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The study of the effects of ageing and fillers on bitumen and mastic properties

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Abstract:

The filler properties have a significant influence on the performance of mastic and hence on the performance of asphalt mixes. This paper presents the results of Dynamic Shear Rheometer (DSR) tests to compare the rheological behavior of four different mastic materials prepared with the same base bitumen for three different aging condi-tions – fresh, Rolling Thin Film Oven Test (RTFOT) aged and Pressure Aging Vessel (PAV) aged. The mastic showed significantly different performance depending on the filler that was used. The results of the DSR tests could be used to support the selection of an appropriate filler for a specific bitumen based on the performance of the mastic. Finally, an appropriate rheological model was used to present the results over a wider frequency range.

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Simple method for characterizing the colloidal-chemical properties of bitumen

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Abstract:

The durability of asphalt pavements is determined not only by their rheological properties but also by the chemical composition of bitumen. According to a simple model derived by Pfeiffer and Saal, asphaltenes associated with polar compounds form "core structures" which are dispersed in a phase consisting mainly of aliphatics and aromatics. Bitumen corresponds to a colloid-chemical system, which can be present in a sol or gel state. There are considerable physical differences between these two forms. A simple way to characterize the sol-gel properties of bitumen is to apply diluted bitumen solutions to a water surface. The method known as "spreading" in surface physics for a long time has hardly been used to characterize bitumen. Although the formation of the spreading structures is random, the formation of the structure is based on an order principle that depends on the chemical composition. The spreading process produces specific structures through which the inner structure of bitumen and in particular the sol-gel character becomes directly visible. Already the visual evaluation of spreading-structures allows a significant differentiation of bitumen of different petroleum provenance. By using an image analysis program, the classification can also be objectively traced back to quantitative measurement data. By the hierarchical cluster analysis of the results of thirty examined samples of the bitumen-type 70/100, an allocation of the crude oil provenances could be made with a high hit rate. The relationship between the development of spreading structures and the chemical composition of bitumen is investigated with the aid of automated HPTLC, which can be used to analyze the bitumen composition in great detail. Possible practical applications: - Bitumen classification: (sol-gel type) (aging state) - Suitability of base bitumen for PmB and emulsion production - Evaluation of "Rejuvenators" - Cause-and-effect investigations - Research

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Extended high-temperature oven aging of loose hot mix asphalt and acceptance testing of the extracted and recovered asphalt binders

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Abstract:

Acceptance grading of asphalt binder is crucial for the control of pavement performance. Hot mix asphalt (HMA) taken directly from the paving equipment represents the actual material placed, removing the need for rolling thin film oven (RTFO) conditioning. However, further ageing in an accelerated fashion is needed to predict long-term cracking performance. The current pressure aging vessel (PAV) method is considerably time-consuming, requires hazardous equipment, and is overall inconvenient. Hence, this study explores high-temperature oven aging of loose HMA for acceptance grading as a more practical alternative. Samples of loose mix were conditioned at a variety of high temperatures for accelerated aging (160, 140 and 120°C) and at specified times, chosen for the convenience of working hours (8, 16, 24 and 40 hours), with the objective of matching rheological with standard PAV and double PAV (40 hours) aging. A total of 12 HMA samples were included and the phase angle and complex shear modulus, measured following extraction and recovery of the binders, were used as aging index properties to determine what temperature and time duration combinations best matched current PAV protocols. It was found that the limiting phase angle temperatures were significantly more sensitive and repeatable compared to limiting stiffness temperatures. Most of the extended high-temperature oven aging (EHTOA) protocols investigated were able to provide grades that were very close to or exceeded the findings for regular PAV-aged samples. However, few if any of the EHTOA-produced binders reached the level of aging obtained after double PAV (40 hours) conditioning. It can therefore be concluded that, from a thermal and fatigue cracking grading perspective, it would be beneficial to switch from RTFO/PAV aging to an EHTOA protocol.

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Impact of asphaltene chemistry on bitumen properties

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Abstract:

It is known that asphaltenes have a large influence on bitumen properties and consequently pavement performance. Many studies have focused on the asphaltenes as a single solubility class with no differentiation between the types of asphaltenes. Recent research has looked at sub-dividing asphaltenes, based on their molecular weight or chemistry. Separation of asphaltenes into sub-fractions using the asphaltene determinator, has opened further possibilities to study the impact of asphaltene chemistry on bitumen properties. Our studies have focused on the quantitative separation of asphaltenes into their respective sub-fractions using a hot extraction technique with cyclohexane and toluene as the extraction solvents. The asphaltene sub-fractions obtained, referred to as ACYC and ATOL for the fractions soluble in cyclohexane and toluene respectively, were analysed for their chemical composition, stacking behavior and influence on basic bitumen properties. Interestingly, laboratory prepared bitumen based only on ATOL were found to be stiffer than those which contained only Acyc, at similar asphaltene concentration levels. This highlighted the effect of asphaltene chemistry on the performance of bitumen. Asphaltenes formed on maltene oxidation was also studied. Interestingly, it was observed that the rate of formation of new asphaltenes was not influenced by the penetration of the original bitumen. The influence of the asphaltenes formed by the oxidation of the maltenes, as compared to the oxidation of the asphaltenes present in the parent bitumen, on bitumen properties was also studied. It was seen that the oxidation of the asphaltenes already present in the bitumen had a greater impact on the properties of the bitumen as compared to the asphaltenes formed on oxidation of the maltenes. The chemistry of asphaltene sub-fractions on the performance of bitumen will be further investigated to enable tailoring of bitumen from the molecular level, allowing for bitumen to be manufactured with specific properties and maintaining quality.

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Bitumen penetration and shear resistance relation

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Abstract:

Over a hundred years bitumen penetration is a criterion for the indirect measuring of the bitumen stiffness. The empirical nature of penetration stimulated researchers to find its relationship with truly rheological characteristics of viscosity (R.N. Saal & G. Koens – 1933) or possibility to replace penetration with complex shear module divided on sinus of phase angle at dynamic deformation (SHRP Superpave – 1991). The conversion of penetration into shear resistance at applied shear rate for the bitumen seems to be more perspective and physic based. Such conversion based on calculation of the shear rate and resistance on the depth of the needle immersion by the G. Carre & D. Laurent viscosity calculation method (1963). Difference in the susceptibility of the resistance to the shear rate for bitumen sol, sol-gel and gel structure accounting is the required condition for this calculation. The determination of this susceptibility based on the fact that equal penetrations bitumen with different structure type have common equipenetration and equirate point at shear. On this point it is possible to calculate shear resistance at different shear rates. The shear rate 1 s-1 is taken as equal for all bitumen in calculations. Relation between viscosity anomaly index and penetration index (PI) as relation between equiviscosity rates / shear resistances and penetration where established on the data of G. Carre & D. Laurent, R.N. Traksler and others authors. To find the bitumen shear resistance by known depths of the needle penetration and penetration index values using established relations is consider as possible. The difference between calculated experimental and shear resistance values no higher than 15 %. The conversion of conditional bitumen index – penetration – into the classical criteria – shear resistance – making the prediction of asphalt concrete shear resistance possible, which has a great practical value.

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New type of chemical modification of asphalt binders to enhance the performance of flexible pavements

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Abstract:

Enhancing the performance of asphalt pavements has been certainly the focus of the research in flexible pavements since the introduction of the Superpave specification. So far, in Germany, the most common solution to achieve this has been using polymers like SBS to modify the asphalt binder. These kinds of polymers create a two-phase system that increase the elasticity of asphalt binders but are susceptible to storage phase separation problems. With this in mind, our research lab tested a new kind of reactive compounds that mimic the performance enhancing capabilities of elastomers but by changing the inner chemical structure of the asphalt binder, thus avoiding any phase separation problems. The additive, which is a low viscous black fluid, creates a chemical bond between the asphaltenes. The purpose of this study was to verify this network through rheology and to investigate the effect of the additive on the performance of flexible pavements. Depending on the quality of the asphalt binder, an amount between 1.5 % and 2.2 % of the additive is required. In order to compare different binders, a 2% additive was used in all variants. The samples were then characterized on an asphalt binder level through tests like dynamic shear rheometer and bending beam rheometer, among others. Afterwards, asphalt tests were performed to address rutting (uniaxial cyclic compression teste and wheel tracking test), fatigue (cyclic indirect tensile strength test) and cold behavior (thermal stress restrained specimen test and direct tensile strength test). After exhaustive laboratory testing, the results show an increase in the performance against rutting and fatigue, without affecting the cold temperature behavior. This was again confirmed after real scale testing, where 12 tons were modified in a mixing plant and afterwards three modified layers were successfully built on our institutes test track.

