Best Value Procurement for Bitumen

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Abstract
BAM Infra Asfalt uses on average around 2000 ton of SBS polymer modified bitumen in porous asphalt layers, thin noise-reducing layers, and other surface layer mixtures. Among all, the significant amount is used in thin-noise reducing layers and porous asphalt mixtures. In the past, procurement contracts for bitumen has mainly been dictated by cost, provided that the chosen bitumen also meets the required specifications. Commonly used parameters in the specifications have mostly been empirical. These parameters as such do not allow performance ranking among various bitumen types deemed suitable for certain application. With the availability of meso-scale mechanistic tools, such as LOT, new possibilities have emerged in differentiating binders based on their expected performance in an asphalt mixture. With the availability of this knowledge, BAM Infra Asfalt invited market players to participate in delivering a high quality polymer modified bitumen that meets certain performance specifications for a pre-determined maximum unit price, i.e., Best Value Procurement. Accordingly, a number of market players took part in developing the requested product. After sample products have been delivered, a rigorous selection process followed. The process involved analyzing the data submitted by the suppliers and, further carrying out a rigorous meso-scale performance evaluation in the laboratory. This include tests on bitumen, mastic ,mortar and stone-bitumen adhesive layers. In this paper the extended laboratory investigation, their relevance for performance evaluation, and how the results were used to select the requested product are discussed.

Key words
BVP, Meso-scale, Bitumen, Mortar, DSR, Stone-bitumen adhesion

1. Introduction

BAM Infra Asfalt uses on average 2000 ton of SBS polymer modified bitumen in various surface layer mixtures. The significant amount of the SBS modified bitumen is used for thin noise-reducing surface layer and porous asphalt mixes. Among available bitumen types on the market that are deemed suitable for use in these types of mixtures, the choice of bitumen is traditionally dictated by price. This implies that a bitumen supplier with the least price usually has a high chance of winning procurement contracts. This approach tends to provide an incentive to the supplier for cutting price, even when a higher price would be in the client's best interest. Thus the system does not lead to the best value for the money spent on the specific product. On the contrary, Best Value Procurement (BVP) incorporates more factors other than just price in the selection process so that the client gets the best value of the price paid for the product based on specific goals.

In relation to commonly used bitumen specifications, most of the parameters are empirical. As such, these parameters does not allow further differentiation among the bitumen types falling under a certain category. However, LOT research results have shown that there does exist performance differences among different bitumen types that are suitable for use in a certain mixture [1,2]. For a mixture performance, it is not only the bitumen behavior that is decisive, but also its interaction with other mixture components. Aspects such as the cohesive strength of the mortar (influenced by the interaction of bitumen, filler and sand), the adhesive strength (influenced by interaction between the filler, bitumen and aggregate types),the mortar relaxation behavior (influenced by bitumen type and its resistance to aging) are crucial in determining the likelihood of failure on a mixture scale. The LOT tools to evaluate bitumen performance in a mixture are now readily available[1]. The availability of such tools implies that further ranking of different bitumen types based on their expected performances in an asphalt mixture is not anymore impossible.

With the availability of this knowledge in house, BAM Infra Asfalt takes the initiative to jump start a new approach for its bitumen procurement contracts. Accordingly, BAM invited market players to participate in the procurement of a high quality polymer modified bitumen that meets certain performance specifications for a pre-determined maximum unit price. Following this invitation, a number of bitumen suppliers express their willingness to take part in developing the requested product. BAM outlines the product evaluation criteria to the participants and then it carried out the selection process in two separate phases.

In the first phase, suppliers were requested to deliver a maximum of two potential products meeting a list of specifications. Regarding the aspects relevant to mechanistic performance, properties were requested for aging performance, stiffness properties, low temperature properties and relaxation properties. Based on the supplied data, the two most promising products were selected for further evaluation. These products are further taken into the second phase evaluation. In the second phase, BAM Infra Asfalt carried out detailed laboratory investigation to further validate data submitted by the suppliers and also to incorporate the effects of other mixture components in to the equation. In this phase, bitumen performance is evaluated in relation to its compatibility with the aggregate, filler types and sand. Such evaluation involved performing tests on bitumen, mastic ,mortar and stone-mastic adhesive layers. All tests are carried out at meso-scale using the DSR machine. Based on the obtained results, final performance ranking was made.

