Position Paper: Performance Related Specifications for Bituminous Binders

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Executive Summary

This document provides the bitumen industry viewpoint on the development of performance related bitumen specifications. It is an update of the industry position reported in 2002. It is intended to facilitate communication with the relevant CEN Committees and exchange of views with the other stakeholders in the specification development processes, in particular with the asphalt industry (EAPA).

Consideration is given to the next generation of specifications for hot applied asphalt mixtures based on a review of specification development activities since 2002 and the internal survey of Eurobitume members' strategic requirements in this area from 2007.

There are three key outcomes of the taskforce work:

(1) A new specification is required only for rheologically "complex" bitumens such as polymer modified and hard paving grade bitumen. Rheologically "simple" bitumen that meets EN 12591 specification does not need new specifications as EN 12591 is considered adequately related to performance.

(2) An up-to-date review of bitumen test methods that could be considered for future specification purposes.

(3) An outline proposal for a future specification framework

January 2012

1. Introduction

The first generation of harmonised bitumen standards (EN12591 Paving grade bitumens, EN14023 Polymer modified bitumens and EN13924 Hard paving grade bitumens) is now being used in most European countries. EN14023 and EN13924 are relatively new and people need time to implement these standards and to build up experience with them.

Although the above standards have been recently published there is a need to start working on the second generation of bitumen standards now because:

- The first generation standards consist of specifications based upon traditional empirical test methods. Work programs are being undertaken to evaluate alternative properties and test methods in order to develop new specifications that are more directly performance related.
- Performance related specifications are required by the Construction Products Directive to avoid barriers of trade.
- Empirical standards are based on experience gained in the past, mainly with traditional binders, while performance related standards would cover a broader range of products and might stimulate new developments.
- The bitumen industry would like to have other/additional tests based upon sound engineering principles.
- Standardisation takes a lot of time and therefore we have to start now to be able to start drafting the second generation standards as soon as possible.

Before the new standards can be drafted to replace existing standards, input is required from all of the stakeholders and users of the standards.

Binder adhesion, the bond strength of bitumen and mineral aggregate, is not addressed in this paper, although it is clearly important to long term performance. However, binder adhesion has been the topic of a substantial amount of work by CEN. This work concluded that no easy-to-use test method exists to characterise bitumen adhesion and it is unlikely that one will emerge in the near future. Adhesion is therefore an aspect that should be considered in the asphalt “system” rather than at binder level.

Finally, a binder specification or an asphalt specification can never be substitutes for functional specification of the end product: the road pavement. Performance related bitumen or asphalt specifications are no guarantee for the final pavement to perform. However, they are an all important step to describe the individual components of the asphalt pavement in rational engineering terms to ensure fit for purpose road materials are specified, chosen and applied.

2. Background

The objective of Eurobitume Task Force Performance Related Specifications (PRS) was to develop a bitumen industry viewpoint on Performance Related Standards for bituminous binders for hot applied paving applications.

The project was undertaken in two phases:

- Develop an updated Eurobitume position for the best way to specify Paving Binders:
  - To outline a proposal for future binder specifications in the form of a specification framework based on output and lessons from TF Data Collection.
  - To prepare the Eurobitume input to TG5 Specifications of CEN/TC 336 WG1.
- To define and implement strategies for input to CEN based upon the Eurobitume position as far as possible.
  - To maintain a close dialogue with other stakeholders in the process, in particular the asphalt industry and CEN/TC 227 WG1 (Bituminous Mixtures).

2.1. Previous Eurobitume position paper

In 2002 Eurobitume published a position paper representing the views of the members on PRS [2]. The position paper recognised that the development of PRS is both desirable and required by the Construction Products Directive. However, future specifications must be practical and avoid over-specification, which would add complexity without adding any benefit.

2.2. CEN/TC 336 Work

The Construction Products Directive (CPD) sets out a series of essential requirements (ER) for construction products. Those applicable to bituminous binders are as follows:

Mechanical resistance and stability

Safety in case of fire

Hygiene, health & the environment

Safety in use

In addition, each CEN Technical Committee (TC) is required to respond to a mandate from CEN dictating the work that the TC must carry out. The CPD was replaced by the Construction Products Regulation (CPR) in March 2011, the main articles of which shall apply from 1st July 2013. However, the work of CEN/TC 336 is already anticipating the CPR.

The CPD (for TC336 covered by Mandate M/124) requires that harmonised standards should be expressed as far as possible in terms which are “performance based”. Most conventional standards are based on empirical (traditional) test methods, which may not be applicable for certain binder types and thus may not comply with the performance based requirements of the mandate. The business plan of CEN/TC336 states that one of the objectives is to develop a performance-based approach to bitumen standardisation.

A Task Group has been established (WG1 TG5) to oversee the development of the next generation of specifications. A stepwise approach is being followed to maintain the commitment of all member states.

The first step in the process was orchestrated by Eurobitume in 1995 with a European workshop on rheology. This was followed in 1999 by an International workshop on performance related properties for bituminous binders. The workshop aimed to identify key properties of binders associated with pavement performance. The workshop was a great success and the proceedings were published by Eurobitume. Binder properties believed to be associated with performance were summarised (see table 1), and areas where further research was necessary were highlighted.

Table 1 - Binder Properties linked to Asphalt Performance

Performance Requirements for Pavement/ Mix	Binder Properties
Resistance to permanent deformation	Rheological property at elevated service temperature
Resistance to surface cracking due to binder ageing	Ageing behaviour: short term and long term
Structural strength	Rheological property: complex modulus
Resistance to low temperature cracking	Combination of rheological and failure properties
Resistance to fatigue cracking	Failure property
Manufacturing and laying	Viscosity vs temperature, Storage stability

Following the rheology workshop, Eurobitume, in conjunction with other associate members, arranged a series of seminars known as BitSpec (Bitumen Specifications) with the aim of determining the needs of the producers and users of bitumen (See section [2].3). This took place during 2003. Liaison with all stakeholders was essential to ensure that the needs of all parties were taken into account. The seminars were well attended by over 1000 representatives from all parts of the industry and the outputs from that project were made available to WG1 and given in the Eurobitume BiTSpec Proceedings[3].

