

RILEM – Interlaboratory tests on performance prediction of pavements

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ABSTRACT: First conclusive results of an ongoing international RILEM test programme are presented where performance predictions of different laboratories based on their own test methods and models are compared. Slabs and technical data of two motorway test sections were provided to 16 laboratories participating on a voluntary basis. This paper focuses on rutting and fatigue predictions for a period of 10 years. It was found that the predicted rut depths varied over a wide range. Compared to rutting, the fatigue predictions were in better agreement. However, the conclusion that fatigue models are more accurate could not be drawn. For both rutting and fatigue prediction, none of the laboratories followed a procedure and methodology which was directly comparable. This made clear that further exchange and co-ordination of research efforts is extremely necessary.

1. INTRODUCTION

Recently, RILEM has carried out interlaboratory tests on bituminous binders as well as mix design and mechanical testing of asphalt mixtures. The results are presented in the RILEM report 17 [Francken, 1998], which also contains the basic elements of a methodology for bituminous mixtures. According to this methodology in Figure 1, the interlaboratory tests carried out by RILEM, so far, correspond to step 1 (characterisation of components and mixtures) and partly to step 7 (mechanical testing).

With respect to step 2 (definition of design parameters), 7 (volumetric and mechanical testing), 8 (data processing and analysis), 9.1 (pavement and structural design, prediction of long term performance) and 10 (long term pavement performance comparison with road survey and full scale tests) of this methodology, the RILEM Technical Committee TC 182-PEB “Performance Testing and Evaluation of Bituminous Materials” has initiated in 1998 an international test programme to evaluate prediction methods for long-term performance of asphalt pavements under different climatic conditions. From this research effort, statements by different laboratories in Europe, USA and South Africa with respect to pavement performance in practice were obtained. This paper presents the first conclusive results of this interlaboratory test programme on rutting and fatigue.

2. TEST PROGRAMME

Two newly constructed test sections on heavily loaded motorways in Austria and Portugal were chosen. From these sections, slabs were cut full-depth from the asphalt pavements and distributed to the laboratories as described in section 2.2.

The test programme consisted of two parts [Partl, 2000].

- Laboratory part: Laboratory tests on field samples and prediction of long term pavement performance.
- Section operator part: Long term pavement performance monitoring of the test sections.