In addition to the mechanistic performance, other criteria used in the BVP include; environment and safety aspects of the product, unit price and supplier's innovative capacity. In this paper emphasis is given to the mechanistic performance evaluation. The extended laboratory investigation, their relevance for mixture performance, and why the test results are used to select the requested product are discussed. Lessons learnt from the process are also highlighted.

2. BVP Procedure and Performance criteria

2.1 The Best Value Procurement (BVP)Method

BVP introduces other aspects than just price in selecting the best value for a specific product. In this way suppliers will get the chance to exploit their expertise in the most effective way so as to develop an optimum product that fulfils clients demands. The traditional approach where price dictates product selection will no longer remain valid. In BVP, the maximum price will be pre-set and bitumen quality(performance), environmental impact and safety issues as well as the suppliers innovative potential will be incorporated in the product selection process. Required specs and score allocations to the various aspects are made available to participants. The supplier will then be the expert and insures that the desired product is delivered to the client.

2.2 Evaluation process

All invited participants were briefed individually over the BVP procedure. It was then requested to submit a maximum of two alternative products per participant with properties conform the specifications provided in the procedure. In addition to the product samples, suppliers were also requested to submit, test results and conditions, explanations for the choices that were made in developing the product, the product price per ton, and environmental and safety performance data.
Based on the supplied data BAM Infra Asfalt evaluated the products in two phases. In the first phase the products were screened based on data obtained from the suppliers. In determining the final score, weighing factors shown in Table 1 have been used.

Table.1 Score allocations in Phase I and PhaseII

Aspects	Phase I	Phase II
	Maximum score (%)	Maximum score(%)
Bitumen property	40	50%
Environmental and safety	10	20%
Unit price	30	30%
Innovative ability	20	N/A

Based on the final score in Phase I, the top 2 potential products were selected for further evaluation in Phase II. In Phase II, the performance of the bitumen in relation to other mixture components, such as filler, sand and aggregate was evaluated. Fig.1 outlines the performance aspects investigated in Phase-I and Phase II selection processes.

