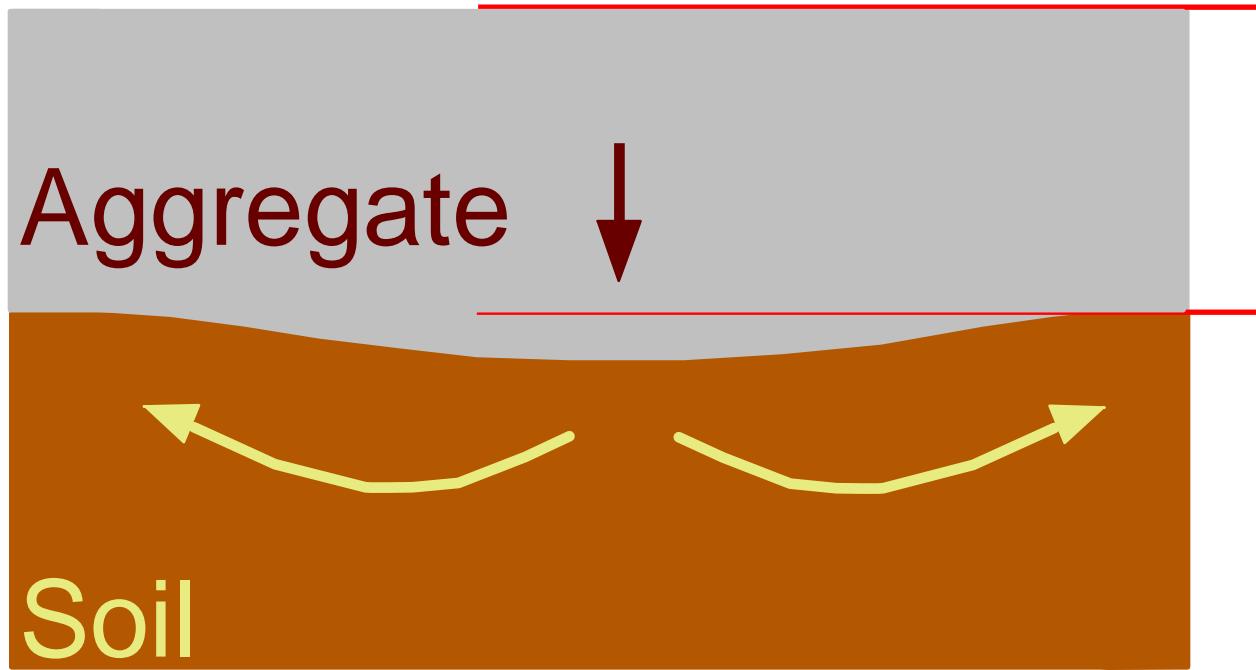


RUTTING MODE 1 – NEAR SURFACE SHEAR





RUTTING MODE 2 – DEEPER SHEAR

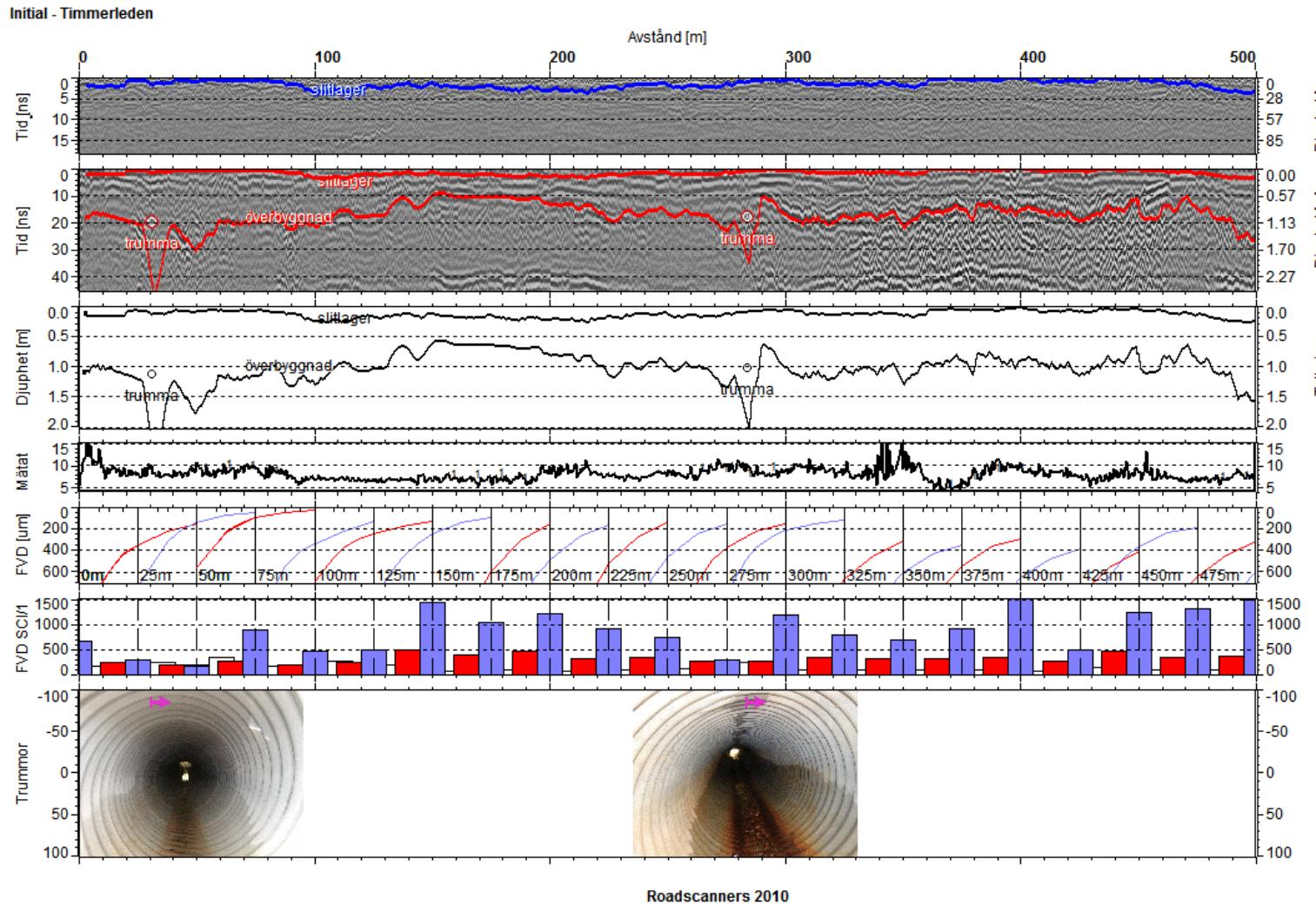




