Functional Durability-related Bitumen Specification (FunDBitS)

Jan Valentin (CTU Prague) et al.

Project introduction

- 11 partners – demanding on organization.
- Project duration 2014-2015 (extended to 2016).
- Project officially started in April 2014 (kick-off meeting during TRA2014 conference).
- Project coordinated by CTU in Prague.
- CEDR Project manager: Gerhard Eberl (ASFINAG).
- Project web page: www.fundbits.eu.
- Project data cloud provided for sharing data (question how to use this data source in the future).
- Originally focused on paving grades and PMBs, during the realization phase recycling, WMAs or CRMBs partly included.

FunDBitS – the project team

Czech Technical University in Prague	University of Kassel	Belgian Road Research Centre
Solvenian National Building and Civil Engineering Institute (ZAG)	TRL Limited	École Polytechnique Fédérale de Lausanne (EPFL)
European Asphalt Pavements Association (EAPA)	Laboratório Nacional de Engenharia Civil, I.P.	Turkish Asphalt Contractors Association (ASMUD)
Vienna University ofTechnology	NYNAS	

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Functional Durability-related Bitumen Specification

FunDBitS – the project

Preliminary Schedule

April 2014
Start of project
Project introduction during TRA 2014

April 2015
Paper compilation completed

August 2015
Correlative performance properties identified

September 2015
Proposal of bitumen performance specifications
End of project

April 2016
Workshop/presentation of results at TRA 2016 conference

June 2016
Presentation of results during Eurasphalt&Eurobitume Congress 2016

Project Coordinator

Jan Valentin
Faculty of Civil Engineering
Czech Technical University in Prague
Thakurova 7
166 29 Praha
Czech Republic
jan.valentin@fsv.cvut.cz

www.fundbits.eu

FUNDBITS PARTNERS

Czech Technical University in Prague
University of Kassel
Belgian Road Research Centre
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TRL Limited
École Polytechnique Fédérale de Lausanne (EPFL)
European Asphalt Pavements Association (EAPA)
Laboratório Nacional de Engenharia Civil, I.P.
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Vienna University of Technology
NYNAS

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Functional Durability-related Bitumen Specification

Functional Durability-related Bitumen Specification (FUNDBITS)

CEDR Transnational Road Research Programme (CEDR-TRRP) 2013

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Sponsors:

This project is sponsored by CEDR (Conference of European Directors of Roads) Transnational Research programme - Energy Efficiency: Materials and technologies and funded by the following countries and their Road Authorities: Germany, Norway, United Kingdom, Austria, Slovenia, The Netherlands.

Project structuring and working packages

- WP1: Management + dissemination (CTU Prague)
- WP2: Data gathering (BRRC)
- WP3: Data collection (University of Kassel)
- WP4: Data evaluation (TRL)
  - Task 4.1 Permanent deformation (rutting)
  - Task 4.2 Stiffness
  - Task 4.3 Low temperature cracking
  - Task 4.4 Fatigue cracking
  - Task 4.5 Binder/aggregate interaction
- WP5: Proposal for specification requirements (EPFL)

Background for the FunDBitS project

- Energy efficient asphalt pavements can be constructed using durable materials, since all is about value for money.
- To improve the durability of asphalt, performance-based (P-R) specifications were introduced in the past for asphalt mixtures.
- Durability of asphalt mixtures is highly dependent on the properties of the bituminous binders, which are specified by well known empirical tests but do not allow a prediction of asphalt performance.
- Particularly for PMBs this is a problem and weakening.
- Ageing of bitumen and asphalt mixtures (durability and recyclability aspects) is at present not taken into account by European specifications – no functional testing after short- or long-term ageing.

Background for the FunDBitS project

- For asphalt mixtures, P-R specifications were set in 2006 (EN 13108-series), whilst P-R bitumen specifications are still not implemented in EN 12591, EN 14023 and EN 13924.
- In FunDBitS project, new internationally available data were reviewed in order to identify potential P-R bitumen characteristics which may be introduced and promoted in bitumen product standards.
- The correlations established may also be applied for special binders containing various additives.
- The required discussions on the feasibility of test procedures and the results used for specifications should be continuously discussed within CEN TC336.

Background for the FunDBitS project

- The selected data sources covered whole Europe and most asphalt mixture types were addressed ➞ development of future climate-specific requirements applicable throughout Europe.

Key project objectives

Evaluate new data sources as a support for proposing a future system for performance-based bitumen specifications based on:

- changes of EN 12591, EN 14023 and EN 13924 for bitumen characteristics applied for performance-based specifications;
- changes of bitumen test procedures in order to be more precise on test conditions and to improve the test precision;
- proposed improvements for EN 13108 including suitable bitumen performance characteristics for selected asphalt mixture types.

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Functional Durability-related Bitumen Specification

What results were targeted?

- The new internationally available reviewed data shall help to develop P-R bitumen characteristics and introduce them to bitumen standards EN 12591, EN 14023 and EN 13924.
- The found correlations may also be applied for special binder products containing various additives.
- By having all stakeholders involved in the project, the required discussions on the feasibility of test procedures and the results for the specifications might shorten later discussions in CEN TC336 and its working groups, in particular CEN TC336 WG1/TG5.
- The project results should be available (at least patly) for the actual 5 year reviews of the bitumen specification standards (EN 12591 closed, EN 14023 discussion ongoing).