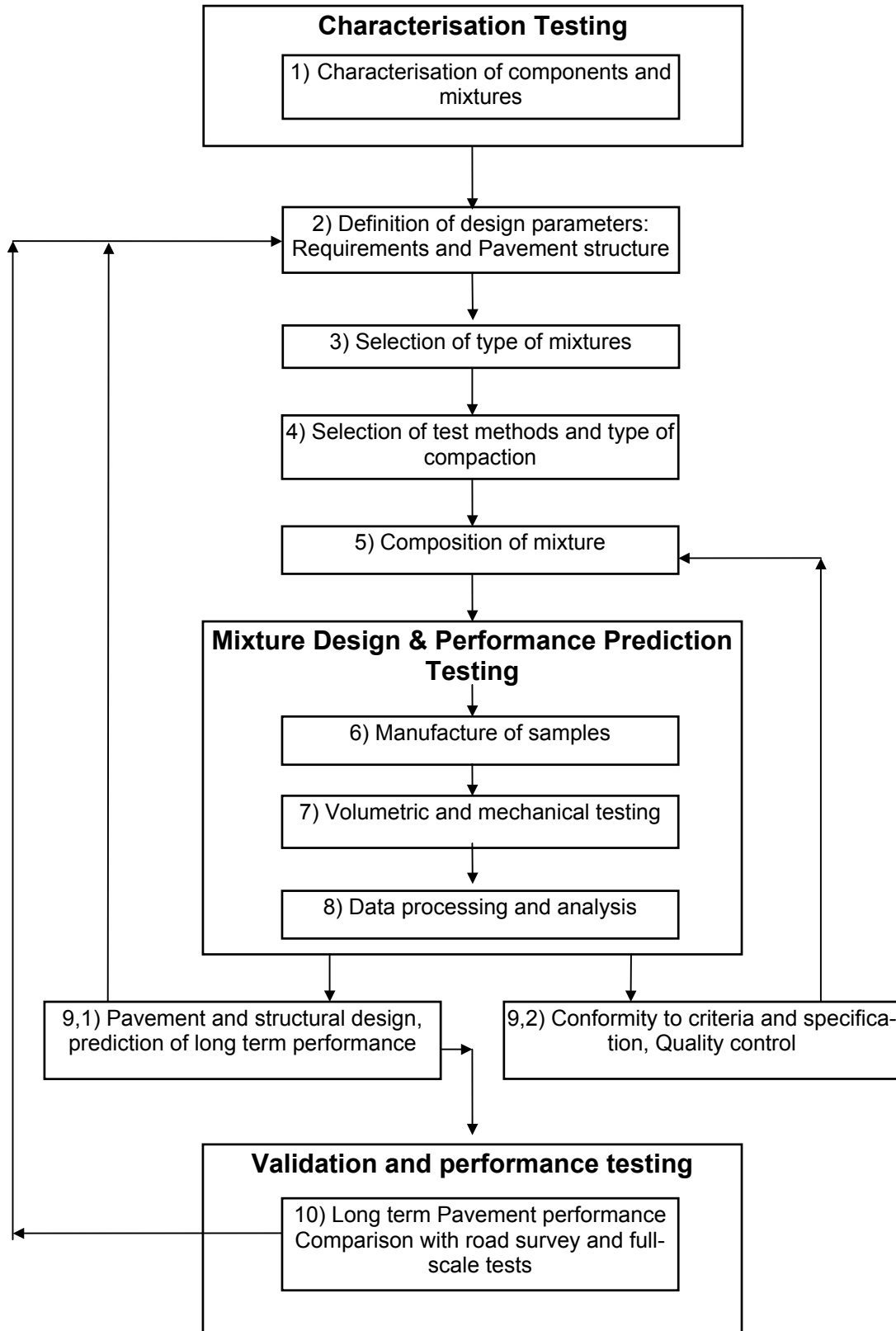


Figure 1. Basic elements of a RILEM methodology for bituminous mixtures [Francken, 1998]

2.1 Laboratory Part

The laboratories were asked to determine the material behaviour with their own test procedures and to predict rutting, thermal cracking, fatigue cracking and surface defects for the two motorways using their own methodology. The prediction of distresses was to classify according to Table 1. In order to elaborate their predictions, the laboratories received standard information on climate, traffic condition, sub-base and sub-soil properties.

For their rutting prediction models, the laboratories used wheel tracking, dynamic compression, indirect tensile test and simple shear tests. Values for pavement design calculation and fatigue behaviour prediction were determined with two-, three- and four-point bending tests as well as indirect tensile and compression tests.

In addition to their task, some of the laboratories also conducted routine tests for mechanical and volumetric materials characterisation (e.g. grading curve, binder content, binder properties, air void content).

As no ranking of the participants was intended, the test and prediction results discussed in this paper are randomly numbered and not related to the individual laboratories.

Table 1. Distress Prediction Classes

No	Type of Damage	Dimension	Class of Distress			
			A	B	C	D
1	Rutting ¹⁾	Mm	< 5	≤ 5 - < 10	≤ 10 - < 20	≥ 20
2	Single cracks (thermal cracking)	m/100 m	< 4	≥ 4		
3	Net cracks (fatigue cracking)	% of 100 m ²	< 5	≤ 5 - < 10	≤ 10 - < 20	≥ 20
4	surface defects ²⁾	% of 100 m ²	< 2	≥ 2		

¹⁾ Rutting in surface course and deformation of each asphalt course, (max. depth and change of thickness)

²⁾ Loss of material and/or ravelling

2.2 Section Operator Part

Initial sampling was conducted by the section operators. Hence, 79 slabs of 250 x 550 mm were taken from a test area of 2,5 x 3,3 m, clearly marked and sent to the laboratories.

In addition, the operators of each test sections started collecting all important traffic and performance data over the 10 years observation period. Therefore, temperatures are still measured permanently at three different depths within the asphalt courses and the traffic census is carried out continuously. To determine the influence of ageing on the performance and for damage assessment, asphalt cores during operation will be taken periodically. Transverse evenness is measured annually and the surface is also inspected at that time interval as indicated in Table 2.

In addition to the transverse evenness measurements, final tests will be performed to determine a transverse evenness profile for all bituminous layers. When the observation ends in 2009, a final sampling (cutting of slabs) and testing of mechanical and volumetric characteristics of the materials will also be done.

Table 2. Time Table

Task	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sampling during operation				+			+				+	
Weather data (daily)	+	+	+	+	+	+	+	+	+	+	+	
Traffic data (daily)	+	+	+	+	+	+	+	+	+	+	+	
Transverse evenness	+	+	+	+	+	+	+	+	+	+	+	
Visual inspection	+	+	+	+	+	+	+	+	+	+	+	
Additional tests		+		+			+				+	
Final test												
Intermediate report			+		+			+				
Final report												+

3. TEST SECTIONS

Two test sections were considered corresponding to typical climatic conditions in Europe:

- one section in Austria (Villach) representing an alpine region with large temperature changes and the risk of thermal cracking, called CCRIPPPE (Cold Climate RILEM Interlaboratory Pavement Performance Evaluation) and
- one section in Portugal (Mindelo) representing a warm mediterranean region with risk of permanent deformation, called WWRIPPPE (Warm Weather RILEM Interlaboratory Pavement Performance Evaluation).

The main weather data are shown in Table 3. In addition, the laboratories received the monthly average maximum, mean and minimum air temperatures. The basic technical data of the test sections are given in Table 4 and 5. The traffic information in Table 6 was complimented by other more detailed data. For the CCRIPPPE section, the laboratories also obtained the spectrum of the heavy traffic, classified according to the type of lorries. For the WWRIPPPE section, the number of average daily axles in the right lane was complementarily provided.

Table 3. Weather Data

Name of the Test Section:	WWRIPPPE Mindelo	CCRIPPPE Villach
Weather station:	Porto - Pedras Rubras (70 m)	Villach - Seebach (492 m)
Number of days with maximum temperatures more than +25 °C:	32 days	46 days
Number of days with minimum temperatures lower than 0 °C:	2 days	128 days
Number of days with snow fall or snow rain:	0	33
Annual average rainfall:	98 mm	1232 mm
Temperatures According to SHRP:		
Mean value of average maximum air temperature of the hottest 7 day period:	30,04 ± 2,46 °C	30,7 ± 1,8 °C
Mean value of annual minimum air temperature:	0,44 ± 2,01 °C	-19,3 ± 3,7 °C

Table 4. Location of Test Sections and Road Geometry.