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The effect of sample preparation on the morphology of polymer-modified bitumen by fluorescence and optical microscopy and it's relation to storage stability.

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Abstract:

Fluorescence microscopy is commonly used to determine the dispersion of polymer in a polymer-modified bitumen (PmB), with sample preparation having a significant effect on the quality of the observed dispersion. This paper explores the effect of various sample preparation techniques (including EN 13632) on the observed dispersion of a number of common polymers in different bitumens. The relationship between polymer dispersion and storage stability is also explored using EN 13399 and other methods.

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Influence of crumb rubber amount and size on aging behaviour of bituminous binders

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Abstract:

Asphalt mixtures are subjected to an irreversible aging process during the manufacturing process and installation as well as during the period of use. The asphalt behaviour is significantly influenced by the binder performance, and thereby, the impact of aging of the bitumen is of great interest. The use of crumb tire rubber as a binder modifier may contribute to improve the performance of road pavements, to conserve nonrenewable resources and to solve waste disposal problems. The objective of this study is to investigate the influence of the amount and size of rubber particles on the aging behaviour of bituminous binders. Therefore, rubber modified bitumen with rubber contents of 10, 15 and 20 % and a variation of the particle size from small (0.4 mm) to middle (0.6 mm) and up to big (1.0 mm) were prepared in the laboratory by using a paving bitumen 50/70 as reference bitumen. Additionally, a polymer-modified bitumen (PmB 25/55-55) has been involved in the investigations to verify the results. All binders were tested at unaged as well as aged conditions (RTFOT, PAV). Different laboratory tests have been selected to evaluate the influence of the selected rubber particles. At first, the impact of the rubber modifications on conventional bitumen tests are presented. Furthermore, DSR tests have been conducted to determine performance related bitumen properties like complex shear moduli and the phase angles as well as fatigue damage resistance and plastic deformation behavior. Based on the results of the comprehensive testing undertaken it will be possible to gain understanding about the influence of the rubber modification on the aging behaviour of bituminous binders in comparison to commonly used binders.

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Improving Mixture Performance with Nano-silica Modified Asphalt Binder

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Abstract:

There is a growing need to improve the performance properties of asphalt binders in order to minimize the occurrence of failure mechanisms such as permanent deformation, fatigue and moisture damage. Nano-structured materials have taken a scientific-industrial boom as asphalt modifiers used to improve performance due to their mechanical, thermal and electrical properties, among others. The chemistry of the nano-material, and thus its inherent physical properties affects the asphalt binder in a comparable form as polymers at a lower or similar cost. The objective of this study was to evaluate and quantify the effect on binder modification with nano-silica on binder and mixture properties and performance. Nano-silica was selected because it is widely used in the painting industry to improve adhesion of the paint to the walls and provides and impermeable coat. The effect of the incorporation of nano-silica into a PG64(22, intermediate temperature) binder at various contents from 3.0% and 6.0% was evaluated. Rheological and chemical analysis techniques were used to quantify the effect of asphalt binder modification. The study included determination of the engineering properties of laboratory-produced asphalt mixtures. The laboratory testing program evaluated mixture stiffness over a wide temperature range (Dynamic Modulus), moisture susceptibility, fatigue cracking (cyclic SCB), and permanent deformation (Hamburg Wheel Tracking Test). In conclusion, modification of the neat binder with nano-silica demonstrated significant improvements in physical and thermal properties. A significant increase in stiffness at low frequencies/high temperatures were obtained with modified binders. In addition, a significant improvement in resistance to permanent deformation and resistance to moisture damage were obtained. No statistical effect on fatigue resistance was obtained.

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Properties and performances of polyurethane modified bitumen

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Abstract:

Bitumen materials are widely used for waterproofing and road pavement applications. Since more than 40 years, these ones are modified with polymers in order to increase their thermo-mechanical properties over a wide range of temperatures. Polymers commonly used to modify bitumen are thermoplastic elastomers such as poly(styrene-b-butadiene-b-styrene) block copolymers (SBS) due to their good compatibility with bitumen and specific interactions with the different chemical species Nevertheless, SBS polymers display poor resistance to UV and therefore give poor aging resistance to the polymer-modified bitumen materials. To overcome these drawbacks, thermoplastic polyurethanes (TPU) are considered in the present study due to their improved durability and rheological behaviour compared to SBS. Furthermore, the architecture and microphase-separated morphology of the thermoplastic polyurethanes which controlled the miscibility and interactions with the bitumen can be easily tuned from the polymerization step by a proper copolymerization of the nature of the soft and hard segments. The aim of this work is to study the relationships between the TPU mixes design and the bitumen fractions, multi-scale microstructures, and thermo mechanical properties in thermoplastic polyurethane modified bitumen (PmB) blends. Thus, several polyurethane modified bitumen blends were prepared in order to evaluate TPU components impact (isocyanate, alcohol, extender and hard blocks ratios) on the thermo mechanical PmB performances in comparison with high SBS content modified bitumen. Both empirical and rheological characteristics like viscosity, Fraass breaking point, elastic recovery, RTFOT, complex shear modulus, fatigue resistance, were investigated in laboratory. Furthermore, Tension/compression complex modulus, fatigue resistance, and thermal stress-restrained specimen tests were performed on semi-coarse asphalt concrete, containing five different polyurethane modified bitumen binders. The results indicate that the proposed innovative polyurethane modified bitumen binders may be from now as a relevant solution for sustainable long-life and high performances overlays.

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Impact of the Production Process on the Thermorheological Properties of Pure and Polymer Modified Asphalt

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Abstract:

Bitumens used as a binder in bituminous pavements are complex materials and Polymer Modified-Bitumens (PMB) were developed to improve their thermomechanical performances. Styrene-Butadiene-Styrene copolymers (SBS) are commonly used for this purpose but their efficiency largely depends on crude oil origin and refinery process. To better understand the impact of the refinery process on PMB thermorheological properties, four bitumens obtained by various refinery processes (direct distillation, propane deasphalting, air-blowing rectification and visbreaking reduction) have been used as base material for PMB. Pure bitumens and PMB performances containing up to 5 wt-% SBS have been evaluated by fluorescent microscopy, differential scanning calorimetry (DSC), dynamic shear rheology (DSR) and dynamical mechanical analysis (DMA). Empirical tests (softening point, needle penetration and FRAASS breaking point) were also accessed. Neat bitumens were first characterized and only slight differences were observed for empirical tests and thermorheological behaviors. High-temperature rheological behaviors are linked to the bitumen colloidal structure and in accordance with (i) the asphaltene content after bitumen refining and (ii) the presence of a yield stress rheological behavior quantified using a specific Carreau-Yasuda model. Concerning glass-state properties at low temperature, correlations were found with the bitumen glass transition and the maltene composition (in particular aromatic fraction content). The use of SBS could largely improve empirical properties and thermorheological behaviors of neat bitumens. However, the impact of SBS content on softening points and elasticity of PMB revealed several trends. Propane deasphalting and air-blowing rectification are clearly detrimental to SBS efficiency whereas direct distillation and visbreaking reduction could favor co-continuous morphologies in PMB at low SBS content. Relationships between morphology and thermorheological behavior are finally discussed together with the role of SBS swelling behavior in aromatic oil of neat bitumen.

