



*Structural pavement monitoring with non-destructive measuring devices - Experience from a pilot project in Germany*



- Pavement condition monitoring and assessment in Germany > Need for structural assessment
- Nondestructive measurement and equipment used in this pilot project (FWD, GPR and HSD/TSD)
- Measurements on 9 selected motorway/highway sections in Germany
- Analysis from traffic data, GPR measurements, core analysis and deflection measurements
- Results & conclusions



**TP 1**

**Evenness 1a: longitudinal  
1b: transverse**



**TP 2**

**Skid resistance**



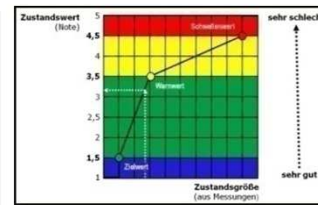
**TP 3**

**Structural surface condition**



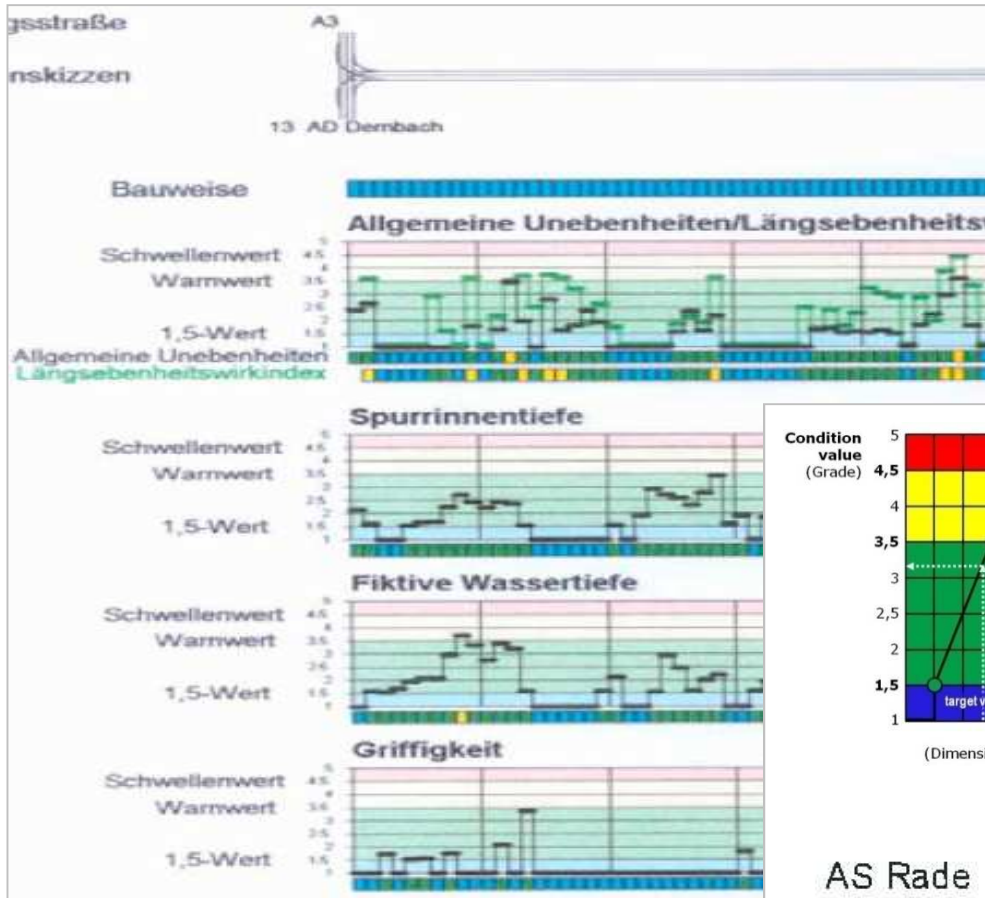
**TP 4**

**Assessment**



ca. 48.000 recorded km on federal highways  
 ca. 41.000 recorded km on federal trunk roads  
 ca. 89.000 recorded km total within four years

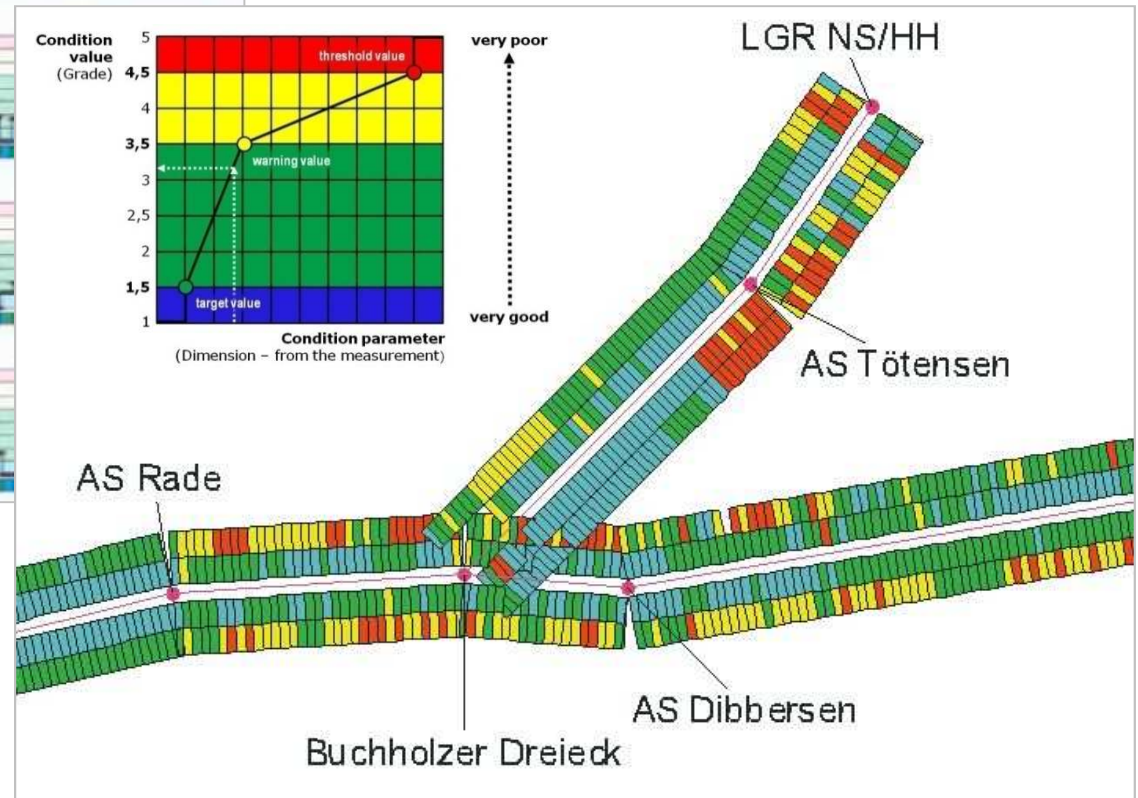
# Condition monitoring and -assessment (ZEB)



Condition profile

Averaged  
100m sections

Condition map



- **Existing data**

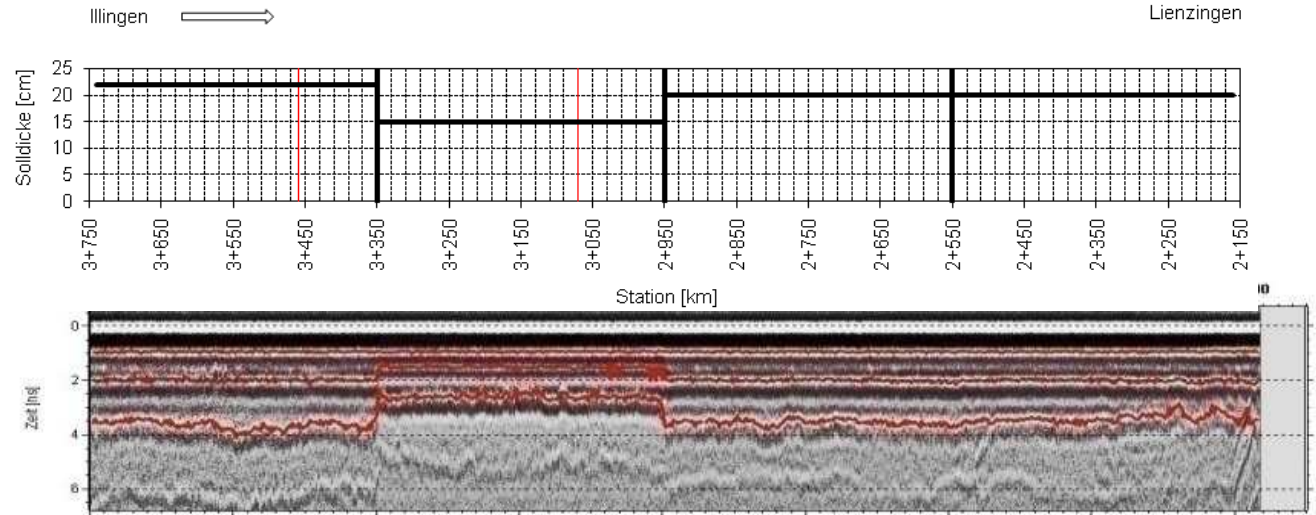
- ZAM structural database (**Z**ustand-**A**ufbau-**M**aßnahme)
- Research Projects
- Traffic data

- **Measurements/Testing**

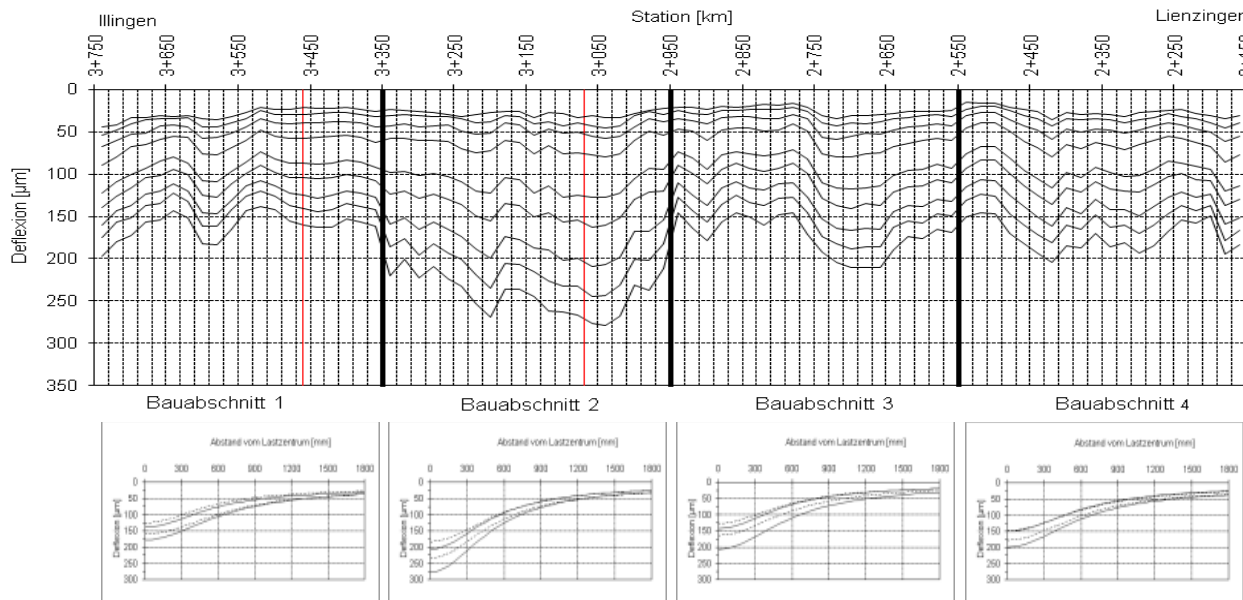
- Deflections (FWD+TSD)
- GPR
- Material tests
- Coring