1st STEP: Data gathering

- Clear identification what relevant information are needed to establish relationships between binder properties and/or corresponding test methods and mixture/ pavement performance in the field.
- Enabling gathering of information in WP3 and, facilitating its further processing into a single database to serve as a tool to select data accordingly to a specific topic to be reviewed in WP4.
- Establish a virtual platform (cloud) for all relevant data.

REVIEWER

Name:	Cliff Nicholls
Affiliation:	TRL

REFERENCE

Title:	
Authors:	
Source:	

Binder properties

Elevated service temperature properties

Complex modulus	DSR	
	other	
Dynamic viscosity	Cone&Plate	
	Coaxial cylinders	
	Capillary viscosimeter	
	other	
Zero Shear Viscosity	Oscillation method	
	Creep method	
	other	
Softening point	R&B	
Creep stiffness	Repeated Creep Test	
Compliance and recovery	MSCR test	
	Elastic recovery	

e and/or low service temperature properties

Complex modulus	DSR	
	other	
Penetration	Penetration	x
Low temperature stiffness	BBR	
	Direct Tensile Test	
	other	
Cohesion	Force ductility	
	Direct Tensile Test	
	Vialit Pendulum Test	
	Fracture toughness test	
	other	
Fatigue	Binder fatigue test	
	other	

Ageing/Wheathering

short term ageing	RTFOT	
	TFOT	
	RFT	
	other	
long term ageing	PAV	
	RCAT	
	Modified German RFT	
	Modified RTFOT	

State binder

Pure	
Modified	
Unaged	
Short term aged	
Long term aged	
Recovered	

Mixture properties

Elevated service temperature properties

Stiffness	Stiffness test	
Permanent deformation	Wheel tracking test	
	Cyclic compression test	
	other	

Intermediate and/or low service temperature properties

Stiffness	Stiffness test	
Strength	Indirect tensile test	
	Direct tensile test	
	other	
Low temperature cracking	Thermal stress restrained specimen test	
	Crack propagation test	
	other	
Fatigue cracking	Fatigue test	
Adhesion	Aggregate/Binder affinity	
	Particle loss of Porous Asphalt	
	other	

Correlations

Binder/Mix	
Binder/Field	
Mix/Field	

Relevance

High	
Moderate	x

Comments:

Abstract:

Relevant data for bituminous binders

Elevated service temperature properties

Complex modulus	DSR	
	other	
Dynamic viscosity	Cone&Plate	
	Coaxial cylinders	
	Capillary viscosimeter	
	other	
Zero Shear Viscosity	Oscillation method	
	Creep method	
	other	
Softening point	R&B	
Creep stiffness	Repeated Creep Test	
Compliance and recovery	MSCR test	
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e and/or low service temperature properties

Complex modulus	DSR	
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Cohesion	Force ductility	
	Direct Tensile Test	
	Vialit Pendulum Test	
	Fracture toughness test	
	other	
Fatigue	Binder fatigue test	
	other	

Comments:

Relevant data for asphalt mixtures

es | ***Mixture properties***

Ageing/Wheathering

short term ageing	RTFOT	
	TFOT	
	RFT	
	other	
long term ageing	PAV	
	RCAT	
	Modified German RFT	
	Modified RTFOT	

State binder

Pure	
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Elevated service temperature properties

Stiffness	Stiffness test	
Permanent deformation	Wheel tracking test	
	Cyclic compression test	
	other	

Intermediate and/or low service temperature properties

Stiffness	Stiffness test	
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	other	
Low temperature cracking	Thermal stress restrained specimen test	
	Crack propagation test	
	other	
Fatigue cracking	Fatigue test	
Adhesion	Aggregate/Binder affinity	
	Particle loss of Porous Asphalt	
	other	

Correlations

Binder/Mix	
Binder/Field	
Mix/Field	

Relevance

High	
Moderate	x

2nd STEP: Data collection

- Collecting available data on performance-related bitumen characteristics in combination with asphalt properties to allow the correlation between these properties.
- Assessment of available data sources according to test methods and parameters, binder types and used asphalt mix designs.
- For each data source, available test values were included to the database to allow in the next step a combined correlation analysis for similar data sets.

2nd STEP: Data collection

DATA SOURCES

- Time period: 2007-2014 (some data from 20 5 included as well).
- International conferences (about 55 tant), national conferences (asphalt paveme events).
- International per-re Materials and Pavement Des journals).
- Key na journals from some countries.
- Analyzed form BiTVal project.
- Focus on b umen topics, asphalt topics and the relations between both fields.