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Ductility behaviour of filler-bitumen mastics: effect of ageing

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Abstract:

Asphalt mixture is a complex composite material due to the unique behaviour of bitumen and the variable microstructure. During fabrication the bitumen combines with the very fine aggregate particles to form the bituminous mastic that involves coarse aggregate particles and binds the mixture altogether. However, the bitumen characteristics change over time due to ageing, and the changes in the bituminous mastic affect asphalt's performance and durability. The objective of this work is to analyse the evolution in the ductility behaviour of bituminous mastic with ageing. Two bituminous mastics fabricated with a paving grade bitumen and two mineral fillers were aged at different levels and characterized. Mastic ageing was imposed with the Pressure Ageing Vessel using different times of exposure in the chamber. The ductility behaviour of mastics was evaluated by means of the double-edge-notched tension test because it allows to distinguish the essential and plastic work contributions to ductile failure. The results showed that bitumen ageing has a detrimental effect on the performance of bituminous mastics. As expected, aged mastics become stiffer and less ductile. The largest variation in properties occurred from the original mastic to the first ageing level that simulated short-term ageing. The filler type affected the evolution of ductility behaviour with ageing. Furthermore, this work demonstrates the importance of using mastics in the characterization of asphalt materials instead of the bitumen.

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Rheological characterization and comparison of aged polymer modified bitumens

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Abstract:

Investigations of low temperature and fatigue cracking in asphalt pavements are a priority in asphalt laboratories. Asphalt resistance to cracking depends mainly on the bitumen characteristics. The development of cracks can be indirectly predicted with the knowledge about bitumen properties, especially after aging. Contractors must ensure the required quality of produced asphalt mixes. To fulfil this obligation the characteristics of bitumens delivered to asphalt plants should be monitored. Investigations of such laboratory aged bitumens allow for their characterization and comparison between aged and non-aged bitumen. For many years the properties of bitumen at low temperatures have been determined based on the Fraass fracture temperatures. Since the Fraass breaking point test has several shortcomings, additional parameters like stiffness and creep rate were introduced in the Bending Beam Rheometer (BBR) method, which has been standardized, but it is still not widely used. Several samples of polymer modified bitumen PmB 45/80-65, which is widely used in our climate region, were extensively tested. The purpose of the study was to determine the impact of aging on bitumens. On neat bitumen the usual scope of bitumen tests (R&B, Penetration, Fraass) and BBR and DSR tests were performed. All tests were subsequently repeated on short term aged (RTFOT method) bitumens. In the last step the bitumens have been laboratory aged with RTFOT and PAV method and then re-tested. In the paper, the sensitivity to laboratory aging for samples of PmB 45/80-65, produced by different manufacturers, is presented.

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Thermo-viscous properties of bituminous binders as a quality indicator

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Abstract:

The viscoelastic character of bitumen predetermines its use in asphalt mixtures. It is generally known that the bitumen properties, in particular, polymer modified bitumen, specified by the softening point and penetration do not allow to predict sufficiently the performance serviceability and efficiency of the bitumen binder and the asphalt. That is confirmed by the experience of asphalt pavers. Therefore, it is an objective to find a method that would allow the identification of bitumen binders with non-standard behaviors while meeting the requirements of the empirical properties defined in the product standards. Within the research activities, the viscosity is verified as a rheological characteristic expressing the structural mechanical behavior of the bitumen under the influence of strain forces (as a function of strain load, the rate of strain and temperature). Samples of paving grade bitumen 50/70 and 35/50 grading and polymer modified bitumen PMB 45/80-75 and PMB 25/55-60 are verified using the Brookfield rotational viscometer. The regression analysis shows that the viscosity values of poorly performed bitumen are outside the confidence interval and of polymer modified bitumen also prediction interval. By comparing with the results of the empirical tests, the relationship of the dynamic viscosity values with the consistency of the bitumen defined by its penetration is shown. Bitumen properties are influenced both by composition (the chemical composition) and by the structure (the physical arrangement) of molecules in the materials. Methods of structural analysis are based on the determination of the elemental composition and group composition of structurally similar compounds in petroleum fractions having a similar chemical structure and behavior. Dynamic viscosity results will be analyzed depending on composition determined by organic elemental analysis and a combination of extraction and liquid chromatography by SARA analysis.

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RELATIONSHIPS AND CORRELATIONS BETWEEN BITUMEN AND ASPHALT MIXTURES

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Abstract:

The current situation of revamping and rationalization from refiners creates concerns about the quality and consistency of the delivered bitumen, especially as the current specifications appear insufficient to ensure satisfactory performance of the finished products. In this context, the search for relationships and correlations between bitumen properties and performance of the asphalt mixtures and the pavement has become very relevant. So, this paper is dedicated to identifying and quantifying such relationships. It focused on asphalt mixes based from a standard mix design with one type of aggregate (similar volumetric properties) and 16 bitumen from various origins. The characterization of asphalt mixes covered various mechanical tests such as modulus, rutting, fatigue and thermal cracking. At the same time, the study allows to analyze the relevance of the bitumen test and highlights the importance to take into account the long-term ageing about low-temperature behavior both bitumen and asphalt mixes.

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Towards a better understanding of the chemical changes of in-service bitumen and the chemistry of recycled asphalt pavements (RAP). Recent studies of RAP chemistry after in-service life of more than ten years.

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Abstract:

Recycling of asphalt pavements at the end of their lives is an essential aspect of road construction and a key facet of the economics and sustainability of asphalt pavements. Recycled Asphalt Pavement (RAP) has been the subject of countless studies and levels of RAP have steadily risen in many regions over the last twenty years, as well as the increased use of softer grades of bitumen this has also given rise to a host of additives many of which claim to rejuvenate or restore the rheological properties of the bitumen in the RAP. Such claims range in their sophistication from the restoring of simple rheological tests such as penetration or viscosity to some claiming that the bitumen is fully restored to its original properties. Bitumen chemistry is complex with hundreds of thousands of different molecules present, such chemistry varies as a result of crude oil sources at the refinery and refinery processing. Furthermore, the chemistry of bitumen changes during the asphalt mixing process and during its service life. An understanding of these changes is vital in realising the potential of RAP in constructing durable roads. This paper examines the chemical properties of RAP taken from three countries, United Kingdom, France and India after service lives between ten and twenty years. Chemical analysis of the binder, including asphaltene structure, polarity and solubility, was studied and the potential impacts on blends of these aged binders with fresh binders were also investigated. The studies show that asphaltenes become more polar over time and that this is largely related to the age of the pavement. The impact of this increased asphaltene polarity can be observed in the laboratory in terms of increased physical hardening in the blended bitumen when aged binders are combined with fresh materials.

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Aging and Field Performance of Polymer-Modified Bituminous Binders

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Abstract:

Laboratory testing has repeatedly shown that polymer modified bitumen (PMB) can improve rheological and failure properties. However, field trials have failed to consistently corroborate that PMB offers improved cracking resistance, with occasional reports of excessive cracking within a few years of service. The objectives of this paper are twofold. First, a better understanding is sought for the differences in aging behavior for PMB in the laboratory and in service. Second, this paper serves to provide users and produces alike with insights on how minor changes in bitumen sample conditioning and specification protocols can be implemented in a practical manner to provide enhanced control over long-term cracking distress. To fulfill these objectives, rheological and chemical parameters were obtained using a dynamic shear rheometer (DSR) and Fourier-transform infrared (FTIR) spectrometer. The results show that a laboratory aging protocol utilizing RTFO and PAV underestimates to a significant degree oxidative hardening that occurs in service. As aging progresses, gel points of PMB are gradually lost, which could be interpreted as a loss of network integrity, leading to a greater susceptibility to damage. DSR based rheological parameters, limiting phase angle temperatures and delta Tcd, are sensitive to binder modification technology and can improve the control of field cracking performance.

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Which are the best rheological criteria for characterization of PMB ?