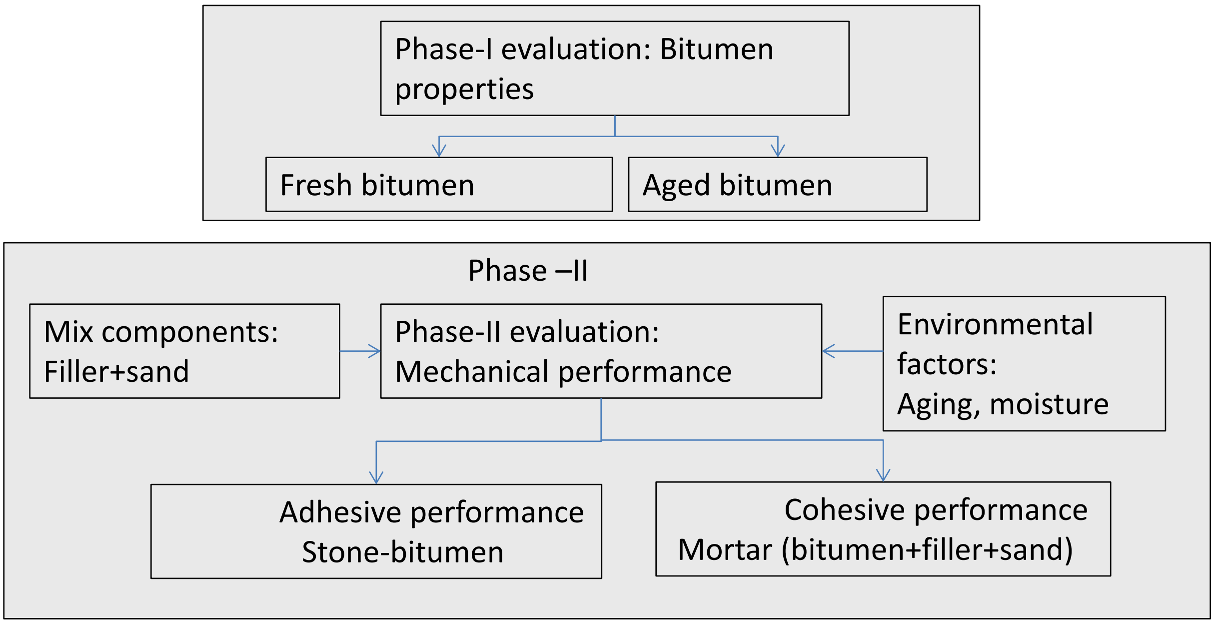

Fig.1 aspects investigated in Phase I and Phase II selection processes

For Phase II evaluation, extended laboratory tests were carried out by BAM. With emphasis on the aspect related to the bitumen property, the relevant empirical and fundamental properties deemed crucial in the selection process are further discussed in the next section.

3. Choosing Performance criteria

In porous asphalt concrete and other thin noise-reducing asphalt layers, the mixture is highly skeletal, and the predominant mode of failure in these kind of mixtures is raveling. Good mixture performance can only be obtained when the performance of the binding agent between the stones (mortar) and the stone-mastic adhesion are optimized. These aspects are influenced among others by the nature and interaction of the mixture components, by environmental aging and moisture infiltration etc. Available tools from LOT offer the possibility to evaluate these aspects so as to choose a bitumen that, in combination with other mixture components, leads to an optimum mixture performance.

Based on knowledge obtained from LOT, properties that are relevant to porous asphalt mixture and other noise reducing thin-layer mixtures were first identified. Requirements regarding these properties were specified. This specification was then used as a guide line to screen out the desired product. Mechanistic properties that are used in Phase-I and Phase II of the BVP process are summarized in Table 2. Their relevance as bitumen quality and performance indicator is discussed thereafter.

Table.2 Properties used for evaluations in Phase I and Phase II of the BVP selection

Phase I evaluation: relevant properties at bitumen scale		
Virgin bitumen	***RTFOT aged bitumen***	***RTFOT + PAV aged bitumen***
Penetratie (EN 1426)	*Penetratie (EN 1426)*	*Bending Beam Rheometer (EN14771)*
R&Ball Temp(EN1427)	*R&Ball Temp(EN1427)*	*Ductility @5°C (EN 13589)*
Elastic recovery @ 25°C (EN 13398)	-	*Elastic recovery @ 25°C (EN 13398)*
		DSR frequency sweep (EN14770)
		Relaxation DSR (EN 14770)
Phase II evaluation: relevant properties at mastic & mortar scale		
-	***RTFOT+PAV aged mastic (bitumen+filler)***	***RTFOT+PAV mortar (aged mastic + sand)***
	Stone-mastic adhesive performance - dry	*DSR-frequency sweep*
	Stone-mastic adhesive performance - wet	*DSR- relaxation properties*
		DSR fatigue performance - dry
		DSR fatigue performance- wet

Penetration and Ring&Ball tests

The results from the Pen and Ring&Ball temperature tests in combination can be used to evaluate the temperature susceptibility of a binder. Such relations however, are not always valid; especially for polymer modified bitumen. For this reason only the penetration result has been used in the BVP selection process. As a criteria, a maximum and minimum Pen-limits were set so that a bitumen with very low penetration that might lead to very stiff mortar, and bitumen with very high penetration that might give problems with binder drainage are prescreened. The sensitivity of the bitumen for aging is also judged based on the change in penetration after RTFOT aging. Due to the empirical nature of the test, results are only used to screen out outliers and thus no further evaluation is performed to relate pen properties with mixture performance.

Elastic recovery

The elastic recovery of a bitumen provides insight on the recovery potential of the binder from a deformed state. There is as such no direct relation between Elastic recovery results and other performances in a mixture scale. However, a bitumen with the highest possible elastic recovery is certainly a desired property for binders used in PA mixtures. The desired product in BVP is thus a binder with the highest possible elastic recovery before as well as after aging.