# NDT Systems: GPR - FWD - HSD



**GPR:**  
Layers/thickness



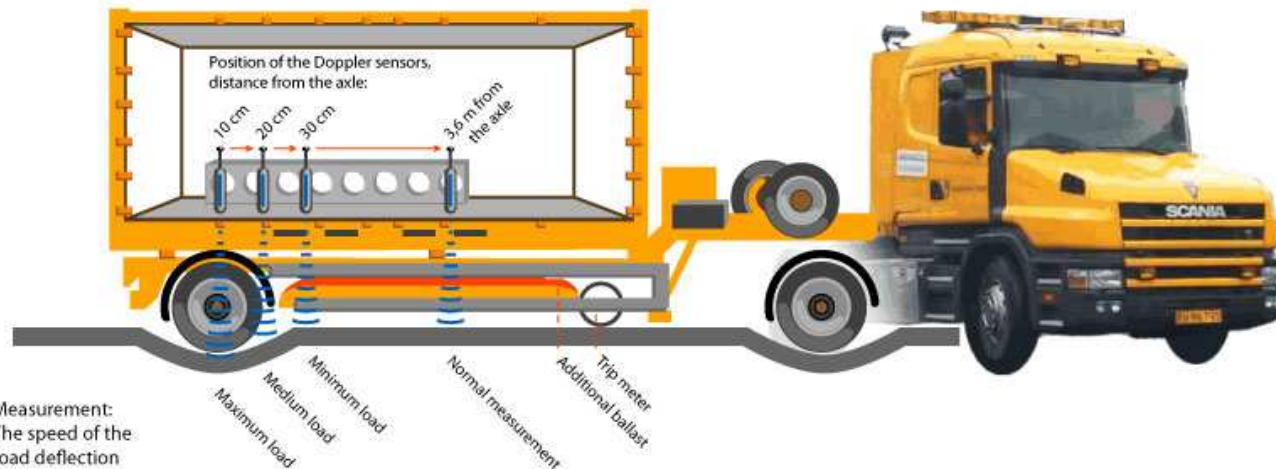
**FWD/HSD:**  
Stiffness



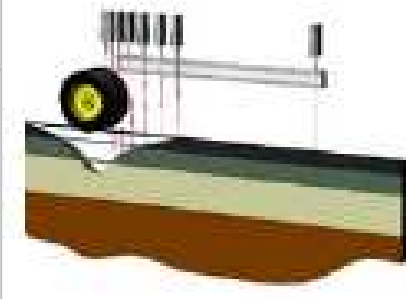
# The High Speed Deflectograph HSD

## High Speed Deflectograph: Structural assessment using the Surface Curvature Index SCI 300

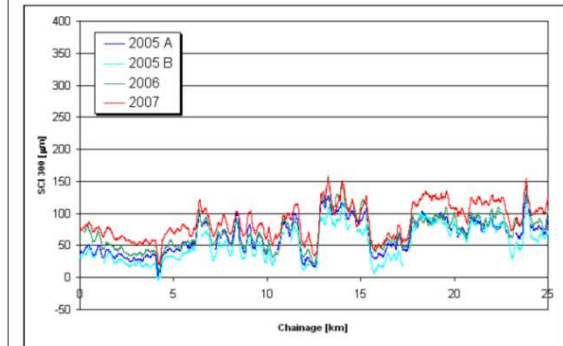
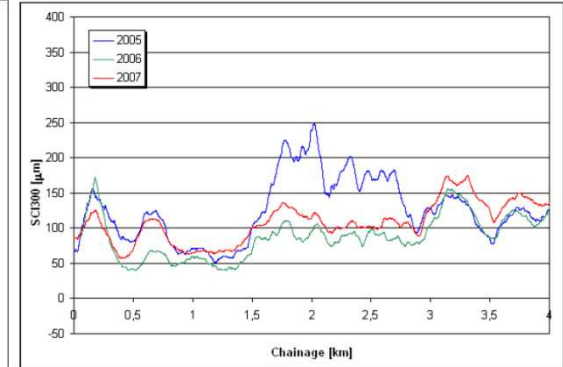
How the High Speed Deflectograph works:



### The Doppler Lasers



Photography: Susanne Baltzer, Graphics: Ditte Kilgaard Møller (dkm@vd.dk), The Danish Road Institute



source:



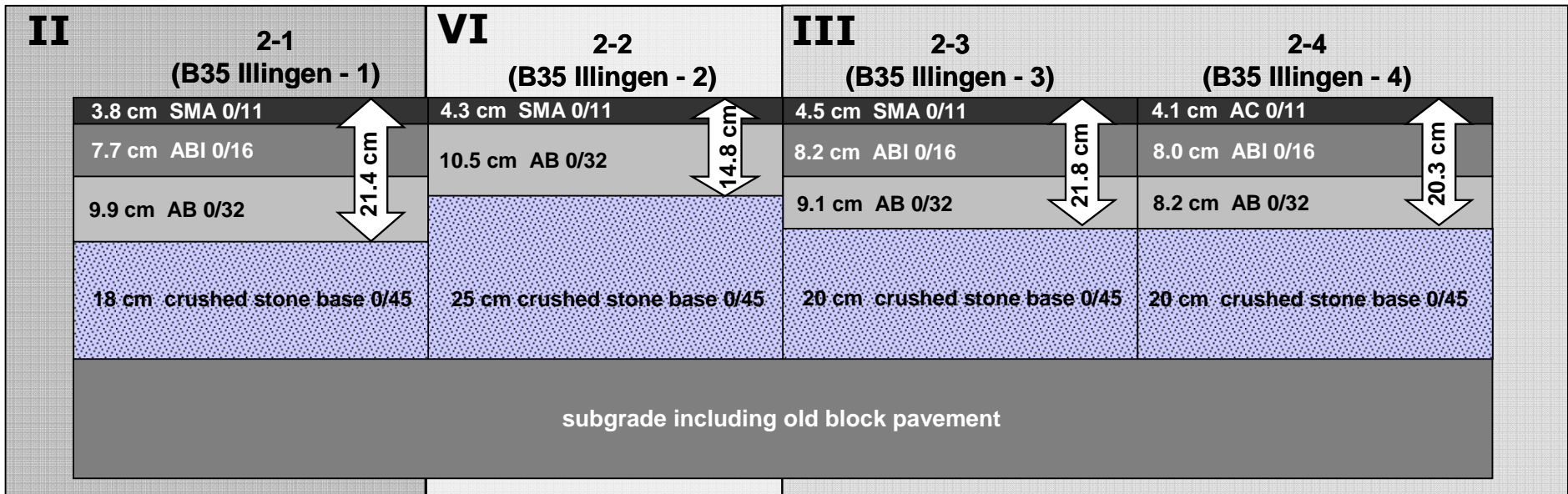
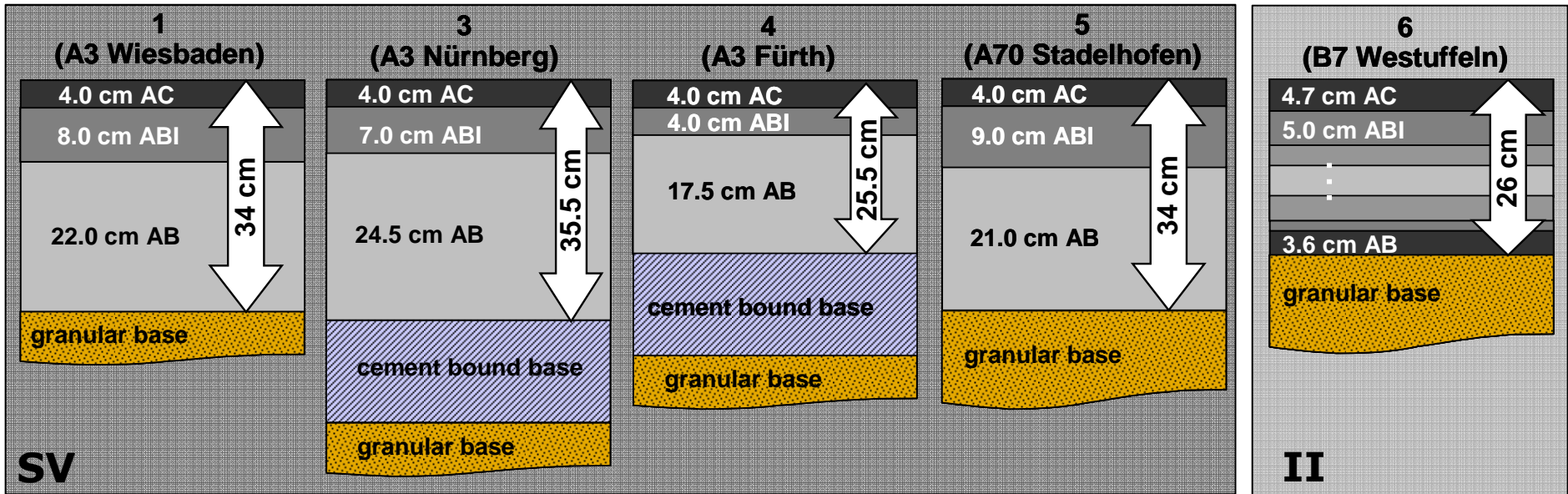
**GREENWOOD ENGINEERING A/S**



**Road Directorate**



# Test section pavements





# Test sections: Basic data



Test section code		1	3	4	5	6	2-1	2-3	2-4	2-1
Parameter	Unit	A3	A3	A3	A70	B7	B35	B35	B35	B35
		Wiesbaden	Nuernberg	Fuerth	Stadelhofen	Westuffeln	Illingen 1	Illingen 3	Illingen 4	Illingen 2
Section length	[m]	500	500	500	500	400	400	400	400	400
Age <sup>4)</sup>	[yrs]	21	28	28	16	n.a.	1	1	1	1
Base <sup>1)</sup>		UG	CEM	CEM	UG	UG	UG	UG	UG	UG
Design class <sup>2)</sup>		SV	SV	SV	SV	II	II	III	III	IV
Min ESALs ( $B_{min}$ ) <sup>3)</sup>	[mio]	32	32	32	32	3	3	0,8	0,8	0,3
Max ESALs ( $B_{max}$ ) <sup>3)</sup>	[mio]	100	100	100	100	10	10	3	3	0,8
HV share <sup>4)</sup>	[%]	18.3	17.8	18.9	19.0	n.a.	17.7	17.7	17.7	17.7
AADT <sup>(HV) 4)</sup>	[V/24h]	10,168	19,148	16,999	4,652	n.a.	1,512	1,512	1,512	1,512
$B_{accumulated}$ <sup>4)</sup>	[mio]	30,124	64,425	57,195	12,162	n.a.	0,389	0,389	0,389	0,389
$B_{accumulated} / B_{min}$ <sup>4)</sup>	[-]	0.94	<b>2.01</b>	<b>1.79</b>	0.38	n.a.	0.13	0.50	0.50	<b>1.32</b>
$B_{accumulated} / B_{max}$ <sup>4)</sup>	[-]	0.30	0.64	0.57	0.12	n.a.	0.04	0.13	0.13	0.50