MORE THAN 600 PAPERS, ARTICLES AND STUDIES FOR REVIEW

ID	Conference	Participant	Reviewer
1	TRB 2007		Stefan Vansteenkiste (BRRC)
2	AAPT 2007		Stefan Vansteenkiste (BRRC)
3	4th International Conference Bituminous Mixtures and Pavements (Thessaloniki)	Clif Nichollls (TRL), Jan Valentin (CTU)	Clif Nichollls (TRL)
4	LJMU International Conference on Sustainable Pavement Engineering and Infrastructures	Cliff Nicholls (TRL)	Cliff Nicholls (TRL)
5	ARRB07		Gulay Malkoc
6	TRB 2008		Stefan Vansteenkiste (BRRC)
7	AAPT 2008	Nicolas Bueche (EPFL)	Nicolas Bueche (EPFL)
8	Euroasphalt & Eurobitume 2008	Cliff Nicholls (TRL), Jan Valentin (CTU)	Cliff Nicholls (TRL)
9	ISAP 2008	Nicolas Bueche (EPFL), Fátima Batista (LNEC)	Nicolas Bueche (EPFL)
10	TRA 2008	LNEC (Maria de Lurdes Antunes)	Fátima Batista/Margarida Sá da Costa (LNEC)
11	LJMU International Conference on Sustainable Pavement Engineering and Infrastructures	Cliff Nicholls (TRL)	Cliff Nicholls (TRL)
12	ARRB08	Cliff Nicholls (TRL)	Cliff Nicholls (TRL)
13	RILEM 2008 - Cracking in Pavements		Konrad Mollenhauer (UNI KASSEL)
14	EPAM3 (Coimbra, Portugal, 2008)	Fátima Batista (LNEC)	Fátima Batista/Margarida Sá da Costa (LNEC)
15	TRB 2009		Stefan Vansteenkiste (BRRC)
16	AAPT 2009		Stefan Vansteenkiste (BRRC)
		Bernhard Hofko (TUW), Jan Valentin (CTU), Fátima	

3rd STEP: Data evaluation

- Identification of relevant information available in the literature, combining and sorting that on each of the major aspects of asphalt performance (*stiffness, rutting, cracking, adhesion, fatigue*).
- Review of the relations between the bitumen and asphalt properties in particular with focus on its durability and service life.
- Consideration on the reliability of the test methods and presence of other factors on the asphalt properties in the data source.
- The work splitted into five tasks, including always a task for each of the main asphalt properties.
- RESULT: Interim Report D.1

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Bitumen Specification

CEDR Transnational Road Research Programm
Call 2013: Energy Efficiency –
Materials and Technology

Funded by Germany, Netherlands,
Norway, UK, Austria and Slovenia

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Bitumen Specification

Functional Durability-related B
Specification (FunDBitS

Identified correlations between bitur
asphalt properties (Interim Rep

Deliverable No I
April 2015

Czech Technical University in Prague (CTU), Czech Repu
University of Kassel (UoK), Germany
Belgian Road Research Centre (BRRC), Belgium
Slovenian National Building & Civil Engineering Institute (Z
Transport Research Laboratory (TRL), UK
École Polytechnique Fédérale de Lausanne (EPFL), Switz
European Asphalt Paving Association (EAPA), Belgium
Laboratório Nacional de Engenharia Civil (LNEC), Portuga
ASMUD, Turkey
Vienna University of Technology (TU Vienna), Austria
Nynas NV, Belgium

Table of contents

CEDR Call 2013: Energy Efficiency – Materials and Technology

7 Low temperature cracking

7.1 Asphalt test methods for low temperature cracking

7.1.1 General

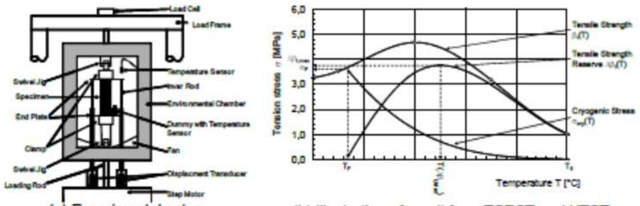
Low temperature cracking is particularly important for evaluating the low temperature behaviour of asphalt. In this Chapter of Report D1, several test procedures for determining the low temperature cracking properties of asphalt are included. These are:

- tensile stress restrained specimen test (TSRST), as specified in EN 12697-46;
- uniaxial tensile strength test (UTST), as specified in EN 12697-46;
- uniaxial relaxation test (RT), as specified in EN 12697-46;
- unrestrained thermal dilation test (TST),
- Indirect tension test for examining low-temperature strength and creep compliance (IDTC)
- Semi-circular bending tests (SCBT), as specified in EN 12697-44;
- Disk-Shaped Compact tension test (DCTT);
- Acoustic emissions test (AET);
- Uniaxial Thermal stress and strain test (UTSST)

7.1.2 Test procedures with uniaxial loading

Several test procedures, which are used for the assessment of low-temperature cracking resistance, are uniaxial tensile tests. The specimen with rectangular or circular cross-section and a length considerably higher compared to diameter or width/thickness is glued to loading platens in order to introduce tensile forces.