Name of the Test Section:	WWRIPPE Mindelo	CCRIPPE Villach
Country:	Portugal	Austria
Province:	Porto	Carinthia
Type of the road:	motorway - open range	motorway - open range
Name and number of the road:	IC 1 (E 01) Valença/Lisboa, Sublanço Perafita/Mindelo	A 10 (E 55) Tauernautobahn
From km to km:	km 331,475 - km 332,000	km 178.900 - km 179,000
Sea level:	35 m	500 m
Number of traffic lanes:	2 separate carriageways with 2 lanes in each direction.	2 separate carriageways with 2 lanes in each direction.
Width of one traffic lane:	375 cm	375 cm
Horizontal alignment:	straight	bend - radius = 2.500 m
Gradient:	0,5 %	0,5 %
Cross fall:		3,4 %
Earthwork:	cutting	embankment - 8 m height

Table 5. Pavement Design and Year of Construction

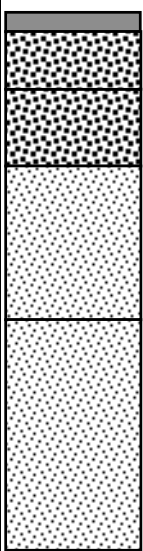
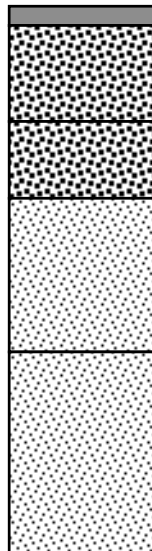
Name of the Test Section:	WWRIPPE Mindelo	CCRIPPE Villach
Design:	 <p> SC: 40 mm PA (1997) B2: 110 mm AC (1996) B1: 110 mm AC (1996) 200 mm unbound material (1996) 300 mm unbound material (1996) cutting (1996) </p> <p> PA = porous asphalt AC = asphalt concrete </p>	 <p> SC: 35 mm SMA 11 (1997) BC4: 80 mm BT I 22 HS (1997) BC3: 80 mm BT I 22 HS (1997) BC2: 65 mm BTS I 22 (1988) BC1: 65 mm BTS I 22 (1988) 200 mm unbound material (1988) 300 mm unbound material (1988) embankment (1987) </p> <p> SMA = stone mastic asphalt BT(S) = bituminous road base </p>
Bearing Capacity of the Unbound Materials		
	Falling Weight Deflectometer:	Loading plate (ÖNORM B 4417):
Test values during construction time	road base and sub - base: 245 ± 65 MPa sub grade: 85 ± 15 MPa	road base: 111 ± 20 MN/m ² sub - base: 79 ± 14 MN/m ² sub grade: 115 ± 60 MN/m ²

Table 6. Traffic Data

Name of the Test Section:	WWRIPPPE Mindelo	CCRIPPPE Villach
Year and type of traffic census:	1996 (automatically)	1995 (by hand)
Average annual daily traffic volume:	9405	16.200
Average annual daily heavy traffic volume:	971	2.350
Traffic forecast:	+ 4 % p.a.	+ 3 % p.a.
Speed restriction:	120 km/h	100 km/h
Traffic restriction:	-	„No Passing for heavy vehicles“ - sign.

4. TEST REPORTS OF PARTICIPATING LABORATORIES

Up to now, reports of the following 13 laboratories and reporters were delivered. Some reports were very detailed and contained valuable additional information on aspects such as traffic, temperature models, test procedures and distress models. This exceeds the original goal of the test programme and allows further evaluation and intensified discussions of the data in the future.

- A: H. Piber, Bautechnik, Klagenfurt
- B: L. Francken, D. Leonard, A. Vanelstraete, Belgian Road Research Centre, Brussels
- CH: M.N. Partl, EMPA, Dübendorf
- CZ: J. Kudrna, Technical University of Brno
- D: K.W. Damm, asphalt Labor, Wahlstedt
- D: Ch. Recknagel, E.J. Vater, BAM, Berlin
- DK: C. Bredahl Nielsen, Danish Road Institute, Roskilde
- E: J.M. Baena – Rangel, CEDEX, Madrid
- I: A. Montepara, University of Parma
- P: J.M.B. Sousa, Consulpav, Porto Salvo
- S: S. Said, H. Jansson, VTI, Linköping
- SA: F.J. Jooste, BMJA Verhaeghe, M. Vlok, Transportek CSIR, Pretoria
- US: D. Hung, C.L. Monismith, University of California, Berkeley

All laboratories based their prediction on mechanical tests on the materials in the original state, i.e. as delivered. Only one participant considered the long term ageing effect. In this case, samples were stored in a climatic test chamber according to the “SHRP Ageing Methods”. Some participants carried out conventional asphalt tests. Hence, additional information on binder properties (penetration, softening point, breaking point etc.), volumetric characteristics of the asphalt courses (density, air void) and mixtures (grading curve, binder content) is also available.