1) UG = Unbound Granular, CEM = Cement Treated Base on granular base

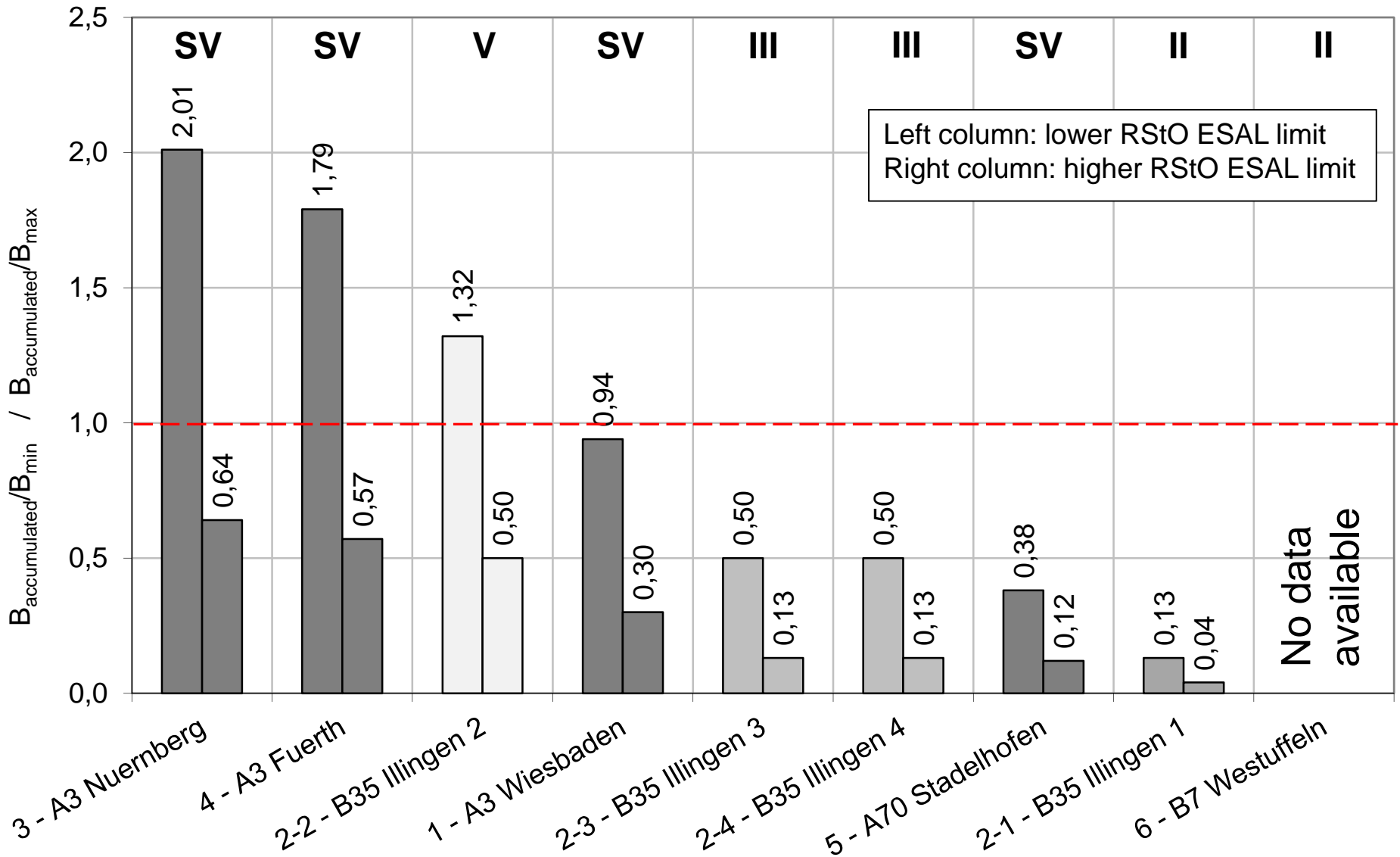
2) (Assumed) design class according to the German Pavement Design Guideline RStO 01/12

3) 10t-ESALs according to the German Pavement Design Guideline RStO 01/12

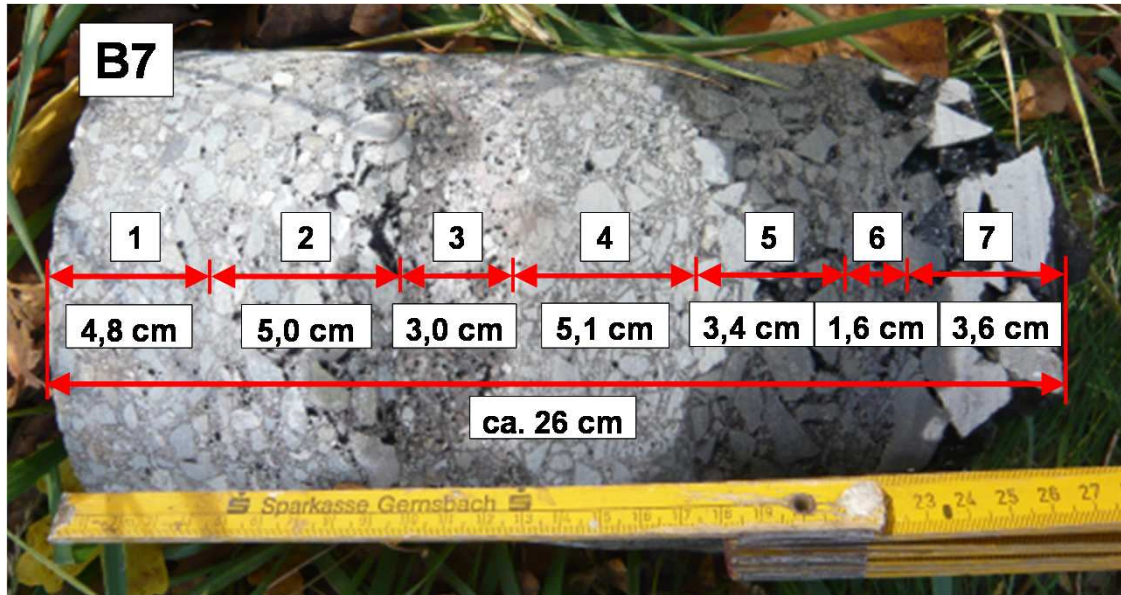
4) Year of evaluation (2008)



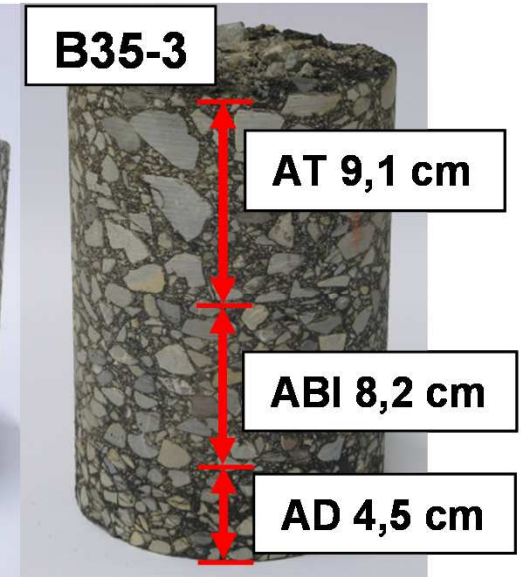
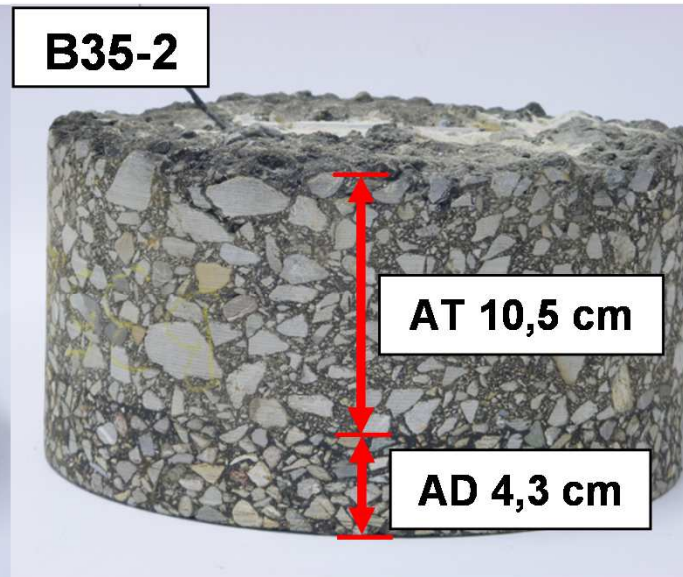
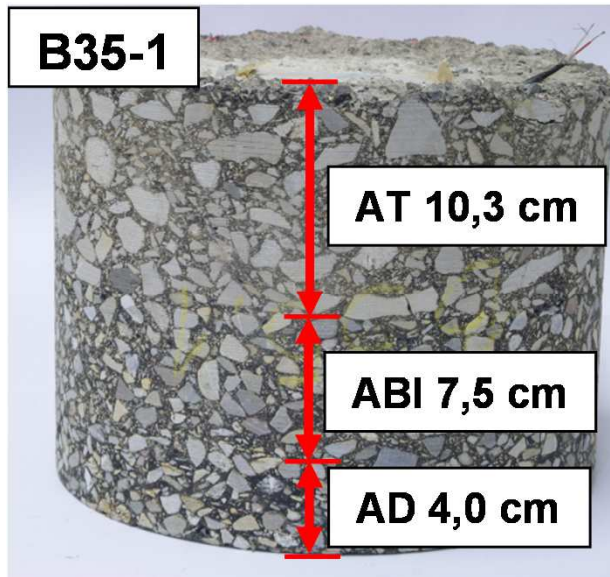
# Traffic loading: Performance ratio



# Core analysis



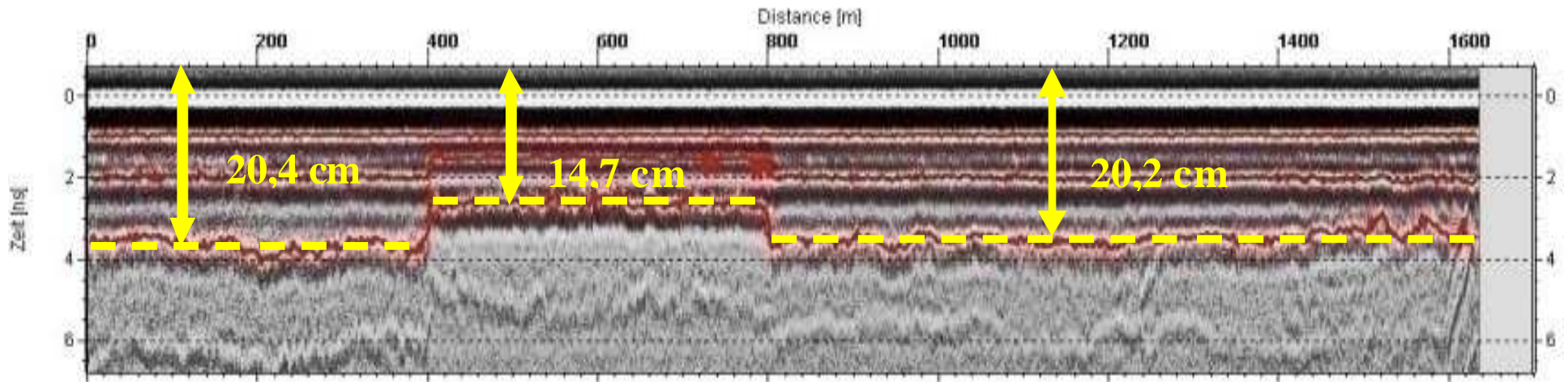
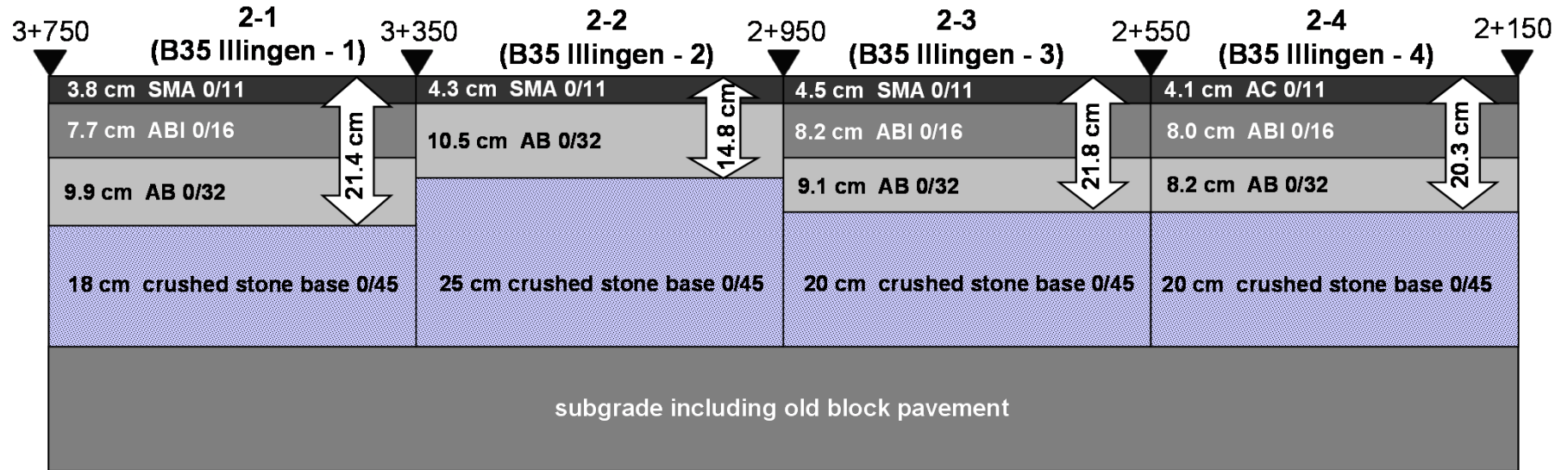
Section	Adhesion
1, 3, 4) A3	Poor
2) B35	Good
5) A70	Poor
6) B7	Good