The following basic sequential steps should be followed to ensure that, for the second generation standards, the performance relationships of a binder property are assessed appropriately before a specification is developed:

- Step 1: Identify the binder properties linked to the performance requirements of asphalt pavements:
  - In conjunction with FEHRL (Federation of European Highway Research Laboratories) Eurobitume organised a series of workshops
- Step 2: Select and standardise appropriate (new) test methods to measure these properties,

- Step 3: Collect data and ensure field validation for establishing (new) binder specifications,
- Step 4: Review the grading system according to the (new) specification.

2.2.1. CEN/TR 15352 - Bitumen and bituminous binders - Development of performance related specifications: status report 2005

CEN/TC 336 WG1 produced a Technical Report (TR) [4] in 2005 summarising the status of work towards performance related specifications. The document contains a synthesis of TC336 WG1 (Paving bitumens) work on the development of second generation (performance-related) specifications for paving grade bitumens. The TR summarises and illustrates the ongoing work in the standardisation area with reference to the process of developing from traditional "empirical" based specifications to new "performance-related" specifications for paving bitumens, as required by the Mandate M/124. The technical report contains a list of candidate test methods for high, medium and low temperature properties as well as ageing regimes. A shortcoming of the technical report is that it has not been updated since 2005 and therefore it does not contain information on recently developed test methods, such as the Multi Stress Creep Recovery test (MSCR), developed in the USA.

2.3. BiTSpec

The BiTSpec project started in 2002 and was designed as a 2-year communication project aimed to support the development of the future specification system for bituminous binders in Europe.

In early 2002 the European organisations representing the supply chain for road materials were asked to express their needs related to the future binder specification system. These different stakeholders developed and delivered position papers:

CEDR - The Conference of European Directors of Roads (formerly WERD)

EAPA - The European Asphalt Pavement Association

Eurobitume - The European Bitumen Producers Organisation

FEHRL - The Forum of European National Highway Research Laboratories

IISRP - The International Institute of Synthetic Rubber Producers.

10 regional BiTSpec seminars were organised which gathered 875 participants from 27 countries between April 2002 and April 2003 offering the opportunity for stakeholders to consider the specific conditions and requirements of the different countries.

In June 2003 the outcome of the regional workshops were presented and discussed with the 155 participants at the European BiTSpec seminar, aiming to find consensus and make progress in the definition of the system.

The industry is presently in a transition period during which the outcome of BiTSpec is being progressed under the responsibility of CEN/TC 336 WG1 TG5; it will require close co-operation with CEN/TC 227 (in charge road of materials and asphalt specifications). The next steps include:

- The publication of new (harmonised) European standards for test methods.
- The design, publication and use of a transition framework to gain experience and collect data with new tests.
- A validation project managed by FEHRL to assess correlation with asphalt and pavement performance.

2.4. BiTVal

The Bitumen Test Validation (BiTVal) project was set up by FEHRL (the Forum of European National Highway Research Laboratories) in response to a request from TC 336, together with other stakeholders in the industry, to assess the relevance of the results of bitumen tests on the required properties of asphalt mixtures. It is envisaged that there will be the following three phases to the project:

- Phase 1: A review of existing literature on bitumen tests used by TC 336 WG1;
- Phase 2: A study of the gaps in the knowledge identified in Phase 1;
- Phase 3: A study of any bitumen test methods missing from the original list.

Phase 1 has now been completed. The key outputs of Phase 1 of the BiTVal project were a database, covering publications of the identified bitumen properties and their relationship to asphalt properties and/or road performance, and a FEHRL report [5] to TC336 WG1 summarising the performance-related aspects for each test method, together with recommendations for their use in the next generation of standards.

At the time of writing FEHRL has reached a funding impasse; phases 2 and 3 will require significant funding and CEN does not contribute funds to standardisation activities. FEHRL is currently in dialogue with CEDR to see whether finding can be made available, although it is likely that the programme of work will need to be less ambitious than originally envisaged.

2.5. Milestones / Timeline

Figure 1 provides an overview of key milestones (historic and future) in the development of performance related specifications.

Figure 1 - Overview of key milestones (historic and future) in the development of performance related specifications

	Bitumen Industry	CEN - Bitumen (TC336)
1995	European Rheology Workshop (Brussels)	
1999	International Rheology Workshop (Luxembourg)	EN 12591 – Bitumen and bituminous binders – Specifications for paving grade bitumens:1999
2002	Eurobitume position paper PRS BiTSpec initiative	

	Bitumen Industry	CEN - Bitumen (TC336)
2003	BitSpec seminars and final workshop (June)	
2005	Eurobitume TF Data Collection started	EN 14771 – Bitumen and bituminous binders – Determination of the flexural creep stiffness – Bending Beam Rheometer BBR): 2005 EN 14770 - Bitumen and bituminous binders – Determination of complex shear modulus and phase angle – Dynamic Shear Rheometer (DSR): 2005 EN 14769 – Bitumen and bituminous binders – Accelerated long-term ageing conditioning by a Pressure Ageing Vessel (PAV): 2005 EN 14023 – Bitumen and bituminous binders – Framework specification for polymer modified bitumens: 2005 CEN/TR 15352 - Bitumen and bituminous binders - Development of performance-related specifications: status report 2005
2006		EN 13924 – Bitumen and bituminous binders – Specification for hard paving grade bitumens: 2006 BiTVal report published
2008		CEN/TS 15324 - Bitumen and bituminous binders – Determination of equiviscous temperature based on Low Shear Viscosity using a Dynamic Shear Rheometer in low frequency oscillation mode: 2008 CEN/TS 15325 - Bitumen and bituminous binders – Determination of Zero-Shear Viscosity (ZSV) using a Shear Stress Rheometer in creep mode: 2008