MODE 2 – DEEPER SHEAR

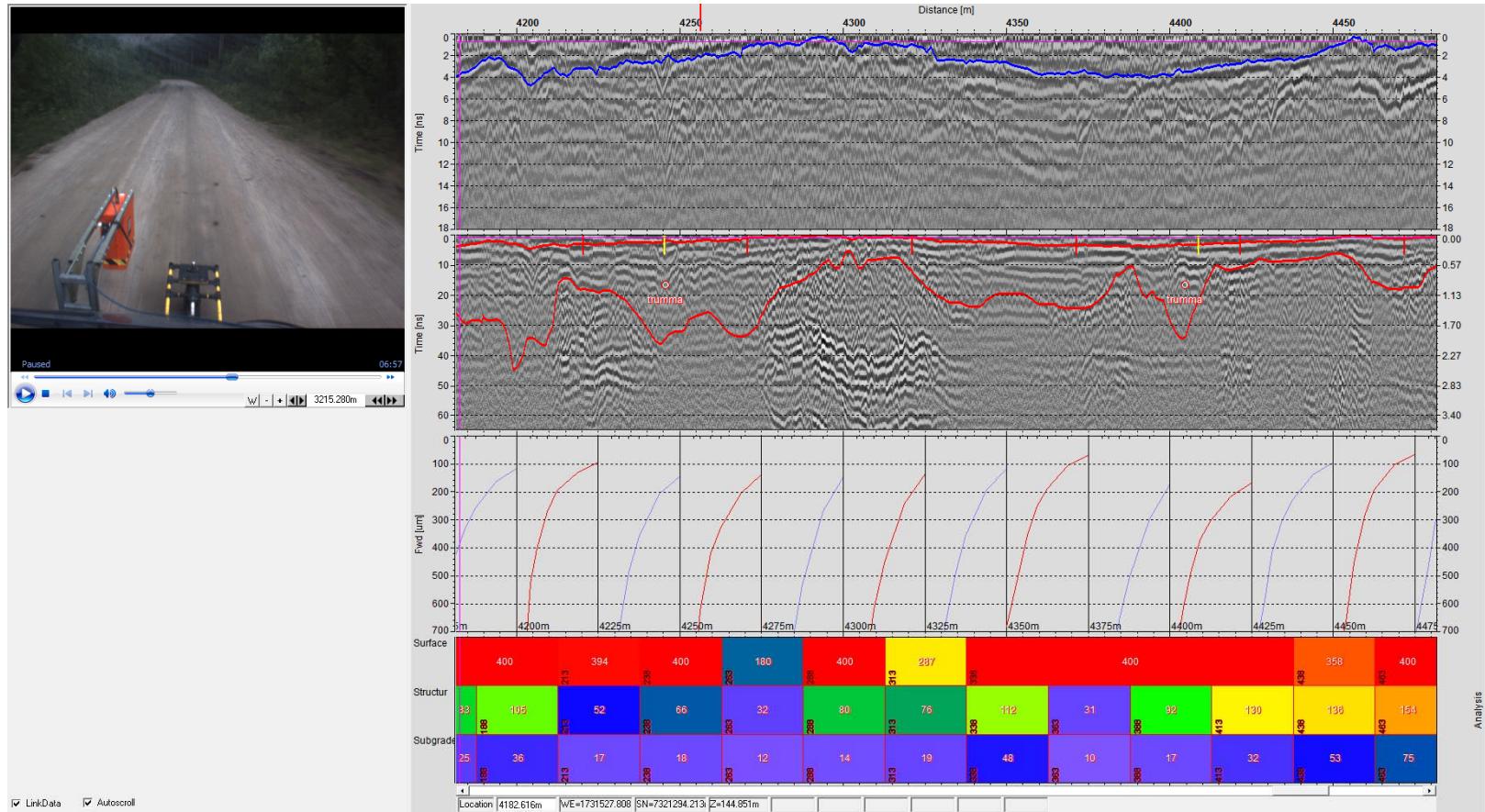


Data from field surveys in Road Doctor



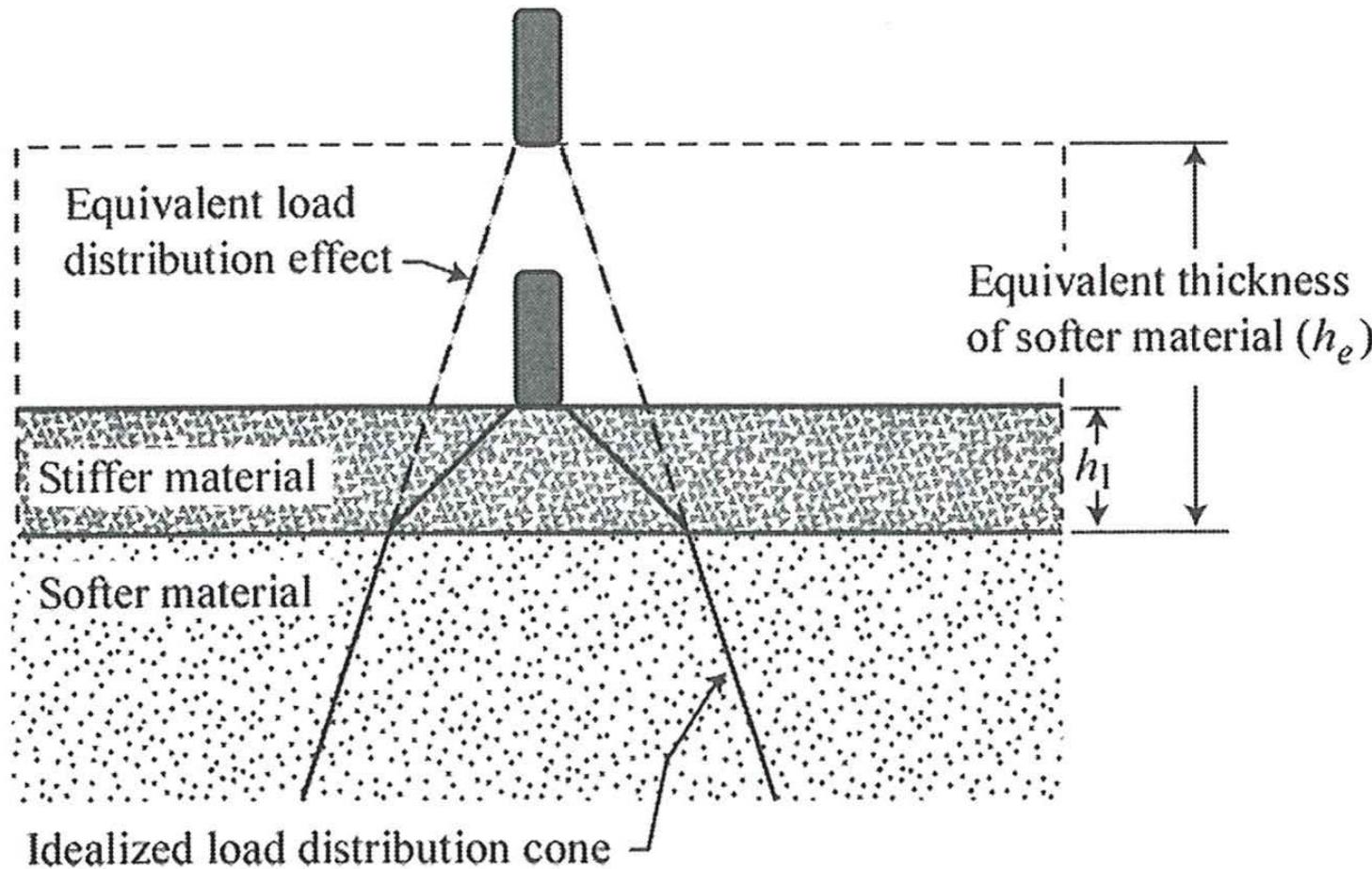
Stepg 3 - Module calculations