# GPR measurements: Layer thickness



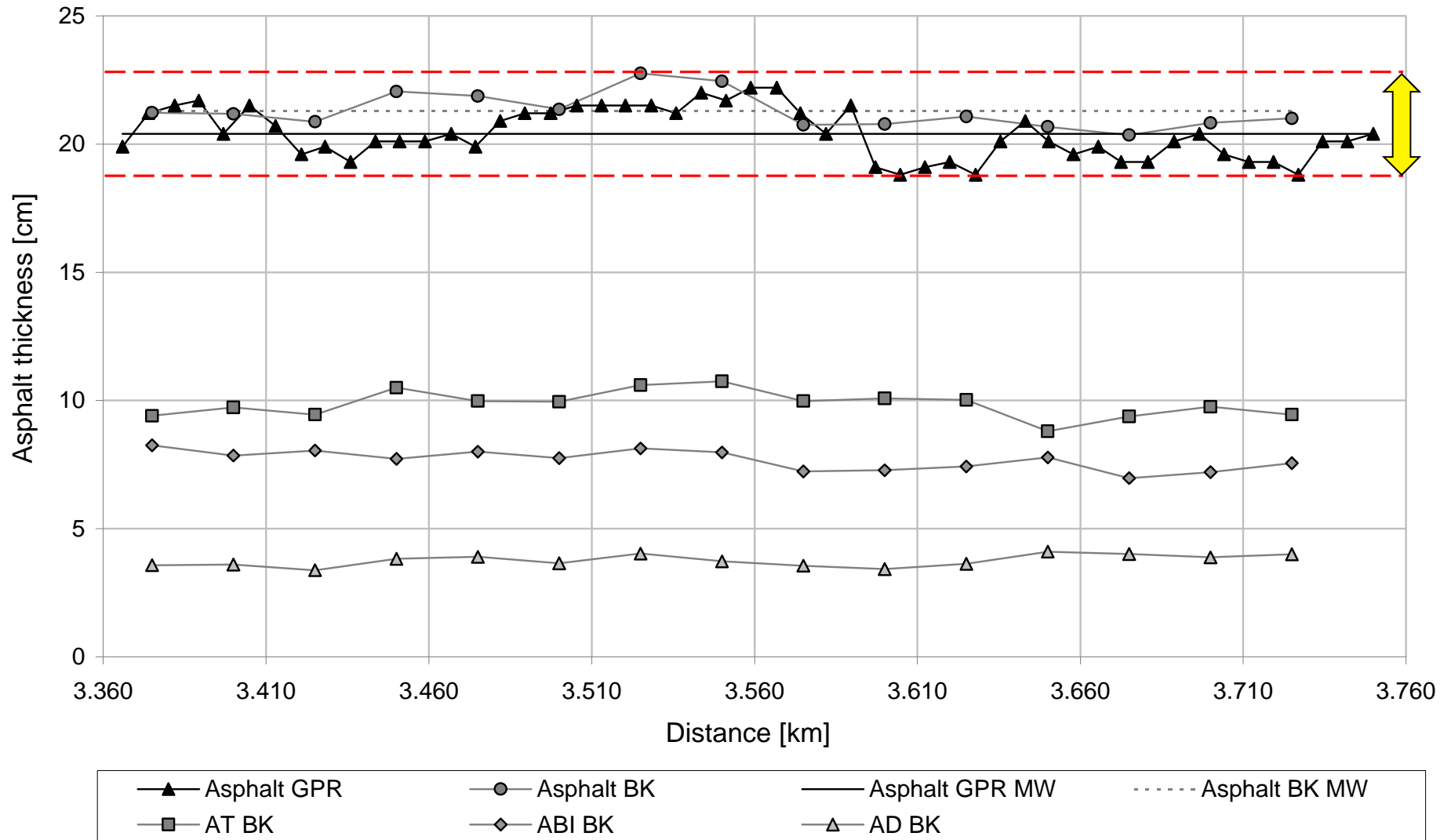
## Asphalt thickness – core



## Asphalt thickness – GPR



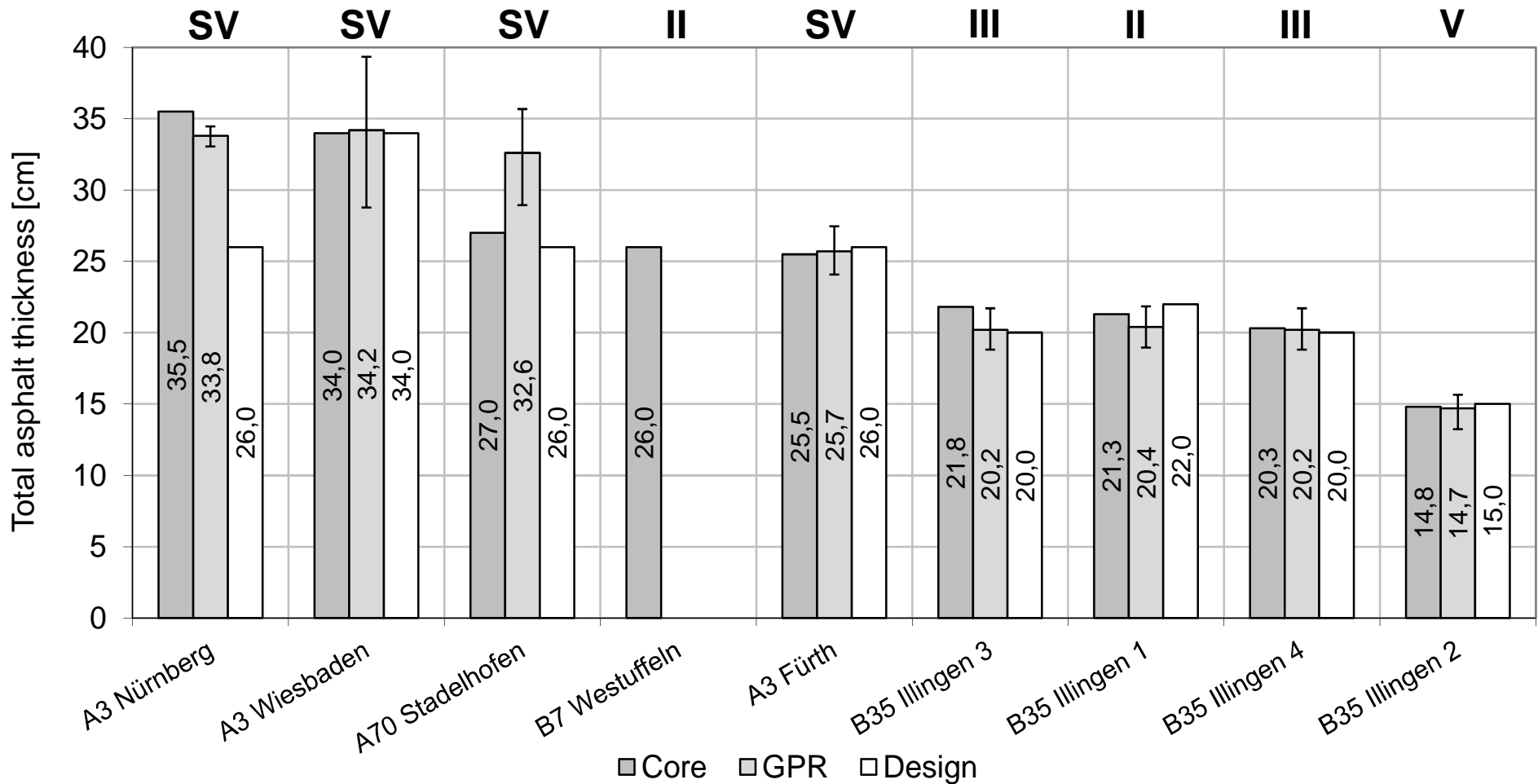
# Asphalt layer thickness: B35 section 1



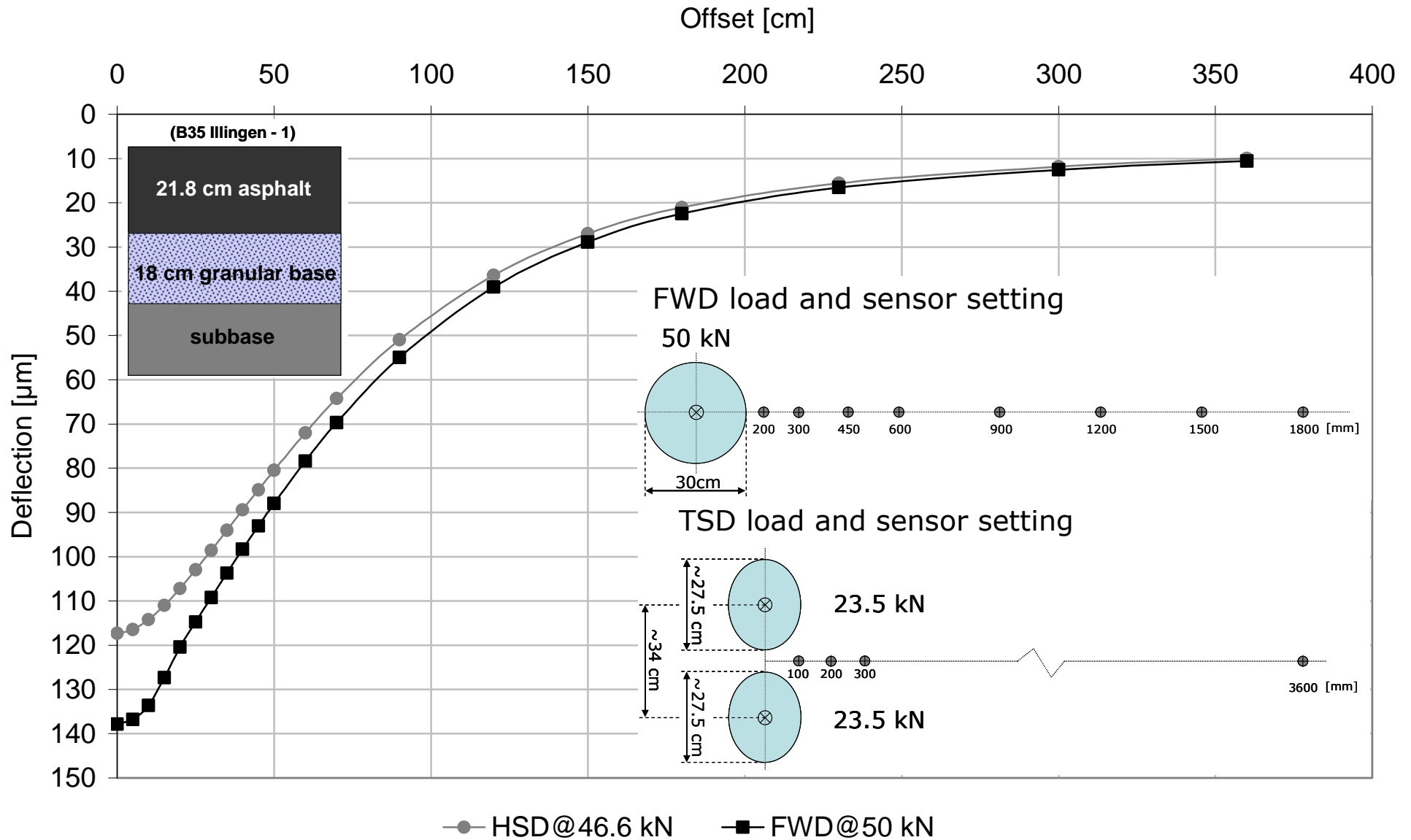
# Total asphalt thickness: Core - GPR - Design