	Bitumen Industry	CEN - Bitumen (TC336)
2009	TF Data Collection Position Paper on Test Methods TF Data Collection Database available	EN 12591, EN 13924 and EN 13808 cited on Official Journal of the EU (OJEU)
2010	TF PRS reinstated / reactivated	EN 12591, EN 13924 and EN 13808 - CE marking mandatory EN 14023 cited in OJEU Systematic review EN 13924
2011	Eurobitume Position Paper PRS Update	
2012		EN 14023 - CE marking mandatory
2014		*Systematic review EN 12591*
2015		*Systematic review EN 14023*

3. Data Collection

3.1. CEN Data Collection project

The evaluation and validation phase of the work of TC336 WG1 requires a framework of the recommended tests and parameters to facilitate collection and analysis of measured data in a systematic and harmonised way. Such a framework would allow evaluation and recommendation of suitable parameters and levels for use in performance-related standards in future.

As a preparatory step TG5 produced a “Data Collection Framework” (see Appendix 1) based on the standardised EN test methods and published in CEN/TR 15352. The framework tables allow input of ‘binder type’ (conventional, modified etc.) and also indicate whether testing is to be carried out on fresh material, or samples after short-term and/or long-term ageing. Note that the framework was slightly updated according to the experiences from the Eurobitume Data Collection Project without publishing a new version of CEN/TR 15352.

Members of TC336 WG1 are collecting test data based around the data collection framework and these data will be incorporated into the database prepared by Eurobitume (see section 3.2.).

3.2. Eurobitume Data Collection project

Eurobitume’s Task Force Data Collection created a comprehensive database of bitumen properties for many of the commercially available bitumens in Europe. The database includes paving grade bitumens, hard paving grade bitumens, polymer modified bitumens (PMB) and special binders that were commercially available at the time of the project. In addition to the database the Task Force prepared a position paper in which the findings from the data collection project were summarised.

The purpose of the project was to allow assessment of the various test methods proposed to measure properties which may be suitable for future bitumen specifications.

Eurobitume compiled a database comprising 146 unique datasets representing commercially available binders including 69 paving grades, 58 PMBs, 15 hard paving grades and 4 special binders, i.e. those not supplied to an existing European Specification. The datasets were collected between 2006 and 2007.

Some conclusions from the Eurobitume data collection project were as follows:

- The outcome of the data collection supports positions taken earlier by bitumen industry representatives in the CEN specification discussions with hard evidence, e.g. on the applicability and limits of test methods.
- Simple tests can and should be used for simple binders i.e. normal paving grades and hard paving grade bitumens. The introduction of more complex tests for simple binders should not be considered unless they provide substantial improvement versus today.
- More complex binders require other tests. Dynamic Shear Rheometer (DSR) equipment offers the possibility to replace several traditional test methods for PMB, e.g. ring and ball softening point, or dynamic viscosity at 60°C, but parameters and limits still need to be agreed on. DSR also offers opportunities for testing simple binders, but this is not the recommended route as simple tests are satisfactory.
- For PMB there is a need to measure high temperature properties in a better way than traditional tests allow. The determination of EVT1 from LSV-testing in DSR might offer a solution, but because the method and the standard are relatively new, further evaluation is necessary.
- The Dynamic Shear Rheometer is considered to be an important tool for testing in future, especially for modified binders. Some test methods are less practical (e.g. Zero Shear Viscosity).
- None of the test methods measuring low temperature properties (Fraass Breaking Point and BBR) are completely satisfactory the way they are currently used.
- Some of the correlations between properties reported in the BiTVal Phase 1 Report were not supported by the data collection project. The database will help discussions on these issues.

4. Eurobitume TF PRS member survey

In 2007 Eurobitume members were asked for their views on the role Eurobitume should take in assisting the development of PRS and whether the views expressed in the 2002 position paper were still valid.

The consensus view was that Eurobitume should support further studies and validation of new test methods and, in addition, move towards a limited or stepwise introduction of PRS, in the first place concentrating on PRS for complex binders.

5. Simple and Complex binder concept

In order to support the Eurobitume members' proposal it is necessary to define which binders are simple and which are complex.

The main criteria in developing future specifications should be to maintain the trust of road users and authorities in the choice of bituminous materials for building and maintaining the highest standard road pavements. The binder supplier can offer objective advice in areas where specific knowledge and experience exists, but the choice of the binder remains the responsibility of the asphalt producer. The specification should provide a common language for discussion between suppliers and users.

The binder specification should be based on a number of different properties, and it is necessary to know the impact of each property in order to differentiate binders. If the impact is known, a grading system can be identified and agreed with the users.

For future specifications, there is the need to differentiate between the binders used for standard asphalt materials and the binders used for more intense traffic and special applications such as porous asphalt and EME.

Paving grade bitumens for standard asphalt materials are specified in EN 12591. The material characteristics in EN 12591 reflect the impact of each property on the asphalt performance and this is sufficient for specifying these binders. Addition of a long term ageing regime is under consideration. The material characteristics of PMBs and other binders for special applications are not adequately described in the existing specifications to enable the impact on the asphalt to be determined. This leads to the concept of Simple and Complex binders:

"Simple" binders are those that comply with EN 12591. Any others are viewed as "Complex" binders.