Bending Beam Rheometer: BBR

BBR results are commonly used to evaluate the extreme low temperature performance of a binder. In the BVP procedure, this property is included as an additional parameter so as to exclude bitumen with too brittle behavior. To avoid brittleness in winter season, the desired bitumen should possess some flexibility at low temperatures. From the slope of the BBR creep curve, the flexibility of the bitumen can be evaluated. The preferred bitumen is the one with the highest slope, m, and with a BBR stiffness that lies within a prescribed range of max and minimum values. Specifications for BBR stiffness are set based on relations developed between the BBR stiffness and master curve properties.

DSR Frequency sweep and relaxation

Based on frequency sweep test results, master curve is constructed at a reference temperature of -10°C. Information on the bitumen response at various temperature and frequencies can thus be obtained from the master curve. Among others, the bitumen and mortar response at the following control points were used in the evaluation process:

- Stiffness at 1E-5Hz at -10°C; relevant for the mixture performance under a 24 hour cycle of temperature loads.
- Stiffness at 10Hz and -10°C; relevant for the mixture performance under normal traffic loading during winter.
- Stiffness at 0.1Hz and 70°C; relevant for mixture performance at extreme hot summer and slow moving traffic.

In addition to the master curve, relaxation test results were also reported. The relaxation behavior can essentially be derived from the master curve results. In the BVP procedure, test result from this test is reported as extra data. In the test, a predetermined deformation is applied and then the deformation is kept constant for a certain time. During this time, the relaxation of the stress is continuously monitored. The ideal bitumen is the one that relaxes fast and thus leads to a minimum residual stress. The test is performed at low temperature.

Ductility

Combinations of traffic and environmental loads cause the surface layer to experience both stress and displacement control loadings. Though pavements do not fail as a result of one monotonic load in practice, results from monotonic tests; such as ductility test, can provide insight on the amount of energy the material can absorb before failure. This property is often reported in bitumen data sheets, and thus included in the BVP process. The elongation at break and the energy under the force-displacement curve are deemed useful parameters. A bitumen with higher energy and elongation at break are sought-after. The properties corresponding for the aged bitumen are considered relevant.

Mortar fatigue

Mortar fatigue is an important performance criteria to evaluate cohesive failure modes in asphalt mixtures. At a selected reference temperature, fatigue tests were carried out to obtain performance data. The fatigue performance of the mortar in wet conditions were also determined. The desired bitumen for BVP is the bitumen which leads to a mortar with excellent fatigue performance. The performance with minimum susceptibility to moisture is preferred. Fig.2 illustrates the utilized DSR test setup for mortar and adhesion tests.

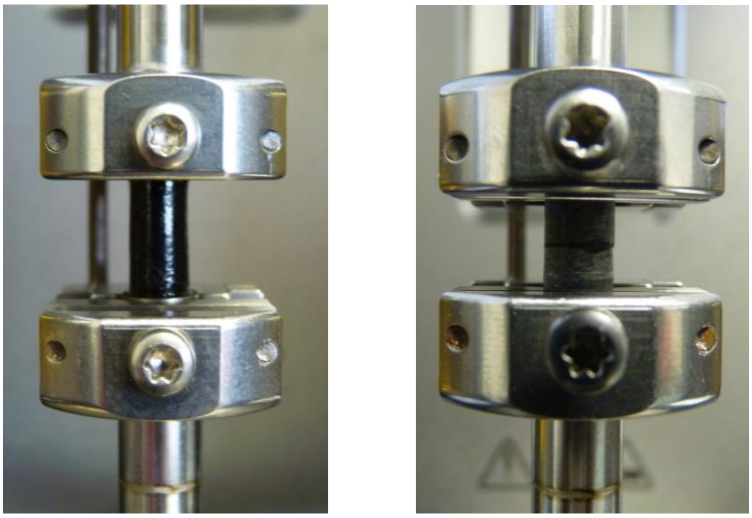

Fig. 2: DSR setups for mortar and stone-column tests

Adhesion performance (stone-column test)

Raveling failure at the interface between the stone and mortar is a result of poor adhesion performance. The adhesion performance is influenced by several factors; the stone type, the bitumen sort, the type of filler, and other external factors such as loading and moisture infiltration to the interface zone. At a mixture level, the indirect tensile strength ratio (ITSR) is the commonly used method to evaluate moisture susceptibility of a mixture. The LOT tool provides an additional meso-scale test, i.e., stone-column, to evaluate adhesion performance at the stone-bitumen/mastic interface. Since moisture infiltration is detrimental to adhesion, tests were carried out both in dry and wet conditions. Unlike the conditions at the mixture scale, where the stones are fully enveloped with thin film of bitumen, the stone-columns used in the DSR setup are not coated. This allows a favorable condition for fast moisture infiltration to the adhesive zone. Fig.3 illustrate the rate of moisture infiltration into a selected aggregate. Effects of moisture on the adhesion performance can thus be determined at different levels of saturation.