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COLAS SA - Campus scientifique et Technique

Abstract:

The classification standard for polymer modified bitumens (PMB) is currently under CEN/TC336/WG1 revision work, an opportunity to take a step towards classifying binders based on their performance. The first attempts were based in particular on the recent evolution of the EN12591 standard for the classification of pure bitumens, for which the declaration of values of certain rheological criteria obtained at the DSR are now compulsory. The selected DSR rheological criteria on RTFOT aged binder are relevant for pure bitumens. They have been chosen to take into account both: - relation with the fatigue behavior (to be in the temperature range such that the elastic component becomes preponderant versus the viscous component i.e phase angle δ> 45 °), and the rutting behavior (within the typical R&B temperature range) - measuring the probable ranges of G* with the same geometry device The first project to change the specification standard for PMB naturally relied on these same criteria at the DSR, also extending it to long-term aging, but are they still relevant for PMB? It was also based on criteria from the MSCR test after RTFOT (repeated creep test behavior at 60 ° C) and the cold behavior BBR test The investigation of a panel of different industrial SBS modified bitumens led us to identify which are among all these rheological tests the most relevant to rely with performance.

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A versatile crosslinker and “de-linker” additive for modified bitumen

Klein Thomas

Lanxess

Abstract:

BA CR36 is a sulfur-rich alkyl polysulfide which acts as a liquid sulfur donor for sulfur-based crosslinking of polymers like SBS which are used to modify bitumen (PmB). It is readily dispersible in bitumen which allows a homogeneous distribution of the crosslinker in the binder matrix. Side reactions such as loss of sulfur due to hydrogen sulfide formation are reduced. The alkyl polysulfide combines acceptable safety characteristics with a high sulfur content. Under specific conditions the polysulfide BA CR36 acts also as a “de-vulcanising” agent, which selectively “de-links” reclaimed tyre rubber granules. The thermal treatment of the rubber particles with BA CR36 under relatively mild conditions cleaves selectively the sulfur bridges in vulcanised rubber. This “de-linking” of the rubber particles accelerates their swelling in bitumen and more homogeneous bitumen-rubber mixtures (CRmB) can be obtained. Mixing time of rubber crumb with bitumen in the manufacture process for CRmB is reduced and the energy consumption is lower. Comparative test results like DSR studies for both PmB and CRmB formulations involving the use of BA CR36 are presented.

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Particle Emission and Dispersion Test for the Early Planning Stage: New and Advanced Wear Measurement Technique for Characterization of Environmental Impacts of Roads

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Abstract:

In modern times,the awareness around the impact of aerosols and nanoparticles on human health and the general ecosystem is growing. Due to this, it is becoming increasingly important to understand, isolate and study the source and dispersion of such particles into air, water and soil. There is extensive ongoing research in this field,to study the real time evolution of such particles from railway tunnels and roadways infrastructures. Although these existing techniques could be powerful tools in measuring the amount of such particles,they are time dependent and unable to identify the source of particle formation. In fact, particles can be discharged from various sources such as tires, exhaust gases, weather events, thereby reducing the ability and accuracy of existing systems to isolate and study the effects of surface abrasion. The proposed characterization technique offers an innovative and novel tool to investigate the effects of surficial abrasion from roads and predict the impact of bituminous materials, aggregates, microfillers and nanofillers on the general ecosystem and human health. The technique provides the ability to experimentally predict the effects of the aforementioned categories of materials in various dispersion mediums. The technique helps estimate the a)Loss of material from surface abrasion, b)Structural stability and integrity of the designed composition, c)The behavior of the material in various environmental and climatic conditions. Thus, providing road-engineers with additional material-indices for responsible road infrastructure design. This is achieved by providing a deeper understanding about the impact of material used on the environment and the responsible utilization and limitations of the material. The proposed technique works by generating, diffusing, isolating and analyzing the particles from specimens. Hence, unlike many existing techniques that require the road infrastructure to be present and functioning, the proposed technique helps isolate and predict the impact of materials during the planning and design phase of roads.

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Ageing Characteristics of Bituminous Binders by Accelerated Ageing Procedure

Erik Nielsen, Matteo Pettinari

Danish Road Directorate

Abstract:

Durability of asphalt materials – either in development in new mix design or documentation linked to type test – calls for an accelerated ageing procedure in the laboratory that can mimic several years of performance in the field. Performance in real life will off course be dependent of several parameters like degree of compaction, voids and thickness, but a well-defined ageing procedure can be of value in assessment of ageing potential and sensitivity study in development of a new mix type as well in evaluating the recyclability of the material. In the development of a rolling resistance optimised surface layer an accelerated ageing procedure was used on several variants of asphalt plant produced mix. The procedure followed the guidelines of the protocol from RILEM TC-ATB-TG5 “Recycling of bituminous materials” (2008). The plant produced mixes (= Short Term Aged) were then artificial aged as lose mix in thin layers in ovens at 85 °C. Material samples were extracted after 0, 1 and 2 weeks. The recovered binders were analysed with respect to traditional data, InfraRed spectroscopy and rheology (DSR and MSCRT). The paper describes the sensitivity study of the new mix type with respect to binder ageing. As some of the mix variant were paved in 2017 it can be possible to follow the ageing of the pavements in the future when some time has elapsed.

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Short Term Ageing Characteristics of Polymer Modified Bitumens from functional surface layers

Erik Nielsen, Matteo Pettinari

Danish Road Directorate

Abstract:

The ability to predetermine the ageing potential of a polymer modified bitumen during asphalt plants production is interesting with respect to requirements in binder product standards. In functional surface layers like noise reducing pavements and rolling resistance optimised asphalt premium and expensive binders are often used. In other cases the asphalts were modified “in-situ”. As a national road administration and customer of asphalt materials access to initial binder data may not always be possible/allowed. For this reason, it has been important as customer to gain experience of the type of binder and magnitude of relative changes that the binder can experience during production and laying of the asphalt mix to the point where the customer can sample the material for delivery control purposes to ensure the required quality. In several research projects the national road administration, Vejdirektoratet, has had the opportunity to gather the initial polymer modified bitumen in according to EN 14023:2010 and the recovered binder after asphalt production, which in some cases were modified “in-situ”. This paper documents from several projects the characteristics of the extracted bituminous binders and the relative changes with respect to traditional binder tests, InfraRed spectroscopy and rheology. Rheology data cover master curves from -10 °C to 100 °C by Dynamic Shear rheometer (DSR) and Multiple Stress Creep and Recovery Test (MSCRT) at 50, 60 and 70 °C. Until recently the Danish experience regarding rheology and ageing has been limited. The objective of the paper is document measurements of bituminous binders from polymer modified asphalt from several functional surface layers and the impact of short term ageing. It is beyond the scope of the paper to link binder properties to the functionality of the surface layer, but the information on variability in relative changes of the binder properties will be valuable in future assessment of delivery control data on asphalt materials.

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Postcarbone road - The endless cycle of bitumen reuse

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Abstract:

In Germany, the reuse of asphalt has a long tradition. Since the 1980s, the reclaimed asphalt has been recycled achieving a reuse rate of around 90% and thus a very high value in the last years. In the future, instead of the amount, the quality of the reclaimed asphalt will be more important because the recycled asphalt will be reused again and again. Thus, these asphalt mixes are in the second or even third cycle of reuse. Concerning this situation, the question arises if asphalt can be reused several times without any loss in quality. An important factor affecting the asphalt quality is the binder bitumen. During the production, construction and service life, the ageing of this binder occurs causing a hardening of the bitumen. To compensate this hardening, additives for the reclaimed asphalt in terms of rejuvenation agents (rejuvenators) gain in importance. With these rejuvenators, the physical properties of bitumen can be modified e.g. the hardness and the stiffness reduced. However, the mechanism of the rejuvenation agents and the effects of the bitumen chemistry are largely unknown because the composition of the products varies very strongly. But with growing knowledge about these mechanisms and effects of the rejuvenation agents, the chemical composition and thus the physical and ageing behavior of bitumen can be targeted modified by the use of suitable rejuvenators. In this work, the actual results of the project Postcarbone road should be presented including investigations about the chemical and physical mechanisms as well as the efficiency of different rejuvenators. Further, a model for the cyclic reuse of bitumen should be developed. Based on this model, the choice of a suitable rejuvenation agent for the considered bitumen or rather asphalt should be possible. The project Postcarbone road (392670763) is funded by the German Research Foundation (DFG).