It is recognised that some hard grade bitumens can be argued to be simple too. However, as these materials are predominately used in special applications such as EME they require more precise description of the performance properties as opposed to relying on description in terms of empirical properties. Consequently hard grade bitumens will be considered as complex.

The impacts of the properties of Simple binders on the properties of the asphalt are reasonably well understood through experience and the binders are identified by the properties in EN 12591. If other properties are necessary, the impacts of the properties on the asphalt need to be determined and the binder is identified as a Complex binder.

Grading of complex binders is only possible if the correlation of binder properties and asphalt properties is proven. The data collection exercise has listed the values of the binder properties measured in Western Europe and development of performance related standards for complex binder could be based on this knowledge.

In the US specifications have been adopted when information has been considered sufficient and Europe could adopt the same principle.

The specification system needs to allow the supplier to state the specification of his product. If he supplies a simple binder according to EN 12591 he will characterise the product with the regular properties of EN 12591 only. For complex binders other properties will reflect the use of his material for specific or complex needs.

6. Proposals for future specifications

6.1. Considerations for the development and use of a specification system

Defining relationships between binder properties and field pavement performance is technically challenging and, with our current understanding, cannot be conclusively established. However, certain properties of bituminous binders are known to be related to mixture properties and therefore test methods that relate to those properties can be considered as candidates for inclusion in a Performance Related Specification.

The aim of performance standards is to measure / predict / declare the performance of the binder, how the performance will change over time and how the binder performance will influence the performance of the asphalt mix. A performance related bitumen standard does not guarantee the functional performance of the asphalt mixture or the final pavement. A performance test or a series of performances tests on bitumen, each *relating* to a specific functional property, is needed to predict the important characteristics according to the essential requirements outlined in the CPD.

However, performance related test methods and ageing procedures are not necessarily suitable or practical to ensure the constancy of binder properties produced or supplied on a day to day basis. For this matter a Factory Production Control system should be implemented.

For bituminous binders the essential requirements are covered under the following areas:

ER 1 Mechanical resistance & stability (including Durability)

ER 2 Safety in case of fire

ER 3 Hygiene, health & the environment

ER 4 Safety in use

6.1.1. Considerations on binder test methods

These essential requirements can be verified by evaluating the binder properties using certain test methods that are related to performance.

For each of the essential requirement, different test methods can be considered as good candidates to be included in the future Performance

Related Specification for bituminous binders. These methods are listed below and are presented in details in the table in Appendix 2.

Essential Requirement 1: Mechanical resistance and stability

Mechanical properties describe how the material responds to a mechanical load. The most commonly used properties are rheological parameters such as viscosity, stiffness/compliance, phase angle, deformation energy.

They change dramatically depending on testing conditions such as temperature, frequency/loading time, stress/strain level, number of loading cycles, ...

By selecting sets of testing conditions one can approach the actual load applied on the binder in the pavement. This is why the response of the binder will provide an indication of its performance in the pavement.

For each type of binder performance, one can select a binder property and testing conditions:

- Stiffness at elevated temperatures (EN 14770)
- Parameter G*/sin(delta) (EN 14770)
- Low Shear Viscosity (CEN/TS 15324)
- Zero Shear Viscosity (CEN/TS 15325)
- Multiple Stress Creep Recovery test (no European standard)

Bearing capacity

Bearing capacity is related to the stiffness of the pavement structure. Stiffness of the pavement is determined by the stiffness of the individual constituents of the asphalt mixture. Therefore bearing capacity is related to binder stiffness (EN 14770).

Fatigue Cracking

Fatigue cracking is the result of the accumulation of damage due to a large number of solicitation cycles. Even though there has been many attempts to relate the fatigue behaviour of bituminous binders to a simple rheological parameter, such relation has not been clearly established yet.

There are currently no harmonised test methods to determine the fatigue behaviour of bituminous binders. However, there are some laboratories developing different methods:

RILEM is evaluating the use of a DSR to determine fatigue behaviour of binders. Further work is required to develop a test for determination of this property.

IFSTTAR (formerly LCPC) is evaluating a Tension-Compression fatigue test based on diabolo shape specimens. Comparisons of results between different laboratories are needed in order to develop the test.

UPC (University of Cataluna) is also evaluating a Tension-Compression Test with cylindrical shaped specimens. The test is in its first stage of development with very promising initial results.

Resistance to fretting

Resistance to fretting is among other parameters related to the cohesive properties of the binder, which can be determined by measuring the deformation energy using the tensile test (EN13587, EN 13703) or force-ductility test (EN 13589, EN 13703).

Low service temperature: resistance to thermal cracking

The resistance of binders to low temperature cracking can be evaluated using different methods:

- Stiffness at low temperatures (EN 14770)
- BBR test (EN 14771)
- Fracture Toughness (CEN/TS 15963)
- Tensile test (EN 13587)

Durability

See chapter 6.1.4.

Essential Requirements 2 and 4: Safety in case of fire and Safety in use

The binder property related to safety is the Flash Point (EN ISO 2592).

Essential Requirement 3: Hygiene, Health and the Environment

This element of future specifications is important, but currently outside the scope of this document. Nevertheless the following properties should be mentioned:

Mixing and Handling

Even though mixing and handling is not an essential requirement, it can be considered as a very important element in relation with the general performance of the binder. It is related to the binder viscosity at handling temperature, which can be measured using different test methods:

- Kinematic viscosity at 135°C (EN 12595)
- Dynamic viscosity (EN 13702)

Storage Stability

Even though storage stability is not an essential requirement, it can be considered as a very important element in relation with the general performance of polymer modified bitumen. For this type of binder, it should be evaluated using the storage stability test (EN 13399).

