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RILEM interlaboratory test on pavement performance prediction and evaluation

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ABSTRACT: The former RILEM TC 182 PEB organized 1997 an international interlaboratory test on pavement performance, prediction and evaluation. The aim was to predict the expected damages after 10 years on the basis of traffic and climatic data. Two sections in Austria and Portugal were constructed and test samples were cut from the pavement and send to the different laboratories. 13 laboratories of 12 countries participated in the study and gave performance predictions according their own methods and standards. The report which summarizes the results in detail is available on the RILEM web site. RILEM TC 206 ATB TG 4 continued the long term observation. Unfortunately, only the Austrian section in Villach could be monitored as planned, since the Portuguese section had problems in the data supply. In 2007 the Austrian road administration stopped the observation of the test section in Villach. The paper summarises the actual road condition and compares it to the predicted performance.

1 INTRODUCTION

With increasing number of vehicles and axle loads on motorways the long term performance of asphalt pavements and its prediction are gaining more and more importance. Numerous long term projects in many countries have been established during recent years to monitor and evaluate pavement performance. In 1997 the former RILEM TC 182 PEB organized an international interlaboratory test on pavement performance prediction and evaluation with laboratories participating from around the world. For this purpose, two test sections, one in a moderate climate (Portugal) and another one in a climate with high summer and low winter temperatures (Austria), were constructed. Test slabs were cut from the pavement and samples send to different laboratories, which were asked to predict the damage for a ten years period (Partl & Piber 2001). The prediction was based on testing the distributed asphalt samples as well as the provided traffic and climate data. Each laboratory was asked to use its own methods and test procedures. Meanwhile the test sections were further monitored and eventually the predicted behavior was compared to the in situ performance. Since only one of the sections, the section in Villach (Carinthia), Austria, could be monitored over the whole observation period, the condition of this section after ten years trafficking was compared to the predicted performance.

2 TEST SECTION

The 100 m long test section was located at an altitude of 500 m above sea level on the motorway “Tauern Autobahn A 10” on the carriageway to Salzburg. The carriageway consisted of two 3.75 m wide lanes and a hard shoulder (emergency lane). The longitudinal gradient was 0.5%. and the cross fall was 3.4%. The motorway runs on an 8 m high embankment and follows a slight left bend with a radius 2500 m. There is a speed restriction of 100 km/h and a no passing zone for trucks. 1997 a base course (160 mm) and a wearing course (35 mm) were laid and the construction work finished (figure 1).

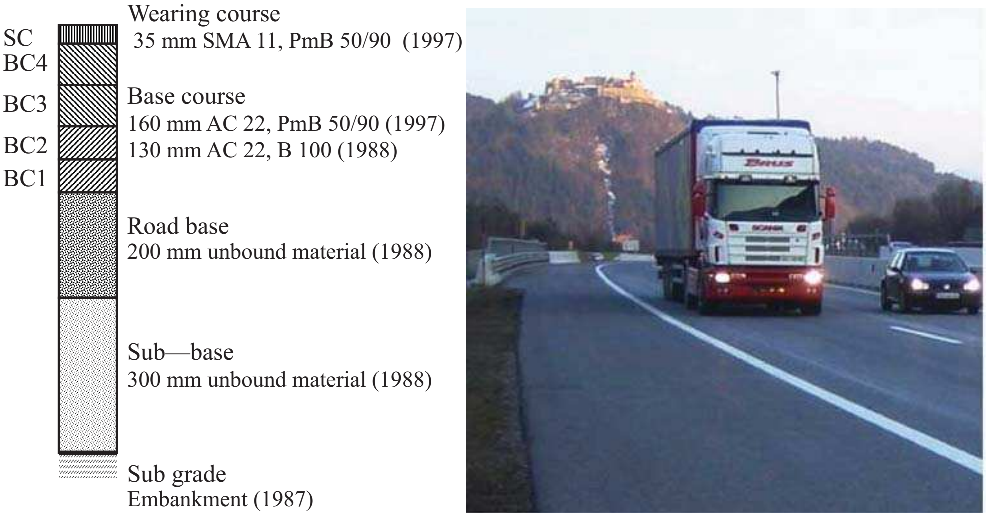

Figure 1. Pavement of the test section and year of construction.