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ESTIMATION OF HIGH TEMPERATURE PERFORMANCE GRADE USING RUTTING DAMAGE AND IMPROVED FUNCTIONS FOR PG VARIABILITY

Geoffrey Rowe, Sérgio Raposo

Abatech

Abstract:

The Superpave performance grading asphalt bitumen classification method relies on climate historical data to predict the environmental conditions for a location where the bitumen will be used. In 2005 the basis for calculating the Performance Grade high temperature (PGHT) grade changed from the use of a 7-day high temperature to a temperature determined from a damage-based approach. The damage-based temperature was then correlated to the degree-days, defined as the summation of days with a maximum temperature greater than 10 degrees Celsius in a year. Algebraic equations then linked this value to the PGHT grade with consideration of the rut depth and latitude. The variation in the PGHT grade was related to latitude via a power law equation. However, this functional fit is only valid over a limited range, greater than 20 degrees of latitude and less than approximately 50 degrees of latitude. This does not create any problems for the USA bitumen grades since the majority of the country lies within this range (excluding Alaska, Hawaii and some tropical territories). However, when applying this power law function to other regions, for example to countries in Northern Europe, Canada or Russia, which are mainly above 50 degrees latitude, as well as other regions of the globe such as the Middle East, etc., problems arise. Work has been conducted to develop a functional fit to the data presented by earlier workers using a geometric law that better describes the variation of the climate coefficient of variation with latitude. A nonlinear optimization method was used to fit an asymmetric sigmoid describing the PGHT coefficient of variability. Updated equations calibrated for the European continent are provided for estimation of PGHT grade. This methodology is implemented in software that calculates the PGHT for any location in the world for which there is available climate data of sufficient quality and quantity.

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Advantages of the use of selective crosslinking agents in PMB production

Santiago Gil, Oscar Herrero

Ravago Chemicals

Abstract:

During Polymer Modified Bitumen (PMB) production it is necessary to store the material till the “digestion time” is completed, in order to achieve the optimal performance and storage stability. Crosslinking agents are used in PMB as essential additives, to ensure the chemical interaction between polymers and bitumen. They improve the storage stability as the crosslinking agent will react chemically in the matrix by forming stable bonds. Selective crosslinking additives allow improve PMB storability, but also provide more efficient, quick and stable Sulphur links, that leads to a shorter digestion time” reduction and polymer content reduction (increase productivity & cost savings). It is desirable to use non-hazardous crosslinking additives, which involve safe handily, in environmental and health terms even minimize the H2S emissions as extra characteristics. This paper presents how to evaluate in the laboratory scale the “Optimal Digestion Time” during PMB production, using selective crosslinking agents.

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New possibilities of assessing bitumens temperature sensitivity and aging

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Abstract:

Use of dynamic shear rheometers (DSR) to characterize aging susceptibility of paving grade and polymer modified bitumens (PMB) is commonplace at research centres and universities. In spite of the huge volume of research devoted to this topic, there are differences in the profession how to transform the complexities of their behaviour into relatively simple specifications. That is why the development of performances related specification is progressing slowly in Europe. The current Czech specification for paving grade bitumens CSN 65 7204 from 2016, included the recommendation to measure the binder temperature sensitivity using temperatures T1 and T2 as typical values. Temperature T1 is evaluated when G* = 5 MPa while temperature T2 is evaluated when G* = 50 kPa. Both parameters are assessed after short term aging using Rolling Thin Film Oven Test (RTFOT). The Czech specification CSN 65 7222-1 for PMB from 2017 included also the determination of temperatures T3 and T4 for the same specified stiffness values as for T1 and T2 after long term aging using Pressurized Aging Vessel (PAV) equipment. The above mentioned parameters were evaluated for a group of paving grade bitumens and PMB obtained from various bitumen producers at middle European market. All samples were tested at authors´ laboratories. Pertinence of the approach in above mentioned norms is discussed and compared with recent developments in USA and in Europe. Based on the data measured and on information from literature an alternative more simple procedure to assess binders' aging susceptibility is proposed. This methodology/testing procedure would allow technicians to determine binder temperature sensitivity using G* as a direct parameter without the need to manipulate the data via interpolation as it is required now.

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First experiences in Argentina to modify commercial bitumen with nanosilica

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Abstract:

Nanomaterials are extensively used to modify and improve different properties of construction materials. The asphalt modification with nanocomposites for pavement purpose is not the exception and can be found researches in the literature about the topic. The incorporation of nanocomposites is used to improves the bitumen characteristics to obtain asphalt mixture with better performance against rutting, fatigue and cracking. The potential of nanocomposites can be evaluated studying the rheological behaviour of modified bitumen. Rheological measures related to the performance in mixture elaborated with these modified bitumen can be measured and result the best way to analyses them. In Argentina there are not investigations at the moment about bitumen modification with nanocomposites. In this work, the incorporation of nanosilica at commercial conventional bitumen was studied. These represent a preliminary study about the changes measured by the incorporation of nano silica in traditional properties as well as in the rheological measures like the performance grade and other performance related properties of bitumen (low shear viscosity, Multiple stress creep recovery test (MSCR), fatigue binder test, etc.). Additionaly, rutting and fracture performance test on asphalt mixture elaborated with these modified bitumens were done. The nanosilica improves traditional properties like viscosity, and softening point as was expected. The performance grade was modified, the high temperature was increased and better behaviour at low and intermediate temperatures was presented. The nanosilica modified bitumens shown lower permanent deformations in the MSCR test and also improvements in asphalt binders fatigue behaviour.

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Detection of the identity of bitumen and its modification based on visualization in spider charts

Martin Radenberg, Daniela Breddemann

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Abstract:

Bitumen shows variations in its material characteristics, depending on the crude oil, its type of production and treatment until use. Moreover, there are complex modifications of bitumen, which detection requires highly elaborated test procedures. In order to realize consistent performance properties of the asphalt, it is of high importance for an asphalt mixing plant to ensure bitumen deliveries with constant material characteristics. This might be possible using complex assay methods; however, the effort appears to be inappropriate for a fast verification of binder properties. So far, rheological characterization of bitumen and modified bitumen, using the dynamic shear rheometer, appears to provide the most comprehensive material description, while simultaneously offering an acceptable effort of quality assurance. The aim of the research project financed by the German Asphalt Association was to develop a three-stage investigation program and to evaluate the identification potential of these three methods. For this purpose, bitumen was examined in virgin and in a simulated long-term aging condition. In order to ensure the least possible effort and a sufficient high aging effect, an extended RTFOT-method (180 minutes at 175 ° C) was used. The tests were carried out on 54 bitumen. The “Simple Approach” examined the possibility of adequate characterization using conventional bitumen characteristics. The “Extended Approach” used the DSR (temperature: 30 to 90 ° C) to derive suitable characteristics of bitumen. Again, a simple and fast test system for this approach is sought. The “Complex Approach”, extended the test system in the DSR by realizing also characteristic values for the low-temperature in addition to the rheological characteristics in the higher temperature range (30 to 90 ° C). For this approach, only one test procedure was conducted to decrease time and effort. In order to evaluate the usefulness of the identification method binder characteristics were visualized in spider charts.

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Development of a test method to determine the low temperature performance of Bitumen

Martin Radenberg, Matthias Staschkiewicz

Ruhr-Universität Bochum, Lehrstuhl für Verkehrswegebau

Abstract:

During recent winter's premature failure of asphalt pavements, due to low temperature thermal cracking, has been observed. However, not the lowest temperature seems to be the reason for the accumulation of thermal cracking, but the frequency of freeze-thaw cycles and gritting actions. Current methods testing low-temperature performance require large amounts of material. Therefore, these methods are unsuitable to analyze in situ samples of damaged pavements. Hence, the current research program aims at developing a test method, which requires only a small amount of bitumen to characterize the low-temperature performance. For this purpose, the focus is on test methods using the dynamic shear rheometer (DSR), already used for measuring the middle- and high-temperature rheological properties. Based on national and international research the current study contains the following four test methods: - The Shear-Relaxation-Test (SRV) - A Creep stress test at -10 °C that uses the 8 mm diameter parallel plates (rotation). - The Tensile-Relaxation-Test (ZRV) - A Creep stress test at -10 °C that uses the 8 mm diameter parallel plates (normal direction). - The 4-mm DSR – An oscillation test, performing a frequency sweep from 0.01 Hz to 10 Hz at various temperatures from -20 °C to 30 °C, using the 4 mm diameter parallel plates. - The Dynamic Mechanical Thermal Analysis (DMTA) – An oscillation test using slender cylindrical samples (h = 12 mm; d = 8 mm). To determine which of these four methods is the most suitable to characterize the low-temperature performance of bitumen, a three-step experimental work is engineered. In a first step all four methods will be used to analyze ten different types of bitumen. After this, two methods will be chosen to characterize additional 40 types. The last step will be a validation of the results, using the Bending-Beam-Rheometer (BBR) and the tensile-retardation-test by Schellenberg.

