Institut für Materialprüfung · Dr. Schellenberg Rottweil GmbH

Beratung, Forschung und Materialprüfung in den Fachbereichen:
Bitumenhaltige Baustoffe, Beton, Erdbau, Mineralische Baustoffe, Chemie, Umwelttechnik

Institut für Materialprüfung · Dr. Schellenberg Rottweil GmbH
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Anerkannt nach RAPStra für Eignungsprüfungen, Fremdüberwachungsprüfungen, Kontrollprüfungen und Schiedsuntersuchungen

Überwachungs- und Zertifizierungsstelle gem. § 25 der LBO Baden-Württemberg für Betonzuschlag und Deponieasphalt

Betonprüfstelle W nach DIN 1045

Mitglied im Bundesverband unabhängiger Institute für bautechnische Prüfungen e.V. bup

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Bericht-Nr.: 11F0042 **Projekt Nr.:** 11 / 37984 - 306 **Berichtsdatum:** 05.09.2011

Betr.:

Title: **Third checking of the hydrated lime test track bypass Bräunlingen meaning of L 181**

1. Introduction

Two test sections were built in 2000 in collaboration with the Federation of German Lime Industry and the IFM Dr. Schellenberg GmbH Rottweil.

In the first test track, there was an SMA wearing course on the federal road B27 in direction Dußlingen - Hechingen. After two sampling due to changes in route of the line was extended.

The second test track is located on the bypass L 181 at Bräunlingen. This track was sampled in 2002 for the first time and in 2005 for the second time.

Subsequently, the results of the 3rd testing in 2011 are represented.

1.1 Description of the test sections

The bypass L 181 has a surface layer of asphalt concrete 0/11. The test track consists of 4 sections. The following compositions of the mixture were selected:

- Section A: no addition of hydrated lime and the optimum binder content from ITT
- Section B: no addition of hydrated lime and 0.3 M. -% reduced binder content compared to the optimum binder content from ITT
- Section C: addition of about 3 M. -% hydrated lime and 0.3 M. -% reduced binder content compared to the optimum binder content from ITT
- Section D: addition of about 3 M. -% hydrated lime and the optimum binder content from ITT

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The surface layer is an asphalt concrete 0/11 (AB 0/11). It was built on 2000-07-31. The track is located in an open field with a sunny location. There is a gradient of up to 1% available. The bank is between 2.5 and 5.0%, they will not injure the existing left turn.

The L 181 is assigned to Construction Class III (0.8 - 3 million equivalent 10-t axis transitions)

2. Procedure

Now, after almost 11 years lying time the actual condition of the test track was checked by a visual assessment, the inclusion of cross sections and the removal and examination of drill cores.

Ten additional core samples were taken in the driving direction parallel to the sampling locations from the years 2002 and 2005.

At the core samples, the following parameters were determined:

- Determination of density and bulk density at the core and MPK (Marshall specimen), Marshall stability and flow value,
- Determination of the mix composition (binder content, particle size distribution)
- Determination of the softening point ring and ball on the extracted binder,
- Determination of the hydrated lime content to determine the recovery rate
- Determination of the deformation resistance at high temperatures by means of pressure expansion test,
- Analysis of the viscosity-temperature behavior of the bituminous mortar specimens prepared from cores.

From the measured values can be drawn insights that lead to a specific statement on the improvement of asphalt properties by the addition of hydrated lime in the long term behavior of the asphalt pavement.

2.1 test track Bräunlingen (L 181) AC 0/11

2.1.1 Recording actual condition of the test track after 11-year lifetime

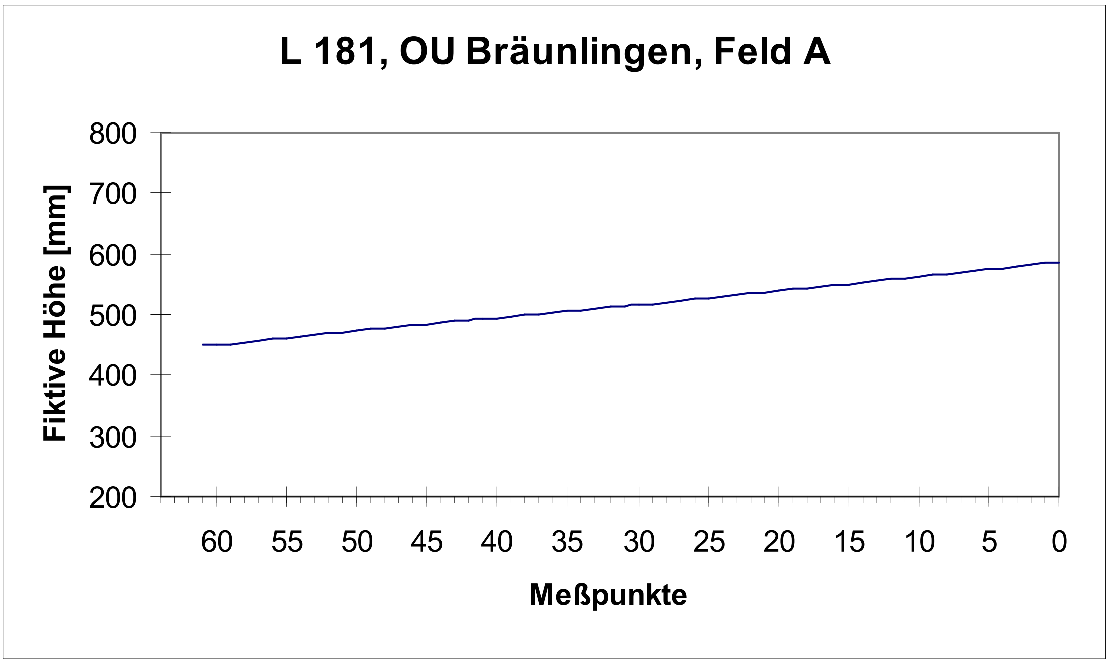
At the four test sections a transverse profile was determined on the place the cores were taken.

Section A

Information about the measuring point	
stationing	0+198
standard cross-section	RQ 10
verbal description of the location	clear track
direction	Bräunlingen
speed limit [km/h]	100
situation of the sampling point	sunny
course of the road	left turn
drainage equipment	left
longitudinal gradient [%]	0,5
transverse slope [%]	4,5

figure 1: view section A, L 181

figure 2: ruts section A, L 181



OU = Bypass; Fiktive Höhe = fictive altitude; Meßpunkte = measuring points

figure 3: transverse profile section A, L 181

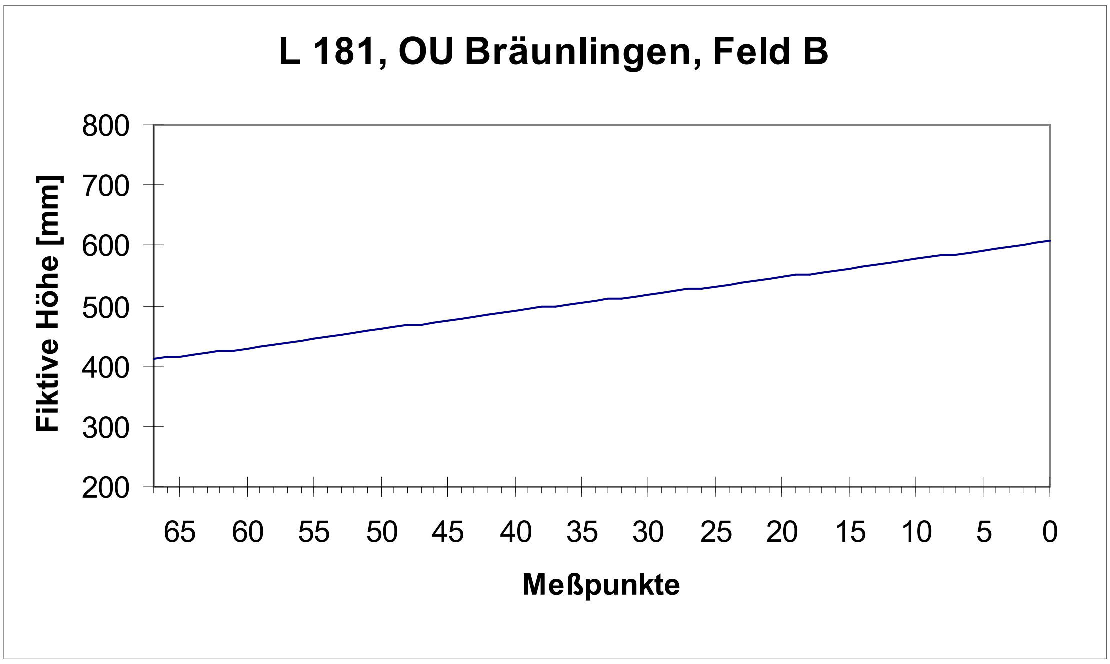
The surface layer of section A has no obvious changes. A rut with 3 mm depth is present on the track.

Section B

Information about the measuring point	
stationing	0+314
standard cross-section	RQ 10
verbal description of the location	clear track
direction	Bräunlingen
speed limit [km/h]	100
situation of the sampling point	sunny
course of the road	left turn
drainage equipment	left
longitudinal gradient [%]	1,0
transverse slope [%]	5,0

figure 4: view section B, L 181

figure 5: ruts section B, L 181



OU = Bypass; Fiktive Höhe = fictive altitude; Meßpunkte = measuring points

figure 6: transverse profile section B, L 181

The surface layer of section B has no obvious changes. A rut with 2-3 mm depth is present on the track.