6.1.2. Short term ageing

The Rolling Thin Film Oven Test (RTFOT) @ 163°C (EN 12607-1) is the commonly used conditioning method for simulating the hardening of the binder undergoes during the mixing and laying procedure. The research for this conditioning was performed in 1962 using paving grade bitumen and a relationship between asphalt produced at the asphalt plant and RTFOT laboratory conditioned binder was established. The relationship between laboratory conditioning and asphalt production for complex binders such as PMBs and hard paving grade bitumens was not studied. Therefore, the conditioning procedure and equipment does not automatically apply with good reliability for all binders.

Other European standardised short term ageing conditioning methods are Thin Film Oven Test (TFOT) (EN 12607-2), Rolling Film Test (RFT) (EN 12607-3), Rotating Cylinder Ageing Test @ 163°C (RCAT) (EN 15323).

6.1.3. Long term ageing

The Pressure Ageing Vessel (PAV), developed for the Superpave specification in the USA, is widely available and there is also considerable experience in Europe with this method as a long-term ageing conditioning (EN 14769). Questions remain whether this, or any other candidate test, is truly representative for all binders and how many years in service it simulates. The Rotating Cylinder Ageing Test (RCAT) (EN 15323) is an alternative to PAV and has a number of advantages over other long term ageing procedures, such as quantity of binder, binder homogeneity and lower pressure. However, very few laboratories have experience with the method. Both PAV and RCAT are standardised at European level but are not yet incorporated in European product specifications.

6.1.4. Durability

Incorporating "durability" in a set of specifications can be achieved in different ways:

(1) Define limits for the *value* of a property after an ageing procedure

(2) Define limits for the *change* of a property after an ageing procedure

(3) A combination of (1) and (2)

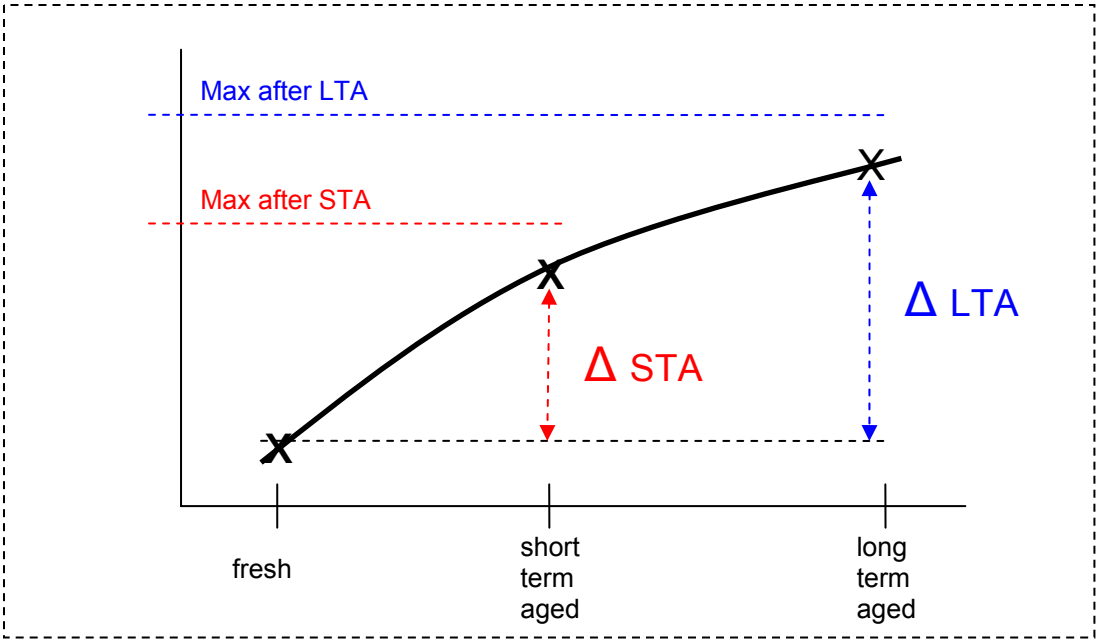

Figure 2 - Options on how to incorporate "durability" in specifications

6.2. Proposal for the structure of a Performance Related Specification for complex binders

One of the conclusions of Eurobitume Data Collection project was that existing empirical tests describe the properties of simple binders adequately and, for this group of products, the traditional tests are considered to be performance related. Therefore simple binders are adequately specified by EN 12591 and this standard does not require further enhancement.

The bitumen industry aims to supply its customers with binders which are fit for purpose for different kind of asphalt applications and provide the confidence that the binders have constant performance. The binder choice remains the responsibility of the asphalt producer, although the supplier can offer objective advice in areas where specific knowledge and experience exists, keeping in mind that no universal binder exists to cover all requirements. The influence of aggregate and fillers and the production of asphalt roads are not taken into account in the product specification of binders. Binder specifications help in facilitating selection and providing a common language for discussion between suppliers and users.

The structure for a performance related specification for complex bituminous binders could follow the structure in the existing asphalt standards. The proposal is to develop a framework specification using fundamental binder properties related to the asphalt mix requirements highlighted in table 1.

Such a specification would comprise a series of tables for each property associated with the characteristics identified for e.g. high, intermediate and low temperature performance and appropriate grading of values, together with the agreed ageing protocols. An outline of the test requirements is provided in table 2.

A future specification could be conceived using a similar system to that used in the asphalt standards. The format would be a framework and could use tables of values for the specified properties to determine classes of performance.