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Aging of rejuvenated RAP binder – a RILEM inter-laboratory study

Laurent Porot[1], Martin Hugener[2], Augusto Cannone Falchetto[3], Di Wang[3], Atsushi Kawakami[4], Bernhard Hofko[5], Andrea Grilli[6], Emiliano Pasquini[7], Marco Pasetto[7], Hassan Tabatabaee[8], Huachun Zhai[9], Margarida Sá da Costa[10], Hilde Soenen[11], Patricia Kara De Maeijer[12], Wim Van den bergh[12], Fabrizio Cardone[13], Alan Carter[14], Kamilla Vasconcelos[15], Xavier Carbonneau[16], Aurelie Lorserie[16], Goran Mladenovic[17], Marko Orešković[17], Tomas Koudelka[18], Pavel Coufalik[18], Edoardo Bocci[19], Runhua Zhang[20], Eshan Dave[20], Gabriele Tebaldi[21]

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Abstract:

The growing use of reclaimed asphalt (RAP) results in a continuous increase in the percentage of added RAP to hot mix asphalt. Within the asphalt pavement, the asphalt binder is the component which is affected the most by the ageing during service life, resulting in considerable hardening of the RAP binder. Therefore, the aged binder needs to be reactivated to meet the requirements for new asphalt mixtures. For high recycling amounts above 50%, often rejuvenating agents have to be added when no conventional binders are available with the required low viscosity. Such additives are of very different chemistry reflecting the base materials used in production which includes petroleum-based oils, but more often side products from industrial process which are very different from bitumen. Consequently, the ageing behaviour may differ from that of pure bitumen, which has been observed already in a number of pavement construction sites. For this reason, the RILEM task group 3 of Technical Committee (TC) RAP decided to examine the ageing behaviour of bitumen rejuvenator blends in more detail. An extracted RAP binder was mixed with varying amounts of virgin bitumen and a rejuvenating agent to simulate different amounts of RAP concentrations in the hot mix. These binder blends were next subjected to laboratory short and long term ageing. At every stage, defined target characteristics have been determined using complex modulus, penetration value, softening point ring and ball, and low temperature creep stiffness. The first results of this research effort are presented in this paper.

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Evaluation of the fatigue life of modified bitumens aged under ultraviolet radiation

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Department of Transportation Engineering, University of Sao Paulo

Abstract:

Bitumen aging has a great influence on asphalt mechanical properties, and due to this fact, current specifications establish limits for some indexes or aging parameters in an attempt to avoid the excessive hardening of the bitumen. However, such specifications do not take into account the effects of ultraviolet (UV) radiation on bitumen aging. The objective of this study is to assess the impact of thermo-oxidative and photo-oxidative aging methods on the rheological properties of a base bitumen and six modified bitumens, including the following modifiers: polyphosphoric acid, crumb rubber, SBS copolymer and low-density PE. The samples were previously aged in the rolling thin-film oven (RTFO). The fatigue performance was assessed by means of the results of the Linear Amplitude Sweep (LAS) test performed in the dynamic shear rheometer (DSR) at 25°C. An innovative approach based on the Linear Elastic Fracture Mechanics (LEFM) was used in the analysis of the results of the LAS test, which proved to be a good tool. The results pointed out that for low pavement strains (or deflections), the effect of the modifiers on the fatigue resistance is positive, particularly under UV radiation. The bitumen+rubber, followed by the bitumen+SBS, presented the best fatigue performance, and the neat binder presented the worst.

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The effect of rejuvenator on the change in rheological and chemical properties of artificial aged asphalt

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TNO, Delft

Abstract:

The ageing of porous asphalt (PA) binders is one of the most important properties that affect the lifetime of porous top-layers. In the present sustainable economy, increasing the lifetime of PA by understanding the process of ageing is therefore of great importance. The many different parameters in design, production and transportation affecting the lifetime of PA, make it very difficult to predict the durability of the asphalt mixtures. Through time, the binder endures physical and or chemical changes due to temperature cycles, diffusion of vapor, air (oxygen) and UV-radiation, which affect the performance properties of the binder. In general, these changes reduce the durability of the material under traffic intensity. This phenomena emerges with changes in mechanical and rheological properties of the binder. Considering upgrading top layer recycling in our present sustainable economy, one of the biggest challenges is the reversal of the ageing of the bitumen which often leads to the end of the road lifespan. Therefore effective rejuvenators are required which can change the bitumen of the strongly aged porous asphalt top layers back to the original level of performance. Therefore, this paper aims to evaluate the potential gain of the use of rejuvenators for circular asphalt by DSR and FTIR measurements on recovered artificial aged bitumen samples. The laboratory research shows that the rejuvenators are effective in the reparation of the rheological properties of artificial aged asphalt mixtures. Keywords: porous asphalt, ageing, rheology, durability, circularity, rejuvenator

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Performance of asphalt determined by the tensile creep test on binder and asphalt mortar

Franz Bommert, Franka Münscher

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Abstract:

The performance of an asphalt surface is largely determined by the used binder. Depending on the location, the asphalt road is exposed to wide temperature ranges. Test methods that are commonly used, generally focus either on the cold end, e.g. with the resistance against low temperature cracking addressed by the thermal stress restrained specimen test or at the warm end, e.g. with the resistance against permanent deformation addressed by the cyclic compression test. Until now, no test method to address both competing ends and therefore the whole scope of the application has been established. The tensile creep test (TCT) is a test method which addresses binder or mortar at low temperatures. However, results of this test method may indicate the performance of an asphalt mixture at both high as well as low temperatures. The paper introduces the test method TCT, results of tests on binder and mortar and correlates them with the asphalt's resistance to rutting and cold-induced cracking.

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Enhanced PmB via crosslinking

Bruno MARCANT, Guillaume ROUSSEAU

ValoChem

Abstract:

Polymer Modified Bitumens (PmB) are massively used in road industry. However, stability of those is a key feature. Phase separation between bitumen and polymer may lead to unacceptable performance fluctuations during use on the field, leading to durability issues of the material. This is the reason why cautious selection of bitumen source and polymer type is crucial. However, it has been demonstrated this may not be sufficient to insure stability. Moreover, the on-going changes in refining industry makes it less and less possible. Crosslinking technology is a way to solve this problem. Its mechanism of action and recent developments in this area are exposed. It is shown what kind of performance characteristics can be achieved, using both EU and US approach. Interesting enough, it is demonstrated that some PmB may pass the EU specifications and fail the US ones. Finally, we conclude with the 2 strategies applicable from the use of crosslinker : either achieve same quality of PmB at lower cost, or increase significantly quality of PmB at same cost.