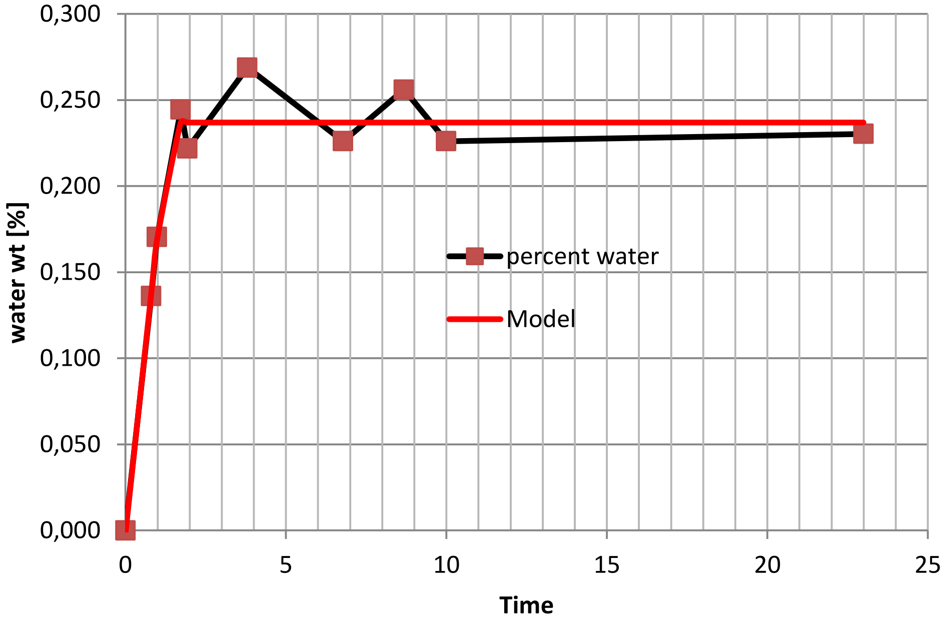

Fig. 3: Illustration: moisture absorption rate for aggregate

In the BVP process, a bitumen that offer the best adhesion performance which is also less susceptible for moisture is desired. All tests were carried out at full saturation level so as to guarantee the presence of moisture in the adhesive zone and thus on the measured results.

3. Results and Observations

The BVP selection process has led to selection of a bitumen with cost-performance balance that meets the clients demand. Performance demands, both in relation to mechanistic and environmental aspect, have been met. The process has also lead to a transparent client-customer relation over the quality and price of the desired product. Moreover, the process further lead to new insights that can certainly be of use in the future.

Empirical test results

Results from empirical tests, such as pen and elastic recovery tests, have been found relevant mainly for prescreening the outliers. Fig.4 and Fig.5 illustrate penetration, Ring&Ball and elastic recovery test results before and after aging.

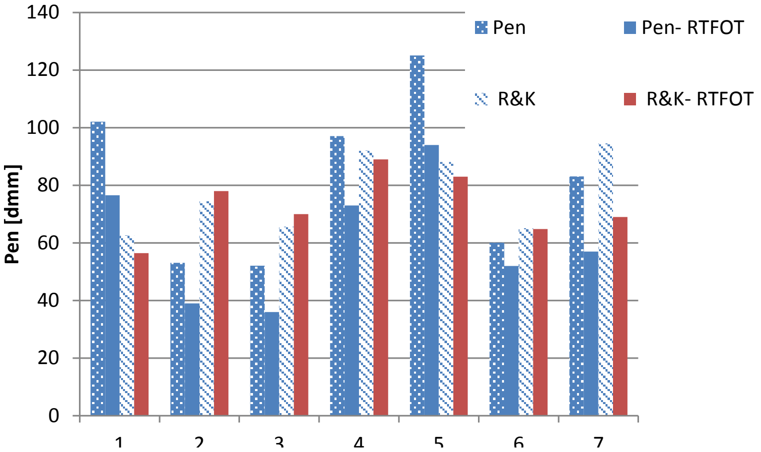

Fig.4 Penetration and Ring&Ball test results for various bitumen before and after RTFOT