for the road structure and the subgrade soil

- 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

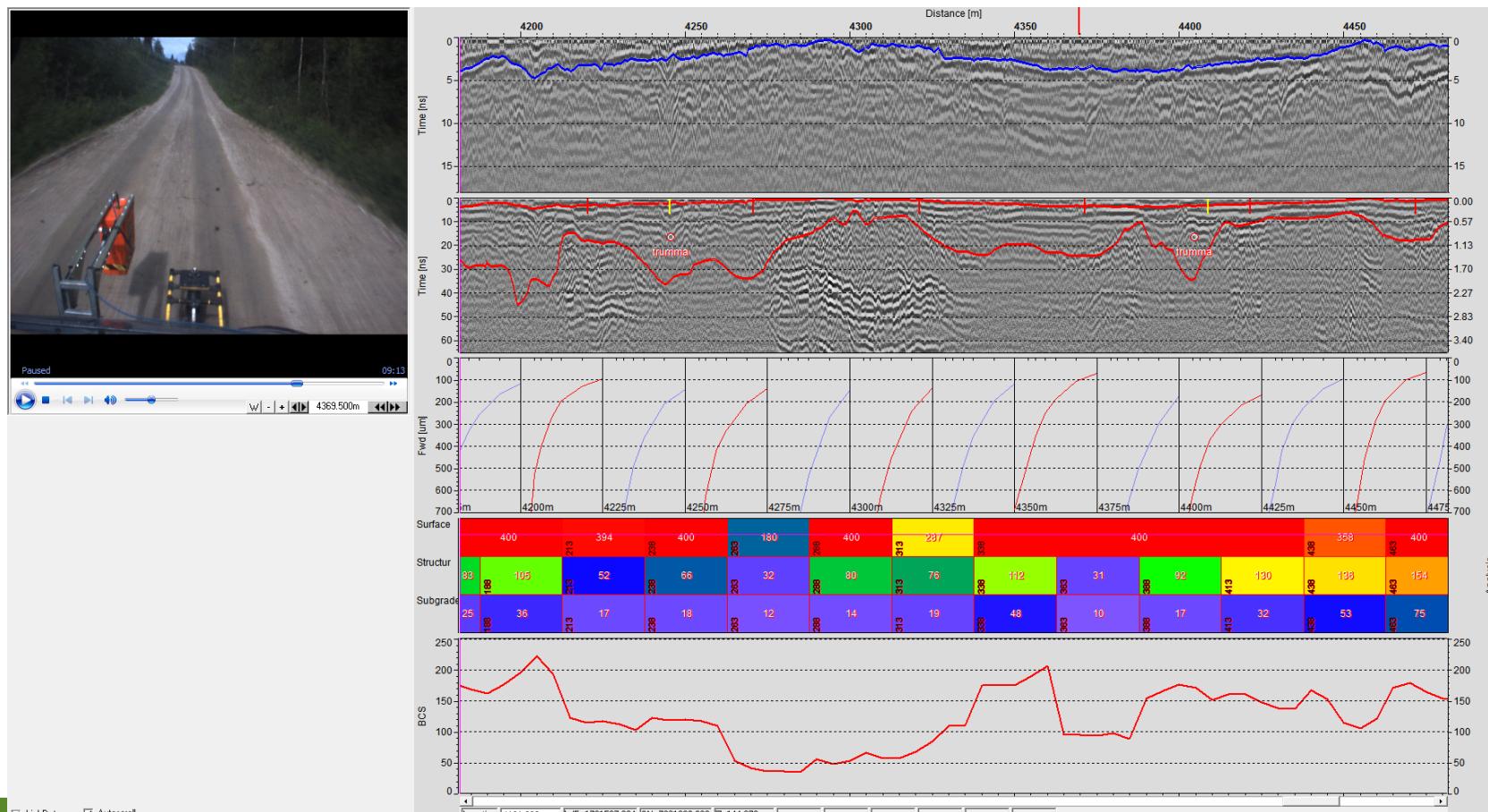
- Odemark's formula.