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Benefits and limits of PPA modification

Bruno MARCANT, Guillaume ROUSSEAU

ValoChem

Abstract:

Since its industrial introduction at the end of the 20th century, modification of bitumen with Polyphosphoric acid has always been a source of controversy. Special handling of the product and incompatibility with some antistripping agents or crosslinkers have led to multiple discussions and some mistakes in use. Through a decade of intensive use, US has gained tremendous experience about this technology, its advantages and its limits. Based on literature review, recent data and common practice, and in the light of the on-going refining changes, we intend to present an updated status about the use of this technology in the four different applications : - PG bump - Combination with polymer - Combination with crumb rubber - Oxidation additive

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Evaluating rejuvenator effectiveness using Binder-Fast-Characterisation-Test

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Abstract:

Throughout Europe, the use of Reclaimed Asphalt Pavements (RAP) for new asphalt pavements is continuously increasing because of environmental aspects and the high amount of RAP available from replacement of old roads. Recently, more and more rejuvenating agents are used to compensate unfavorable properties of the aged RAP bitumen to allow a higher percentage of RAP in the asphalt mixture. Conventional bitumen tests used for asphalt mix design, such as needle penetration and Ring and Ball softening point are often used as the only indicators for evaluating the bitumen properties. However, today's bitumen are getting more and more complex, resulting from the mix of virgin bitumen, RAP bitumen and rejuvenator. Numerous authors have reported significant problems using conventional bitumen test methods for assessing properties of complex bitumen [1–5]. The Binder-Fast-Characterisation-Test (BTSV; German for Bitumen-Typisierungs-Schnell-Verfahren) in the Dynamic Shear Rheometer (DSR) has been established in Germany for a precise rheological characterization of bitumen in the high temperature range. From BTSV, two rheological key parameters (TBTSV and δBTSV) are obtained, that can be used to differentiate bitumen in regard to the bitumen hardness and to the degree of modification. These parameters form a solid basis for bitumen evaluation in the high temperature range. In this study, BTSV is used to analyze different rejuvenators in regard to their effects on different bitumen extracted from RAP. The dosage of the rejuvenators is systematically changed and the blended bitumen are analyzed with the BTSV. As outcome, a linear change of the two key parameters was detected for the blending processes, indicating necessary amounts of rejuvenators to produce target bitumen with specific rheological properties in the high temperature range. Additionally, the ageing susceptibility of the bitumen blended with rejuvenator was analyzed by RTFOT and PAV laboratory ageing to simulate multiple recycling.

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Deriving and Characterising Alternative Bitumen from Waste Plastics

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Abstract:

This study presents a research on laboratory production and experimental characterisation of an alternative bitumen using municipal waste plastics. Six different waste plastics produced by local waste recycling manufacturers were selected and characterised to investigate their feasibility in modifying the bitumen binders. Thermal characteristics were firstly obtained using Differential Scanning Calorimetry (DSC) device and the chemical functional groups were obtained by Fourier Transform Infrared Spectroscopy (FT-IR) test, which was used to identify the plastic types existing in the recycled plastics. Then the rheological properties of the bitumen modified with two nominated plastic waste (LDPE and MR10) were examined using the Dynamic Shear Rheometer (DSR) device by conducting frequency sweep tests. Additionally, the engineering performance of the waste plastics-derived bitumen was also obtained and compared against the control bitumen, including fatigue, rutting and healing performance using Time Sweep (TS) test, Multiple Stress Creep and Recovery (MSCR) test and Healing test, respectively. Results show that the LDPE and MR10 were consisting of low-density polyethene (LDPE) and polypropylene (PP), respectively. The recycled waste plastic MR6 (plant and batch) are mainly LDPE as well. Whereas, other recycled plastics (MR8-V1 and MR8-V2) consist of a variety of materials and impurities. Thus The LDPE and MR10 were selected in the current study to modify the bitumen binder. The LDPE-modified bitumen exhibited more elastic and less viscous behaviour compared to the control bitumen, showed by increased shear modulus and reduced phase angle. Whereas, the MR10 (mainly PP) reduced the shear modulus significantly for the control bitumen. Both LDPE and MR10-modified bitumen had a substantially improved resistance to rutting and fatigue cracking compared to the control bitumen. Meanwhile, the LDPE led to an increased healing potential to the bitumen while the MR10 did not show obvious improvement to the healing performance of the bitumen.

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Rheological properties of phase-incompatible bituminous binders

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Abstract:

The North American bitumen specification system, SuperPave™, is the newest and the most elaborate specification system for bituminous binders. The system was developed and validated for straight-run refinery-produced bitumens and it has been implemented in the United States and Canada throughout the 1990s. Since then, there has been increased use of modified grades, Recycled Asphalt Pavement and artificial “softeners” such as recycled engine oil bottoms, aromatic or paraffinic oils, bio-based oils, etc. Not all these compositional changes manifested in adequate bitumen long-term performance in the field. It was demonstrated that the current SuperPave™ system cannot prevent acceptance of some of the lower quality materials. There has been a significant effort in the US and Canada to improve the SuperPave™ system to address these challenges, more specifically to prevent premature binder aging and pavement cracking. Current paper is showing how excessive oxidative aging and physical hardening susceptibility together with loss of cohesion in inadequately modified binders relates to phase compatibility and how this can be reliably manifested in measurement of rheological phase angle in Dynamic Shear Rheometer (DSR). It is shown that the DSR test performed on the Pressure Aging Vessel (PAV) residue can be simply modified to exclude phase incompatible binders from passing the specification. The discussion of evolution of SuperPave™ specification system in North America is important from the European perspective too as Europe is heading towards a rheology-based specification system in the near future.

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Waxphaltenes - when waxes become asphaltenes; wax model compounds and how they influence the fractionation of bitumen.

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Abstract:

In the bitumen and petroleum industry, fractionation or component separation is a common tool to describe the chemical nature of materials. From all components, the asphaltenes are definitely the most studied material in bitumen. Operationally, asphaltenes are defined as the material insoluble in n-heptane or n-pentane and soluble in toluene. Chemically, this fraction is associated to large conjugated polyaromatic compounds, and is also regarded as the most polar fraction present in bitumen. Other material classes including saturates, aromatics and resins have also been defined. The aim of this study is to investigate the validity and the risks of assigning chemical classes to fractions predominantly determined by solubility. In this study the authors investigated specifically if and under what conditions, a fully saturated hydrocarbon may become part of the asphaltene fraction. Fully saturated hydrocarbons would chemically be associated to the saturate fraction. For this purpose, several n-alkane substances were added to a wax-free naphthenic bitumen. In a first step, infra-red spectroscopy and calorimetry were used to assure a full blending between the n-alkanes and the bitumen, when preparing the blends at elevated temperature. Fractionation tests were conducted according to two common procedures: the Iatroscan method (IP 469) and the asphaltene separation method denoted as IP 143. Calorimetric data clearly show a melting point depression when adding n-alkanes to bitumen, as well as an increase in melting enthalpies with higher n-alkane percentages. The data also demonstrate that a recrystallization upon heating can take place, especially for the low molecular weight n-alkanes. The fractionation tests show further that low molecular weight n-alkanes are as expected part of the saturates or the maltene fraction, but for larger n-alkanes this is not always valid. The findings and its consequences are discussed in detail in the paper.

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Durability parameters evaluated on binders recovered from various field sites in Europe

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[1]Nynas, [2]Colas

Abstract:

Recently, a number of rheological parameters have been proposed as performance indicators for aging and aging-induced crack formation. These include parameters derived from BBR measurements, as for example delta Tc, or parameters derived from DSR measurements, such as the Glover Rowe parameter, the crossover frequency and parameters related to the shape of Black- and master curves. Delta Tc is defined as the difference between the limiting stiffness temperature (LST) and the limiting slope temperature (LmT). The more negative this difference, LST-LmT, the higher is the risk for aging-induced cracks. The Glover-Rowe parameter is calculated from DSR measurements, more specifically, from the complex modulus and phase angle values taken at 15°C and 0.005 rad/s. This parameter relates also to the ductility recorded at 15°C and at 1 cm/min. In literature, good relations between the various parameters and cracking on field sites have been observed. However, up to now these validations were mainly conducted on North American pavements. The main purpose of this study is to evaluate if the rheological parameters, proposed for US sites, can also be valid for European conditions. Therefore, field test sites from which binders could be recovered were identified. In addition, before taking cores, the road condition, as well as traffic situation was evaluated. From the cores, binder- and void content were determined. And the recovered binders were subjected to a full characterization based on DSR measurements, including 4 mm DSR measurements. The aging state of the binders was further evaluated based on FTIR measurements. Although the original binders were not available, it was possible to draw important conclusions from this study.