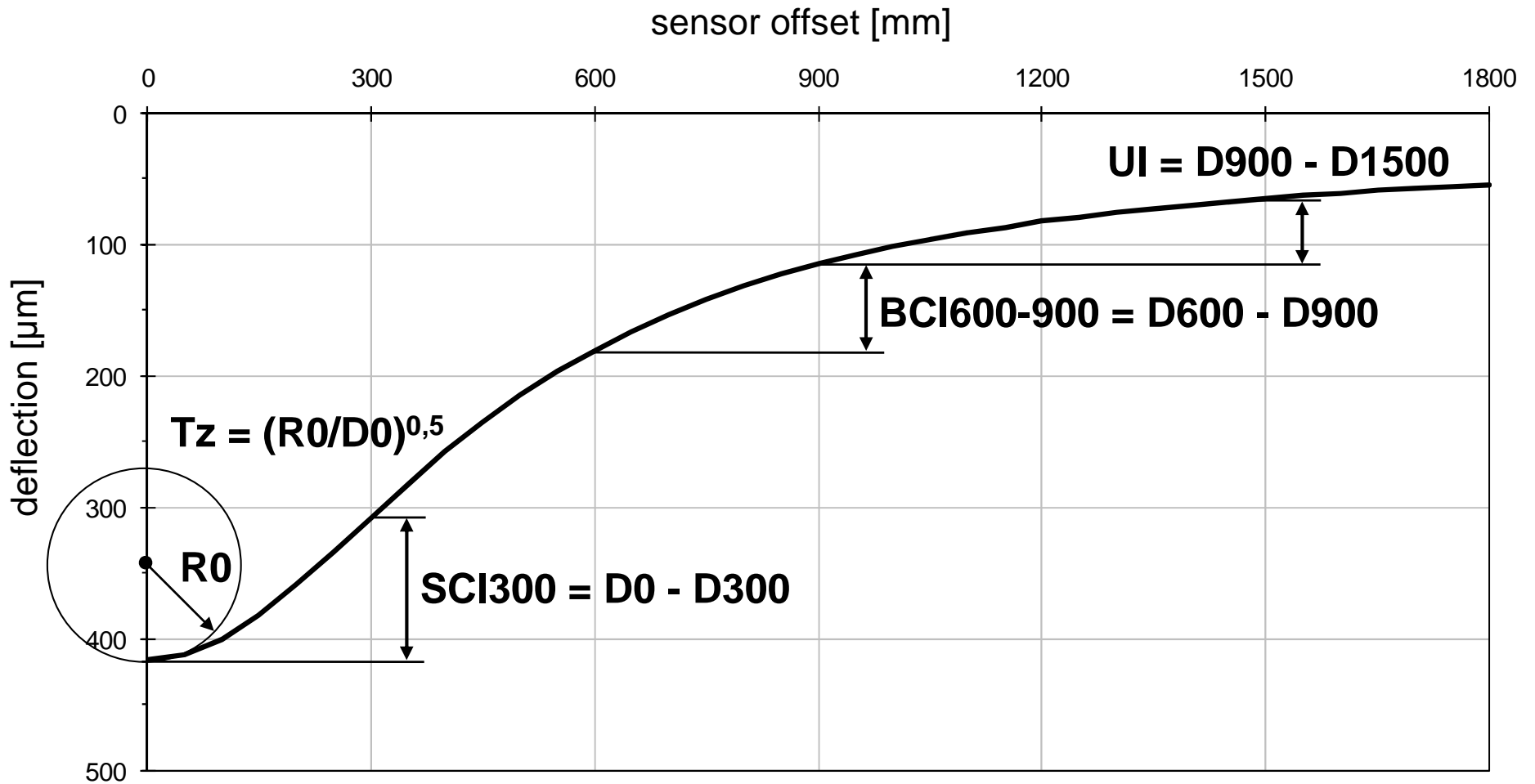
Decreasing asphalt core thickness



# Deflections: FWD vs. TSD

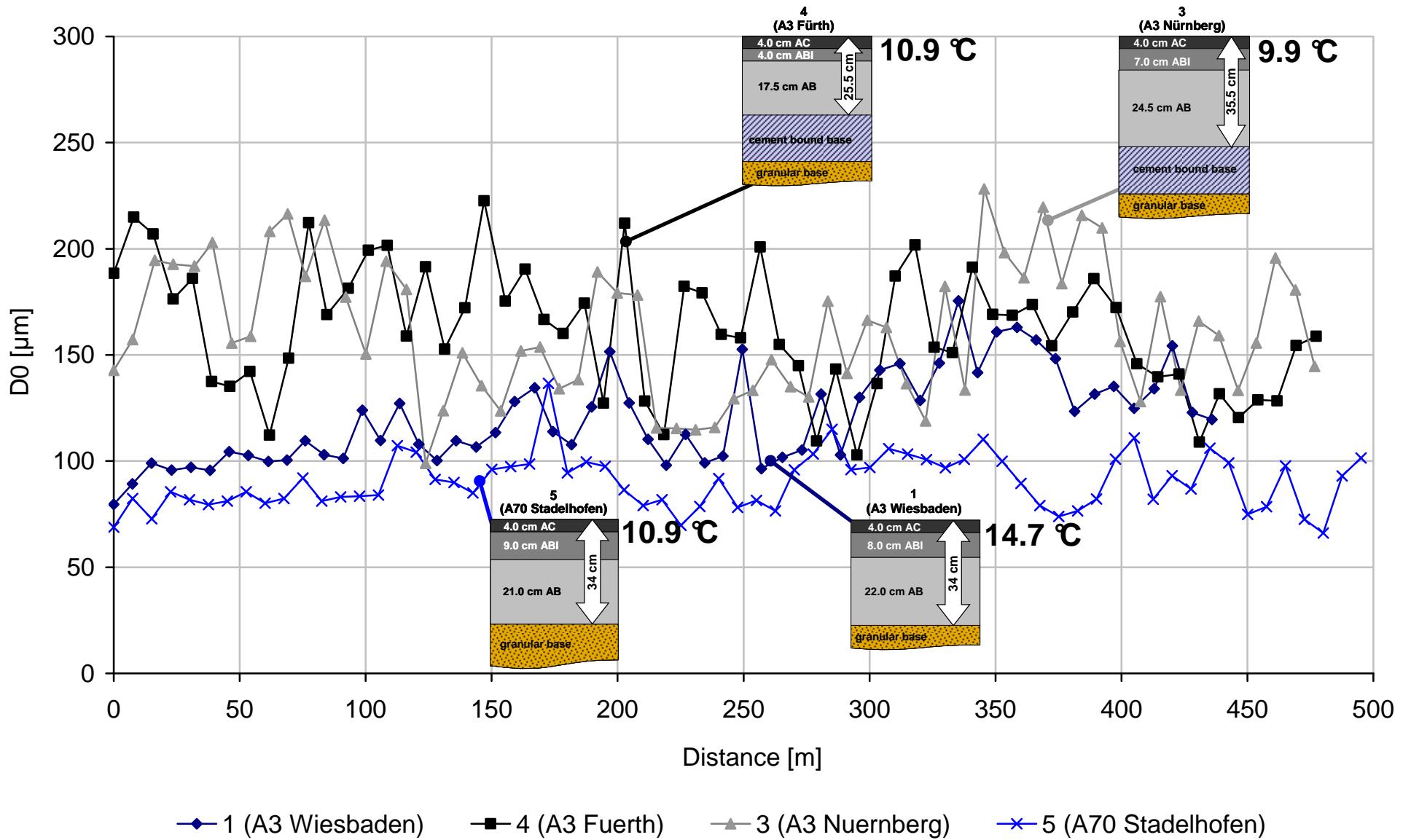


# FWD deflection bowl parameters

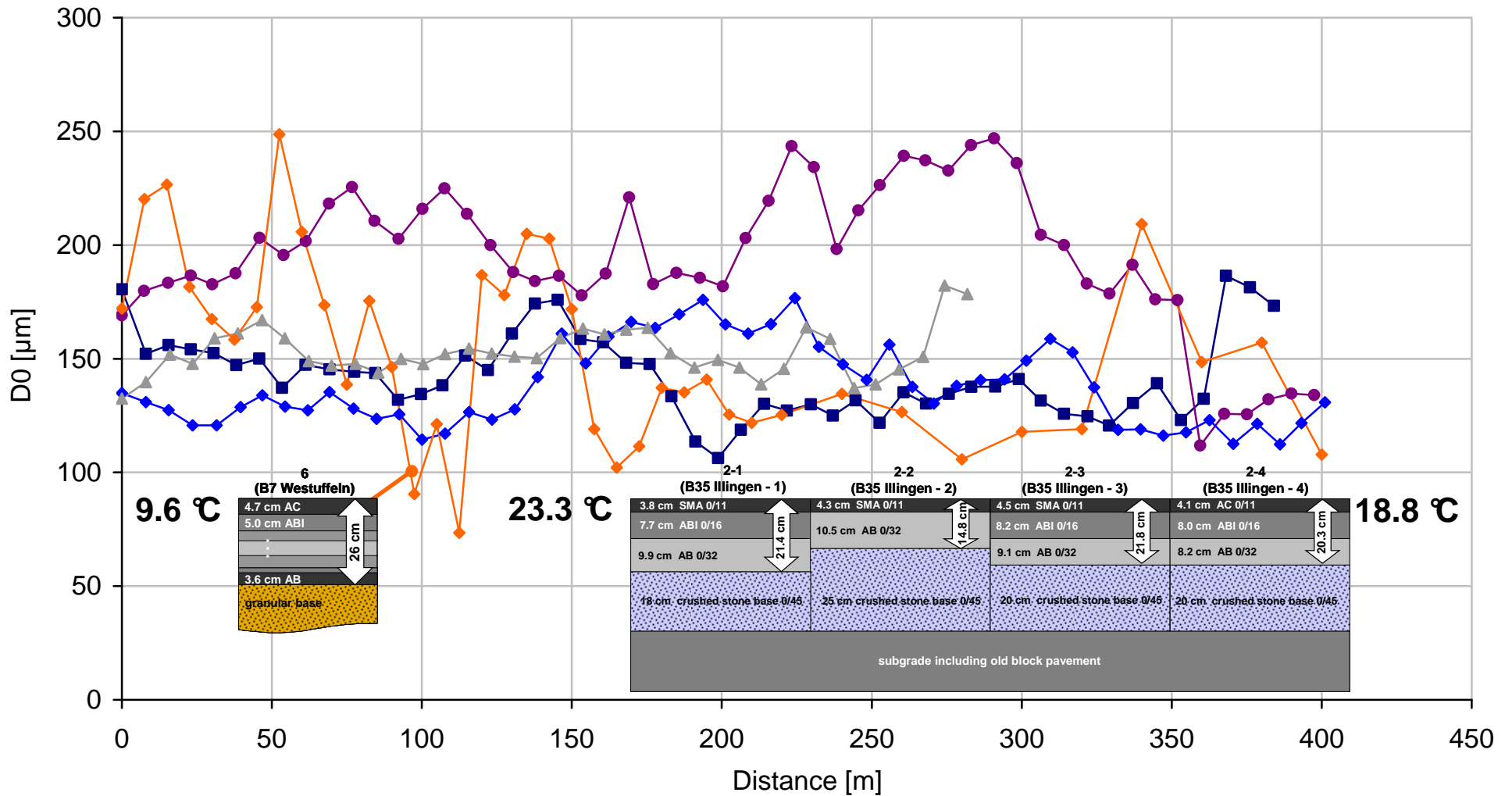