The tensile stress restrained specimen test (TSRST) addresses loading conditions occurring in field when the road is cooled down. Therefore, the specimen is cooled down while it is held at constant length. Any movement of the specimen as a consequence of thermal shrinkage is monitored by LVDTs, activating a screw jack that stretches the specimen back to its original length. The restrained thermal shrinkage results in cryogenic stress in the specimen which increases with decreasing temperature. According to EN 12697-46 the *failure temperature* T_f and the associated *failure stress* σ_f are the results of the test. Further the cryogenic stress at predefined temperatures $\sigma_{cry}(T)$ can be assessed. Usually applied test parameters are a temperature rate of -10 °C/h starting from a temperature of 20 °C. An illustration of the test procedure of the TSRST is given in Figure 7-1.



(a) Experimental setup (b) Illustration of result from TSRST and UTST

Figure 7-1 – Tensile stress restrained specimen test (EN 12697-46)

Interim report - overview

RECOMMENDATIONS FROM BiTVal:

- Identify the binder properties linked to the performance requirements of asphalt pavements. **(addressed by CEN TC336)**
- Select and standardize appropriate (new) test methods to measure these properties. **(addressed by CEN TC336)**
- Collect data and ensure field validation for establishing (new) binder specifications. **(addressed by FEHRL)**
- Review the grading system according to the (new) specification.

BUT finally the continuity of BiTVal approach was followed only partially.

Interim report – available bitumen tests

SUMMARY ON AVAILABLE BITUMEN TESTS (part I):

- Complex shear modulus and phase angle on DSR (EN 14770)
- MSCR Test (EN 16659)
- Bending Beam Rheometer Test (EN 14771)
- Direct Tensile Test (not standardized in Europe)
- Capillary Viscometer Test (EN 12595, EN 12596)
- Cone and Plate Viscosity Test (EN 13702-2)
- Coaxial Cylinder Viscosity Test (EN 13702-2)
- Creep Zero Shear Viscosity Test (prEN 15325)
- Oscillation Zero/Low Shear Viscosity (ZSV/LSV) Test (CEN/TS 15324; within TC 336)
- Linear Amplitude Sweep Test

Interim report – available bitumen tests

SUMMARY ON AVAILABLE BITUMEN TESTS (part I):

- Oscillatory Squeeze Flow Rheometer (no standards, possibly could be part of EN 14770)
- Repeated Creep Test (only AASHTO standard not standardized in Europe)
- DSR Fatigue Test (only few laboratories in the world)
- Fracture Toughness Test (partly standardized in the UK)

Interim report – available bitumen tests

<u>SUMMARY ON AVAILABLE BITUMEN TESTS (part II):</u>

- Needle Penetration (EN 1426)
- Softening point R&B (EN 1427)
- Penetration Index (EN 1427)
- Fraass Breaking Point Test (EN 12593)
- Elastic Recovery Test(EN 13398)
- Force Ductility Test (EN 13589 + EN 13703)
- Tensile Test (EN 13587)
- Vialit Pendulum Test (EN 13588)

Interim report – permanent deformations

ASPHALT TESTS:

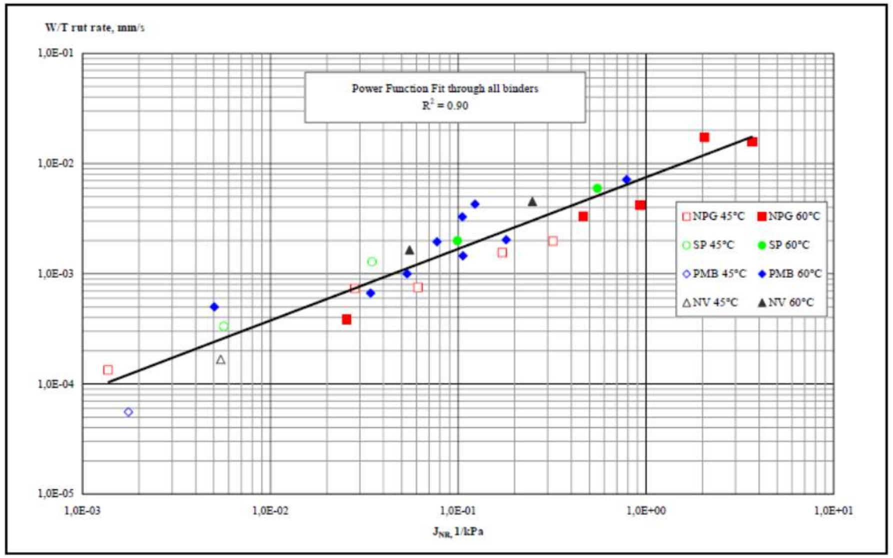
- Wheel tracking test
- Cyclic compression test (EN 12697 25)
- SUPERPAVE Shear Tester
- Simple Performance Tests (SPT)
- Coaxial Shear Test (CAST)
- Carleton in-situ shear strength test
- Uniaxial Shear Tester (European invention)

Interim report – permanent deformations

- Relationship between bitumen viscosity properties and asphalt resistance to permanent deformation
  - Capillary Viscometer Test
  - Coaxial Cylinder Viscosity Test
  - Cone and Plate Viscosity Test
  - Creep Zero Shear Viscosity (ZSV) Test
  - Oscillation Zero/Low Shear Viscosity (ZSV/LSV) Test
- Relationship between bitumen softening point and asphalt resistance to permanent deformation
- Relationship between bitumen elastic and recovery properties and asphalt resistance to permanent deformation
  - Multiple Stress Creep and Recovery (MSCR) Test
  - Elastic Recovery Test
  - Repeated Creep Test