3 LABORATORY TESTS AND PREDICTION

13 laboratories of 12 countries participated on a voluntary basis in this performance prediction. The laboratories received asphalt samples (250 × 550 × 325 mm) cut from the pavement for mechanical testing and evaluation. Additionally, information concerning climatic conditions (meteorological data), traffic census data including heavy traffic data and the annual growth rate of traffic were given.

All laboratories were asked to conduct their testing and evaluation based on their own national standards and methods. Their damage prediction for a 10 years period had to be characterized in terms of level of severeness A to D the following damage types: rutting, single cracking, net cracking and surface defects.

Since the laboratories tested the different layers either separately or as multilayer system and the test equipment and conditions differed considerably, the results of could not be compared in a direct way.

Table 1 shows the categorized performance prediction (A…C) by the participating laboratories:

Regarding the damage types “single cracks” “net cracks” and “surface defects” all laboratories came to the same conclusion that cracking was not expected to be a major issue and therefore these types of damage were categorized as “A”. Concerning the damage type “rutting”, on the other hand, the assessment is widely scattered. The detailed results of this project can be downloaded (Partl and Piber 2001) and were summarized later by Piber et al 2003.

4 FIELD MEASUREMENTS

4.1 *Surface characteristics*

The road administration of Carinthia (Austria) observed and monitored the test section continuously. After 10 years, the road surface showed neither single cracks nor net cracking or surface defects. Therefore, the class of damage was in all cases “A”. This result was in a good agreement with the prediction by all laboratories.

Table 1. Result of the interlaboratory test; number of labs and performance prediction categories (A…D).

Type of damage											
Rutting[1] mm				Single cracks (Thermal cracking) m/100 m		Net cracks (fatigue cracking) % of 100 m^2				Surface defects[2] % of 100 m^2	
<5	5–10	10–20	≥20	<4	≥4	≥5	5–10	10–20	20	<2	≥2
A	B	C	D	A	B	A	B	C	D	A	B
Number of laboratories corresponding to the performance prediction categories											
5	3	4	0	4	0	9	0	0	0	2	0

[1]Rutting in surface course and deformation of each asphalt course. (max. depth and change of thickness)
[2]Loss of material and/or raveling.