# FWD deflections D0: Motorway sections (A)



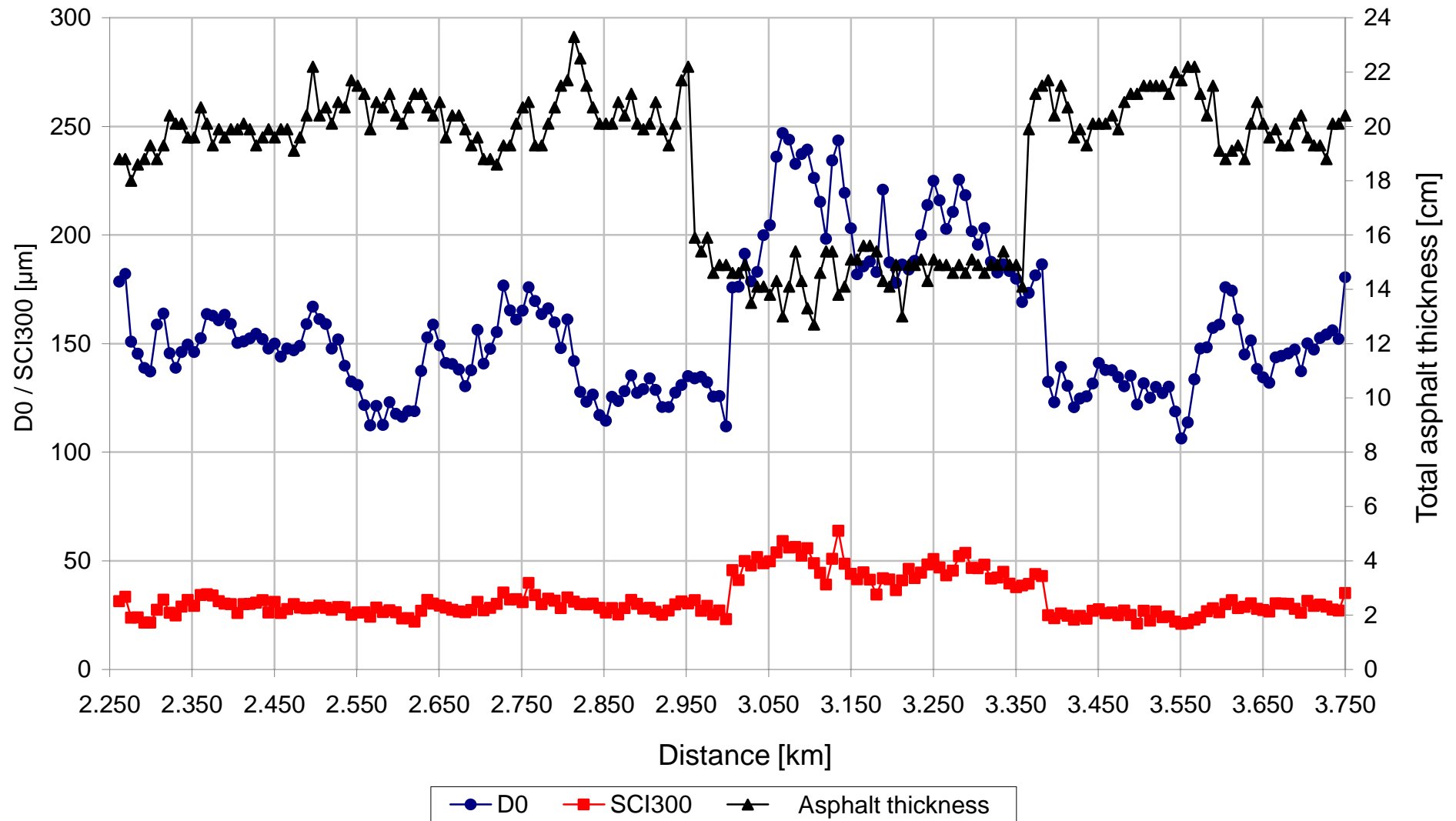
# FWD deflections D0: Highway sections (B)



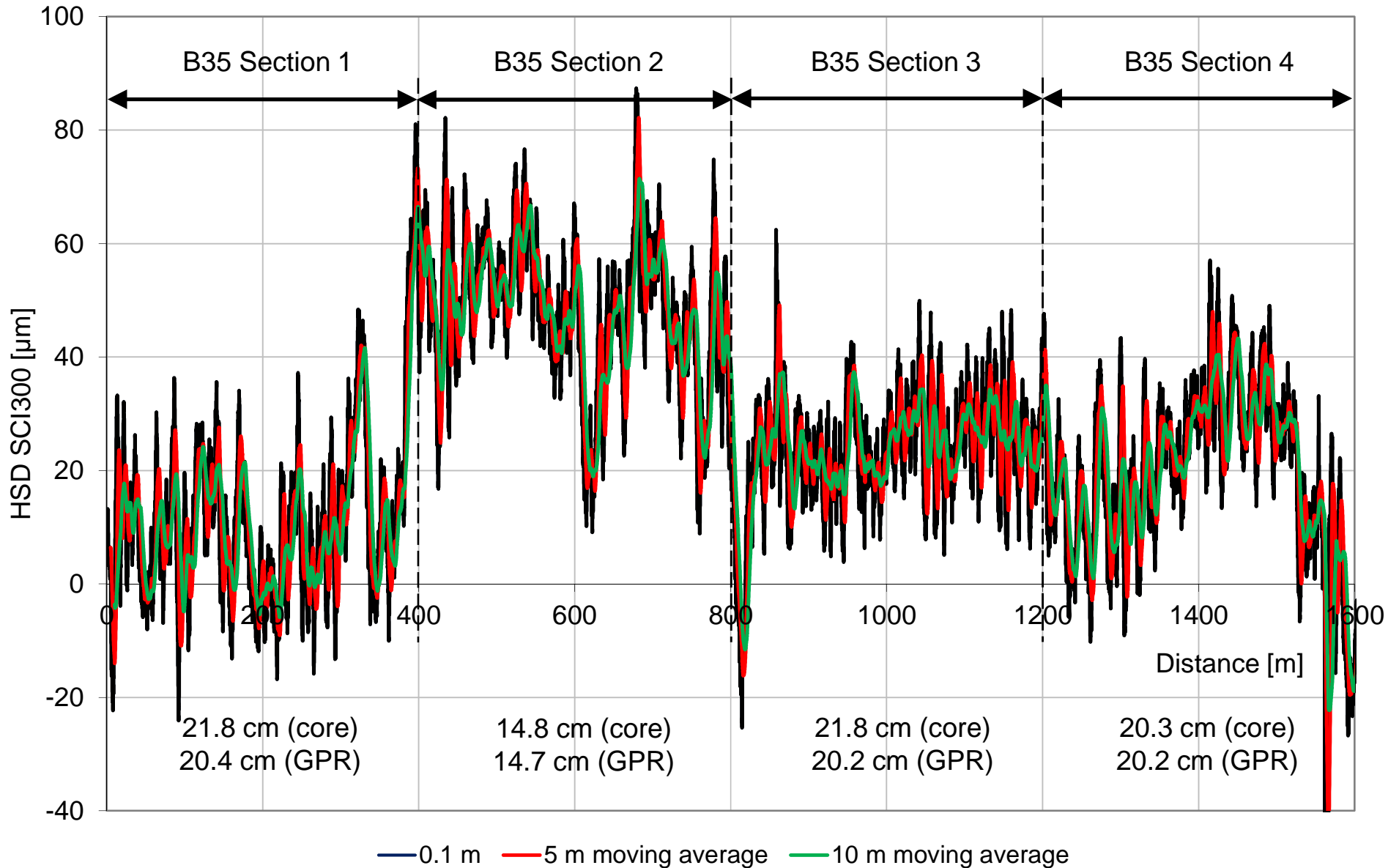
■ 2-1 (B35 Illingen 1)  
 ● 2-2 (B35 Illingen 2)  
 ◆ 2-3 (B35 Illingen 3)  
 ▲ 2-4 (B35 Illingen 4)  
 ◇ 6 (B7 Westuffeln)