Interim report – permanent deformations

- Relationship between bitumen complex modulus + phase angle and asphalt resistance to permanent deformation
  - Dynamic Shear Rheometer (DSR) Test
- Relationship between bitumen Performance Grading and resistance to permanent deformation



MSCR vs. rut rate

Interim report – permanent deformations

- Only in limited studies/papers the ageing effect on test results used and evaluated for interpretation of permanent resistance of asphalt mixtures.
- Precision related to correlations of available tests is needed.
- Some papers identified during the review contained scattering data for the results given (e.g. relatively high coefficient of variation obtained for HWTT results).
- Some papers where uncertainty of correlations is addressed were identified as well.

Interim report – stiffness

ASPHALT TESTS:

- Two point bending test on trapezoidal specimens (2PB-TR) or on prismatic specimens (2PB-PR; EN 12697-26)
- Three point bending test on prismatic specimens (3PB-PR) and four point bending test on prismatic specimens (4PB-PR; EN 12697-26)
- Indirect tension to cylindrical specimens (IT-CY; EN 12697-26)
- Direct tension-compression test on cylindrical specimens (DTC-CY; EN 12697-26)
- Direct tension to cylindrical specimens (DT-CY) or to prismatic specimens (DT-PR; EN 12697-26)
- Cyclic indirect tension to cylindrical specimens (CIT-CY; EN 12697-26)
- Dynamic complex modulus according to AASHTO TP62

Interim report – stiffness

- Relationship found between bitumen properties (moderate and elevated temperatures) and asphalt stiffness
  - Needle Penetration, Softening Point and PI
  - Complex Shear Modulus and Phase Angle
  - Creep Zero Shear Viscosity (ZSV) Test
  - Oscillation Zero/Low Shear Viscosity (ZSV/LSV) Test
- Relationship found between bitumen properties (low temperatures) and asphalt stiffness
  - Fraass Breaking Point
  - Bending Beam Rheometer (creep stiffness) and Direct Tension Test
- PG grading and possible relationships with asphalt stiffness
  - Focus on Master Curve (mainly)
- Effects of different additives and modifiers
  - Natural asphalt, crumb rubber, WMAs

Binder test	Asphalt test			
	SMA/wheel tracking	AC(basalts)/stiff.	AC(limest.)/stiff.	PA(basalts)/stiff
Penetration	0.43	0.88	0.67	0.97
Penetration mod. I	0.58	0.87	0.70	0.96
Softening point	0.90	0.23	0.22	0.37
Fraass Break Point	0.5	0.55	0.55	0.57
Kinematic viscosity	0.57	0.50	0.19	0.58
Dynamic viscosity	0.66	0.44	0.18	0.56
Penetration/RTFOT	0.53	0.89	0.72	0.94
Soft. point/RTFOT	0.94	0.25	0.23	0.40
Dyn. visc./RTFOT	0.44	0.67	0.25	0.75
Elastic recovery	0.47	0.00	0.03	0.00
Deformation energy II	0.48	0.93	0.78	0.97
Deformation energy III	0.86	0.08	0.50	0.23
Cone Plate viscosity IV	0.72	0.54	0.30	0.66
Cone Plate viscosity V	0.57	0.57	0.34	0.63
Ekviviscous temp. VI	0.68	0.54	0.36	0.61
Coaxial cyl. visk. VII	0.50	0.67	0.32	0.73
Coaxial cyl. visk. VIII	0.55	0.51	0.20	0.58

(Sybilski et al., 2009)

Interim report – stiffness

- Repeatedly confirmed: the mix stiffness is dependent largely on binder stiffness.
- Several test methods for asphalt stiffness but still not sufficient knowledge about their comparability. Potential correlations in different studies made with different test methods.
- Precision related to correlations of available tests is needed.
- Very low focus paid on ageing, but stiffness is a performance characteristic related to service life ➞bitumen ageing will have an impact.

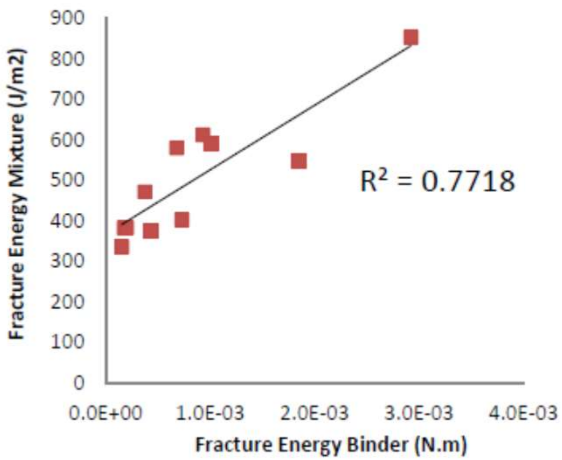
Interim report – low temperature cracking

ASPHALT TESTS:

- Tensile stress restrained specimen test (TSRST) (EN 12697-46)
- Uniaxial tensile strength test (UTST) (EN 12697-46)
- Uniaxial relaxation test (RT) (EN 12697-46)
- Unrestrained thermal dilation test (TST)
- Indirect tension test for examining low-temperature strength and creep compliance (IDTC)
- Semi-circular bending tests (SCBT) (EN 12697-44)
- Disk-Shaped Compact tension test (DCTT)
- Acoustic emissions test (AET)
- Uniaxial Thermal stress and strain test (UTSST)

Interim report – low temperature cracking

- Relationship found between bitumen properties and asphalt low temperature cracking
  - Binder-Mix relations and TSRST
  - Binder-Mix relations and uniaxial test methods on asphalt mixtures
  - Binder-Mix relations and IDT/IDTC results
  - Binder-Mix results and findings from fracture energy assessments



Comparison of fracture tests on bitumen (by Fracture Toughness test) and asphalt samples (FENIX test)

Interim report – low temperature cracking

- According to paper review by far the most used test method is TSRST.
- Precision on correlations of TSRST and other low-temperature tests not well evaluated.
- Several papers contained scattering data for the results given.
- Standard deviations for test results can be compared with standard deviations found on the air void content of the test samples applied.
- Fraass breaking point suitable only for assessing the failure temperature obtained in TSRST. In general only weak correlations between bitumen characteristics and asphalt resistance to low-temperature cracking.
- Bending beam test results showed that temperature T(300 MPa) is suitable for predicting the failure temperature of TSRST asphalt mix test. However, this property demands comparably high test effort and large bitumen samples.

Interim report – fatigue life

General

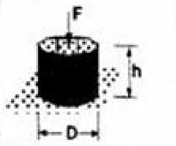
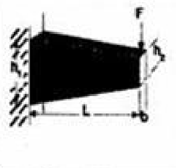
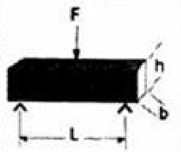
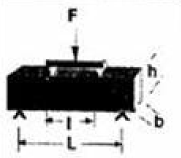
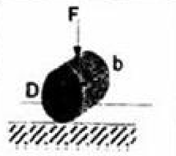
Fatigue tests on asphalt are undertaken under cyclic loading on specimen cut from pavements or manufactured in the laboratory using two types of sinusoidal loading.

BUT…. there are no reliable data on extensive bitumen fatigue testing in Europe.

Interim report – fatigue life

Findings made already by RILEM study 1996:

- The determined fatigue life values are significantly affected by the test method employed.
- No correlation was found between the fatigue lives obtained from stress- (load-) and strain- (displacement-) controlled fatigue tests.
- The results of the beam tests (2PB, 3PB and 4PB) appeared to be dependent on the kind of used test as well as on the size of the sample.
- For a given strain (or stress) amplitude, the beam tests (2PB, 3PB, and 4PB) generally resulted in longer fatigue life compared to homogeneous tension/compression (T/C) tests.
- Biasing effects (are not fatigue) exist during a fatigue test and affect the result, e.g. the heat caused by the accumulation of dissipated energy or the thixotropy of the binder.

Type	Test Geometry	Type of loading/ Country of the team	Amplitude (10^{-6} m/m or MPa)
T/C		Tension-Compression "Homogeneous" F_1, S_1	Strain: (80), 100,140, 180 Stress: 0.9
2PB		Two-Point Bending "Non Homogeneous" F_2, B_1, B_2	Displacement; max strain: 140, 180, 220 Load; max stress: 1.4
3PB		Three-Point Bending "Non Homogeneous" N_1	Displacement; max strain: 140, 180, 220 Load; max stress: 1.4
4PB		Four-Point Bending "Non Homogeneous" N_2, P, PL, UK	Displacement; max strain: 140, 180, 220 Load; max stress: 1.4
ITT		Indirect Tensile Test "Non Homogeneous" S_2	Load; max strain: at first cycle: ~25, ~40, ~65

+

Alternative methods:

- The strain sweep test (EBADE)
- Overlay tester
- Application of viscoelastic continuum damage (VECD) mechanics – used for binders.
- Binder fracture energy test (DT test)

Interim report – fatigue life

- Relationship found between bitumen properties and asphalt fatigue cracking
  - Standard bitumen properties
  - DSR related characteristics (G*.sin(δ))
  - Bending Beam Rheometer and low temperature cracking
  - Linear Amplitude Sweep Test (LAS)
  - Comparison of master curves
  - Binder content in the mix
  - Bitumen type including its modification and effect on fatigue
- Fatigue life of unconventional mixtures (higher RAP content, crumb rubber, WMA)
- Fatigue life and healing effect
- Binder ageing effect on fatigue cracking

Interim report – fatigue life

BINDER EFFECT

- Generally, the asphalt mixtures with higher bitumen content or polymer modification show a higher resistance to fatigue cracking.
- No proper binder test to describe bitumen impact on fatigue properties.
- Important parameter for fatigue evaluation seems to be critical strain/deformation of bituminous binders in a DSR test.