Table 2 – Example of possible binder test requirements in a performance related specification framework

CPD	Performance requirement of Binder (Characteristic)	Property	Test method	Levels / classes
Unaged				
Binder grading properties				
	Mixing & Handling	Dynamic Viscosity @ XX °C	EN 13702	Table 2.1
ER 3	Safety	Flash Point	EN ISO 2592	
	Storage Stability			
STA				
ER 1 (hi T)	High Service Temperature Permanent deformation	Non-recoverable creep compliance, 1/kPa	Not an EN standard method	
ER 1(int T)	Bearing capacity	Complex Modulus, kPa/° C	EN14770	Table 2.2
ER 1 (int T)	Fatigue cracking (incl. healing)		No harmonised method yet	
LTA				
ER 1(int T)	Fatigue cracking (incl. healing)		No harmonised method yet	
ER 1 (lo T)	Resistance to fretting			
ER 1 (lo T)	Low temperature cracking	BBR, Temperature at 300MPa Change in properties vs Unaged	EN14771	

Table 2.1

Class	Dynamic Viscosity @ ??? °C, Pa.s
1	≤
2	≤
…	…
n	≤
	No requirement

Table 2.2

Class	Complex Modulus at 60°C - 1 Hz
1	300
2	600
3	900
…	……
…	…...
n	18000
	No requirement

(Note: data in this paper are only an example)

It is envisaged that this proposal would apply to binders currently specified by EN 13924 and EN 14023. As with the existing Asphalt Mixture standards it is proposed that the PRS framework is incorporated into the existing framework specifications. It is envisaged that the existing empirical approach for specifying polymer modified and hard paving grade bitumens would remain in place and that, as users gain experience with performance based testing, there will be a shift towards greater use of the fundamental approach for choosing the appropriate binder for each application.

6.3. Recommendations for the implementation of a FPC system

Routine control testing should be compatible with production and supply constraints. Most performance-related test methods and ageing procedures use sophisticated equipment and are typically time-consuming, and therefore do not fulfil this condition, however, they are appropriate for Type Testing (ITT, FTT).

Consequently, for routine control and routine acceptance testing purposes, adequate surrogate test methods with specified limits should be selected that are applied to the unaged binder. Surrogate test methods could, for example, include existing empirical test methods such as penetration, softening point, elastic recovery etc. as appropriate. The frequency of testing should be defined depending on the rate of production or supply.

Appendix 1 - The CEN Data Collection framework

EN 12591 Paving Grades - EN 13924 Hard Grades - EN 14023 Polymer Modified Bitumens

Product type	
	Normal Paving Grade
	Hard Grade
	PMB
	Special Bitumen

Characteristic	**Test method**	**Unit**	**Reported value**		
			Binder condition		
			Fresh	**STA**	**LTA**
Nominal penetration range	EN 1426	0.1 mm			
Penetration @ 25 °C	EN 1426	0.1 mm			
Softening point R&B	EN 1427	°C			
Penetration index	(2)	-			
Dynamic viscosity @ 60 °C	EN 12596	Pa.s			
Kinematic viscosity @ 135 °C	EN 12595	mm^2/s			
Fraass breaking point	EN 12593	°C			
Elastic recovery @ 10 °C (1)	EN 13398	%			
Elastic recovery @ 25 °C (1)	EN 13398	%			
Storage stability (1)	EN 13399	°C			
Resistance to hardening	EN 12607-1				
Change in mass	EN 12607-1	%			
Retained penetration @ 25 °C	EN 1426	%			
Increase in softening point R&B	EN 1427	°C			
Flash point	EN ISO 2592	°C			
Solubility	EN 12592	%			
Density	EN ISO 3838	kg/m^3			

(1) to be reported for PMB's only

(2) Normative Annex B of EN 12591:2008 Calculation of the penetration index (Pl Pfeiffer)

PART 2: PERFORMANCE-RELATED PROPERTIES

Indicate the Long Term Ageing Procedure temperature	

Characteristics	Test method	Unit	Reported value – Binder condition: Fresh	STA	LTA
At high service temperature					
Complex modulus (DSR)					
G* and phase angle - for temperature sweep 40 - 80 °C (at certain frequencies) - for frequency sweep 0.1 - 10 Hz (at certain temperatures)	EN 14770	kPa / deg			
Low Shear Viscosity (DSR)					
Equiviscous temperature EVT1 @ LSV = 2,0 kPa.s and 0,1 rad/s	CEN/TS 15324	°C			
Equiviscous temperature EVT2 @ LSV = 2,0 kPa.s and 0,001 rad/s	CEN/TS 15324	°C			
Zero Shear Viscosity (DSR)					
Zero shear viscosity (creep mode) @ 60°C	CEN/TS 15325	kPa.s			
At intermediate service temperature					
Complex Modulus (DSR):					
G* and phase angle - for temperature sweep 10 - 40 °C (at certain frequencies) - for frequency sweep 0.1 - 10 Hz (at certain temperatures)	EN 14770	kPa / deg			
At low service temperature					
Bending Beam Rheometer (BBR)	EN 14771				
Stiffness @ -16°C		MPa			
m-value @ -16°C		-			
Temperature Stiffness @ 300 MPa		°C			
Temperature m-value @ 0.300		°C			
Cohesion (choice of test)					
Force ductility @ 5- 25 °C	EN 13589 -13703	J/cm²			
Tensile test @ 5- 25 °C	EN 13589 -13703	J/cm²			
Testing speed of tensile test	EN 13589 -13703	mm/s			
Vialit pendulum: maximum	EN 13588	J/cm²			

Appendix 2: Detailed considerations on test methods

General comments: Except for handling conditions, safety and storage stability, **the performance tests on the unaged binders are not justified since the binder in place is not representative of the unaged binder.**
However initial testings of the binder would be appropriate for quality control purposes --> relevant tests to be determined