- 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

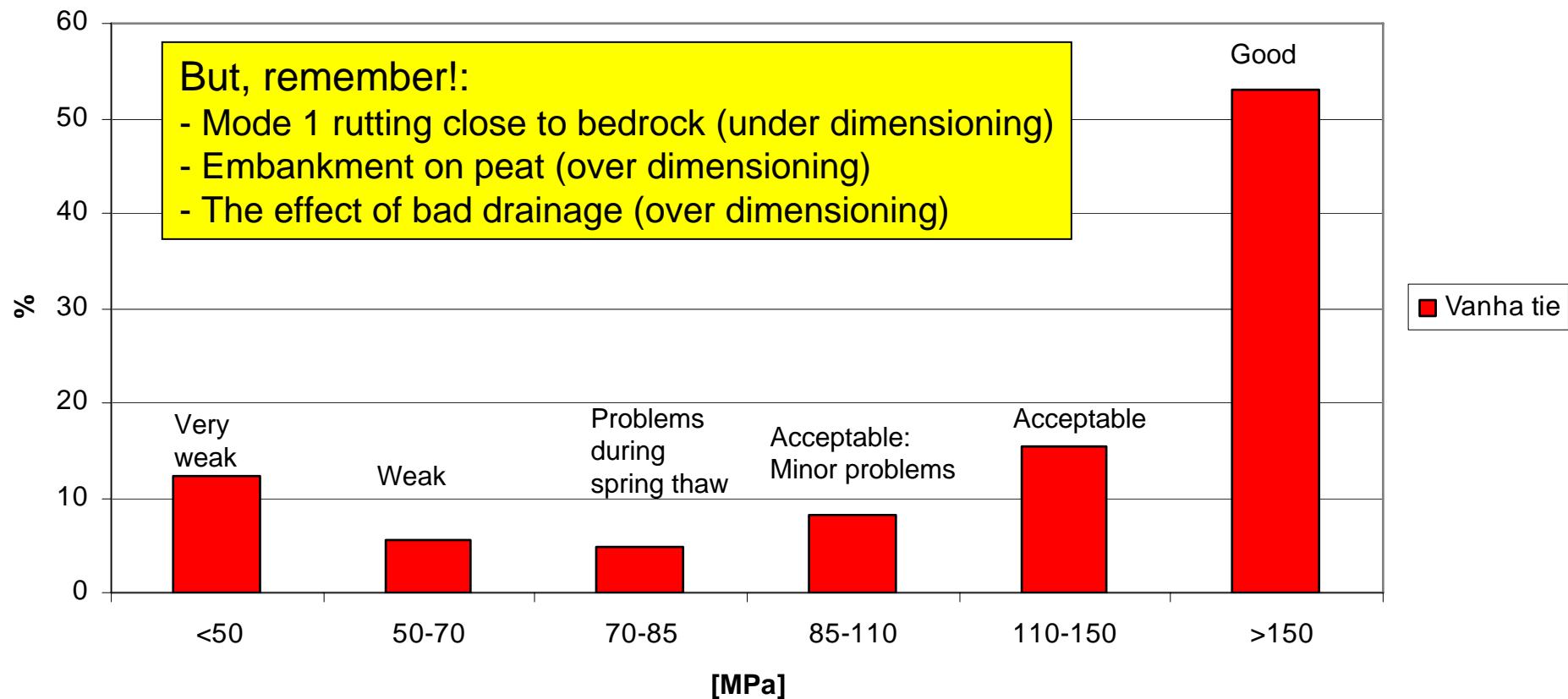
- Calculated initial bearing capacity according to Odemark
 - Using forward calculated modules from FWD-measurements
 - Using thickness interpreted from GPR-data