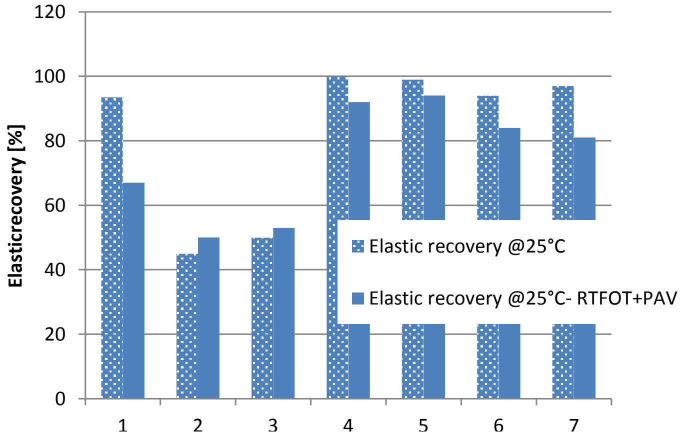

Fig.5 Elastic recovery before and after RTFOT+PAV ageing

From Fig.4, product 3 and Product 4 have the lowest penetration before and after RTFOT aging. The results in Fig.5 also indicate that these products have significantly lower elastic recovery. On the other hand the penetration value for Product 5 is the highest, while the elastic recovery result is comparable with product 4 and 7.

Due to the empirical nature of these tests, distinct performance ranking could not be made with these results alone, however the results were found relevant for prescreening outliers.

And they also provide supplemental information when results are interpreted together with ductility and DSR test results.

DSR and BBR test results

The DSR and BBR results at low temperatures are complementary to each other. Thus BBR results are used in conjunction with the DSR master curve to evaluate low temperature properties. Fig. 5 and Fig. 6 illustrate the DSR and BBR test results. Product 2 , 3 and 7 have higher stiffness's at low temperatures. The m values from the BBR test show that product 2 and 3 have the most sensitive for low temperature cracking (m<0.3). On the other hand, products 1,4, 5 and 6 are among the products with the highest m values (from BBR) and lower DSR and BBR stiffness at low temperatures.