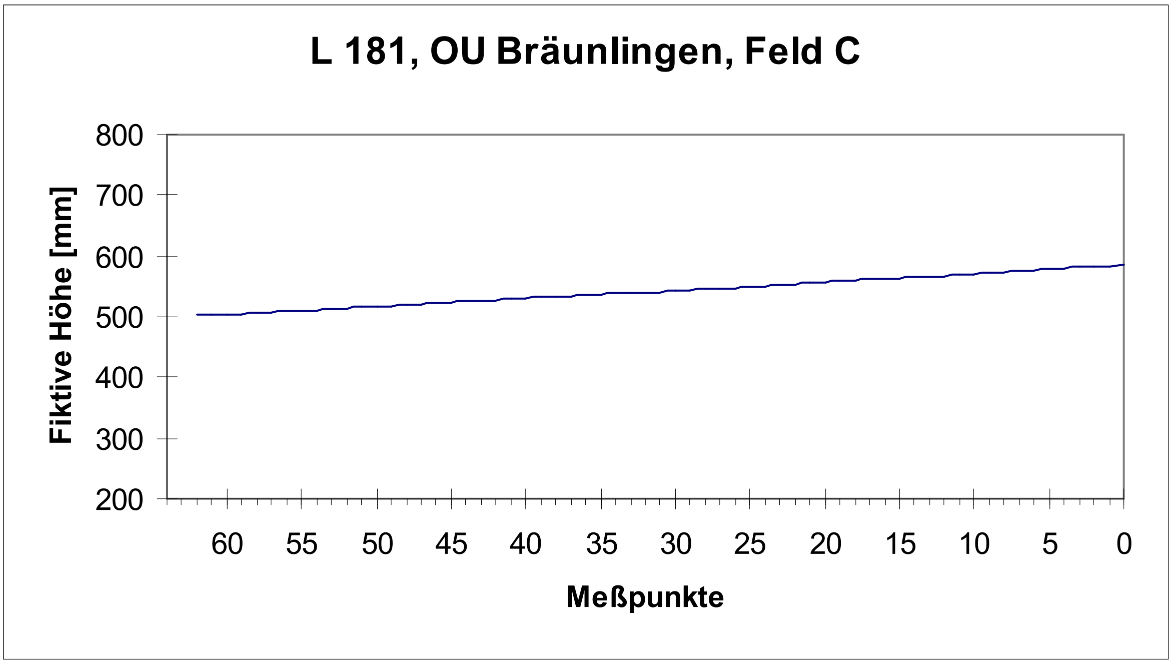
Section C

Information about the measuring point

stationing	0+460
standard cross-section	RQ 10
verbal description of the location	clear track
direction	Bräunlingen
speed limit [km/h]	100
situation of the sampling point	sunny
course of the road	straight line
drainage equipment	left
longitudinal gradient [%]	0,5
transverse slope [%]	2,5

figure 7: view section C, L 181

figure 8: ruts section C, L 181



OU = Bypass; Fiktive Höhe = fictive altitude; Meßpunkte = measuring points

figure 9: transverse profile section C, L 181

The surface layer of section C has no obvious changes. A rut with max 2 mm depth is present on the track.

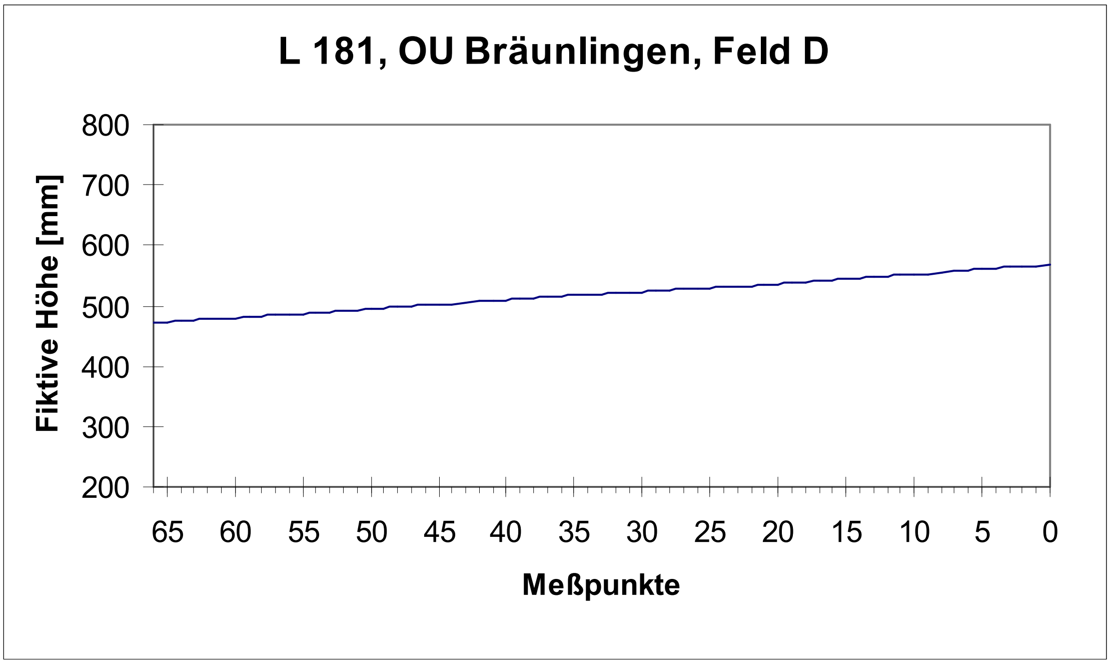
Section D

Information about the measuring point

stationing	0+619
standard cross-section	RQ 10
verbal description of the location	clear track
direction	Bräunlingen
speed limit [km/h]	100
situation of the sampling point	sunny
course of the road	straight line
drainage equipment	left
longitudinal gradient [%]	not measurable
transverse slope [%]	2,5

figure 10: view section D, L 181

figure 11: ruts section D, L 181



OU = Bypass; Fiktive Höhe = fictive altitude; Meßpunkte = measuring points

figure 12: transverse profile section D, L 181

The surface layer of section D has no obvious changes. Ruts are not measurable.

The general impression of the surface of the track was found to be good.

4. Results

4.1 Cores

In table 1 the bulk densities of the cores are given. Using the appropriate specific densities the void contents were calculated. For comparison, the values from the first (1.NU) and second analysis campaign (2.NU) and the results from the control test (KP) are also given.

Section A

Core Nr.	bulk density [g/cm³]	spec. density [g/cm³]	Void [V-%]
2000 (KP)	2,313	2,451	5,6
2002 (1.NU)	2,348	2,448	4,1
2005 (2.NU)	2,390	2,457	2,7
2011 (3.NU)	2,387	2,451	2,6

Section B

Core Nr.	bulk density [g/cm³]	spec. density [g/cm³]	Void [V-%]
2000 (KP)	2,372	2,461	3,6
2002 (1.NU)	2,389	2,467	3,2
2005 (2.NU)	2,390	2,471	3,3
2011 (3.NU)	2,410	2,459	2,0

Section C

Core Nr.	bulk density [g/cm³]	spec. density [g/cm³]	Void [V-%]
2000 (KP)	2,367	2,466	4,0
2002 (1.NU)	2,375	2,461	3,5
2005 (2.NU)	2,393	2,465	2,9
2011 (3.NU)	2,396	2,448	2,1

Section D

Core Nr.	bulk density [g/cm³]	spec. density [g/cm³]	Void [V-%]
2000 (KP)	2,361	2,447	3,5
2002 (1.NU)	2,370	2,471	3,9
2005 (2.NU)	2,396	2,458	2,5
2011 (3.NU)	2,374	2,438	2,6

Table 1: Properties to the original layer

4.2 asphalt analysis

For analyzes, the core samples 1-10 per field summarized. The following tables show the analysis results (2011) with the results of the test, (2000), the first Follow-up (2002) and the second Follow-up (2005).

Section A				
typ of asphalt	AC 0/11	AC 0/11	AC 0/11	AC 0/11
year of analysis	2000 **without hydrated lime**	2002 **without hydra-ted lime**	2005 **without hydrated lime**	2011 **without hydra-ted lime**
Binder Content [M-%]	6,3	6,2	6,2	6,0
Softening point R&B [°C]	55,5	56,0	57,9	54,1
Filler [M-%]	8,2	9,1	9,0	8,8
fine aggregates[M-%]	38,3	36,4	35,7	35,9
crushed coarse aggegates [M-%]	53,5	54,5	55,3	55,3
Marshall specimen bulk density [g/cm³]	2,391	2,399	2,363	2,402
spec. density [g/cm³]	2,451	2,448	2,457	2,451
void contentt [V-%]	2,4	2,0	3,8	2,0
Marshall stability [kN]	10,5	12,0	12,0	11,5
flow value [mm]	3,4	3,6	3,5	4,0
Proportion of hydrated lime with respect to filler content [%]	-	-	-	-

Table 2: Comparison of the analysis results of the cores at AB 0/11 from section A without hydrated lime for the observation period of 11 years

Section B				
typ of asphalt	AC 0/11	AC 0/11	AC 0/11	AC 0/11
year of analysis	2000 **without hydrated lime**	2002 **without hydra-ted lime**	2005 **without hydra-ted lime**	2011 **without hydra-ted lime**
Binder				
Content [M-%]	6,2	5,8	6,0	5,7
Softening point R&B [°C]	55,5	56,0	56,5	53,8
Filler [M-%]	8,9	10,1	10,0	9,7
fine aggregates[M-%]	36,8	35,6	34,6	34,3
crushed coarse aggegates [M-%]	54,3	54,3	55,4	56,0
Marshall specimen				
bulk density [g/cm³]	2,405	2,407	2,393	2,402
spec. density [g/cm³]	2,461	2,467	2,471	2,459
void contentt [V-%]	2,2	2,5	3,2	2,3
Marshall stability [kN]	11,0	12,0	11,5	12,5
flow value [mm]	3,4	3,6	3,5	4,0
Proportion of hydrated lime with respect to filler content [%]	-	-	-	-

Table 3: **Comparison of the analysis results of the cores at AB 0/11 from section B without hydrated lime for the observation period of 11 years**

Section C				
typ of asphalt	AC 0/11	AC 0/11	AC 0/11	AC 0/11
year of analysis	2000 **with hydrated lime**	2002 **with hydrated lime**	2005 **with hydrated lime**	2011 **with hydrated lime**
Binder				
Content [M-%]	5,8	5,8	5,8	5,7
Softening point R&B [°C]	49,5	49,0	51,9	51,5
Filler [M-%]	9,4	10,0	10,1	10,1
fine aggregates[M-%]	33,5	35,6	34,7	34,2
crushed coarse aggegates [M-%]	57,1	54,4	55,5	55,7
Marshall specimen				
bulk density [g/cm³]	2,403	2,408	2,381	2,400
spec. density [g/cm³]	2,466	2,461	2,465	2,448
void contentt [V-%]	2,6	2,2	3,4	2,0
Marshall stability [kN]	10,5	13,5	11,0	11,5
flow value [mm]	3,8	3,5	4,0	4,5
Proportion of hydrated lime with respect to filler content [%]	-	19,8	22,2	22,7
Recovery rate [%]	-	83,9	93,7	95,8