5. RUTTING PREDICTION

5.1 Selection of representative layers for testing

All laboratories used a sample of the top layer of the base course for rutting prediction (BC4 in case of CCRIPPPE and BC2 in case of WWRIPPPE). It was surprising that the surface course was not taken into account by some laboratories. In case of CCRIPPPE, only one participant and in case of WWRIPPPE, only three participants determined and used the material properties of all asphalt courses. From Table 7 follows that one laboratory used two different tests. Hence, the total number

of tests was 14. It can be seen that the laboratories tested the layers either individually or in a combined way. Note, that test 9 and 13 were partly performed with different course combinations.

Table 7. Courses an Number of Tests Used for Rutting Prediction.

Test-N°	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Test Section: CCRIPPE Villach														
SC														
BC4														
BC3														
BC2														
BC1														
Test Section: WWRIPPE Mindelo														
SC														
BC2														
BC1														

5.2 Type of test

Table 8 and 9 contain information on how the different test methods were conducted. The test methods can be attributed to six classes. Most laboratories preferred compression and wheel tracking tests and used load controlled procedures. Test temperatures for the materials of the two sections were equal with the exception of the shear test. It is interesting to note, that in case of test 7 the test temperature for the CCRIPPE section was chosen higher than for the WWRIPPE section, whereas for test 6 the temperatures were chosen in a reversed way. This demonstrates that the input results for the models depend not only on the test procedure but also significantly on the individual interpretation of the data initially provided to the participants. Note, that test 14 was carried out on horizontally cored test specimens using double haversine cycles. Generally, input results for the models are deformations. Details on the energy based deformation modulus resulting from test 1 are reported by Herbst [1997].

Table 8. Sample Size, Test Temperature, Loading Condition and Input for Prediction Model

Test N°	Sample Size:	Test-Temp.		Loading – Condition	Input Result for Model:
		CCRI PPPE	WWR IPPPE		
Cyclic Compression Test, Cylindrical Sample – C-CO – CY					
2	d=150 mm h=200-249 mm	40°C	40°C	<u>Load controlled</u> Loading area Ø=100mm, repeated load, load=100 kPa, 30 cycle/min, loading time=1s, unloading time=1s	Deformation, Creep rate
3	d=100-110 mm h=213-288 mm	40°C 20°C 5°C -10°C -15°C	40°C 20°C 5°C -10°C -15°C	<u>Load controlled</u> Loading area Ø=100mm, sinusoidal load, frequency = 5; 10; 20 Hz	Complex modulus
4	d=150 mm h=60 mm	40°C	40°C	<u>Load controlled</u> Loading area Ø=100mm, repeated load, load=100 kPa, 30 cycle/min, loading time=1s ,unloading time=1s	Deformation, Creep rate Creep modulus

Table 9. Sample Size, Test Temperature, Loading Condition and Input for Prediction Model (Cont.)

Test N°	Sample Size:	Test-Temp.		Loading – Condition	Input Result for Model:
		CCRI PPPE	WWRI PPPE		
Static Compression Test, Cylindrical Sample - S-CO-CY					
1	d=100mm, h=60mm	50°C	50°C	<u>Deformation controlled</u> Loading area Ø=100 mm, constant deformation rate=0,27 mm/s	Energy based deformation modulus
Cyclic Compression Test, Prismatic Sample - C-CO-PR					
5	w=340 mm l=380 mm h=220-325 mm	30°C 40°C 50°C	30°C 40°C 50°C	<u>Load controlled</u> Loading area Ø=100mm, haversine loading, load= 0,4; 0,7; 1MPa, loading time=0,2 s, rest period=0,8 s	Deformation rate
Simple Shear Test, Cylindrical Sample – SH-CY					
6	d=152,4mm h=50,8mm	43°C	50°C	<u>Load controlled</u> , Haversine loading, shear load=84 kPa, strain level=4,5%, loading time=0,1s, rest period=0,6s.	Shear strain
7	d=152,4mm h=50,8mm	52°C	48°C	<u>Load controlled</u> , Haversine loading, shear load = 84 kPa, strain level=1;2;3;5%, loading time=0,1s, rest period=0,6s.	Shear strain
Cyclic Indirect Tensile Test, Cylindrical Sample – C-IT - CY					
14	horizontal cores! d=200 mm h=250 mm	44°C 40°C 34°C 25°C		<u>Load controlled</u> , Double haversine loading, load=6,3 kN, 1 cycle = 2,04s; (1 st loading time=0,02s, 1 st rest period=0,02s, 2 nd loading time=0,2s, 2 nd rest period=1,8s) 61034 cycles, 85754 1 cycles, 6100844 cycles, 964446 cycles,	Permanent deformation
Wheel Tracking Test, Cylindrical Sample - WT - CY					
13	d=100 mm h=50-100 mm	45°C	45°C	1 rubber tyre 198 x 22 mm, track length=314 mm, load=0,32 kN, frequency = 175 cycle/min	Permanent deformation,
Wheel Tracking Test, Plate - WT - PL					
8	h=30-100mm w=180 mm l=500 mm	35°C 45°C	35°C 45°C	1 pneumatic tyre 400 x 80 mm, treadless, tyre pressure = 600 kPa, track length=500 mm, load=5 kN, frequency = 60 cycle/min	Permanent deformation,
9	h=40-100 mm w=160 mm l=480 mm	38°C 60°C	38°C 60°C	1 pneumatic tyre 400 x 80 mm, treadless, tyre pressure = 600 kPa, track length=410mm, load=5 kN, frequency = 60 cycle/min	Permanent deformation, Secant modulus
10	h=35-50mm w=260 mm l=310 mm	50°C	50°C	1 rubber tyre 200 x 47 mm, track length=230 mm, load=0,6 kN, frequency = 52,4 cycle/min	Permanent deformation,
11	h=30-106 mm w=260 mm l= 320 mm	50°C 40°C	50°C 40°C	1 steel wheels 203 x 47 mm, track length = 230 mm, load=0,7 kN, frequency = 53 cycle/min	Permanent deformation,
12	h=220-250 mm w=250mm l=550mm	20°C 25°C 40°C 50°C	20°C 25°C 40°C 50°C	1 pneumatic tyre 400 x 80, with tread, tyre pressure = 600 kPa, track length = 410 mm, load=5 kN, frequency = 100 cycle/min	Permanent deformation,