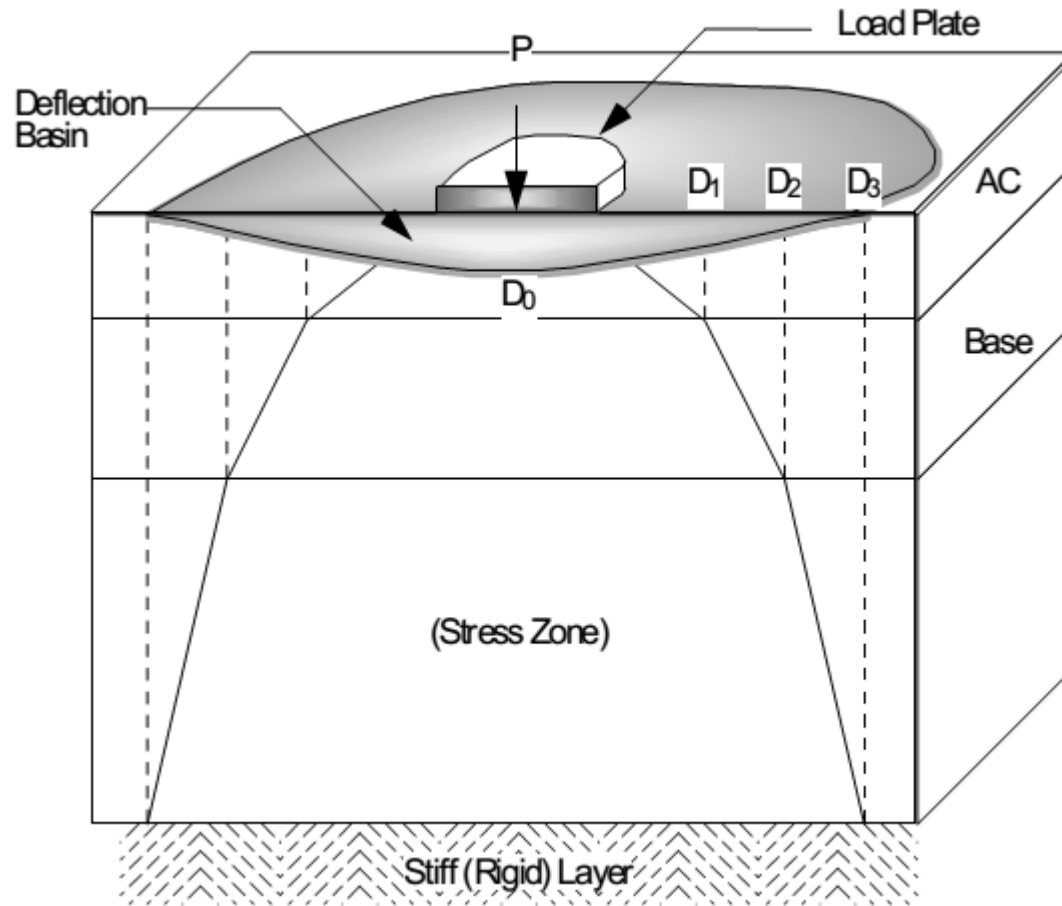


# Asphalt thickness and FWD deflections: B35



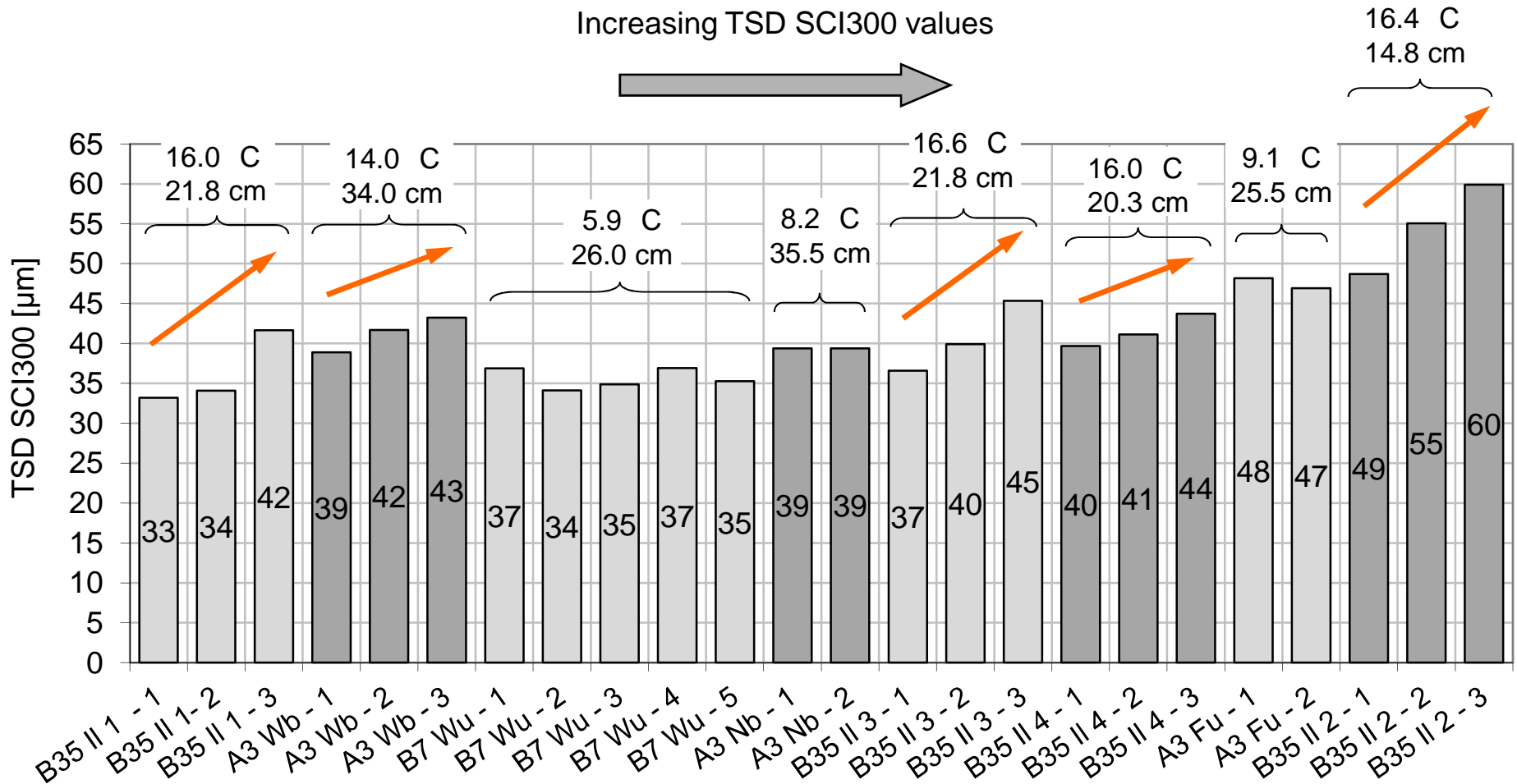
# HSD measurements: „Raw“ data





source: EVERSERIES® USER'S GUIDE  
Pavement Analysis Computer Software  
and Case Studies

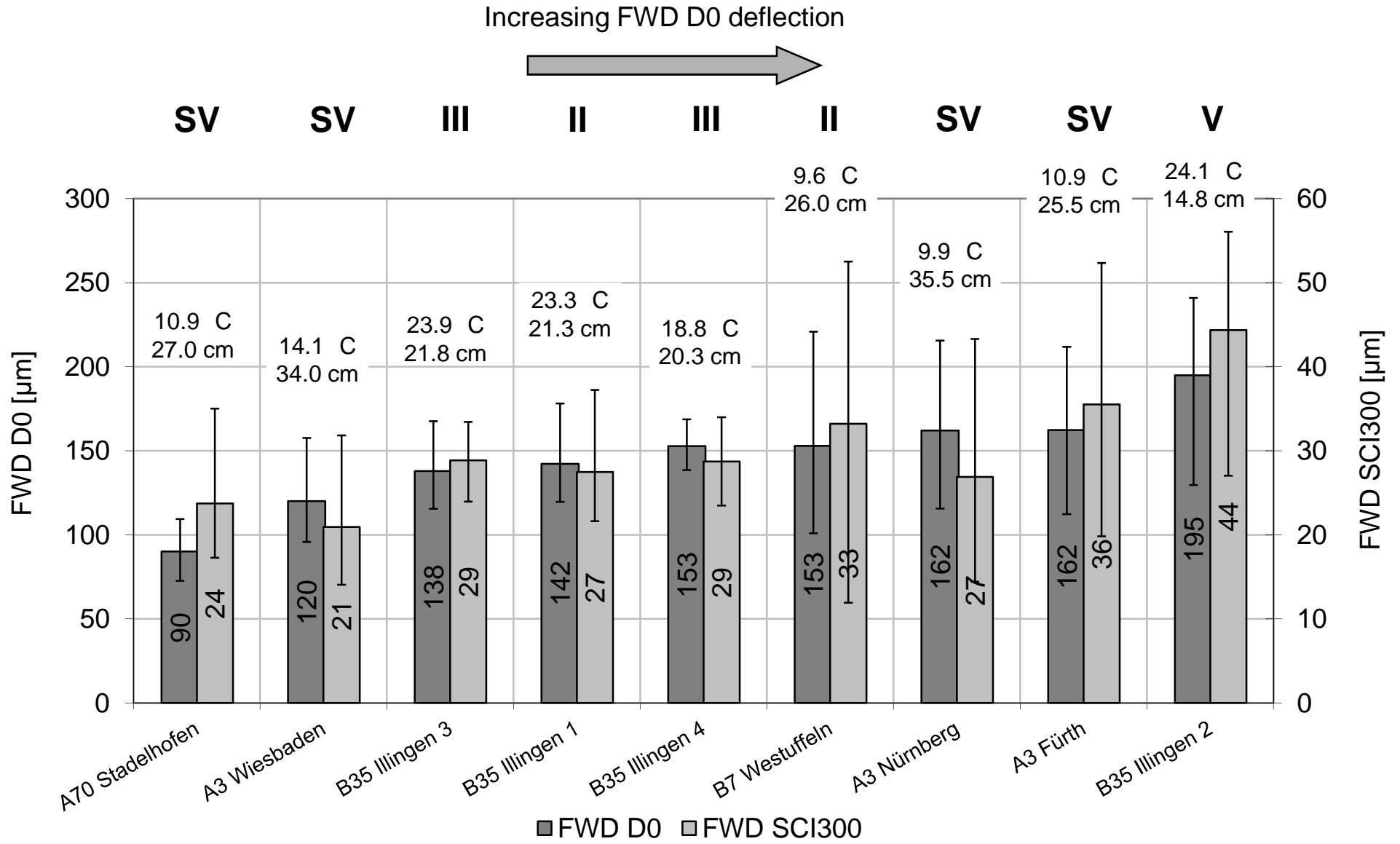
# TSD SCI 300: Mean value & repetitions



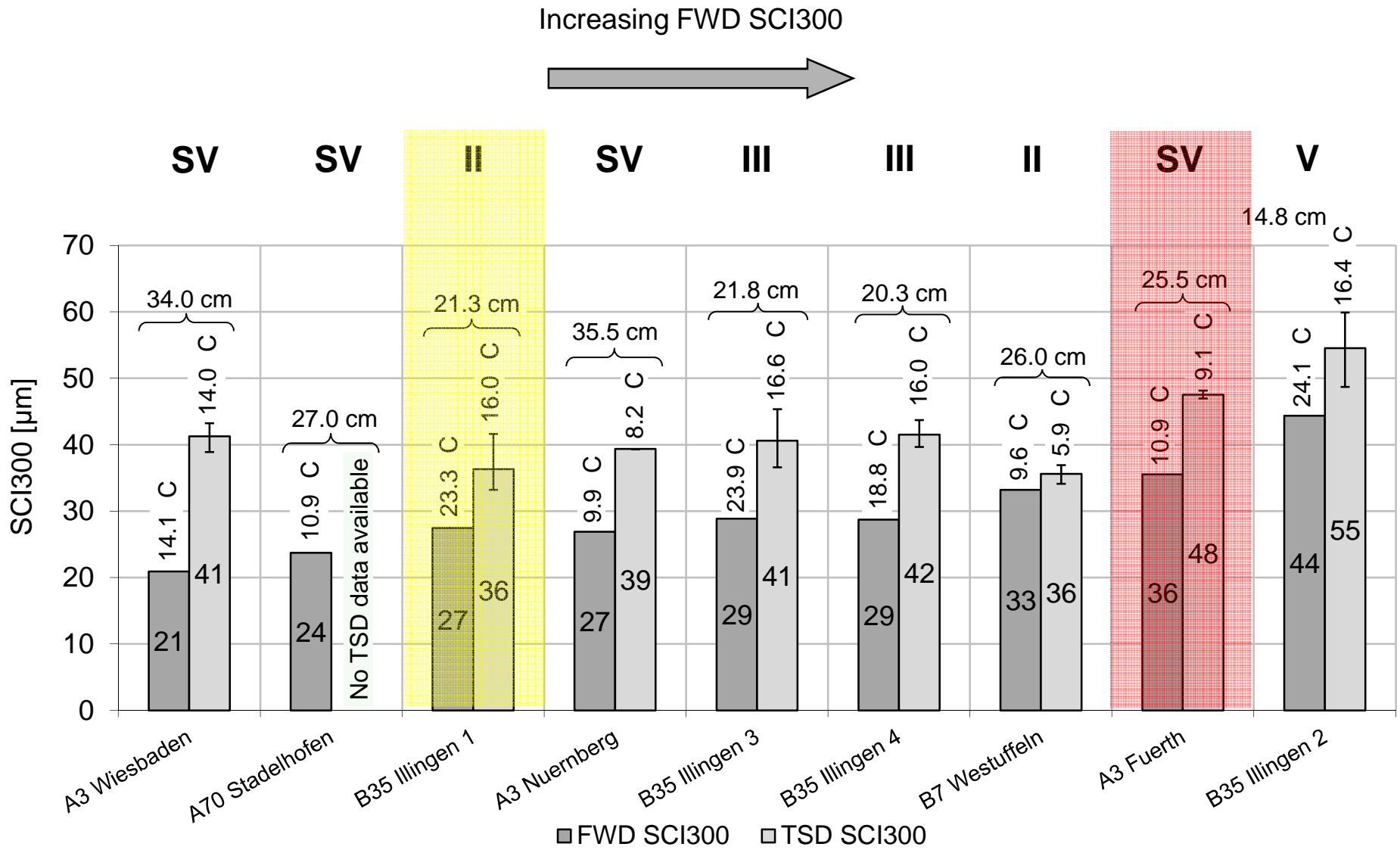
- Measuring beam locally warmed up by lasers
- Bending of the beam results in increasing SCI300 values



# SCI300: FWD vs. HSD mean values



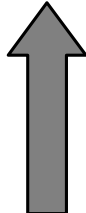
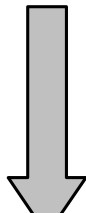
# SCI300: FWD vs. HSD mean values