Table 4: **Comparison of the analysis results of the cores at AB 0/11 from section C with hydrated lime for the observation period of 11 years**

Section D				
typ of asphalt	AC 0/11	AC 0/11	AC 0/11	AC 0/11
year of analysis	2000 **with hydrated lime**	2002 **with hydrated lime**	2005 **with hydrated lime**	2011 **with hydrated lime**
Binder Content [M-%] Softening point R&B [°C]	 6,1 49,5	 6,0 49,0	 6,0 52,0	 6,0 50,0
Filler [M-%] fine aggregates[M-%] crushed coarse aggegates [M-%]	9,1 35,6 55,3	9,6 34,2 56,2	9,8 34,9 55,4	9,6 34,3 56,1
Marshall specimen bulk density [g/cm³] spec. density [g/cm³] void contentt [V-%] Marshall stability [kN] flow value [mm]	 2,401 2,447 1,8 10,5 4,2	 2,413 2,471 2,1 13,5 3,5	 2,372 2,458 3,5 10,5 4,2	 2,407 2,438 1,3 11,5 4,5
Proportion of hydrated lime with respect to filler content [%]	-	20,7	22,5	22,6
Recovery rate [%]	-	87,7	90,5	91,1

Table 5: **Comparison of the analysis results of the cores at AB 0/11 from section D with hydrated lime for the observation period of 11 years**

4.3 expansion pressure test

The address of the deformation behavior in heat on two to be compared to the AB was "technical testing for asphalt in road construction (TP A-StB) part: Deformation behavior of rolled asphalt with heat using the expansion pressure test, 1999 Edition".

In a expansion pressure test, the prepared specimen are tested at a constant temperature with a tensile expansion load in the direction of the compactionDuring the test, before each new load impulse the permanent deformation of the specimen in load direction is recorded. From the resulting impulse creep curve (cumulative sum of the permanent deformation), the deformation behavior of asphalt descriptive feature sizes strain rate $\acute{\varepsilon}_w$ *, load impulse number n_w and strain $\acute{\varepsilon}_w$ in the watershed identified. The lower the strain rate $\acute{\varepsilon}_w$ * is, the higher the heat resistance.

From the reheated cores were manufactured according to DIN 1996 part 4 Marshall specimen. These were ground to the floor space in a disk grinder orthogonal plane-parallel. To minimize the friction on the pressure surfaces and reach the full height of the specimen, a uniform transverse strain, after drying of the ground surfaces are each 0.2 to 0.3 grams silicone grease "Baysilone medium viscosity" (adhesive) is applied uniformly and with graphite flakes "S 40 92/94" (lubricant) sprinkled everywhere. Excess graphite is then removed by gently shaking the specimen again.

The tests were carried out in the Rottweiler hydropulser. The test conditions are listed in table 6 below:

test parameter	**expansion pressure test**
test temperature [°C]	+ 50 (± 0,3 K)
tempering	air bath
underload, axial [kN]	0,200 (0,025 N/mm²)
upperload, axial [kN]	1,571 (0,200 N/mm²)
duration of the underload [s]	1,5
duration of the upperload [s]	0,2
cycle time [s] (load duration + load break)	1,7
loading image	Sinusoidal threshold load (haversine) with load break

Table 6: test conditions in expansion pressure test

Strain rates of the expansion pressure test:

In table 7 the values from the control test (2000), the first (2002), the second (2005) and the third analysis campaign (2011) are given.

The impulse creep curves are shown in annex A

	Dehnungsrate ε_W * in ‰ / n			
	2011	2005	2002	2000
Section A	**$3,66*10^{-4}$**	$8,03*10^{-4}$	$5,38*10^{-4}$	$7,20*10^{-4}$
Section B	**$3,41*10^{-4}$**	$6,07*10^{-4}$	$3,28*10^{-4}$	$4,73*10^{-4}$
Section C	**$2,99*10^{-4}$**	$3,99*10^{-4}$	$5,65*10^{-4}$	$4,98*10^{-4}$
Section D	**$2,92*10^{-4}$**	$5,35*10^{-4}$	$5,68*10^{-4}$	$5,26*10^{-4}$

Table 7: **strain rates of the expansion pressure test AC 0/11**

4.4 tensile viscosity:

Table 8 shows the temporal representation of the tensile retardation tests of AC 0/11

The retardation curves are shown in annex B.

	size [mm]			ϑ [°C]	σ [N/mm²]	t [min]		ν [Ns/mm²]			
	height	width	length			load	release	2000	2002	2005	2011
section A without hydrated lime	40	40	100	30,0	0,025	60,0	10,0	$4,04*10^{4}$ $3,69*10^{4}$	$2,67*10^{4}$ $2,84*10^{4}$	$5,34*10^{4}$ $5,53*10^{4}$	$6,80*10^{4}$ $6,10*10^{4}$
								$3,87*10^{4}$	$2,76*10^{4}$	$5,44*10^{4}$	$6,45*10^{4}$
								mean value			
section D with hydrated lime								$4,59*10^{4}$ $4,70*10^{4}$	$4,15*10^{4}$ $3,95*10^{4}$	$5,48*10^{4}$ $4,83*10^{4}$	$8,19*10^{4}$ $6,07*10^{4}$
								$4,65*10^{4}$	$4,05*10^{4}$	$5,16*10^{4}$	$7,13*10^{4}$
								mean value			

Table 8: tensile viscosity of AC 0/11

5. Evaluation of test results

5.1 At testing the cross-sections, there were only small rut depths. For section **D**, with an optimum binder content and 3 M. -% hydrated lime, no deformations in the wheel-rolling tracks can be determined.

5.2 There is a tendency at all test sections: The void content of asphalt-concrete surface layer decreases - due to the traffic impacts – in the course of time. Section **D** shows the slight changes with an optimum binder content and 3-M -% hydrated lime, in which the void contents at a level of 2.6 V. - % stagnate since 2005.

5.3 The results of cyclic compressive strength on Marshall Specimen show with time decreasing strain rates. This means that even at relatively low void content in the surface layer high heat resistance is available with strain rates:

Section A and B (mean value of 3.54 * 10^{-4} ‰)

Section C and D (mean value of 2.96 * 10^{-4} ‰)

5.4 The results of cyclic compressive strengths correspond with the results of tensile viscosity.

The results from the tensile retardation test of the original surface layers shown an increasing from the control test (2000) to the third analysis campaign (2011) with a value of 6.45 * 10-4 Ns / mm ² (section A) and a value of 7.13 * 10-4 Ns / mm ² (section D).

5.5 Softening point’s R&B were determined on extracted binder

Section A and B (mean value of 54.0 °C)

Section C and D (mean value of 51.8 °C

5.6 The addition of hydrated lime gives a higher thermal stability without increasing the softening point of the extracted binder.
However, the grading of the aggregates, the bitumen 50/70 and the low void content of the asphalt concrete layer is not susceptible to embrittlement, because even without the addition of hydrated lime the softening point of the extracted binder increases not so much.

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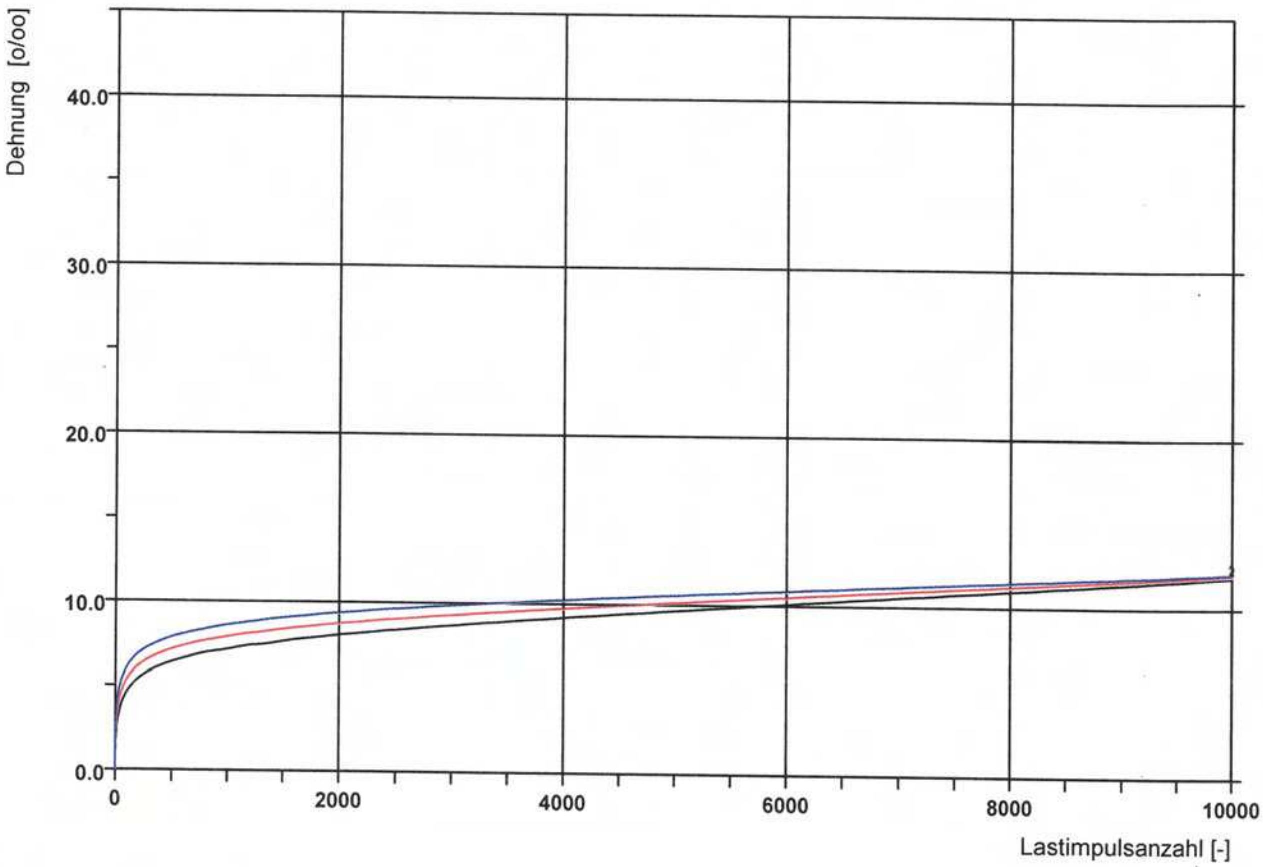
Prof. Dr. Kurt Schellenberg Dipl.-Ing.(FH) Rainer Braun