Design of new structure-

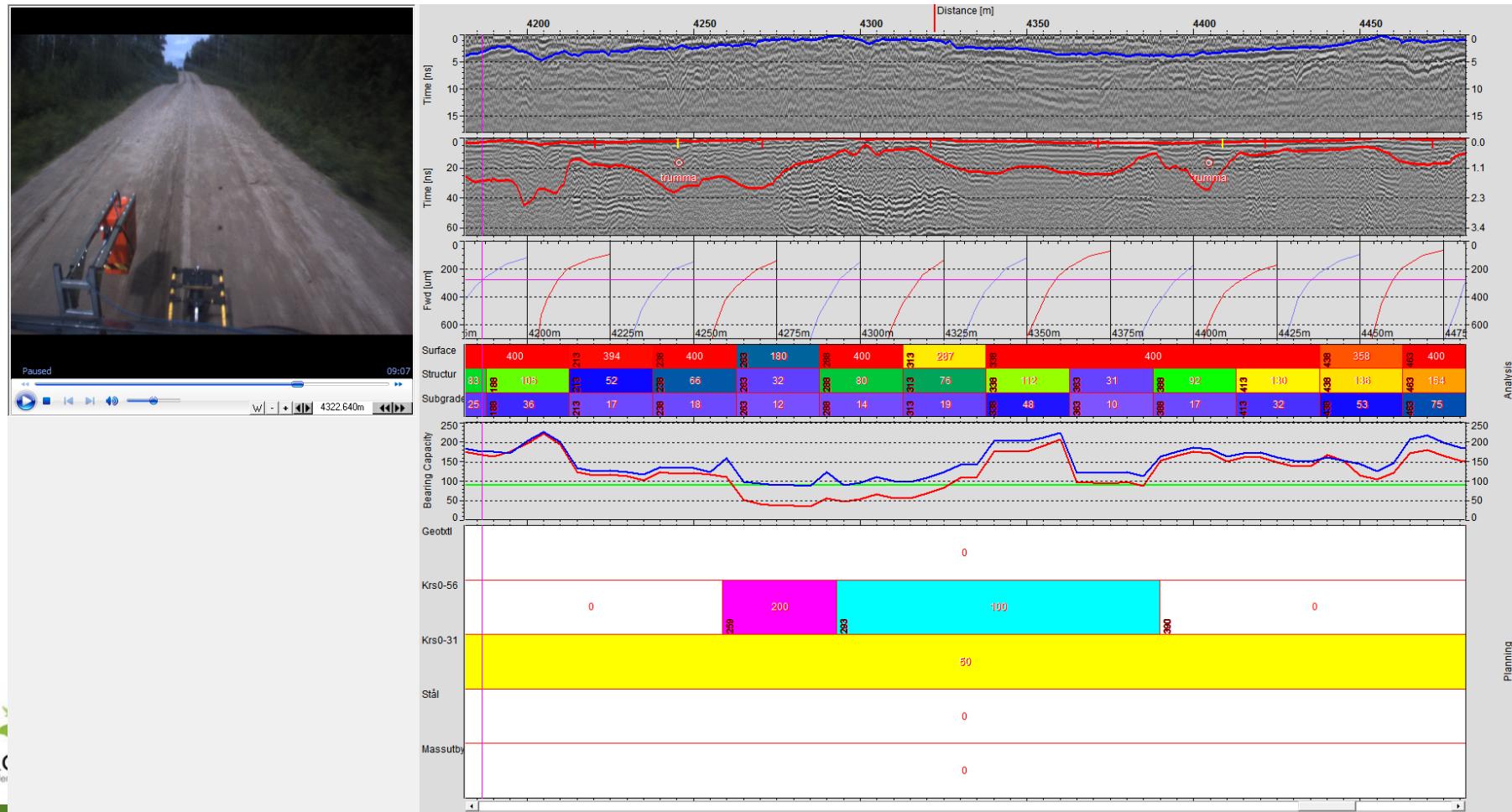
Setting up target bearing capacity according to Odemark, 90 MPa