Interim report – fatigue life

AGEING EFFECTS

- Only two papers found dealing more extensive with ageing (one study only using unaged and aged bitumen).
- Ageing studied by following changes in stiffness behavior comparing aged and unaged materials.
- Two papers and different ageing protocols.
- There is generally any consistent and vast collection on knowledge how ageing affects fatigue life if comparing bitumen and asphalt mix.

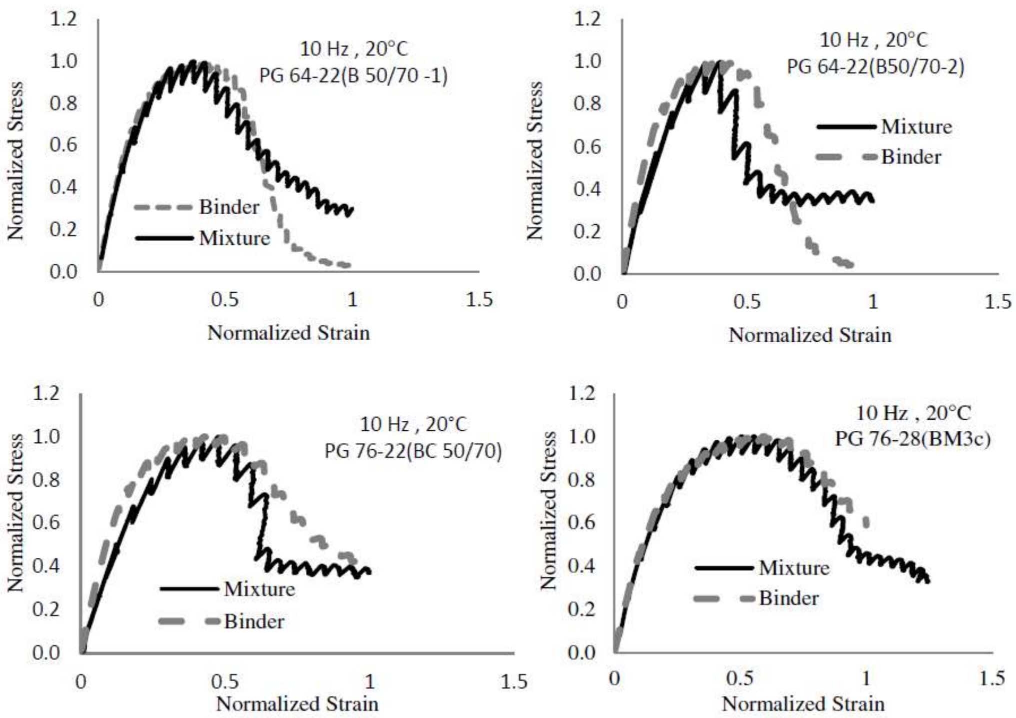
Interim report – fatigue life

CORRELATIONS

- It was found that it is very difficult to find a direct relationship between the fatigue properties of the binder and the asphalt mixtures.
- Very little information on correlation between bitumen and asphalt fatigue cracking.
- Mixture stiffness is to some extend related to the mixture fatigue properties – this might be a good start.
- Strong binder vs. asphalt mix correlations found in stiffness chapter.
- No found data and correlations comparing binders and asphalt mixtures from real pavement structures.

Interim report – fatigue life

- Only one paper found with good correlation between stress/strain response of the mixture (EBADE) and the binder (LAS).



Interim report – binder/aggregate interaction

Adhesion in general

Adhesion is defined as the bond between only two materials, but in case of composite asphalt mixture the situation is more complex.

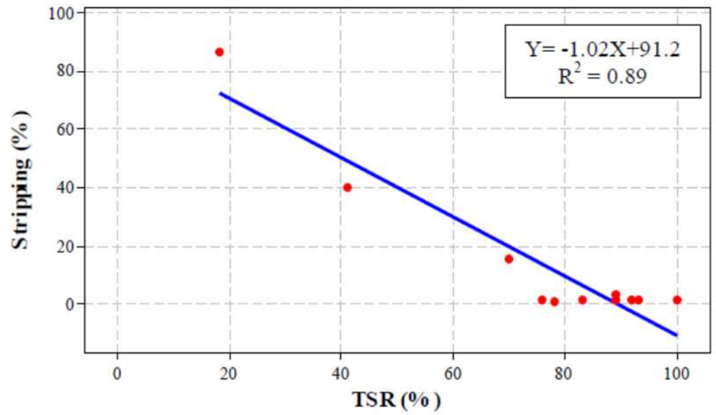
Basic asphalt test methods used in Europe:

- Determination of the affinity between aggregates and binder (EN 12697-11)
- Determination of the water sensitivity of bituminous specimens (EN 12697-12)