	Aging Condition	Test		Practicality of the test		Applicability to binders	Experience with the test	Correlation with binder/mix property (including BitVal data)	General comments - other advantages / difficulties
		Name	Standard	Repeatability	Timing				
Performance Related									
Mixing and Handling	Unaged	Kinematic viscosity at 135 °C (capillary tube)	EN 12595	Poor for highly viscous binders. r = 4%, R = 6 to 9%	Less than 2 hours	Test is applicable for most grades, but only Newtonian liquids can be tested properly. More adapted to unmodified bitumen	Extensive	Not related to the performance of the binder but only to handling	
		Dynamic Viscosity (rhéomèter) - **temperature to be defined**	EN 13702	• Difference between two results under repeatability conditions > 5 % in one case in twenty. • Difference between two results under reproducibility conditions > 15 % in one case in twenty.	Less than 2 hours	Applicable for all binders.	Extensive	Not related to the performance of the binder but only to handling	
		Determination of equiviscous temperature: For instance: - One threshold value of vicosity related to the binder pumpability (e.g. 2 Pa.s) - One threshold value of vicosity related to the binder- aggraget mixing (e.g. 0,2 Pa.s)	EN 13702	• Difference between two results under repeatability conditions > 5 % in one case in twenty. • Difference between two results under reproducibility conditions > 15 % in one case in twenty.	Less than 2 hours	Applicable for all binders.	Extensive		Suitability for different purposes: To provide a practical imfomation about the minimal T that is needed for the binder to be pumped and mixed with teh aggregates
Safety	Unaged	Flash point	EN ISO 2592		Less than 2 hours	Applicable for all binders.	Extensive	Not related to the performance but can be an indicator of the quality of the binder	Well known test for HSE and handling purposes
Storage Stability	Unaged	Storage Stability	EN 13399	The test uses a difference in properties between the top and bottom sections of a sample and therefore the precision of the softening point and the needle penetration apply here.	Three days of conditioning and 3 hours of testing.	Relevant for modified bitumen	Extensive	This property is critically important for handling and storage and therefore must be addressed by manufacturers of PMB; however, the test results obtained may not necessarily indicate actual behaviour in practice.	Is change in R&B the most appropriate parameter? Penetration change could be considered as well.

	Aging Condition	Test		Practicality of the test		Applicability to binders	Experience with the test	Correlation with binder/mix property (including BitVal data)	General comments - other advantages / difficulties
		Name	Standard	Repeatability	Timing				
Performance Related									
High service temperature permanent deformation / rutting	Short term aged	DSR: G*/sin(delta)	EN 14770	The repeatability can be quite high, up to 20-30% on G* [Ref. "Complex Modulus of Bituminous Binders: Results of the Round Robin Test of the GE1 working group (France)" - B. Eckmann et al, Eurasphalt & Eurobitume 2008 Congress, Copenhagen 21-23 May 2008]. In general, the standard sets a rather wide precision range; this needs to be assessed.	Full testing may take some time (temperatures and frequencies), but can be fully automatic with modern DSR equipment. Testing over a full sweep is not considered as a quality control test. Temperature sweep at a specific frequency could be a faster option and in general faster than e.g. R&B or penetration test. The test takes 2 hours to one day per sample, depending on the sample preparation and testing conditions. To obtain results this test is faster than LSV and ZSV.	Applicable for all binders.	Extensive	Penetration has been correlated with DSR measurements. It is generally considered that, for paving grade bitumen, the R&B softening point is equivalent to a penetration of 800 x 0.1 mm. It has been found that the stiffness of the binder can be predicted from the penetration index and R&B softening point for paving grade bitumen. At very low testing frequency, the ratio G*/sin δ is related to the oscillation ZSV. Hence, there is also a relation with creep ZSV.	
	Short term aged	DSR: MSCR	ASTM D 7405	Firstly to check form US litterature To be determined through RRT during the standardisation process Recent works shown that reproductibility of MSCRT is comparable to the one of stiffness measurement in the DSR	2 to 3 hours	Applicable for all binders.	Limited in Europe	Criteria and Threshold to be defined. The non recoverable compliance appears to be a good candidate to correlate with rutting. MSCRT capture the non-linear behavior and stress dependency of binders	To be standardised in Europe. Several published R&D works from Total confirm the main US results. Unlike the other tests, it captures the non-linear behaviour of the binder under high stresses and strains, which is closer to the type of solicitation involved in the rutting of asphalt. It does not measure only stiffness (as G*/sin δ) or viscous flow (as LSV), the response of the binder to repeated stress, and different stress levels. The response of the binder will depend on its stiffness, but also on its elastic properties (i.e. its ability to recover strain). MSCRT capture the binder's sensitivity to stress, as two different stress levels are tested (0,1 and 3,2kPa)
	Short term aged	DSR: LSV	CEN TS 15324	According to the precision data given in the project standard (Round Robin test performed in 2003), it is estimated that R (paving grade bitumen) = 2.0 to 2.8°C and R (PMB) = 4.3 to 5.3°C. This is comparable or worse than Reproducibility indicated for R&B softening point (resp. 2.0°C for paving grade bitumen and 3.5°C for PMB).	Between half a day and a full working day. The testing is shorter than that of ZSV, but can be longer than a frequency sweep at high temperature (complex modulus see 4.1). EVT2 results need long testing time because of low frequency.	???	Fair	BITVAL: Probably there is an acceptable link with rutting for EVT1, but in case of EVT2, the frequency may be too low to be linked with rutting.	. EVT1 is more preferred than EVT2 as there is a very good correlation between EVT1 and EVT2. In addition, it is less time consuming to measure only EVT1 and this parameter could also be deduced from a frequency sweep which would avoid performing several tests on the same binder and thus save time.
	Short term aged	DSR: ZSV	CEN TS 15325	For unmodified bitumen: r = 5 to 10% (Bitval) R = 15% (BitVal)	Depends very much on tested binder. Can be very time-consuming for polymer-modified bitumen	Not adapted for polymer-modified bitumen	Limited in Europe	Not suitable because it merely applies to unmodified bitumen only, and definetly not to PmBs	Standardised as CEN/TS but very few results and hardly not performed. Not applicable to polymer-modified bitumen, because the steady state is not reached within a reasonable time of testing in the creep test