5.3 Rutting results and predictions

On principle, the laboratories used four different methods to assess the test results:

1. Simple comparison of test results with requirements from national standards.
2. Comparison of the design traffic load and the traffic load calculated from test results based on an acceptable rut depth of 12,5 mm.
3. Comparison of the design traffic load and the traffic load calculated from test results based on an acceptable strain on the top of the subgrade.
4. Calculation of the rut depth based on experimental data without comparison to any requirement.

In the first method, the test conditions and requirements are fixed in a regulation or national standard, taking into consideration the regional weather and traffic conditions. Hence, the assessment from this method is restricted to this specific situation. The results are shown in Table 10. According to tests 10 and 11 the surface course of the WWRIPPPE section does not fulfil the requirements.

The results for the second method are shown in Table 11. The tests 6 and 7 are based on a SHRP procedure where the test temperature has to be calculated from weather data. The number of load cycles to obtain an acceptable strain in the shear test are converted into 130 kN or 80 kN ESALs which are equivalent to a rut depth of 12,5 mm. According to Table 11 the WWRIPPPE section fails in test 6 whereas the CCRIPPPE section fails in test 7.

The third method is quite similar. Therefore test 6 could also be applied in this case. The experimentally determined complex modulus is used to calculate the strain on the top of subgrade with an elastic multi-layer response model. The number of load cycles to obtain an acceptable strain on top of the subgrade is converted into 130 kN ESALs and compared to the acceptable design traffic load. From Table 12 follows that both sections passed this design criteria. Note, however, that the acceptable number of 130 kN ESALs was different for test 3 and 6 by a factor of three.

As far as the fourth method is concerned, six laboratories using different test methods tried to determine the rut depth curve exactly. The climatic and traffic conditions were considered either in the definition of the test conditions or in the prediction model. The different procedures are listed in Table 13 and the results are compared in Figure 2 and 3. Generally, the different procedures predict larger permanent deformations for the CCRIPPPE than for the WWRIPPPE section. However, the values of the CCRIPPPE section are more scattered. Most curves show a successive decrease of the rutting rate except for test 1 which led to an almost linear rutting characteristic.

In Table 14, a summary of the classification of all rutting test and prediction results is presented. The result surprises: In spite of considerable world wide long term efforts to improve the accuracy of rutting prediction, the only general agreement from this interlaboratory test programme is that rutting will probably not exceed 20 mm in both sections. The predictions based on the wheel tracking test are extremely unfavourable for the WWRIPPPE section, whereas the prediction with the compression test 5 leads to a completely reverse conclusion.

Table 10. Results of the First Method

Test N°	Type of Test	Criteria	Measured Value (mm)			
			CCRIPPPE Villach		WWRIPPPE Mindelo	
			Surface course	Base course 4	Surface course	Base course 2
10	WT-PL	Permanent deformation at 20.000 cycles	1,09	0,83	3,77	0,89
			required < 1,8			
10	WT-PL	Deformation increase between 10.000 and 20.000 cycles	0,29	0,15	1,57	0,24
			required < 0,32			
11	WT-PL	Permanent deformation at 20.000 cycles	1,82	3,17	9,38	8,00
			required < 4,5			

Table 11. Results of the Second Method

Test N°	Type of Test	Criteria	ESALs		Number of ESALs	
					CCRIPPE Villach	WWRIPPE Mindelo
6	SH-CY	Shear strain	130 kN	Calculated	770 10 ⁶	3,3 10 ⁶
				Acceptable	> 7,0 10 ⁶	> 5,4 10 ⁶
7	SH-CY	Shear strain	80 kN	Calculated	3,3 10 ⁶	12,5 10 ⁶
				Acceptable	> 10,0 10 ⁶	> 6,8 10 ⁶

Table 12. Results of the Third Method

Test N°	Type of Test	Property	ESALs	Number of 130 kN ESALs		Calculation Model
				CCRIPPE Villach	WWRIPPE Mindelo	
3	C-CO-CY	Complex modulus	Calculated	50,0 10 ⁶	74,0 10 ⁶	Shell/BISAR
			Acceptable	> 2,3 10 ⁶	> 1,9 10 ⁶	
6	4PB-PR	Complex modulus	Calculated	470 10 ⁶	180 10 ⁶	Shell/BISAR
			Calculated	450 10 ⁶	160 10 ⁶	Asphalt Institute
			Acceptable	> 7,0 10 ⁶	> 5,4 10 ⁶	