Annex A

Impulse creep curves

Einaxialer Druckschwellversuch

FA AIF AB 0/11 Bräunlingen Feld A
BK 2011



Ergebnisse

Datensatz	Probe	Versuchs-temperatur	Probekörperhöhe	Unterlast	Oberlast	ε_W^*	ε_W	n_W
		[°C]	[mm]	[kN]	[kN]	[°/₀₀ /n]	[°/₀₀]	[-]
1 (schwarz)	kh11-a1	50.0	60.00	0.200	1.571	4.208e-04	10.20	6217
2 (rot)	kh11-a2	50.0	60.00	0.200	1.571	3.646e-04	10.57	6248
3 (blau)	kh11-a3	50.0	60.00	0.200	1.571	3.125e-04	10.91	6200

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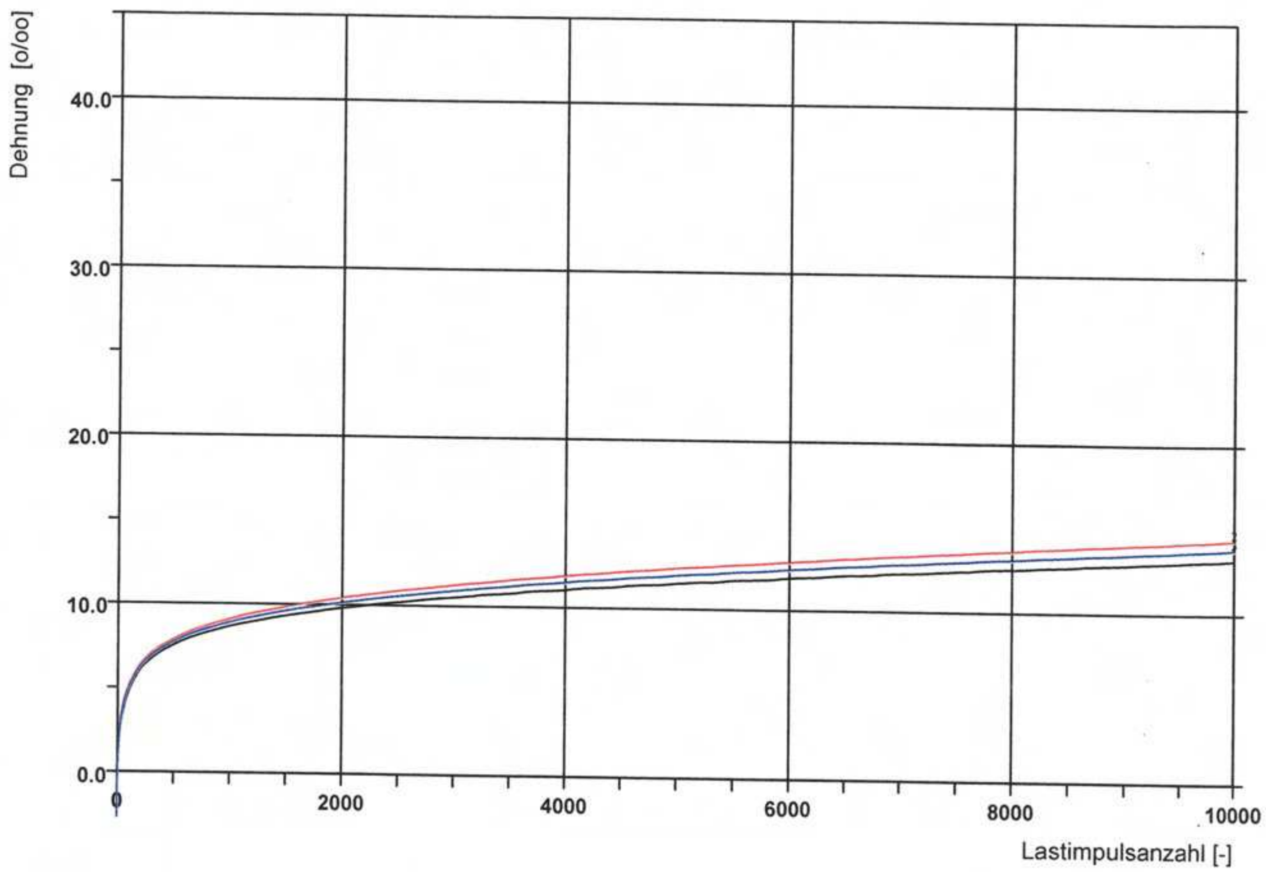
FA AIF AB 0/11 Bräunlingen Feld B
BK 2011



Ergebnisse

Datensatz	Probe	Versuchs-temperatur	Probekör-perhöhe	Unterlast	Oberlast	ε_W^*	ε_W	n_W
		[°C]	[mm]	[kN]	[kN]	[°/₀₀ /n]	[°/₀₀]	[-]
1 (schwarz)	kh11-b1	50.0	60.00	0.200	1.571	2.792e-04	12.12	6567
2 (rot)	kh11-b2	50.0	60.00	0.200	1.571	4.000e-04	13.04	6550
3 (blau)	kh11-b3	50.0	60.00	0.200	1.571	3.438e-04	12.58	6563

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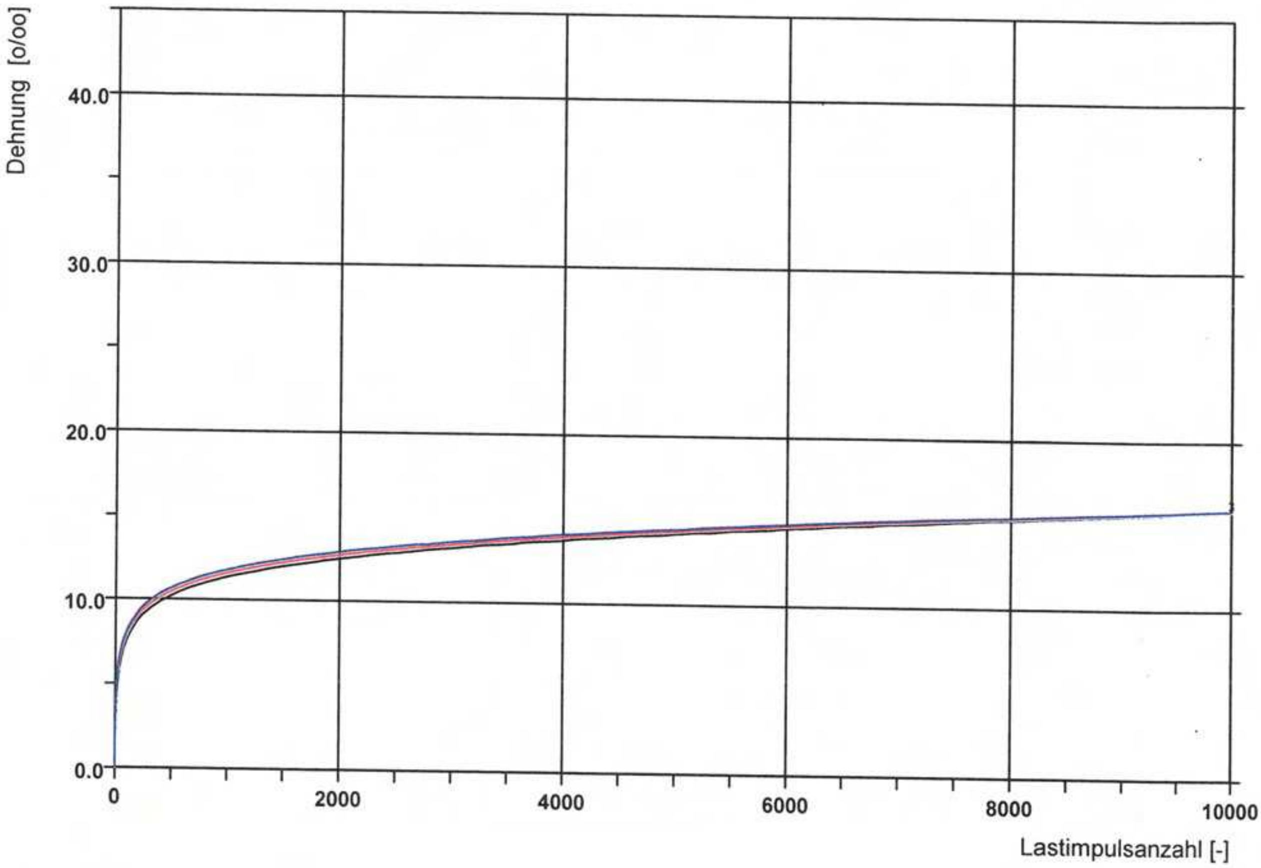
Einaxialer Druckschwellversuch

FA AIF AB 0/11 Bräunlingen Feld C
BK 2011



Ergebnisse

Datensatz	Probe	Versuchs-temperatur	Probekör-perhöhe	Unterlast	Oberlast	ε_W^*	ε_W	n_W
		[°C]	[mm]	[kN]	[kN]	[°/₀₀ /n]	[°/₀₀]	[-]
1	kh11-c1	50.0	60.00	0.200	1.571	2.667e-04	14.82	6548
2	kh11-c2	50.0	60.00	0.200	1.571	3.083e-04	14.91	6553
3	kh11-c3	50.0	60.00	0.200	1.571	3.208e-04	14.97	6502