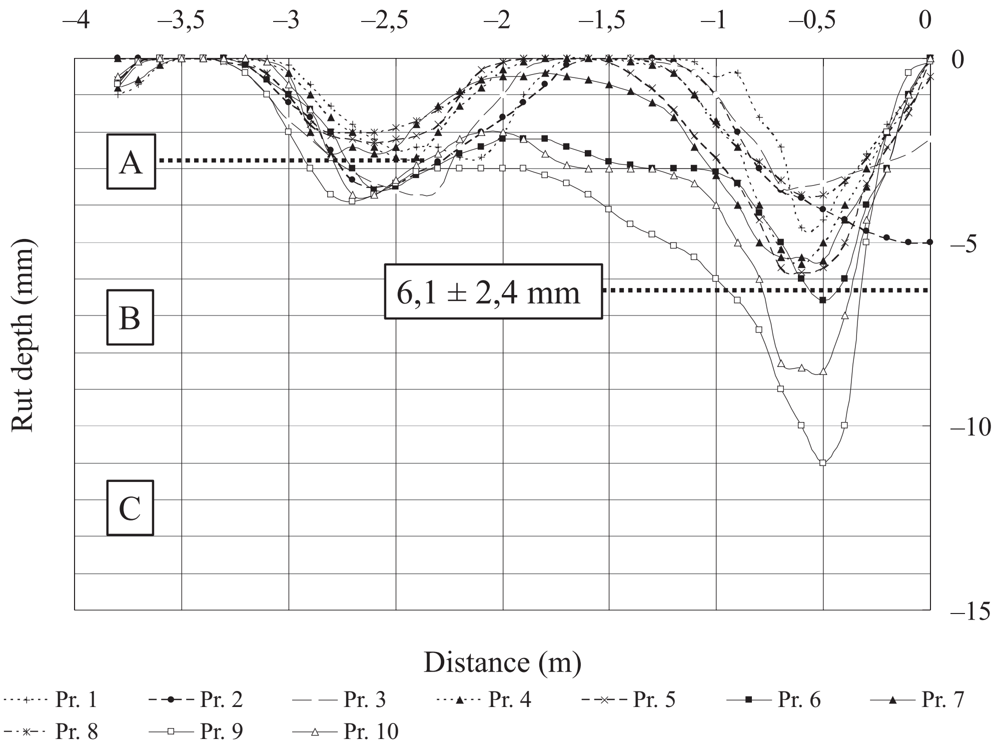

Figure 2. Rut depth measurement 2007.

To investigate rutting, 10 cross profiles were defined on the 100 m long section and the rut depth was measured annually. Already in the first year ruts were measurable in the right lane. As shown in figure 2, at the end of 2007 the average rut depth in the right wheel track of the right lane was 6.1 mm (±2.4 mm). With a rut depth of 5 mm rutting occurred mainly in the wearing course (SMA 11). While the bituminous base course was affected by 1 mm only. The actual rut depth after 10 years of trafficking was in accordance with the damage class "B", a prediction which was given by 3 of the 12 laboratories.

The development of the rut depth shown in figure 3 follows a potential curve. The equation 1 has a high regression ($R^2 = 0.99$).

$$RD = -0.2406 \cdot HV^{0.2113} \tag{1}$$

where:
RD = rut depth (mm)
HV = Number of heavy vehicles.

4.2 *Traffic census*

The traffic census 1995 had been the basis for the performance prediction. The AADT (Average Annual Daily Traffic) was 16.200 vehicles and the AADHT (Average Annual

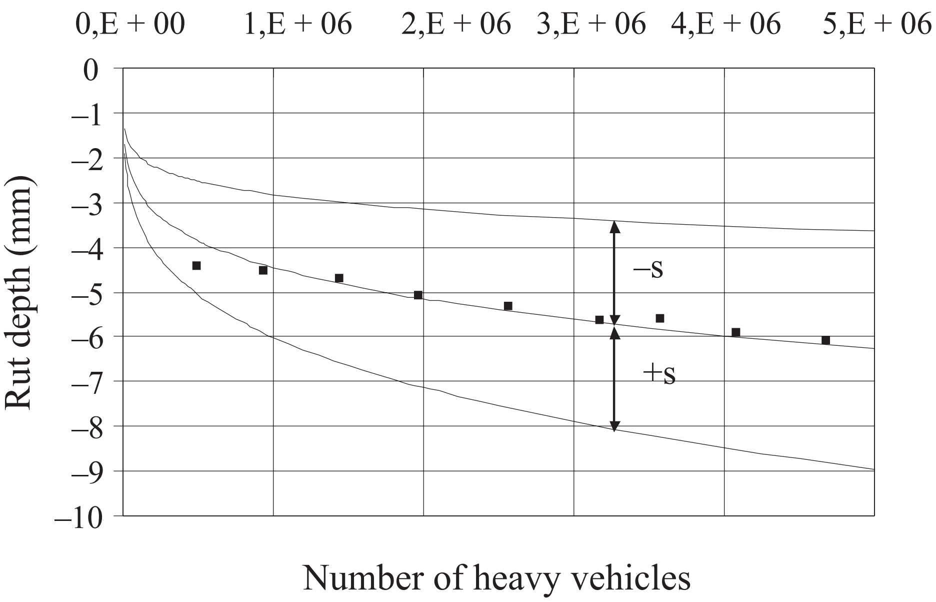

Figure 3. Development of the average rut depth.

Table 2. Composition of the heavy traffic permissible total weight and proportion.