Table 13. Results of the Fourth Method

Test N°	Type of Test	Property	Climatic and Traffic Conditions	Calculation Method
1	S-CO-CY	Energy based deformation modulus	100 kN ESALs at days with air temperatures > 25 °C are considered in the evaluation.	Empirical formula developed by laboratory compares test and field data
2	WT-PL	Permanent deformation	100 kN ESALs at days with air temperatures > 25 °C are considered in the evaluation.	Formula based on power function
5	C-CO-PR	Deformation rate	Tyre load changes at different periods of temperature considered in the evaluation	Formula developed by laboratory
8	WT-PL	Permanent deformation	100 kN ESALs at different periods of temperature considered in the evaluation	Formula developed by laboratory
9	WT-PL	Secant modulus	100 kN ESALs at days with air temperatures > 25 °C are considered in the evaluation.	Rut calculation with BISAR
14	C-IT-CY	Permanent deformation	Axle load changes at different periods of temperature considered in the test and evaluation	Formula developed by laboratory

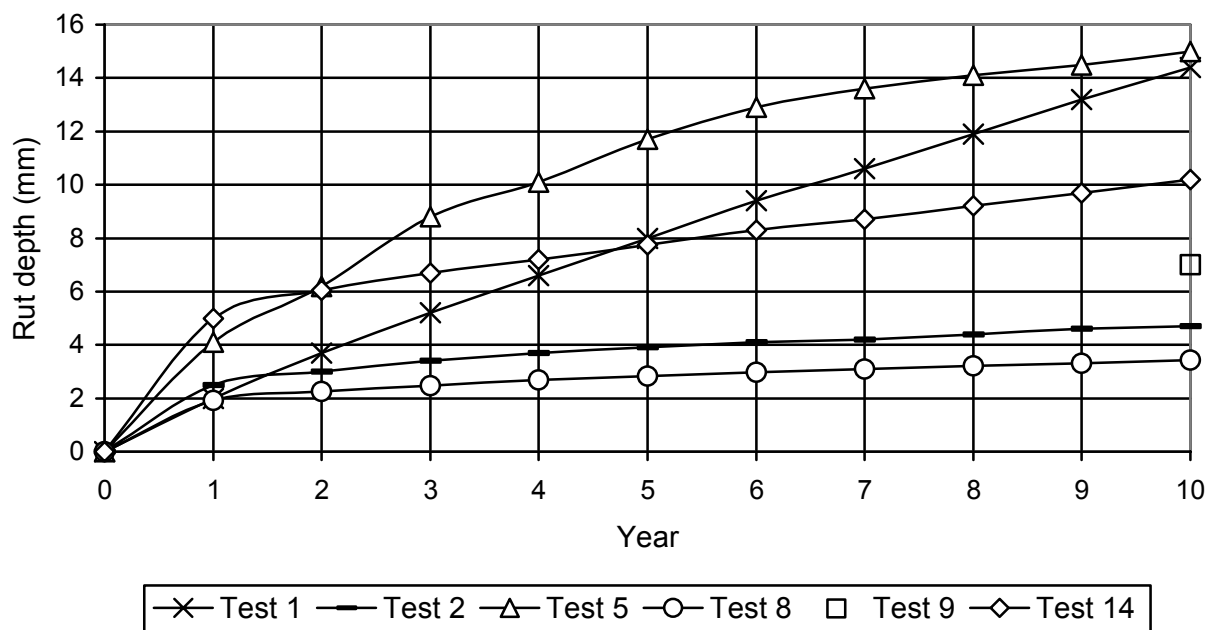


Figure 2. Calculated Rutting for CCRIPPPE section

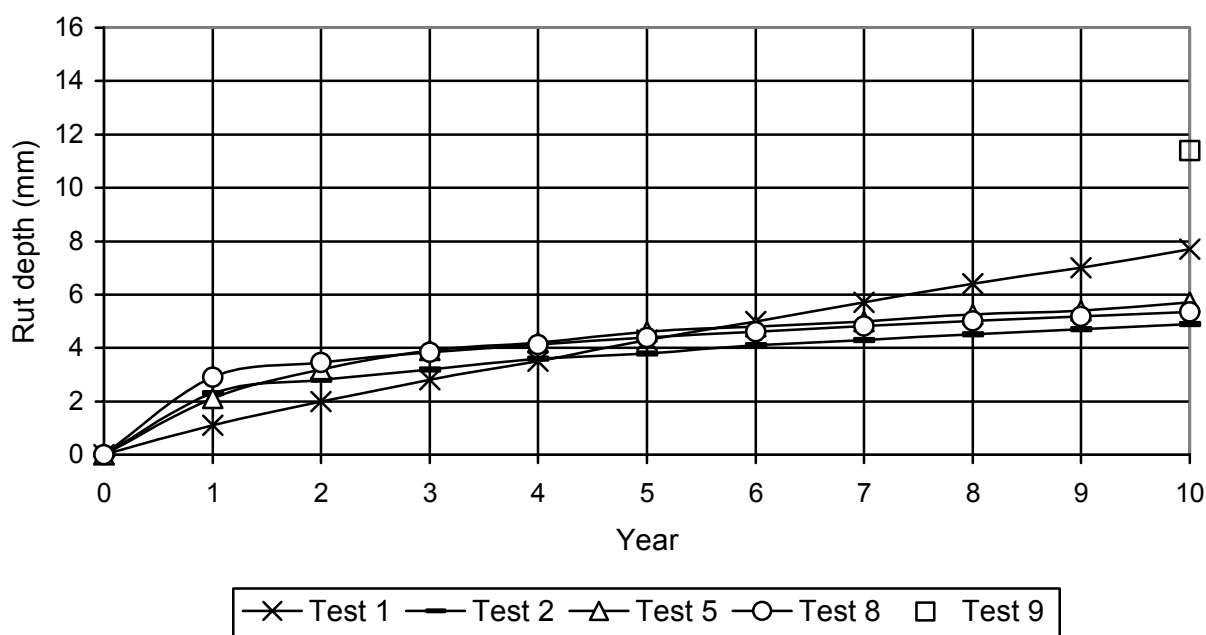


Figure 3. Calculated Rutting for WWRIPPPE section

Table 14. Classification of Rutting Test and Prediction Results for 10 Years

	Rut Depth ¹⁾ (mm)							
	CCRIPPE Villach				WWRIPPE Mindelo			
	<5	≤5 -<10	≤10 -<20	≥20	<5	≤5 -<10	≤10 -<20	≥20
Test N°	3	2+12	1		3	1	9	
	4	8	5		4	2+12	10+13	
	6	9	7		5	7	11	
	10+13		14		6	8		
	11							
Total:	5	3	4	0	4	4	3	0

1) Rutting in surface course and deformation of each asphalt course (max. depth and change of thickness)

+ Combination of two tests

6. TESTS FOR FATIGUE PREDICTION

6.1 Selection of representative layers for testing

As shown in Table 15, the majority of laboratories used specimens from the lowest layer of the base course (BC1) for fatigue prediction. In three cases (CCRIPPE) and two cases (WWRIPPE) all layers were tested. For test 2 a combination of layers was investigated.

Table 15. Courses Used for Fatigue Tests.

Test N°	1	2	3	4	5	6	7	8	9
CCRIPPE Villach									
SC									
BC4									
BC3									
BC2									
BC1									
WWRIPPE Mindelo									
SC									
BC2									
BC1									

6.2 Type of test