Test method	Advantages	Limitations
Rolling bottle test	Simple and easy to perform	Visual and, therefore, subjective evaluation of test result, making it a screening technique
Boiling water stripping test	Objective test	Need for chemicals
Ultrasonic method	High sensitivity	Highly dependant of experimental set up
Net adsorption test	Thermodynamic basis (Langmuir isotherms)	Further research needed in order to predict the in service performance
Vialit plate test	Considerable experience	Interpretation in terms of adhesion hampere by other parameters such as cohesion and ductility
Indirect tensile strength	Takes into account the effect of water conditioning Test carried out on a asphalt mixture	Validation with in situ performance not straightforward Interpretation of test results by the use of a single parameter (moisture) is questionable
PATTI	Well established test used in coating industry	Mode of failure changes with water conditioning (cohesive to adhesive)
SATS	Replicates observed loss of adhesion	Limited experience Results highly dependent on aggregate
Surface energies of materials	Based on solid thermodynamic principles	Sophisticated instrumentation needed Theoretical model only valid for systems in equilibrium
Water immersion test, aggregate method	–	Designed specifically for bitumen emulsions only
Shaking abrasion test	–	Designed specifically for bitumen emulsions in slurry surfacings only

Interim report – binder/aggregate interaction

- Bitumen tests correlating with binder/aggregate interaction
  - Tests conducted on compacted mixtures (ITSR, MIST etc.)
  - Tests conducted on loose coated aggregate



The correlation between tensile strength ratios limited to 100 % and stripping percentages in boiling test

- Binder ageing effect on binder/aggregate interaction
  - Discussed in only a very limited number of publications
  - How does short- and long-term ageing influence adhesive and cohesive properties of bitumen

Interim report – binder/aggregate interaction

- Uncertainty for binder/aggregate interaction is largely arising from the fact that while assessing the water sensitivity of asphalt mixtures other parameters/factors than adhesion also play a role in the outcome of the test such as choice and grading of the mixtures, sample preparation and conditioning method. Therefore, interpretation in term of adhesion is often hampered.
- Precision of the test methods themselves is sometime unsatisfactory. A typical example is the water sensitivity test according to EN 12697-12 where a R = 23% is stated in the standard.
- Tests carried out on loose mixtures such as the Rolling Bottle method (EN 12697-11) rely on a visual assessment of the stripping percentage which is decreasing the efficiency of such method.

Interim report – binder/aggregate interaction

- Ageing is addressed more often than ii case of the other monitored characteristic.
- However, it is still not a regular must for all test.
- Uncertainty of fatigue cracking addressed by several papers.
- One strong conclusion related to fatigue testing: „It will not be possible to base the framework of future performance specifications solely on tests such as DSR and BBR as currently conducted“.
- Maybe special treatment in the load response modeling for pavement design is needed when WMA and RAP are used.

4th STEP: Proposing recommendations for bitumen specifications

- Focus on detailed correlations between bitumen and asphalt mixture for the key durability characteristics.
- Based on the observed relations between bitumen characteristics and obtained performances, some specification requirements proposed.
- These do not aim at being normative but propose some limitations which might be considered for choice on binders during asphalt mix design.
- The proposed recommendations on specs take also into account the expected solicitations (climate, traffic).
- RESULT: reports D.2a – D.2e + the final report.

CEDR Transnational Road Research Programme
Call 2013: Energy Efficiency – Materials and Technology

Funded by Germany, Netherlands, Norway, UK, Austria and Slovenia

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

FunDBitS
Functional Durability-related Bitumen Specification

Functional Durability-related Bitumen Specification (FunDBitS)

Correlations between bitumen and asphalt properties

Binder/aggregate interaction (water sensitivity)

Deliverable D.2e
August 2016

Czech Technical University in Prague (CTU), Czech Republic
University of Kassel (UoK), Germany
Belgian Road Research Centre (BRRC), Belgium
Slovenian National Building & Civil Engineering Institute (ZAG), Slovenia
Transport Research Laboratory (TRL), UK
École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
European Asphalt Paving Association (EAPA), Belgium
Laboratório Nacional de Engenharia Civil (LNEC), Portugal
ASMUD, Turkey
Vienna University of Technology (TU Vienna), Austria
Nynas NV, Belgium

Additional data sources and feedbacks from the practice

- Regular presentation of the project progress to EAPA committees.
- Presentation of the project progress to CEN TC336 and TC227 – cooperation in terms of joint approach towards revised versions of European standards set.
- Additional data Exchange with the U.S. via NAPA (American Asphalt Pavement Association) – used partially.
- Knowledge exchange with experts from Russia and some Middle East countries.

Dissemination and publicity

- 6th International Conference Bituminous Mixtures and Pavements (Greece)
- CAPSA2015 conference (South Africa) – information about the project presented and experience exchanged
- Eurobitume & Eurasphalt Congress 2016 (Czech Republic)
- Presence on TRA 2016 (Poland)
- 5th International Conference on PMBs (Russia)
- ARGUS Asia Europe Conference 2015 (Turkey)
- ARGUS Conference 2016 (Spain)
- 3rd MESAT 2015 Conference on Performance related specs

General conclusions

- Several correlations found and proven by different studies and paper.
- Suitable performance related test methods can be identified for most of the followed characteristics:
  - Complex shear modulus for stiffness,
  - MSCR test for permanent deformation,
  - BBR test for cold temperature cracking,
  - Linear Amplitude Sweep Test (promising for fatigue).
- Ageing is missed mainly for asphalt mixtures ➞ what kind of behavior do we evaluate and qualify?
- Image analyzing techniques for binder/aggregate interaction should be reviewed.
- Development toward mechano-chemistry seems to be unavoidable.

Thank you for your attention