Type	Number of axles	Total weight	Proportion 1996	Proportion 1998–2006
Truck	2	<18 t	17.1%	13.3%
Truck	3	<25 t	6.8%	4.6%
Truck	4	<32 t	1.1%	0.7%
Trailer truck	2 + 2	<36 t	8,2%	7.4%
Trailer truck	2 + 3	<38 t	11.3%	5.7%
Trailer truck	3 + 2	<38 t	9.5%	11.5%
Trailer truck	3 + 3	<38 t	1.1%	0.8%
Semi trailer truck	2 + 1	<36 t	0.1%	0.6%
Semi trailer truck	2 + 2	<38 t	2.2%	1.1%
Semi trailer truck	2 + 3	<38 t	40.6%	53.0%
Semi trailer truck	3 + 2	<38 t	1.3%	0.7%
Semi trailer truck	3 + 3	<38 t	0.7%	0.4%

Table 3. Axle load distribution and heavy vehicle type in percent on the “Tauern Autobahn A 10”.

Axle load	T2	T3	T4	TT 2+2	TT 2+3	TT 3+2	TT 3+3	ST 2+1	ST 2+2	ST 2+3	ST 3+2	ST 3+3
<1 t	0,0	0,9	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,1
1–2 t	0,0	3,5	3,5	4,3	0,5	0,3	0,0	0,5	0,0	0,2	1,4	2,1
2–3 t	0,8	2,4	9,1	2,6	4,2	1,9	0,0	3,1	7,7	3,7	3,9	6,3
3–4 t	1,9	5,6	15,9	6,0	7,8	6,6	16,7	13,5	26,8	7,5	11,4	12,5
4–5 t	3,8	10,0	15,1	11,2	4,2	16,9	16,7	14,6	12,7	8,4	9,4	14,6
5–6 t	9,7	17,1	17,8	12,9	13,5	19,2	33,3	25,0	17,7	13,2	13,9	22,9
6–7 t	23,5	17,7	20,1	18,1	31,2	20,3	25,0	15,1	17,3	28,3	21,4	6,3
7–8 t	13,8	16,5	7,4	24,1	17,1	16,6	8,3	8,9	5,0	21,7	18,9	12,5
8–9 t	3,5	10,3	4,3	9,5	9,1	8,9	0,0	7,8	5,9	4,4	8,3	10,4
9–10 t	8,6	8,3	2,4	5,2	5,5	4,2	0,0	3,1	1,4	3,9	3,3	8,3
10–11 t	14,9	5,0	2,1	4,3	4,4	3,8	0,0	4,2	2,7	4,0	4,4	0,0
11–12 t	16,8	1,8	0,4	0,9	2,1	1,1	0,0	2,6	2,3	2,9	1,7	0,0
12–13 t	2,4	0,3	0,2	0,9	0,5	0,4	0,0	0,5	0,5	1,1	1,9	2,1
13–14 t	0,3	0,3	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,3	0,0	0,0
14–15 t	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0
15–16 t	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Daily Heavy Traffic) counted 2.350 trucks in both directions. The annual increase of the heavy traffic was 3%.

The traffic census occurred automatically. Until the end of 2006 a total of 4.70 millions trucks drove over the right lane of the test section, which met the predicted number of 4.76 millions trucks by 98.8%.

4.2.1 *Heavy traffic composition*

Heavy traffic composition changed in the last 10 years as depicted in table 2.

The increase of semi trailer trucks with five axles was significant. The total weight went up 3.5%. The total number of axles was with 22.7 millions about 3% higher than expected. The sum of 10 t ESALs in the right lane of the test section was 5.22 millions, whereas only 3.92 millions ESALs had been predicted.

4.2.2 *Axle load distribution*

The axle load distribution was provided by the Institute of road construction of the technical University of Vienna (ISTU Wien). In the frame of their research work, investigations of axle load distributions were carried out on Austrians motorways (table 3).

4.3 *Temperature data*

4.3.1 *Air temperature*

The climatic data were provided in terms of temperature data. For their performance prediction the laboratories obtained the monthly maximum, the average monthly maximum, monthly average, the average monthly minimum and monthly minimum temperature. The comparison in figure 4 shows that the average monthly temperatures of the last ten years were clearly higher than in the previous years. In summer the difference measured was +2°C.

The number of days with temperatures higher than 25°C with average 59 days was clearly higher than before 1996 where 46 days were counted. The evaluation according the SHRP (Strategic Highway Research Program) (SHRP-A-637, SHRP-A-645, SHRP-A-648 & Anderson 1999), showed similar results, as presented in table 4.

Table 4. Comparison of the SHRP temperatures.