# Strength ranking of test sections

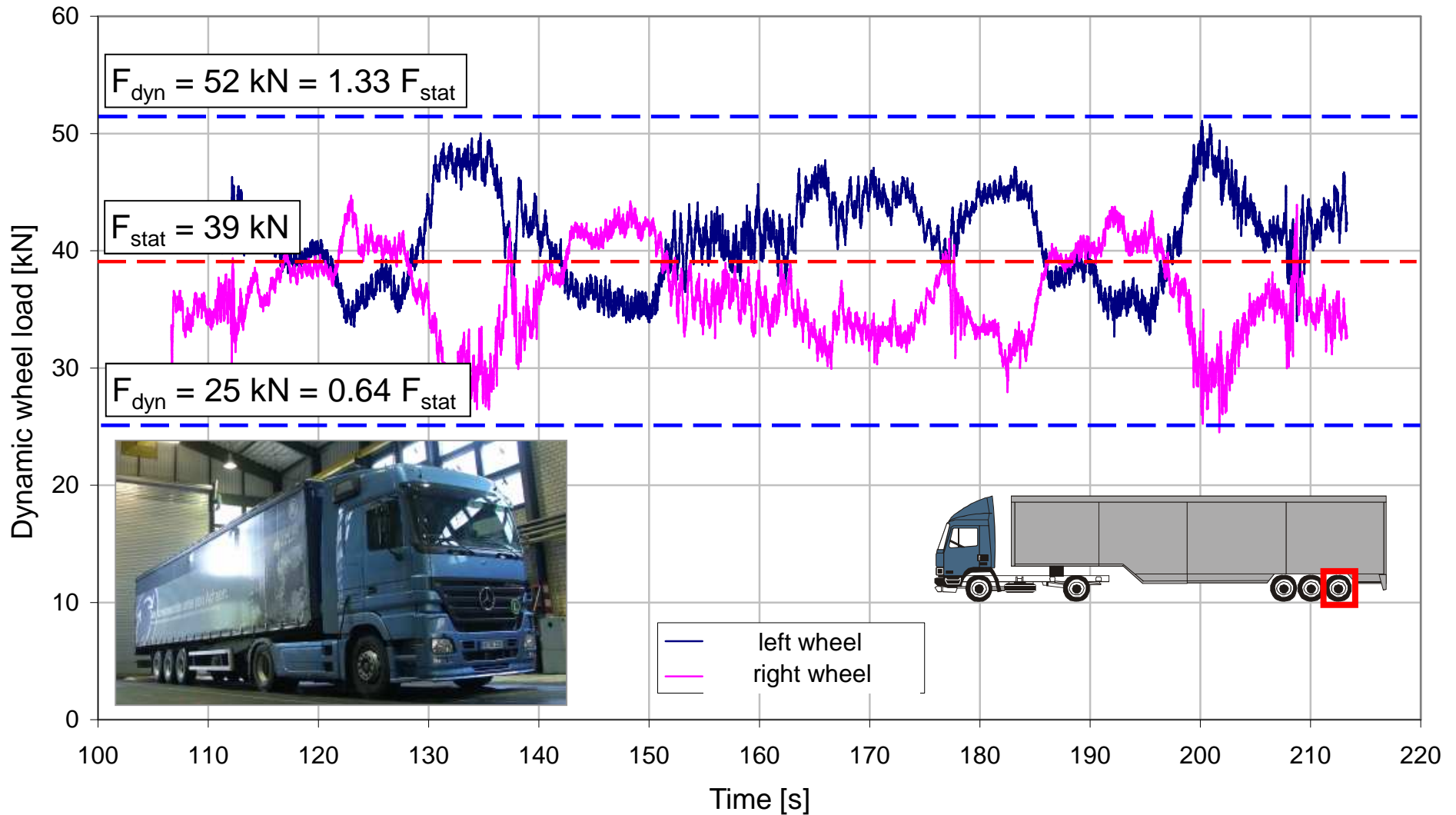


Rank		FWD D0 [μm]		FWD SCI300 [μm]		HSD SCI300 [μm]	
strong   weak	1	<b>5</b> (A70 Stadelhofen)	90	<b>1</b> (A3 Wiesbaden)	21	<b>2-1</b> (B35 Illingen 1)	36
	2	<b>1</b> (A3 Wiesbaden)	120	<b>5</b> (A70 Stadelhofen)	24	<b>6</b> (B7 Westuffeln)	36
	3	<b>2-3</b> (B35 Illingen 3)	138	<b>2-1</b> (B35 Illingen 1)	27	<b>3</b> (A3 Nuernberg)	39
	4	<b>2-1</b> (B35 Illingen 1)	142	<b>3</b> (A3 Nuernberg)	27	<b>2-3</b> (B35 Illingen 3)	41
	5	<b>2-4</b> (B35 Illingen 4)	153	<b>2-3</b> (B35 Illingen 3)	29	<b>2-4</b> (B35 Illingen 4)	42
	6	<b>6</b> (B7 Westuffeln)	153	<b>2-4</b> (B35 Illingen 4)	29	<b>1</b> (A3 Wiesbaden)	44
	7	<b>3</b> (A3 Nuernberg)	162	<b>6</b> (B7 Westuffeln)	33	<b>4</b> (A3 Fuerth)	48
	8	<b>4</b> (A3 Fuerth)	162	<b>4</b> (A3 Fuerth)	36	<b>2-2</b> (B35 Illingen 2)	55
	9	<b>2-2</b> (B35 Illingen 2)	195	<b>2-2</b> (B35 Illingen 2)	44		



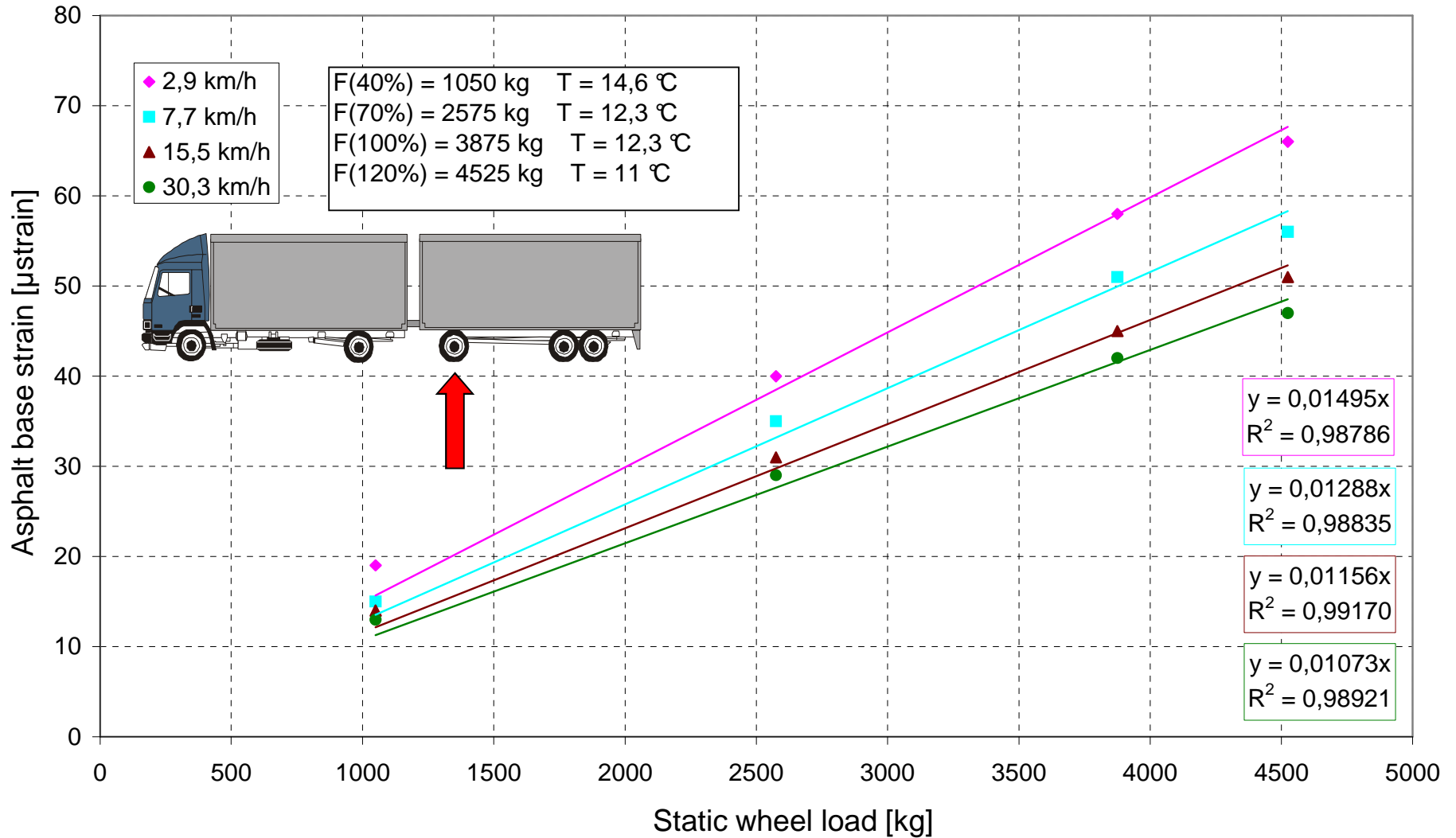
# Dynamic wheel loads: Testing@BAST

5 axle truck-semitrailer - 40 t gross weight - winding country road - v ~40-50 km/h



# Static wheel load vs. asphalt strain

F3 L23 A3 FM - DMS 06 R1 x AT



- TSD SCI300 data show a very high scatter on all test sections and drift due to temperature problems
- Short term repeatability of the TDS SCI300 on some sections seems acceptable
- TSD data show unreasonable negative SCI 300 values (problem on thick pavements)
- Dynamic wheel load measurement is essential
- In this project, TSD data hardly seem appropriate for project level assessments up to now, but it should aim at screening homogenous sections of high or low strength on network level

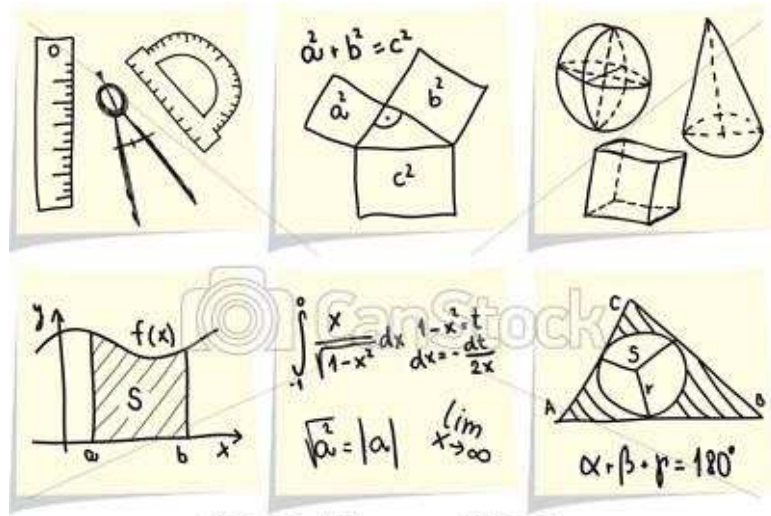
- GPR mean value of total asphalt thickness matches very well with core thickness
- A70: GPR and FWD data showed that total asphalt thickness determined on core is obviously wrong >> poor layer adhesion
- Total asphalt thickness determined by GPR showed variations of up to 3.5 cm within one section of the same structural design
- TSD SCI300, FWD SCI300 and FWD D0 each provides a different strength ranking of the test sections

Parameter	FWD	TSD
Defined vertical load	+	-
Number of „deflection“ values	<b>Up to 13</b>	<b>3 (up to 9)</b>
Centre deflection	+	-
„Continuous“ measurements	-	+
Surface influences	+	-
Complexity of the system	+	-
Traffic obstructions	-	++

## 1. Load



k8099540 www.fotosearch.de



© Can Stock Photo - csp9118861

## 2. Geometry

## 3. Material



# Thank you !

rabe@bast.de  
www.bast.de

# TSD wheel load measurement

H020080613005 - wheel load (adjusted) vs. distance