Distribution of the bearing capacity of the Timber Road

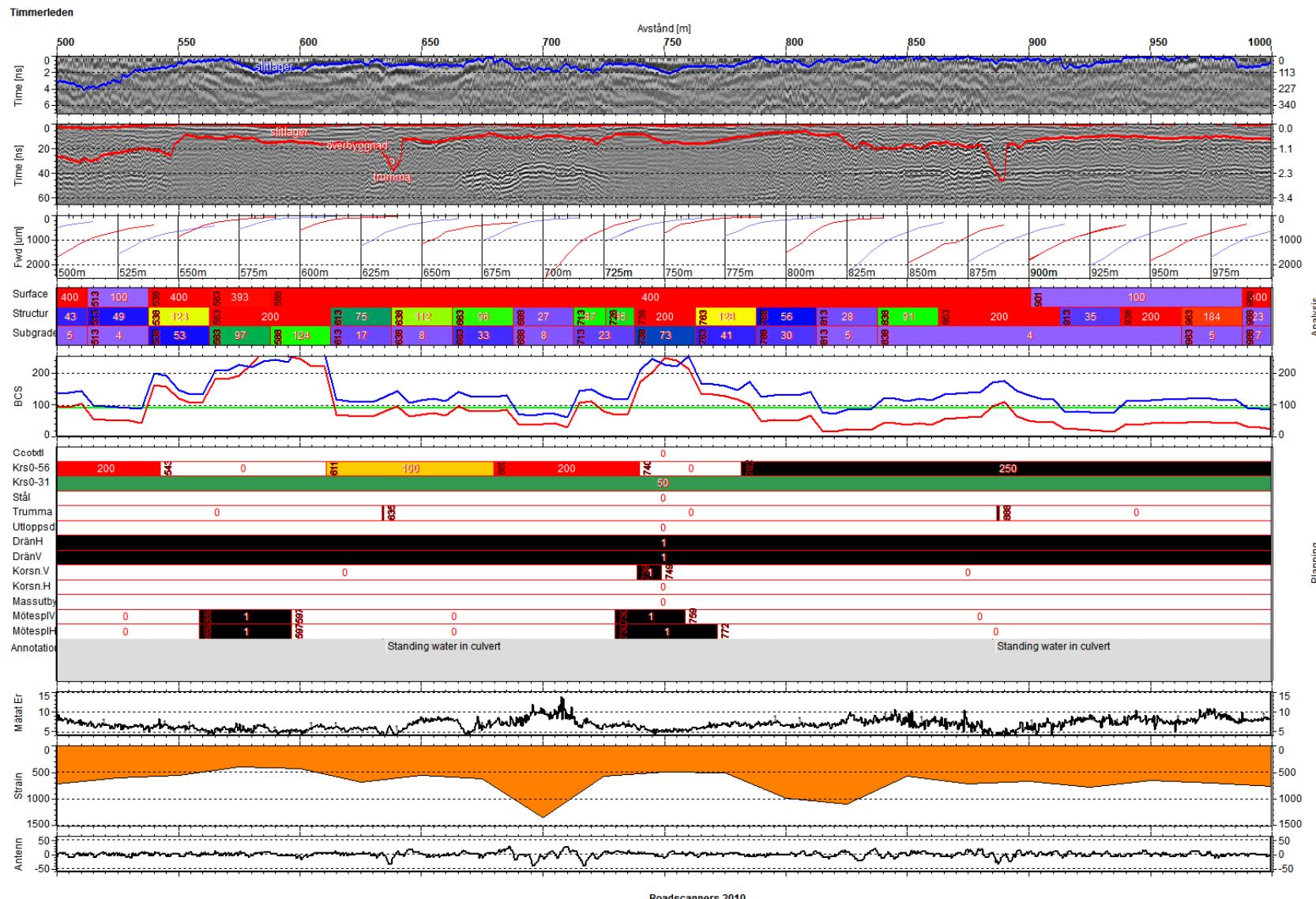


Step 5 - new design; target bearing capacity 90 MPa

- Target bearing capacity and new layers included



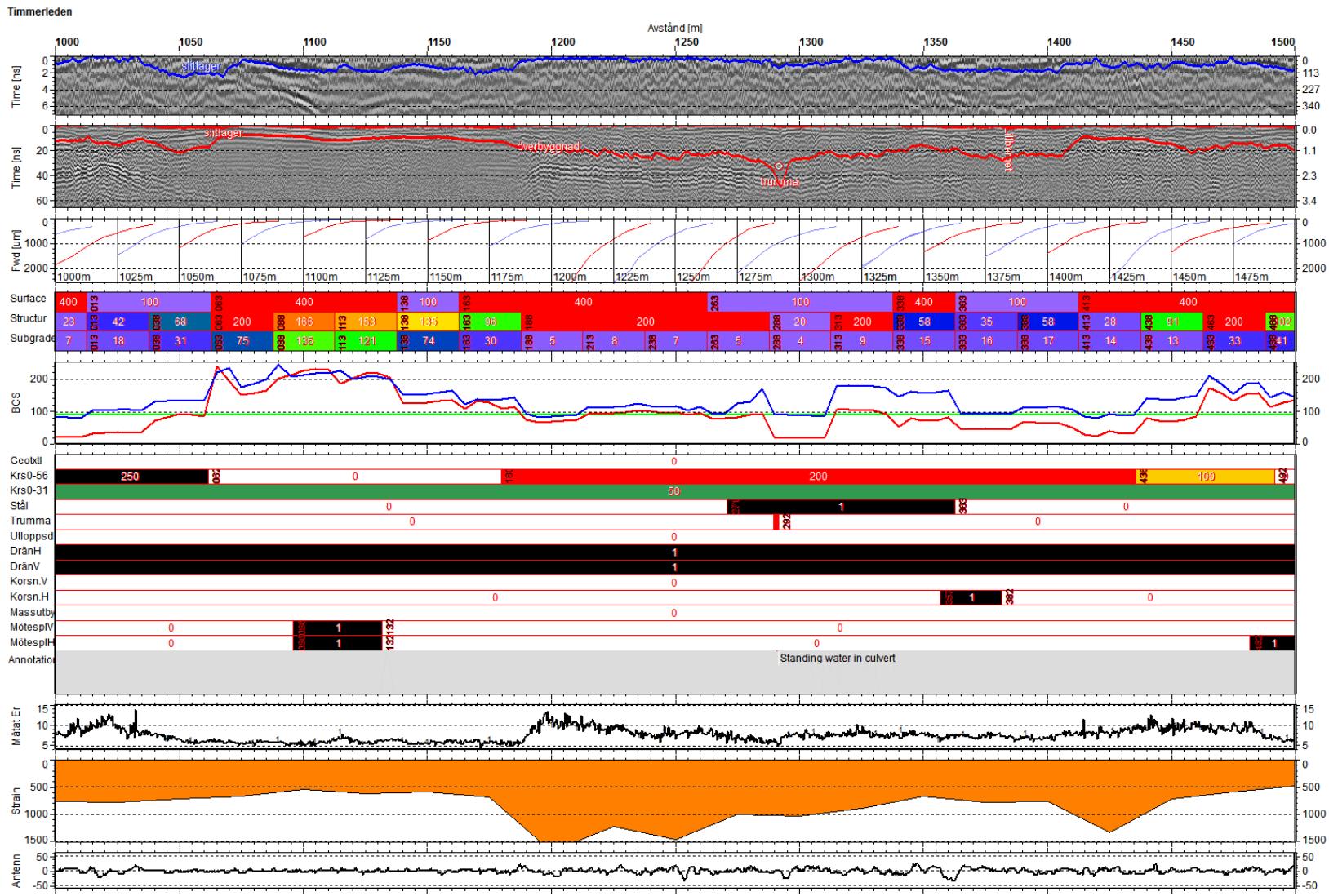