	<1996	1998–2007
Mean value of the average maximum temperatures of the hottest 7-day period of a year	30.7 ± 1.8°C	32.0 ± 1.4°C
Mean value of the annual minimum temperature	–19.3 ± 1.4°C	–16.2 ± 1.8°C
Maximum Asphalt temperature 20 mm below surface (A_{MAX})	52.6°C	53.1°C
Minimum Asphalt temperature 20 mm below surface (A_{MIN})	–18.6°C	–16.7°C
Required "Performance Grade" of Bitumen	PG 58–22	PG 58–22

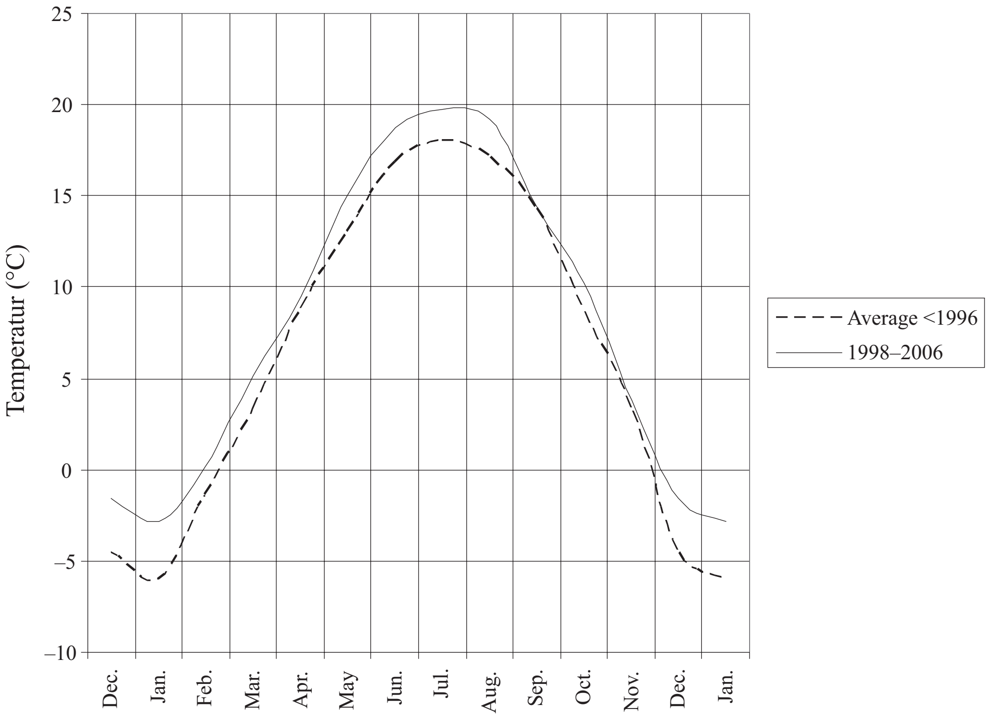

Figure 4. Comparison of the average monthly air temperature before 1996 and between 1998 and 2006.

4.3.2 *Pavement temperatures*

Temperature gauges were located in the asphalt pavement 25, 50, 80 and 180 mm below the surface. Temperatures were measured hourly. Figure 5 depicts the maximum temperatures in the courses measured between 1998 and 2007.

The maximum temperature in the wearing course (35 mm) was higher than 52°C. In the upper layer of the base course (80 mm) the maximum temperature achieved between 43 and 52°C and in the lower layer of the base course (80 mm) still 37 to 43°C was measured.

4.4 *Pavement temperatures and heavy traffic*

The previous evaluations showed that in reality the amount of heavy vehicles was slightly lower but the total loads in term of axles were higher than predicted. Due to climatic warming the summer temperatures proved to be higher than expected.