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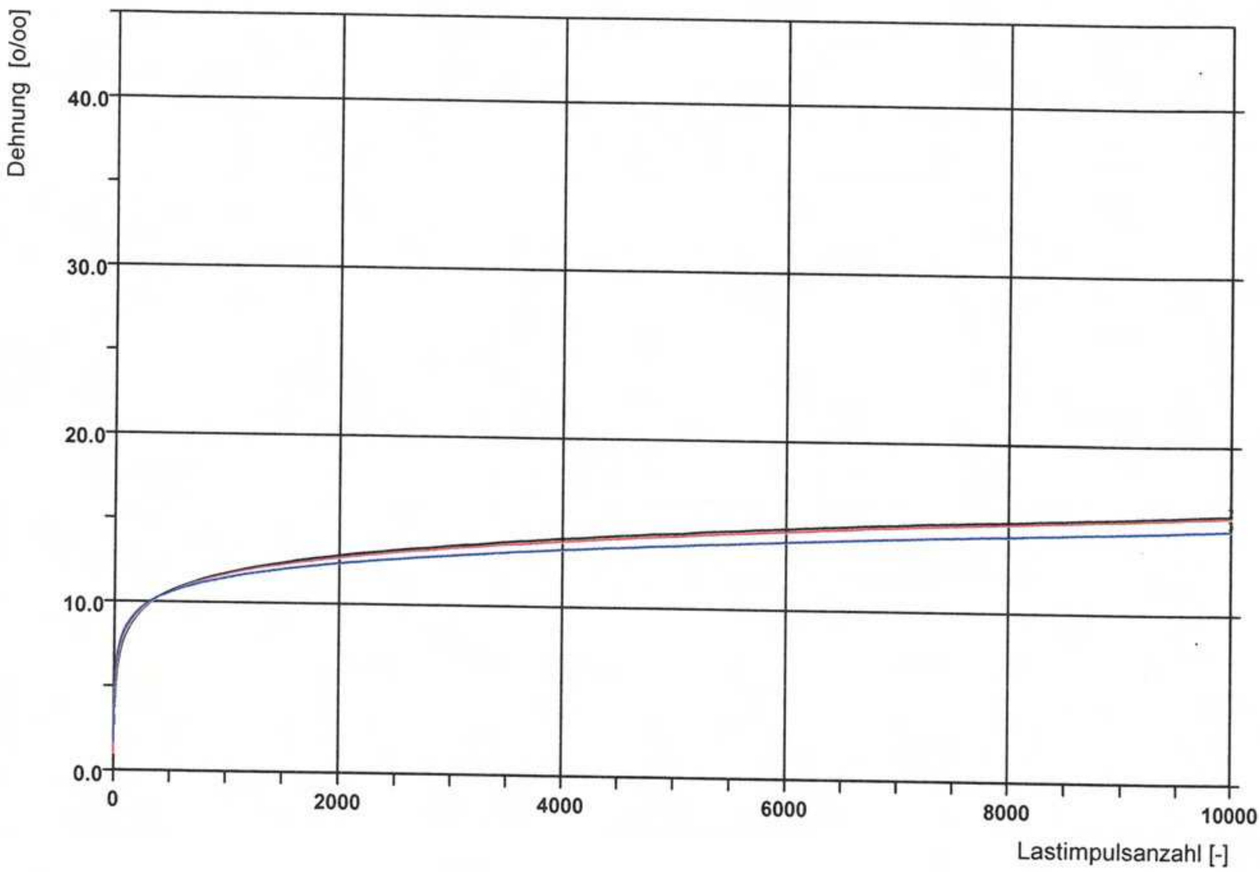
Einaxialer Druckschwellversuch

FA AIF AB 0/11 Bräunlingen Feld D
BK 2011



Ergebnisse

Datensatz	Probe	Versuchs-temperatur	Probekör-perhöhe	Unterlast	Oberlast	ε_W^*	ε_W	n_W
		[°C]	[mm]	[kN]	[kN]	[°/₀₀ /n]	[°/₀₀]	[-]
1 (black)	kh11-d1	50.0	60.00	0.200	1.571	3.375e-04	15.00	6589
2 (red)	kh11-d2	50.0	60.00	0.200	1.571	2.792e-04	14.90	6884
3 (blue)	kh11-d3	50.0	60.00	0.200	1.571	2.604e-04	14.19	6731

Annex B

Retardation curves

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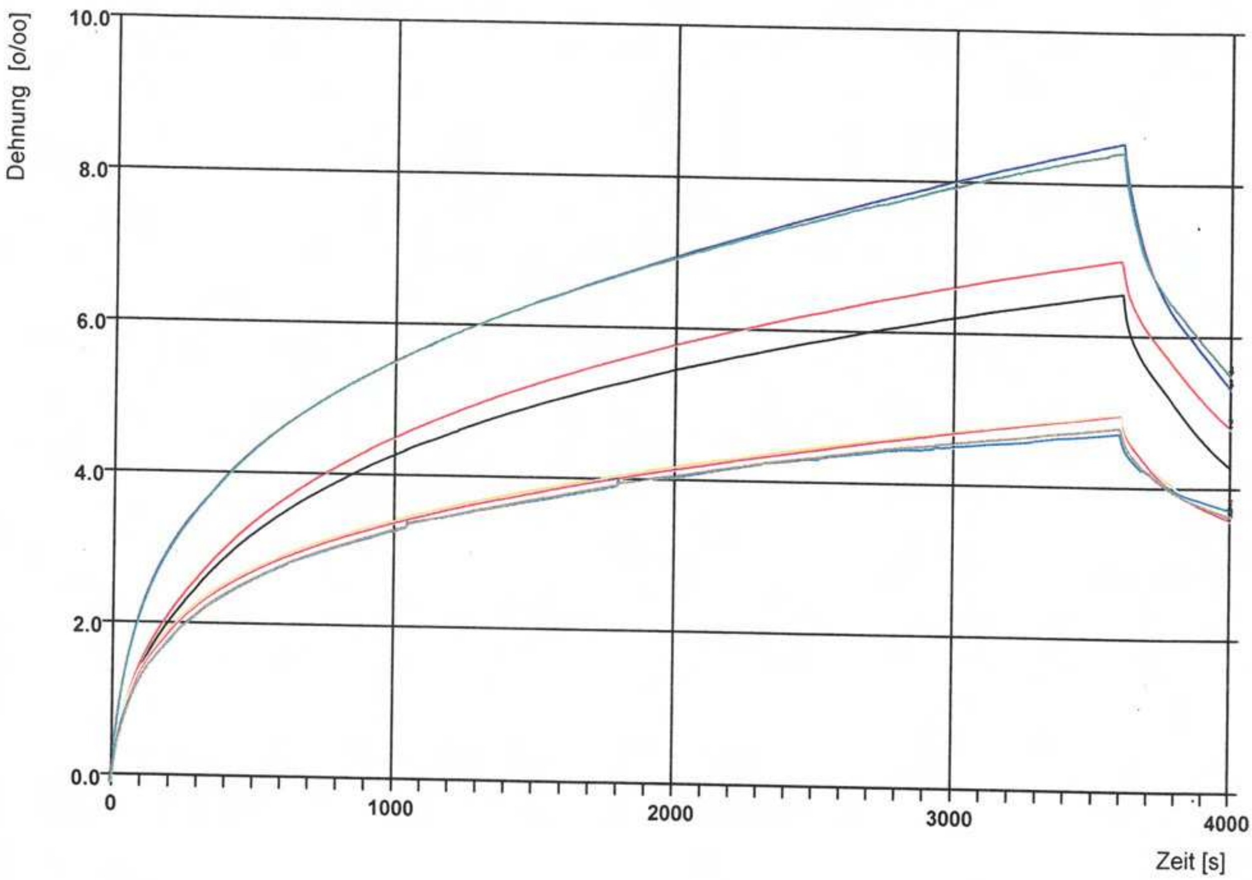
Zugretardationsversuch

FA AIF AB 0/11 Bräunlingen Feld A
Datensatz : Nr.1+2 EP 2001, 3+4 BK 2002 , 5+6 BK 2005 , 7+8 BK 2011



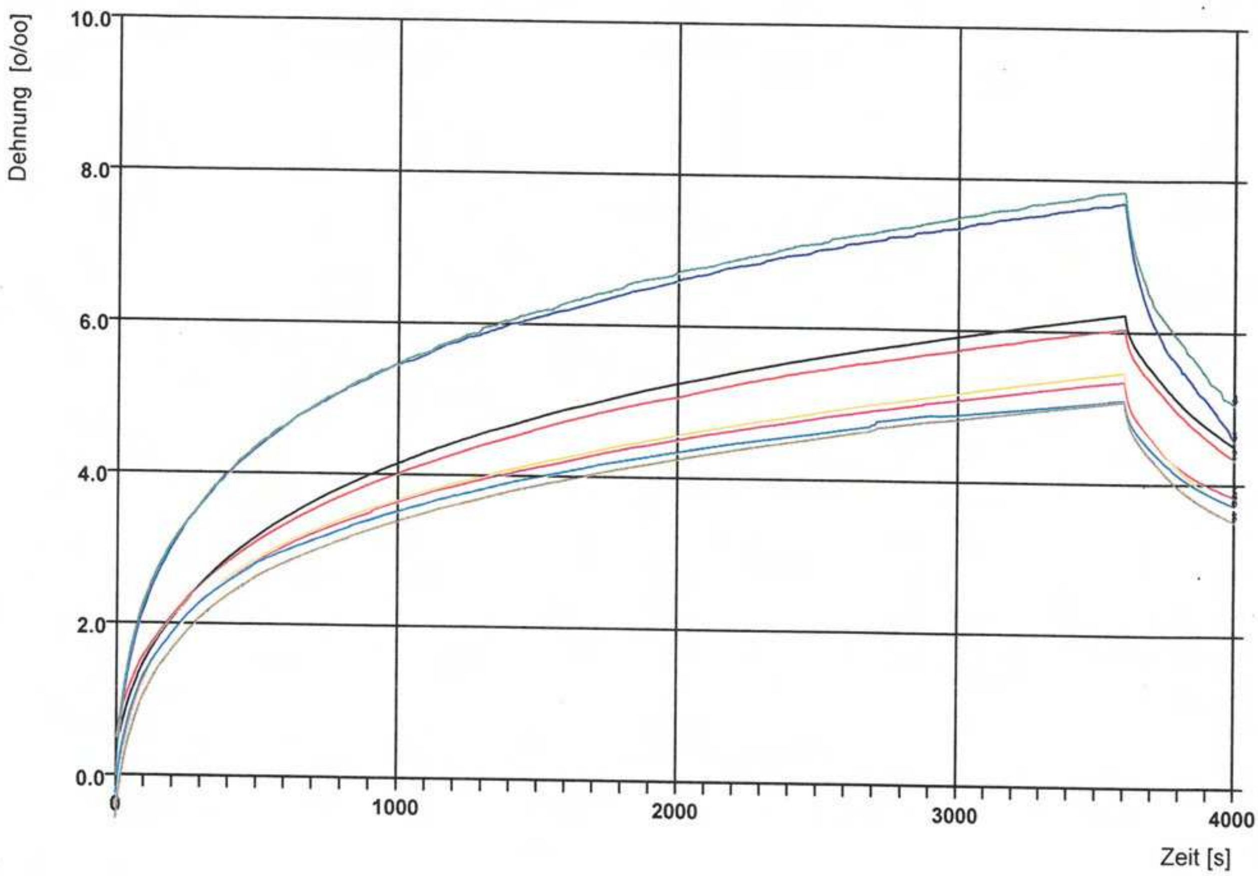
Ermittlung der Zugviskosität über die Steigung