Table 16 contains information on how the different test methods were conducted. Similar to rutting, the test methods can be attributed to six classes. Most laboratories preferred bending beam tests and used deformation or strain controlled methods. With the exception of tests 5 and 6, fatigue test temperatures for the materials of the two sections were equal. The input results for the models were generally complex modulus and fatigue curves.

Table 16. Sample Size, Test Temperature, Loading Condition and Input for Prediction Model

Test N°	Sample Size:	Test-Temp.		Loading – Condition	Input Result for Model:
		CCRI PPPE	WWRI PPPE		
Static Compression Test, Cylindrical Sample - S-CO-CY					
1	d=100mm, h=60mm	30°C 10°C -20°C	30°C 10°C -20°C	<u>Deformation controlled</u> Loading area Ø=100mm, constant deformation rate =0,21; 0,15; 0,06 mm/s	Energy based deformation modulus
Cyclic Compression Test, Cylindrical Sample - C-CO - CY					
2	d=100 mm h=125-170 mm	15°C	-	<u>Load controlled</u> Loading area Ø=100mm, sinusoidal load, load=0 - 241 kPa, frequency=10 Hz	Complex modulus,
Two Points Bending Beam, Trapezoidal Sample - 2PB - TR					
3	B=75mm b=30mm e=35-50mm h=250mm	-20°C	-20°C	<u>Load controlled</u> Frequency = 1, 3, 10, 30 Hz	Complex modulus, Phase angle,
		-10°C	-10°C		
		0°C	0°C		
		10°C	10°C		
		20°C	20°C		
		30°C	30°C		
		15°C	-	<u>Load controlled</u> Frequency = 30 Hz	Fatigue curve
4	B=75mm b=30mm e=35-50mm h=250mm	25°C 10°C	25°C 10°C	<u>Strain controlled</u> Frequency = 25 Hz	Complex modulus, Fatigue curve
Three Points Bending Beam, Prismatic Sample - 3PB - PR					
5	w=50 mm h=50 mm l=300 mm	18°C	20°C	<u>Deformation controlled</u> Distance between support=270mm, frequency = 10 Hz	Complex modulus, Fatigue curve
Four Points Bending Beam, Prismatic Sample - 4PB-PR					
6	w=62,5mm h=50 mm l=380 mm	16°C	20°C	<u>Strain controlled</u> Repeated sinusoidal loading, frequency =10 Hz, strain = 0,0003; 0,0005; 0,0007	Complex modulus, Fatigue curve
7	w=60 mm h=50 mm l=400 mm	20°C 5°C	20°C 5°C	<u>Strain controlled</u> Strain = 0,0002, frequency = 10 Hz	Complex modulus, Fatigue curve
8	w=63,5mm h=50,8mm l=381mm	20°C	20°C	<u>Strain controlled</u> Repeated sinusoidal loading, strain = 0,0002 and 0,0004, frequency =10 Hz	Complex modulus, Fatigue curve
Indirect Tensile Test, Cylindrical Sample - IT - CY					
9	d=100 mm h=60 mm	10°C	10°C	<u>Load controlled</u> Repeated load=2 Hz, loading time = 0,1s, rest period = 0,4 s	Resilient modulus, Fatigue curve