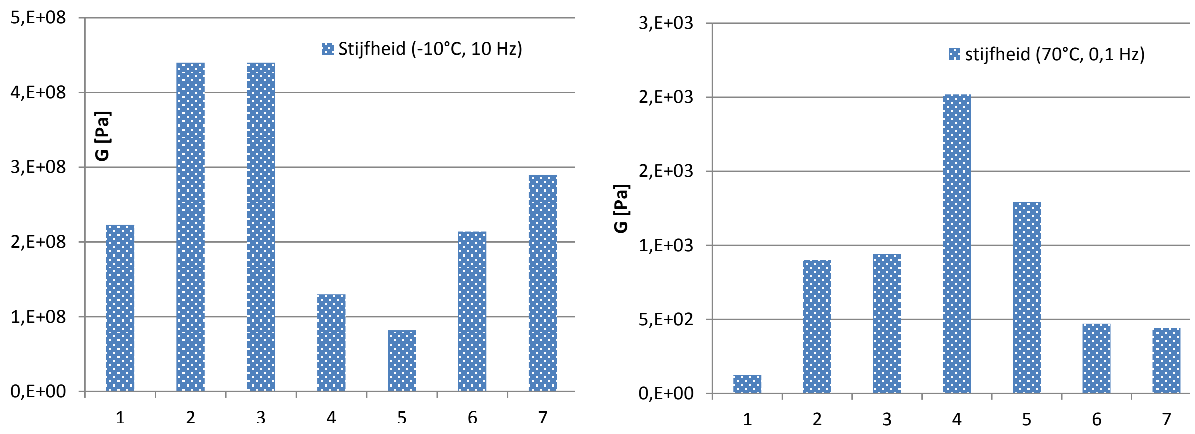

Fig.6 Stiffness properties at low and high temperatures; after RTFOT+PAV aging

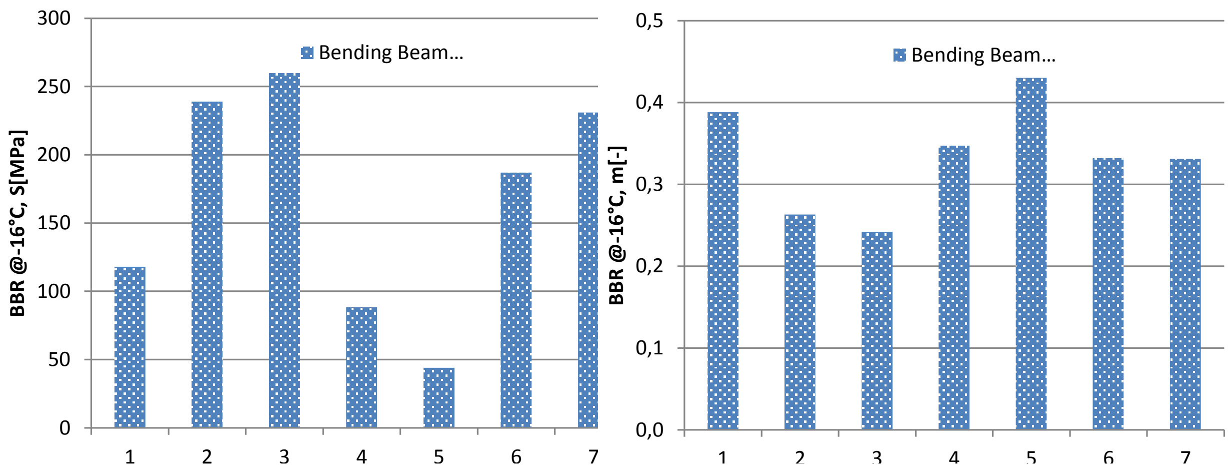

Fig.7 Overview: BBR results after RTFOT+PAV aging

For the investigation on the mortar level, the most promising products were first prescreened. For a selected number of products DSR research were carried out on a mortar level. In this evaluation phase, results from response and fatigue were solely used for ranking. To evaluate adhesion performance, results obtained from stone-column tests were also used. Based on master curves at a reference temperature of -10°C, the effects of water on response is illustrated in Fig.8.

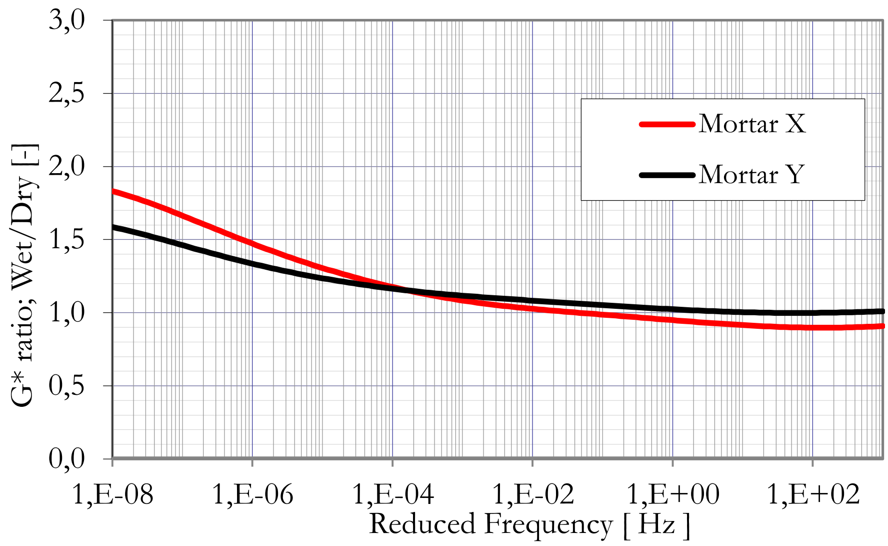

Fig.8 Effects of water on mortar response.