Datensatz	Probe	Versuchs-temperatur	Spannung	Dauer der Belastung	Dauer der Entlastung	Zugviskosität
		[°C]	[N/mm²]	[min]	[min]	[N·s/mm²]
1	02371	30.0	0.025	60	10	4.0422e+04
2	02372	30.0	0.025	60	10	3.6944e+04
3	02366	30.0	0.025	60	10	2.6717e+04
4	02369	30.0	0.025	60	10	2.8360e+04
5	02665	30.0	0.025	60	10	5.3433e+04
6	02666	30.0	0.025	60	10	5.5333e+04
7	03073	30.0	0.025	60	10	6.8033e+04
8	03077	30.0	0.025	60	10	6.1029e+04

Institut für Materialprüfung · Dr. Schellenberg Rottweil GmbH

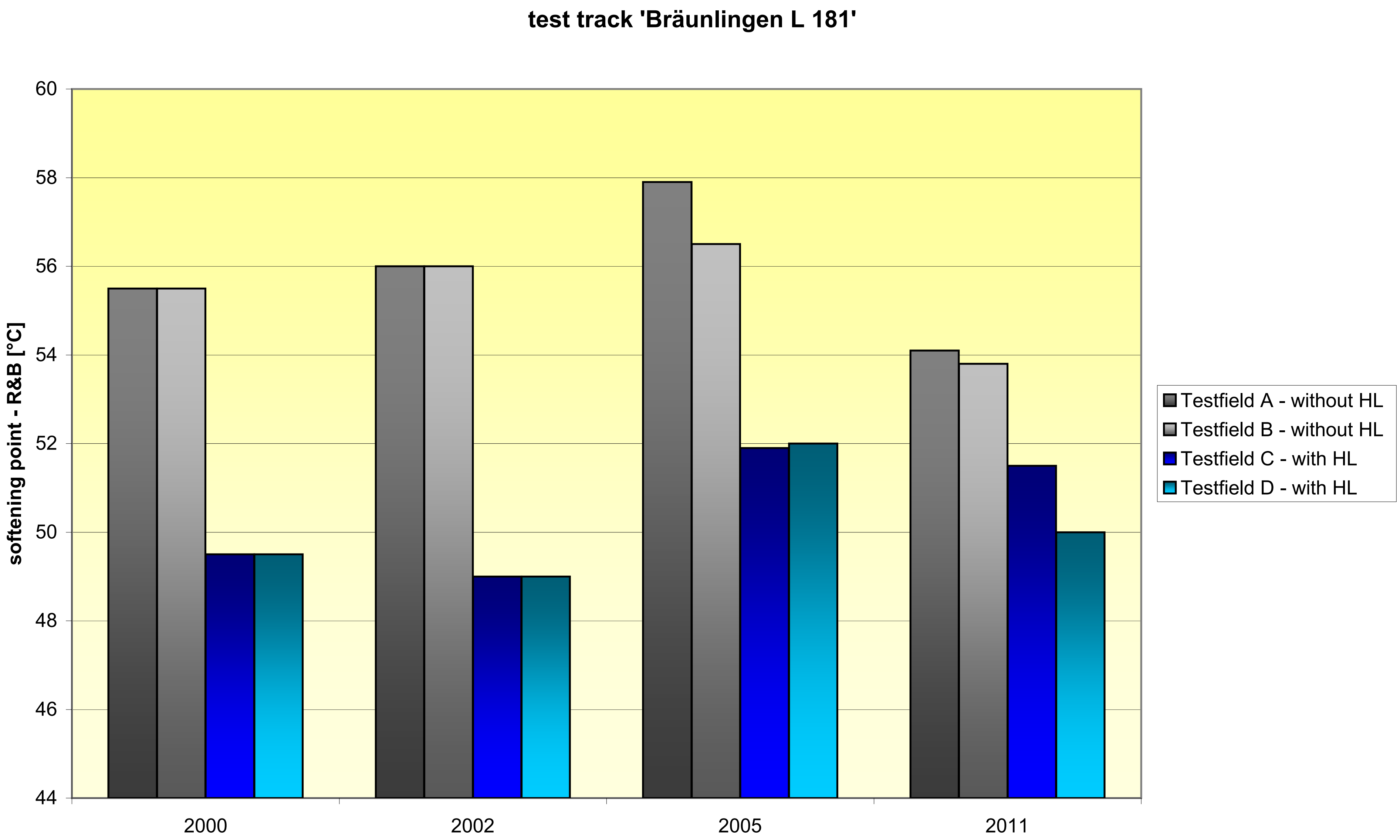
Zugretardationsversuch

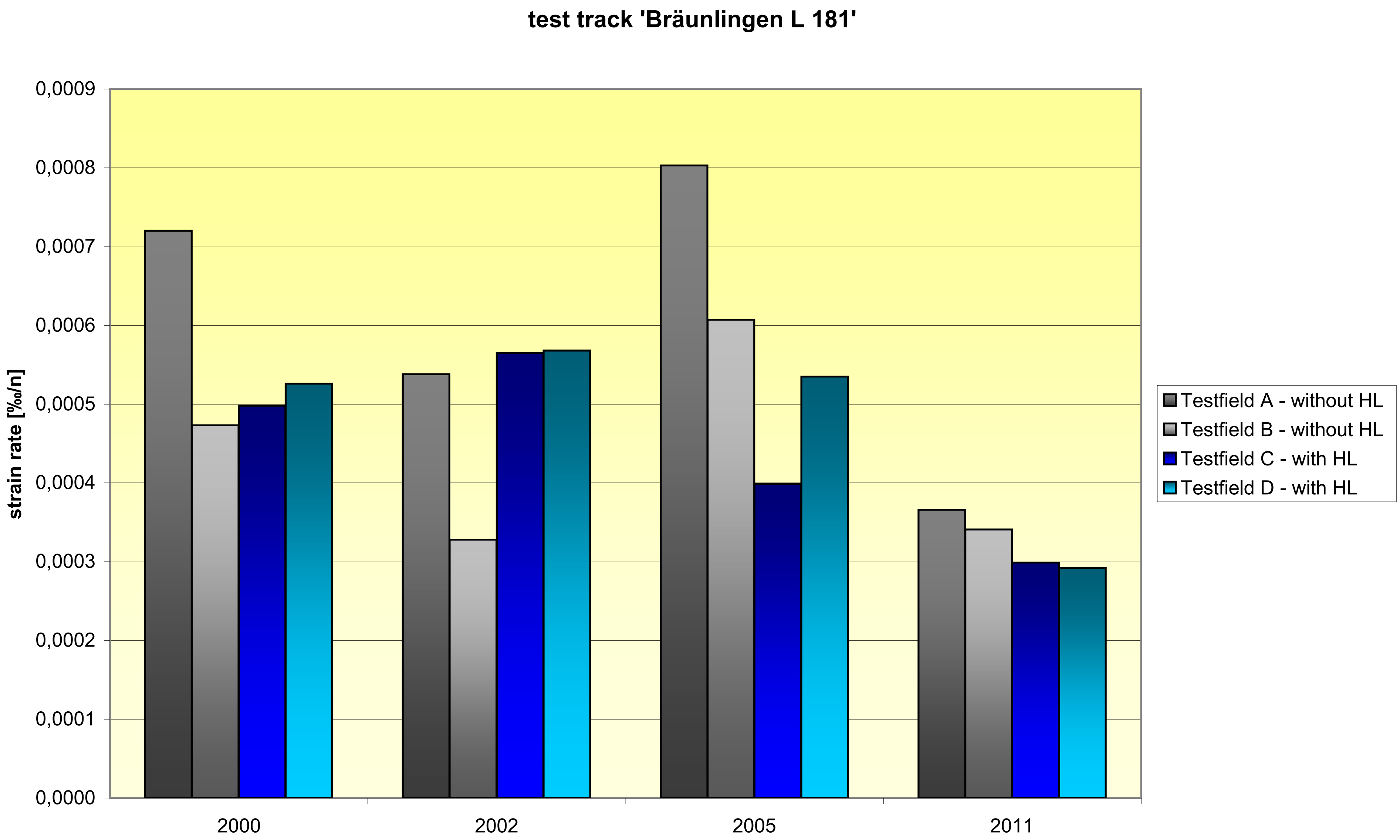
FA AIF AB 0/11 Bräunlingen Feld D
Datensatz : Nr.1+2 EP 2001, 3+4 BK 2002 , 5+6 BK 2005 , 7+8 BK 2011