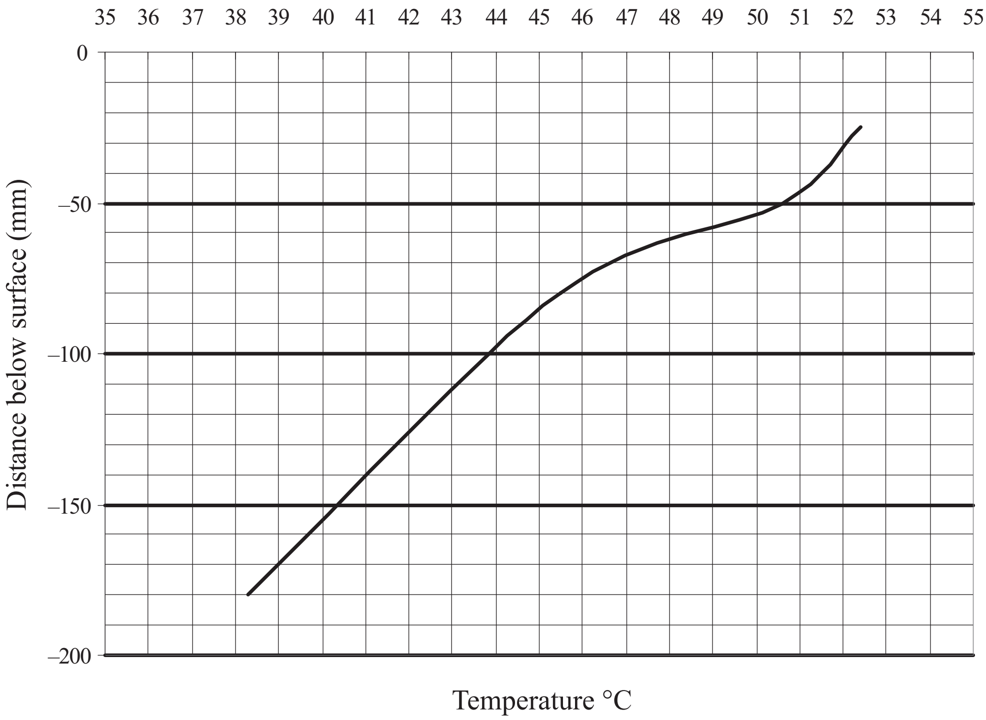

Figure 5. Maximum temperature in asphalt pavement.

The climate and traffic investigations were combined. Table 4 contains the combination of the temperature measurements in various depth below the surface and the census of heavy traffic at temperatures between 30 and 53°C.

The wheel loads were calculated from the axle loads in table 3. These wheel loads were combined with the proportion of heavy traffic (table 2) and in this way for each pavement layer the total number of wheel loads at specific layer temperatures (table 4) was determined. Figure 5 shows an example for the wearing course. Altogether, at temperatures higher than 30°C more than 3.2 million wheel loads drove over the test section. 1.0 million wheel loads were counted at temperatures higher than 40°C, 0.4 million at temperatures higher than 45°C and still 47.000 wheel loads passed at temperatures of more than 50°C. The majority of wheel loads (65%) ranged between 2.5 and 4 t, whereas wheel loads of more than 5 t were the exception (0.2%).

5 ASSESSEMENT OF THE LABORATORY TESTS

When looking at the monitoring results, rutting proved to be the most critical parameter for the long term performance. As predicted by all laboratories other damages such as single cracking, net cracking or surface defects were negligible. In the prediction of the rutting behavior the laboratories showed quite some differences. Six out of 12 laboratories derived the development of the rut depth from their rutting test method, while others based their prediction on the test result compared to the requirement of their national regulation or standard. All of these six laboratories used different test devices. Lab 1 used a static compression test (S–CO), lab 2 a cyclic compression test (C–CO), lab 6 a cyclic indirect tensile test (C–IT) and the labs 3, 4 and 5 conducted a wheel tracking test (WT–large device). In figure 7 the results for all six laboratories are shown:

Table 5. Temperatures in different depth below surface and number of heavy vehicles (1998–2006).