6.3 Fatigue and prediction model

On principle, all laboratories followed the same procedure. The modulus of the bituminous courses and layers were determined by different test methods and the modulus of subgrade and subsoil estimated. Strain and stresses were calculated by means of elastic multi-layer models and converted to ESALs which were compared to the acceptable design traffic loads. Where the participating laboratories did not provide an estimate on the remaining life after 10 years, this value was calculated during the general evaluation of the different test reports using the following equation:

$$RL = 1 - \frac{N}{n} \quad (1)$$

where RL denotes the remaining life after 10 years in percent; n stands for the calculated ESALs from the test results and N is the design traffic load in ESALs. The results are presented in Table 17. With the exception of test 9 the CCRIPPPE section is predicted to last much longer than the WWRIPPPE section. For the CCRIPPPE section the remaining life after 10 years is generally expected to be more than 80 %. For the WWRIPPPE section no agreement is observed. In this case, the estimation of the remaining life ranges from 0 to 84 %.

Table 17. Fatigue Test Characteristics and Estimation of Remaining Life after 10 Years

Test N°	Type of Test	Characteristic	Calculation Model	Remaining Life after 10 Years	
				CCRIPPPE Villach	WWRIPPPE Mindelo
1	S-CO-CY	Energy based modulus, stress	Jones	90 %	52 %
2	C-CO-CY	Complex modulus	BISAR	99 %	-
3	2PB-TR	Stiffness modulus	PAMINA BISAR	a	a
4	2PB-TR	Stiffness modulus	BISAR	95 %	3 %
5	C-CO-CY 3PB-PR	Dynamic modulus Fatigue curve	BISAR	94 %	0 %
6	4PB-PR	Stiffness modulus	BISAR	86%	82 %
			Asphalt Institute	15 %	9 %
		Fatigue curve		98 %	20 %
7	4PB-PR	Stiffness modulus Fatigue curve	PROPAD	b	b
8	4PB-PR	Stiffness modulus Fatigue curve	ELSYM5	99 %	84 %
9	C-IT-CY	Resilient modulus Fatigue curve	VAGDIM95 CHEVRON	50 %	67 %

a expected cracked area was provided (CCRIPPPE = 0,0 % and WWRIPPPE = 0,6 %)

b engineering judgement was provided

Fatigue life prediction by all laboratories in terms of net cracking is summarised in the classification Table 18. Whereas the laboratories reached a good agreement for the CCRIPPPE section, the results for the WWRIPPPE section were different in two cases.

As compared to rutting, the fatigue prediction was generally in better agreement. However, it has to be kept in mind that the prediction period of 10 years was about half of the real design period of the motorways. Therefore it can not be concluded from these results that the fatigue models are more accurate than the permanent deformation models.

Table 18. Classification of Fatigue Test and Prediction Results for 10 Years

	Net Cracking (% of 100 m ²)							
	CCRIPPE Villach				WWRIPPE Mindelo			
	<5	≤ 5 -<10	≤10 -<20	≥20	<5	≤ 5 -<10	≤10 -<20	≥20
Test N°	1				1	8		5
	2				3			
	3				4			
	4				6			
	5				7			
	6				9			
	7							
	8							
	9							
Total:	9	0	0	0	6	1	0	1

7. CONCLUSION

From the first results of this ongoing RILEM interlaboratory test programme the following conclusions can be drawn. Note, that the conclusions deal only with the pavement performance prediction by the laboratories. A comparison with the in field behaviour of the two sections is not possible yet.

- None of the laboratories followed a procedure and methodology which was directly comparable to one of the others.
- The rut depths predicted by different laboratories using their own test methods and prediction models varied over a wide range.
- In those cases where the curve of rut depth development was determined exactly, generally the larger permanent deformations were predicted for the CCRIPPE than for the WWRIPPE section. The values of the CCRIPPE section were more scattered.
- Some laboratories compared their rutting results with requirements which are fixed in regulations or national standards and came partly to contradicting conclusions. Hence, in some cases, the CCRIPPE section and in other cases, the WWRIPPE section did not pass the requirements.
- It was generally agreed, that rutting will probably not exceed 20 mm in both sections. As compared to the other methods, the predictions based on the wheel tracking test were extremely unfavourable for the WWRIPPE section.
- Compared to rutting, the fatigue predictions were in better agreement. However due to the fact that the prediction period was only about half of the design period, it can not be concluded that the fatigue models are more accurate than the permanent deformation models.
- With one exception the remaining life after 10 years of the CCRIPPE section is predicted to be higher. For the WWRIPPE section the prediction showed less agreement. Fatigue life prediction by all laboratories in terms of net cracking confirmed this finding.
- In summary, the findings clearly demonstrate that further exchange and co-ordination of research efforts is extremely necessary.

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10. KEYWORDS

Performance prediction, rutting, fatigue, test methods