Roadscanners design proposal



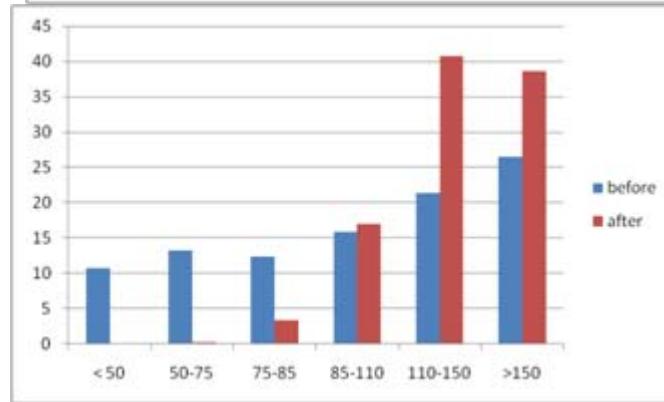
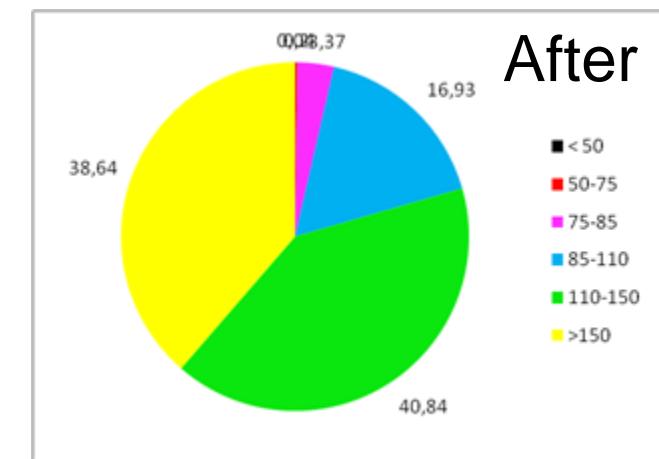
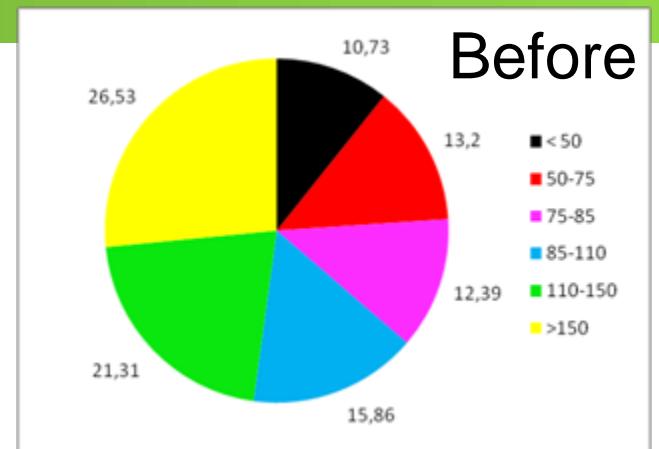
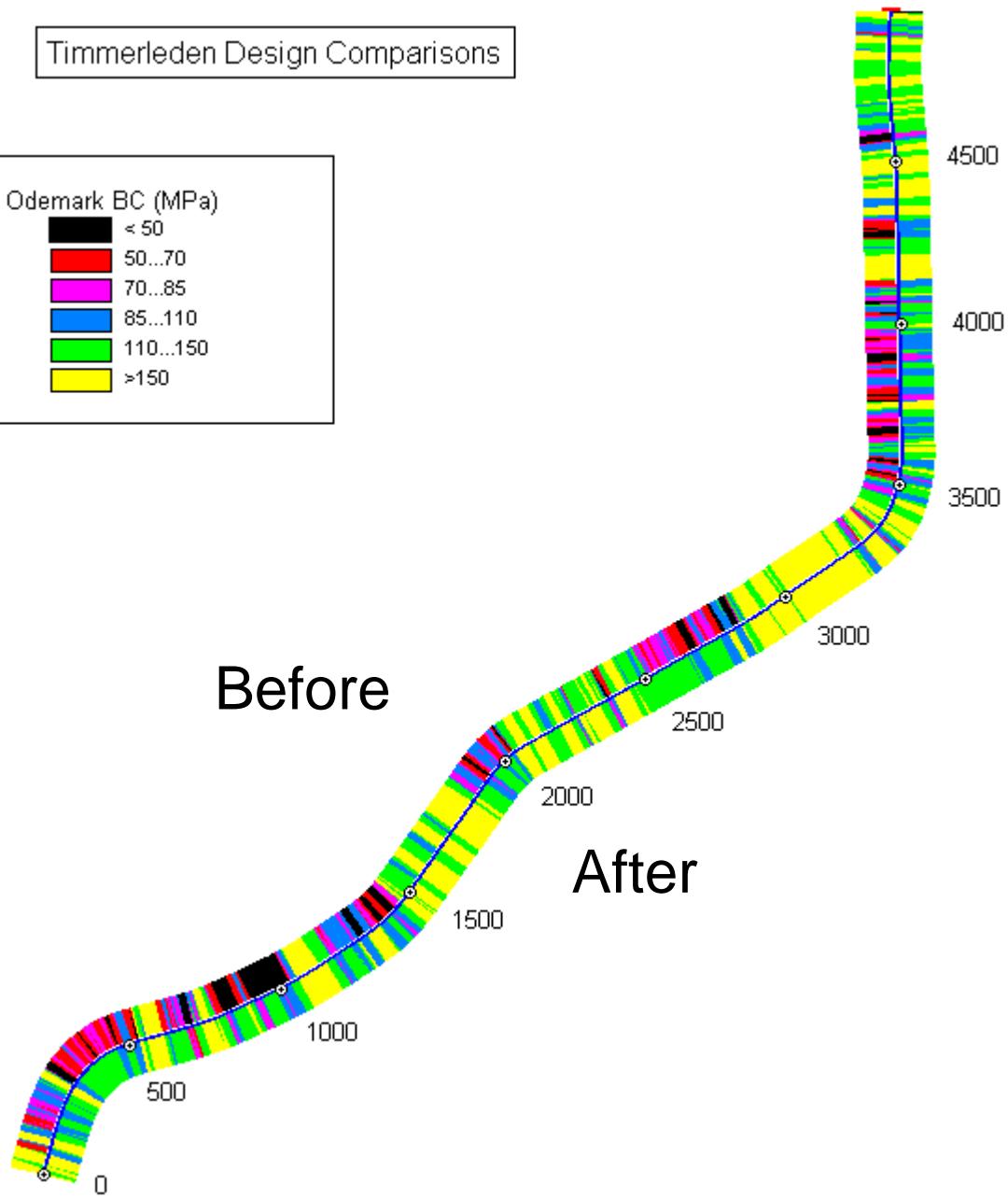
Step 6 - Check of the design proposal with additional data