25 mm below surface		50 mm below surface		80 mm below surface		180 mm below surface	
T (°C)	Trucks	T (°C)	Trucks	T (°C)	Trucks	T (°C)	Trucks
54	0	54		54		54	
53	335	53		53		53	
52	1 601	52	0	52		52	
51	2 521	51	86	51		51	
50	6 320	50	475	50		50	
49	8 898	49	2 440	49		49	
48	13 861	48	5 325	48		48	
47	14 150	47	6 937	47	0	47	
46	18 542	46	13 476	46	315	46	
45	25 580	45	17 503	45	1 579	45	
44	25 521	44	20 486	44	4 792	44	
43	24 551	43	24 608	43	7 191	43	
42	30 728	42	32 922	42	15 174	42	
41	29 070	41	32 164	41	19 343	41	
40	34 180	40	34 694	40	23 111	40	0
39	33 092	39	32 060	39	28 751	39	305
38	35 890	38	26 045	38	33 869	38	1 270
37	39 771	37	37 667	37	37 197	37	5 166
36	43 462	36	40 872	36	40 460	36	10 161
35	49 793	35	51 818	35	51 001	35	21 393
34	47 790	34	52 439	34	53 827	34	35 937
33	52 808	33	54 123	33	68 019	33	55 757
32	52 722	32	59 390	32	66 500	32	62 511
31	70 460	31	73 739	31	83 496	31	81 591
30	65 585	30	79 805	30	89 250	30	97 557

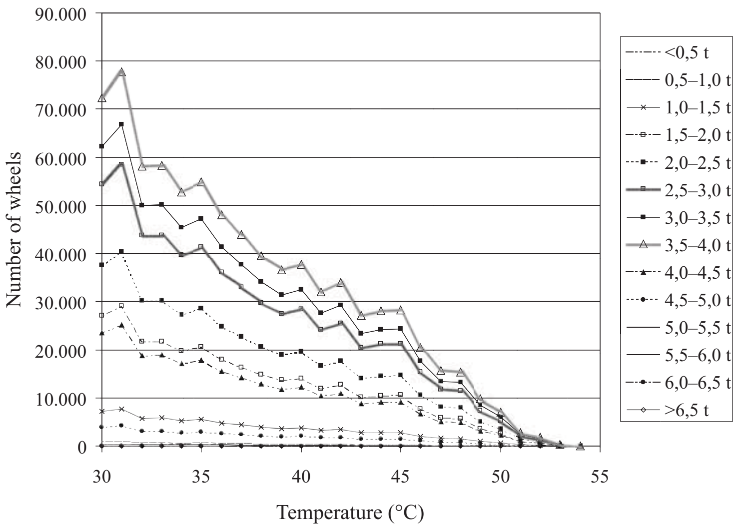

Figure 6. Number of wheel loads and temperature in the wearing course (–35 mm).

The in situ measured rut depth after 10 years monitoring was 6.1 mm (σ ± 2.4 mm). Comparing this result with the laboratory prediction shows that the laboratories number 3, 4 and 5 came very close to this value. It is notable that the best predictions are based on the wheel tracking test (large devise). All three laboratories used a testing machine with a