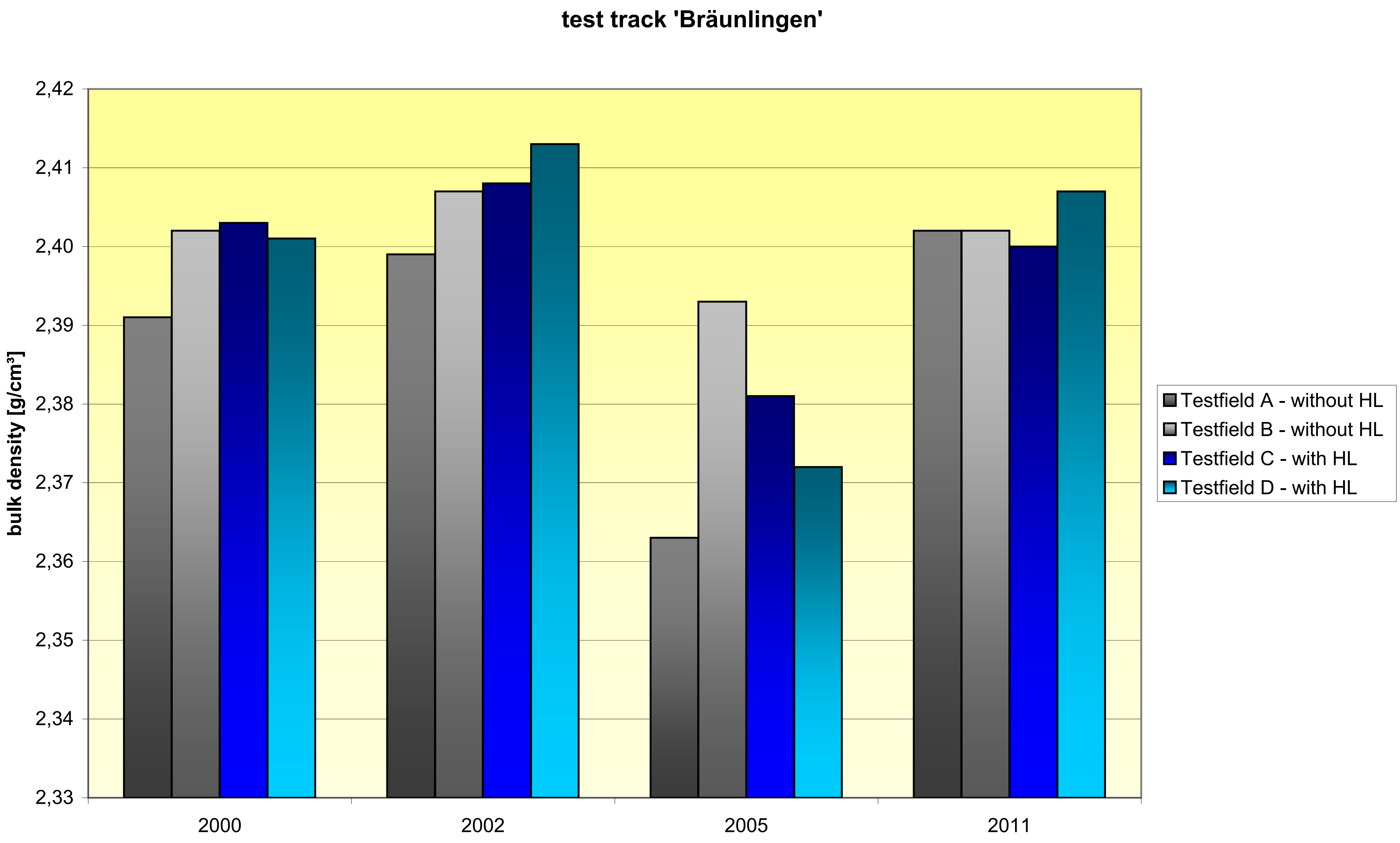


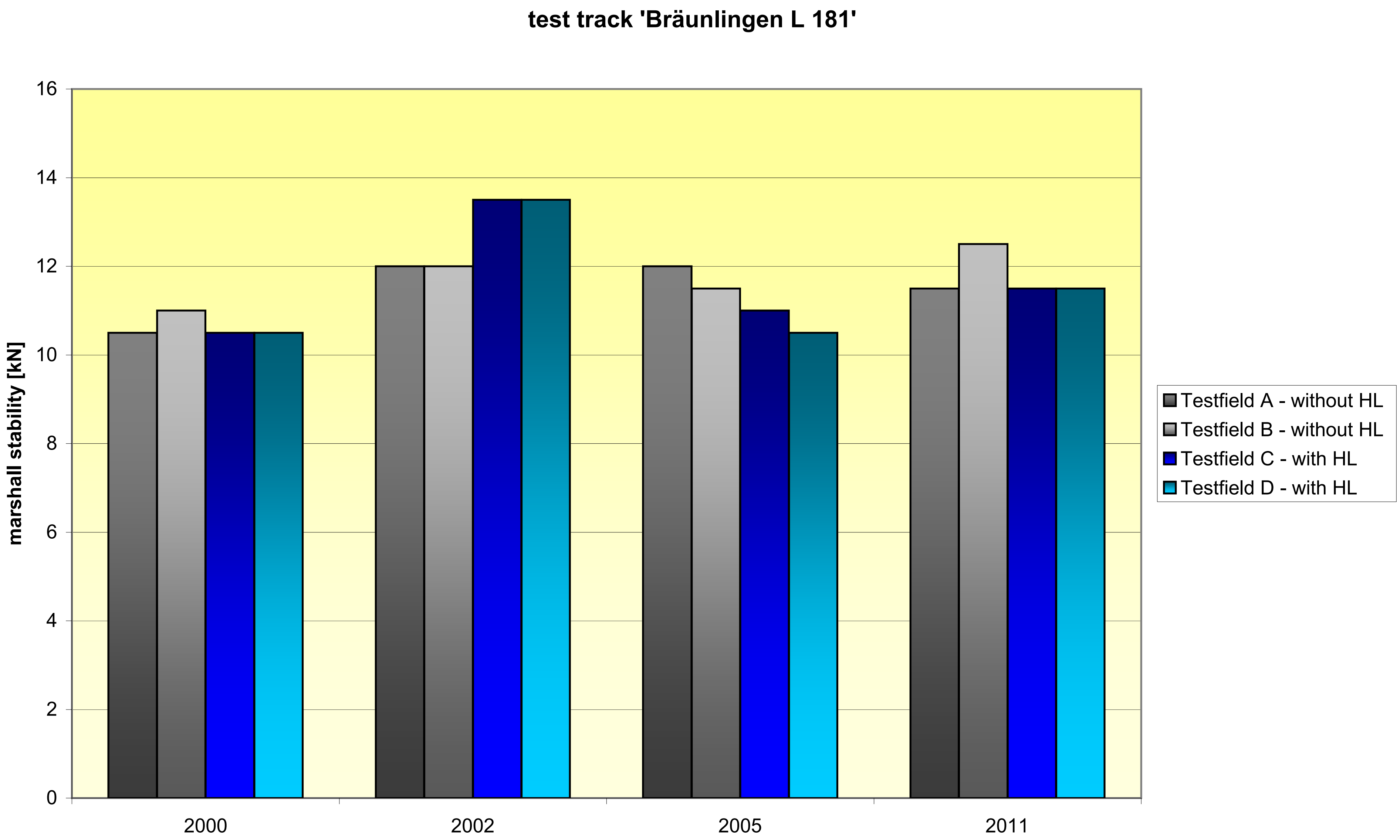
Ermittlung der Zugviskosität über die Steigung

Datensatz		Probe	Versuchs-temperatur	Spannung	Dauer der Belastung	Dauer der Entlastung	Zugviskosität
			[°C]	[N/mm²]	[min]	[min]	[N·s/mm²]
1	schwarz	02374	30.0	0.025	60	10	4.5941e+04
2	rot	02375	30.0	0.025	60	10	4.6981e+04
3	blau	02377	30.0	0.025	60	10	4.1500e+04
4	grün	02378	30.0	0.025	60	10	3.9524e+04
5	pink	02668	30.0	0.025	60	10	5.4846e+04
6	gelb	02670	30.0	0.025	60	10	4.8256e+04
7	hellblau	03076	30.0	0.025	60	10	8.1908e+04
8	braun	03080	30.0	0.025	60	10	6.0732e+04