	Aging Condition	Test		Practicality of the test		Applicability to binders	Experience with the test	Correlation with binder/mix property (including BitVal data)	General comments - other advantages / difficulties
		Name	Standard	Repeatability	Timing				
Performance Related									
Bearing capacity	Short term aged	DSR: Complex Modulus	EN 14770	The repeatability can be quite high, up to 20-30% on G* [Ref. "Complex Modulus of Bituminous Binders: Results of the Round Robin Test of the GE1 working group (France)" - B. Eckmann et al, Eurasphalt & Eurobitume 2008 Congress, Copenhagen 21-23 May 2008]. In general, the standard sets a rather wide precision range; this needs to be assessed.	Full testing may take some time (temperatures and frequencies), but can be fully automatic with modern DSR equipment. Testing over a full sweep is not considered as a quality control test. Temperature sweep at a specific frequency could be a faster option and in general faster than e.g. R&B or penetration test. The test takes 2 hours to one day per sample, depending on the sample preparation and testing conditions. To obtain results this test is faster than LSV and ZSV.	Applicable for all binders.	Extensive	Gives good correlation with mix modulus. Temperature and frequency susceptibilities are fundamental properties of binders and, as such, may be useful for future specifications. However the standard, as such, provides too much data to be used in specifications. Suitable parameters and limits would need to be determined from mixture properties and field performance. A combination with ageing procedures could be considered.	Suitable, available, well regulated
Fatigue cracking (including healing)	Short term aged (optionally) Short term + Long term aged	**Three experimental test: RILEM based on DSR, LCPC based on Tension-Compresion diabolo specimen shape, and UPC based on Tension-Compresion cylinder specimen shape**	**No available**	Precission data not satisfactory in RILEM Test. In the other two, not stablished.		At the moment the trhree test have been applied to conventional binders.	No experience	In the LCPC test a good correlation between E6 of binder and mixture has been obtained.	Fatigue is a major mode of deterioration of asphalt pavement. Many studies have shown that the nature of the bituminous binder has a very significant influence on the fatigue resistance of asphalt mixes and pavements. Therefore, fatigue should naturally be addressed in a binder performance-related specification system The design of a fatigue test for binders remains a challenge that has not been fully resolved yet. Rheological time sweeps in the DSR could be interesting, but such test is too time-consuming to be suitable for specification purposes. Even though other accelerated test procedures are under investigation, none is considered satisfactory
Resitance to fretting	Short term + Long term aged	–	EN 13859 & EN 13703	The precision data of the method were evaluated in an European round robin test and are given in the standard. They are deemed to be satisfactory, especially if the test is performed on 3 samples, taking 2 of the results into account.	The time needed to prepare and perform the test is acceptable, with 2 to 4 hours needed per sample and temperature.	Suitable for PMBs	Extensive	BITVAL: Correlation between the maximum energy of the force ductility curve and penetration has been found. The force ductility curve gives qualitative information on the cohesive and elastic properties of polymer modified bitumen. These properties are determined by the polymers in terms of their type, distribution, concentration and network. The force ductility device can also be used for the determination of the elastic recovery, EN 13398.	**The test is not recommended for specification purposes after long term ageing, because either not all binders can be tested when long term aged or a good correlation exists between deformation energy on fresh and on long term aged binders.** Furthermore, as the procedure is limited to one specific speed it is therefore also limited in performance prediction. The results allow a differentiation between polymer modified and unmodified binders.

	Aging Condition	Test		Practicality of the test		Applicability to binders	Experience with the test	Correlation with binder/mix property (including BitVal data)	General comments - other advantages / difficulties
		Name	Standard	Repeatability	Timing				
Performance Related									
Resistance to thermal cracking under Low service temperature	Short term + Long term aged	BBR after RTFOT & PAV	EN 14771	The precision given in EN 14771 is a repeatability, r, of 9 % of the mean value and a reproducibility, R, of 27 % of the mean value for the creep stiffness and a repeatability, r, of 4 % of the mean value and a reproducibility, R, of 13 % of the mean value for the m-value.	Approx. 6 hours	Applicable to all binders	Good	BBR values only provide a measurement of binder rheological behavior in the linear domain. It should be completed by a failure test to relate with mixture resistance to thermal cracking	BBR is more accurate than DSR at low temperatures in elimnating compliance problems.
	Short term + Long term aged	DSR after RTFOT & PAV at low temperature Stiffness measurements	EN 14770	The repeatability can be quite high, up to 20-30% on G* (variability is maximum at low temperature)	2 to 3 hours	Applicable to all binders	Good	DSR values only provide a measurement of binder rheological behavior in the linear domain. It should be completed by a failure test to relate with mixture resistance to thermal cracking	BBR is more accurate than DSR at low temperatures in elimnating compliance problems. However, if an equipement supplier was able to solve this issue, DSR could be used as an universal tool for bitumen analysis. Furthermore, transfer functions exist to pass from BBR to DSR results.
	Short term + Long term aged	Fracture Toughness after RTFOT & PAV	CEN TS 15963	The most recent studies show that variability of this test method is approximately equal to the variability of Fraass test results	Approx. 6 hours	Applicable to all binders	Limited		Failure test (as Fraass test). Promising, relevant, but needs to be optimised to improve easiness and repeatability/reproducibility. Currently under investigation for improvement of the notched sample preparation.
	Short term + Long term aged	Direct Tensile Test	EN 13587	Variability is quite high, as for most failure tests.	Approx. 6 hours	Applicable to all binders	Fair		

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