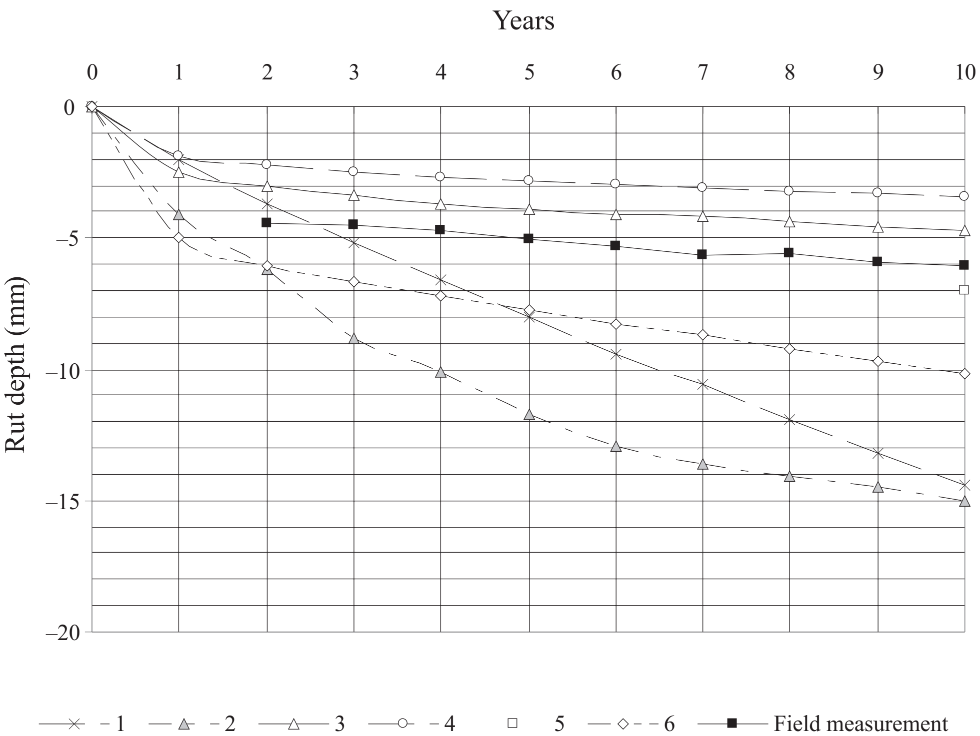

Figure 7. Calculated rutting; the figure indicated the number of the laboratory.

Table 6. Test and configuration.

Lab	Type of test	Sample size	Loading conditions	Test temperature	Test result
3	WT	l = 550 mm	L = 5 kN	40°C	SC + BC4 + BC3 + BC2
		w = 250 mm	p = 600 Pa		ε_{10000} = 1.24 mm,
		h = 250 mm	f = 0.6 Hz		ε_{40000} = 1.82 mm,
4	WT	l = 500 mm	L = 5 kN	35°C	SC: ε_{10000} = 6.3%,
		w = 180 mm	p = 600 Pa		BC4: ε_{10000} = 2.4%,
		h (SC) = 30 mm	f = 60 cycle/min	45°C	SC: ε_{10000} = 6.1%,
		h (BC4) = 100 mm			BC: ε_{10000} = 4.2%,
5	WT	l = 480 mm	L = 5 kN	38°C	SC + BC4: ε_{10000} = 1.4%,
		w = 160 mm	p = 600 Pa		BC4 + BC3: ε_{10000} = 1.0%,
		h = 100 mm	f = 1 Hz	60°C	SC + BC4: ε_{10000} = 13.6%,
					BC4 + BC3: ε_{10000} = 4.0%,

pneumatic tire (400 × 80 mm). However, the sample size varied. Some laboratories tested each course separately others tested the courses together. The test characterizations and results are represented in table 6.

6 CONCLUSIONS

The prediction of long term performance of asphalt pavements on motorways is still not an easy task. Test sections which have been established during recent years provided a good base for monitoring the pavement conditions under specified traffic and climate data. The RILEM test section in Villach, Austria showed that in a middle European climate with high summer and low winter temperatures rutting proves to be one of the most likely damage cases.

Although traffic and temperature data can be collected and their development can be predicted quite precisely, it seems difficult to give damage predictions based on laboratory experiments and theoretical analysis as the variety of test methods and prediction models seems quite large.

Since rutting proved to be the most critical damage case, test devices to evaluate this parameter have attracted major focus. The interlaboratory study showed that the rutting behavior can best be estimated using large size wheel tracking tests with pneumatic tires.

The prediction of the maximum pavement temperature with help of SHRP equations was very precise.

Regarding the prediction of long term performance it seems important that uniform and standardized methods based on material characteristics and mechanical properties will be developed.

REFERENCES

Anderson, D. 1999. *SUPERPAVE Binder Test and Specification*. Eurobitume Workshop, Workshop Briefing, Luxembourg.

Partl, M.N. & Piber, H. (editors) 2001. *Pavement Performance Prediction and Evaluation (PPPE)*-Report of RILEM TC 152-PBM and 182-PEB, Report rep029, e-ISBN: 2912143683 download from www.rilem.net–Publications—Reports.

Piber, H. & Partl, M.N. 2003. *RILEM—Interlaboratory tests on performance prediction of pavement*. Proceedings of the 6th International RILEM Symposium, Zürich 2003.

SHRP-A-637. Analysis of the Integrated Model of Climatic Effects on Pavements.

SHRP-A-645. Asphalt Cements. A conceit Data Compilation.

SHRP-A-648. Weather Database for the SUPERPAVE Mix Design System.