The results in Fig. 8 illustrate the effects of water on the mortar response. Measured effects on the response were found comparable for the two binders analyzed. In these analysis possible changes in geometry of the samples, because of swelling , has not be taken into account. The increase in stiffness for the wet samples might be attributed to the swelling phenomenon because of water infiltration. Stone column tests also showed the effects of water on the adhesion performance. Fig. 9 illustrate the reduction in adhesion performance because of moisture. Because of moisture the adhesion performance decreased drastically.

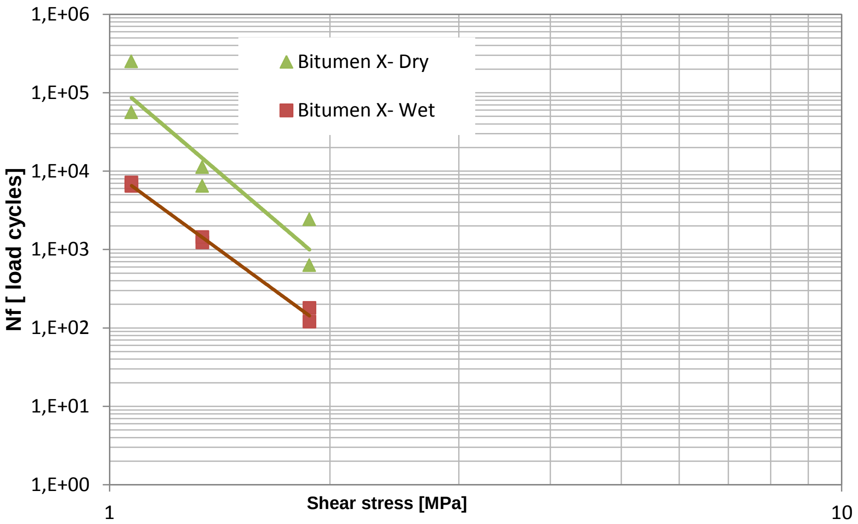

Fig. 9 Effect of moisture on adhesion performance

Similarly the results from relaxation test and mortar fatigue were analyzed. Evaluation were made based on dry test results and wet results. As shown in Fig. 8 and Fig. 9, the effects of moisture on response, adhesive performance were measured. However, moisture effects were comparable in both bitumen types. Thus differentiation based on the effects of water on mortar response, effects of water on adhesion performance were not made in the selection process. Rather the performances and properties of the mortar in the dry condition were ranked based relevant pre-set demands. With respect to the DSR test results, the following remarks could be made:

- Moisture effects were measured, However, for the binders evaluated in phase II, measured performance differences between mortars or stone column tests were not distinct enough to allow objective performance ranking. Fatigue performance and mortar properties were thus evaluated based on dry test results only.
- With respect to response; the BVP process has resulted in a mortar with an optimum behavior with respect to the following pre-determined performance aspects:
    - Optimal response behavior for loading rates corresponding to a day-night temperature fluctuations in the winter period
    - Optimal response for extreme low temperature to avoid very brittle behavior
    - Optimal response at very high temperatures to avoid binder drainage
    - Optimal response for frequencies corresponding to traffic loads.

4. Conclusions

The possibility of carrying-out meso-scale tests on bitumen, mastic and mortar level created new possibilities in bridging the existing knowledge gap in matching desired mixture performance with component properties such as bitumen and filler type. Progress has been made in exploiting this possibility in the BVP process for selecting a bitumen. In the process new lessons have been learnt and the process also created a platform for suppliers to maximize their own expertise in developing the desired product.

In comparison to the traditional procurement contracts, the BVP process allowed extra means for selecting a bitumen with desired properties with respect to various performance aspects; among others;

- response behavior for temperature loading in the winter period
- response for extreme low temperature to avoid brittle behavior
- response at high temperatures to avoid binder drainage
- mortar fatigue performance
- adhesive performance in dry and wet conditions

lessons learnt based on this first-hand experience imply that the same approach can further be tailored to suit procurement contracts for other types of bitumen intended for different kinds of mixtures.

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