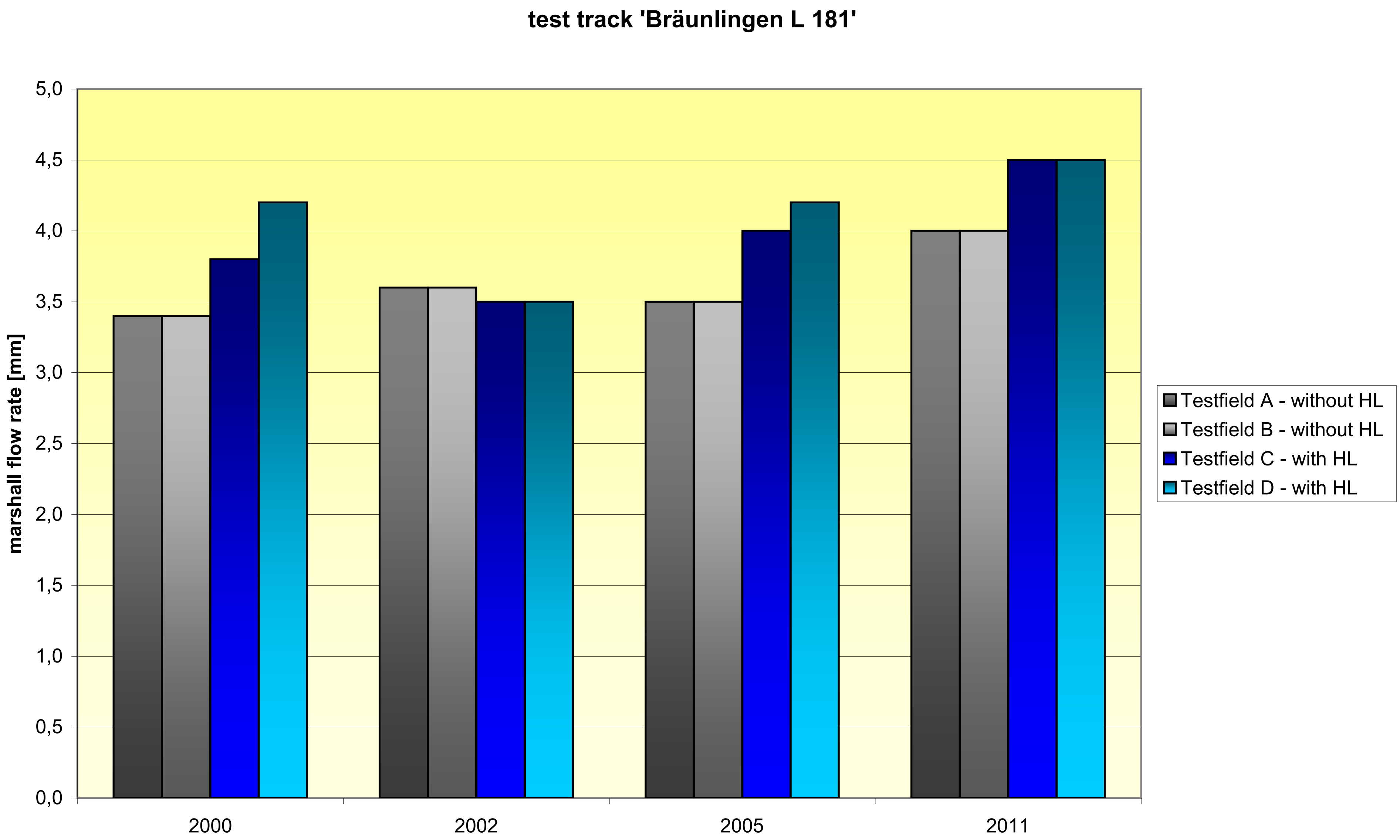

test track 'Bräunlingen L 181'
softening point - R&B [°C]
60
58
56
54
52
50
48
46
44
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL

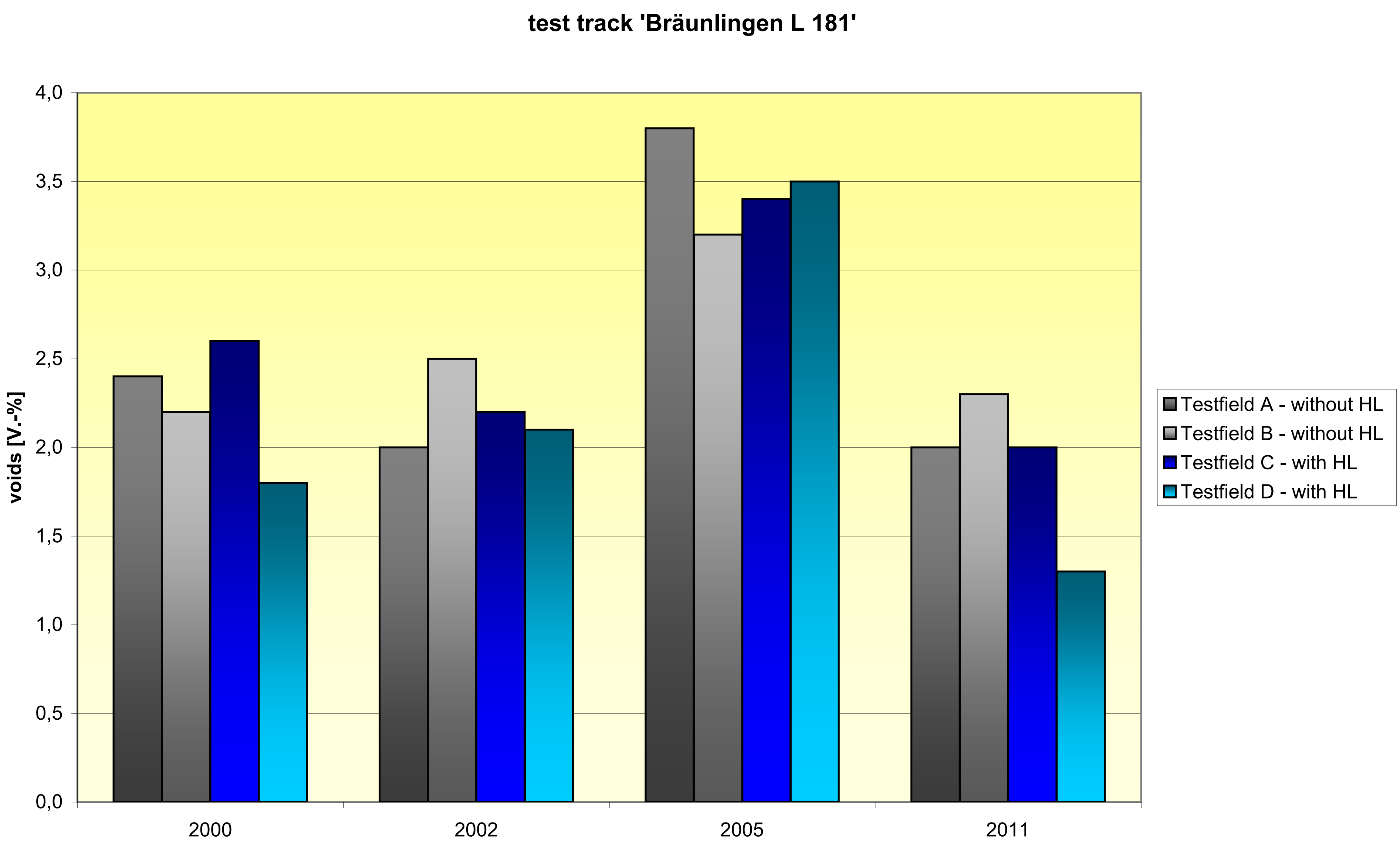

test track 'Bräunlingen L 181'
strain rate [‰/n]
0,0009
0,0008
0,0007
0,0006
0,0005
0,0004
0,0003
0,0002
0,0001
0,0000
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL

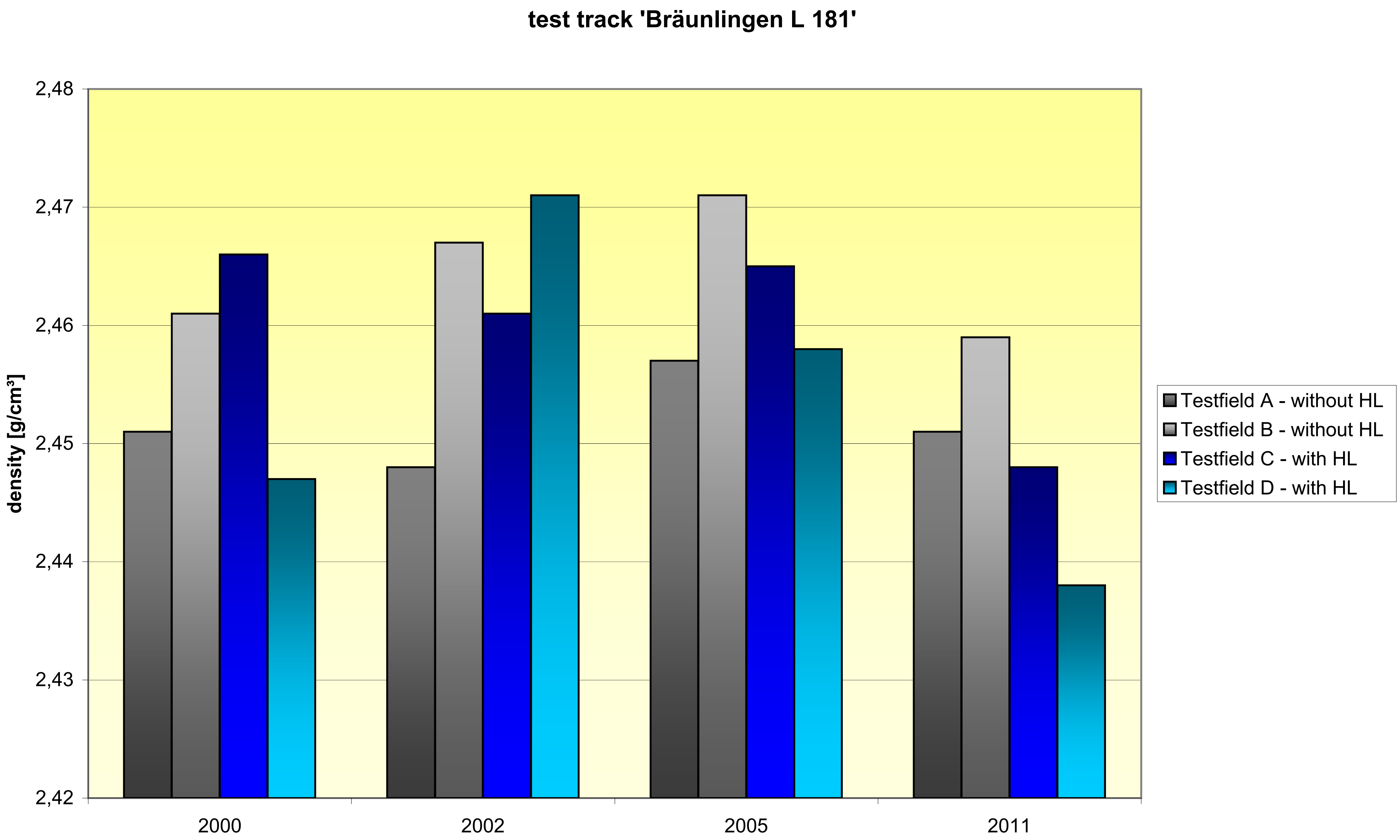

test track 'Bräunlingen'
bulk density [g/cm³]
2,42
2,41
2,40
2,39
2,38
2,37
2,36
2,35
2,34
2,33
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL



test track 'Bräunlingen L 181'
marshall stability [kN]
0
2
4
6
8
10
12
14
16
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL


test track 'Bräunlingen L 181'
marshall flow rate [mm]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL


test track 'Bräunlingen L 181'
voids [V.-%]
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL


test track 'Bräunlingen L 181'
2,48
2,47
2,46
2,45
2,44
2,43
2,42
density [g/cm³]
2000
2002
2005
2011
Testfield A - without HL
Testfield B - without HL
Testfield C - with HL
Testfield D - with HL