- 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

Step 6 - Design check



Timmerleden Design Comparisons



Comparison of design proposals 0 - 1000 m

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

Road sections

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

Wearing course	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	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
Road base	200	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
Road base	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
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
Road base	250				200	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

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	250	250	100	100	100	100	100	100	100	100	100	100	100	250	250	250	250	250	100	100
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
Base course	100	100	100	200	200	100	100	100	100	100	100	100	100	200	200	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	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base	100																			
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
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Swedish Forest Agency

Wearing course	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
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
Base course	100	100	100	100	100	100	100	200	200	200	200	200	200	200	200	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
Road base	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

Roadscanners

Wearing course	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Road base																			
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
Road base	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
Base course	200	200	200	200	200	200	200	100	100	100	100	100	100	100	100	100	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
Road base	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

Roadscanners

Wearing course	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

Comparison of rehabilitation proposals for the "Timber road", width 5 m incl shoulders

Aggregate volumes

Company	Wearing course M3	Road base M3	Sub-base M3	Sum aggregate M3	Ditching M
Swedish Forest Agency	1750	3469	0	5219	0
Swedish Cellulosa AB, SCA	1750	3335	0	5085	60
Svea Forest (Sveaskog)	1500	1500	3750	6750	0
Roadscanners	1242	2234	0	3476	10000

Comparison of design proposals

Cost comparison

COMPARISON OF COSTS FOR REHABILITATION OF THE TIMBER ROAD

COSTS

Company	Swedish Forest Agency	Swedish Cellulosa AB, SCA	Svea Forest (Sveaskog)	Roadscanners
Materials/Work				
Aggregate 100 SEK/m ³	521 900	508 500	675 000	347 600
Field survey & design	?	?	?	85 000
Steel reinforcement 40 SEK/m ²	-	-	-	18 400
Grading?				
Ditching?				
Environmental costs?				
Costs, SEK/m forest road	104	102	135	90

Estimated design costs for bigger projects

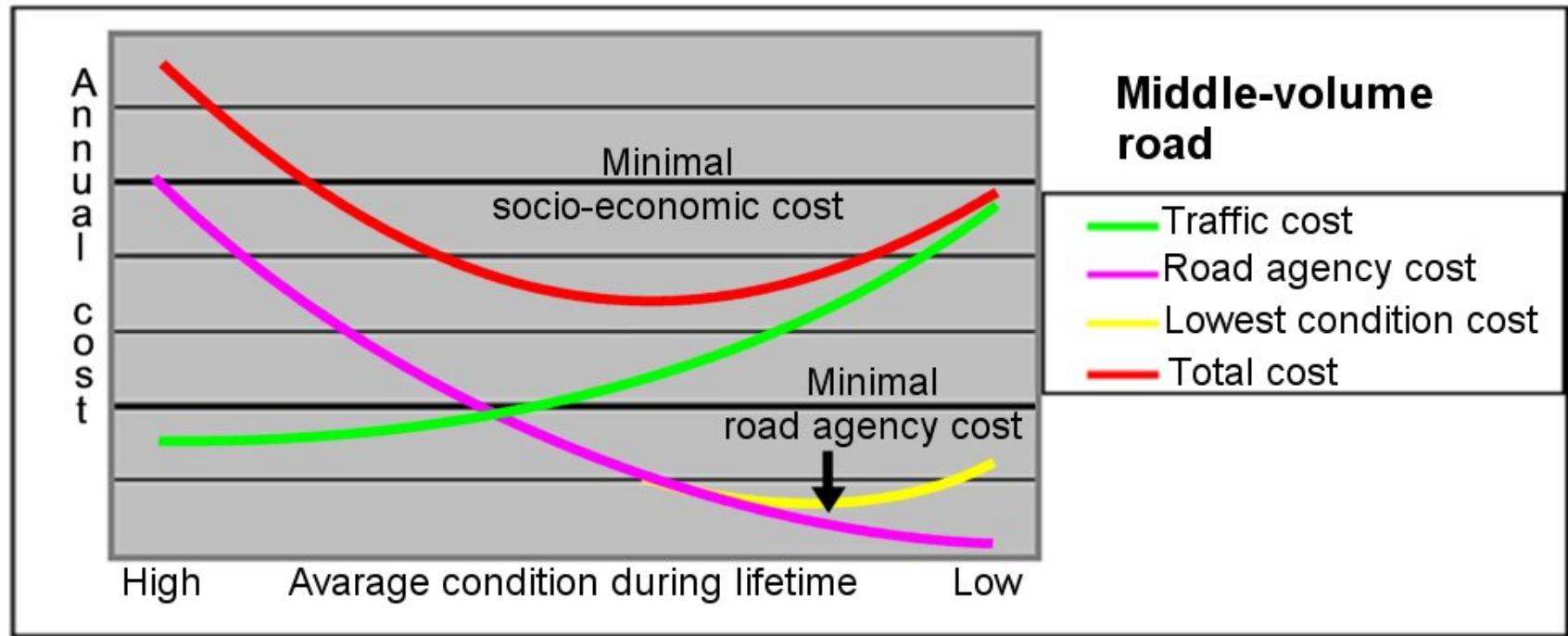
- Depending on project size and the sampling frequency for FWD and sampling
- 6-10 SEK/m + establishment cost

The Swedish demo-project

- Performance and life length
 - It was planned to estimate performance and life length by using models
 - So far no satisfying model found
 - The search continues

Longterm aim - to minimize the socio-economic costs

- Road Management Costs = rehabilitation costs + costs for planned and routine maintenance
- Traffic Costs = Accident Costs + Vehicle Operation Costs + Travel Time Costs + Raw Material Costs + Stock Costs + Environmental Costs



Thanks for your attention!



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