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Investigation of the effect of short-term ageing on rejuvenated reclaimed asphalt binder

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Abstract:

Because of the deteriorated properties of aged reclaimed asphalt (RA) binder (e.g. increased brittleness), compensation steps should be implemented to achieve a certain level of durability. This compensation can be done by using recycling agents. In this study the effect of recycling agents is investigated by exploring their impact in the binder scale before and after applying short term ageing (STA). Three groups of samples are investigated in this study. The first group are binder blends extracted and recovered from three comparable (in terms of composition and binder content) lab-produced asphalt mixtures: one reference mixture with only virgin materials, one with 40% RA (on total binder mass) and virgin binder, one with 40% rejuvenated RA and virgin binder. The second and third set of binder blends are reproduced in the laboratory, using the same materials and compositions as the first set, before and after rolling thin film oven test (RTFOT) ageing accordingly. For all binder samples, penetration, softening point and rheological properties, are determined. Furthermore, the fatigue resistance of the binders is evaluated in terms of Linear Amplitude Sweep (LAS) test. Next, the ageing indexes are investigated in terms of sulfoxides and carbonyls increase using Fourier transform infrared (FTIR) spectroscopy. The objectives of this study are firstly to evaluate the effect of rejuvenating 40% RA binder in terms of binder properties and fatigue performance and secondly to investigate the effect of ageing on binders derived from lab-produced mixtures by comparing them with the RTFOT-aged binder blends. The results show that both ageing due to RTFOT and asphalt mixture production led to similar rheological properties, but different chemical indexes. Concerning the influence of the rejuvenator, the conventional and fatigue properties do not indicate any significant changes. On the other hand, the chemical and rheological properties were influenced.

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Asphalt Binder Quality Assurance Test Method (ABQT)

Raj Dongre[1], Jack Youtcheff[2]

[1]Dongre Laboratory Services Inc., [2]Federal Highway Administration (FHWA)

Abstract:

An innovative, simple, and easy-to-use test method for Quality Control and Assurance of asphalt binders was developed. This new method, called the binder Asphalt Binder Quality Assurance Test (ABQT), uses an air jet to produce indentation loading. A laser deflectometer installed coaxially to the air jet is used to measure the resulting deflection from the indentation. The ABQT is conducted under stress control at an air pressure of 15 psi and test temperature of 77oF (25oC). The ABQT test protocol is similar to traditional Penetration test (ASTM D5) except instead of the penetration needle an air jet is used with a loading time of 20s and recovery time of 70s under no load. Unlike the Penetration test, the ABQT measures both the loading and recovery characteristics of a binder. The complete creep-recovery curve is measured and stored. The measurement of recovery properties allows for successful testing of both unmodified and polymer modified binders. Fractional single spring-pot with a dashpot in series was used to successfully model the creep and recovery data. A new software to predict PG Grade from the parameters derived from the creep and recovery curve has also been developed by DLSI. The software can successfully predict (greater than 95% success rate) the continuous PG Grade of a binder from the creep and recovery curve of asphalt binder conducted using the ABQT testing protocols. The binder is tested in unaged condition at 25oC. The ABQT device and the PG Grade prediction model was evaluated by three State DOTs (PennDOT, CDOT, and UDOT). Data obtained to date suggests that the ANN application has successfully predicted over 95% of the PG grades accurately at each State DOT. In this presentation, the new developments in analysis of the ABQT test data and its use in binder quality assurance will be discussed.

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A Simple Test Method for Asphalt Binder Fatigue Specification

Raj Dongre[1], Jack Youtcheff[2], Adrian Andriescu[3]

[1]Dongre Laboratory Services Inc., [2]Federal Highway Administration (FHWA), [3]SES Group

Abstract:

The contribution of asphalt binder properties to fatigue behavior of hot-mix asphalt pavements is a subject of current research (e.g. NCHRP 9-59 and 9-60). New tests and parameters are being proposed to determine the impact of asphalt binder characteristics to fatigue distress in pavements. The research team at TFHRC is evaluating creep and recovery characteristics of asphalt binders using the DSR test to address this distress. Two test protocols conducted at 25C are being evaluated. The first, called Multiple Time Creep Recovery (MTCR) characterizes the time dependent behavior of asphalt binders. In MTCR a set of four loading and recovery times are used at a single stress level. The second protocol called the Multiple Stress Creep Recovery is used to determine non-linearity or stress dependence of the viscoelastic properties of asphalt binder. In MSCR a set of four stress levels are used at a single loading and recovery time. A total of 24 asphalt binders with known fatigue performance were selected for this study. MTCR and MSCR tests were performed on unaged, RTFO and PAV aged conditions for all binders tested. Traditional G* and phase angle data was also measured at 25oC for all binders. Preliminary results suggest that asphalt binders are not stress dependent under the test conditions of MSCR in this study. So MSCR testing may not be necessary for fatigue characterization. The MTCR data for binders, however, shows differences in linear viscoelastic properties at 25oC. In this presentation, the results from these two approaches to asphalt binder fatigue testing will be discussed. Implications of not finding stress dependence will also be examined. Based on data analysis from this study a strawman specification criterion for binders will be proposed to estimate the contribution of binder properties towards fatigue distress in hot-mix pavements.

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Implication and Implementation of New Low Temperature Binder Specification at UDOT

Raj Dongre[1], Howard Anderson[2], Jack Youtcheff[3]

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Abstract:

When implementing the PG grading system, UDOT included the DTT test, which was developed by SHRP. Utah is the only state that explicitly requires failure strength (4 MPa) and failure strain (1.5%) as part of the PG binder specification. After more than a decade of experience with the DTT, engineers have observed that thermal cracking is substantially reduced for UDOT HMA projects. Although we are satisfied with the DTT specification, the existing test equipment is no longer being supported by the original manufacturer (Instron) due to lack of demand for the procedure. Alternative equipment is also not available at a reasonable cost. UDOT has decided to eliminate the DTT test and replace it with the newly developed Delta Tcr requirement, aged for 20 h in the PAV. The UDOT binder database containing PG grade verification data as well as DTT data was analyzed to determine the impact of eliminating the DTT. UDOT engineers wanted to make sure that as a result of eliminating the DTT the binder quality (source and formulations) remained unchanged. In addition to the data from UDOT, results from a comprehensive study of BBR data from more that 20 State DOTs conducted by the research team at TFHRC (FHWA) was also studied. Delta Tcr values were estimated for the historical data and it was found that Delta Tcr alone may not be enough to guarantee continuation of existing binder supply. Data analysis showed that If a limit is also placed on the minimum S(60) value of BBR creep stiffness, DTT may be eliminated without causing significant thermal cracking problems. The new UDOT Binder specification is now being implemented. The criteria requires a bottom limit on S(60) of 150 MPa and a top limit on S(60) of 300 MPa in addition to the Delta Tcr and ER.

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Cold supply chain of bitumen pellets for pavement: binder free flowing and mixture performances

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[1]IFSTTAR, [2]TOTAL MS, [3]EIFFAGE Infrastructures

Abstract:

The GLOBE project aims to develop a bitumen pellet supply chain, from the refinery to the asphalt plant in a collaborative research program framework between IFSTTAR, TOTAL MS and EIFFAGE Infrastructures. One of the project's objectives is to evaluate the storage behavior of bitumen pellets under mechanical loading in controlled climatic conditions. The purpose of this paper is to develop a laboratory methodology that evaluates the free-flowing behavior of bituminous pellets' viscoelastic behavior. The method is based on soil mechanics and granular mixtures tests at controlled temperatures. The test method is detailed in this paper along with illustrated results for solutions provided by the industrial partners of the project.

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PAST, PRESENT AND FUTURE OF THE STANDARDIZATION OF BITUMEN

Lucía Miranda[1], Fco José Lucas Ochoa[2], Francisco Guisado[1]

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Abstract:

Describing the historical evolution of asphalt products (bitumen and emulsion) can mean many pages, starting with the extraction process in its beginnings, its manufacture, its multiple uses, as well as the entire regulatory process that has developed around it to define specifications. However, the objective of this communication, is to present a vision of the evolution of bitumen and emulsion regulations in the years prior to the appearance of the CE Marking, at the present time, where its implementation is already established and, above all, to describe how the future is presented to offer quality materials, with adequate services for the intended use and taking into account what are the requirements to achieve products capable of offering services adapted to the requirements that are increasingly being imposed with more force environmental and durability criteria.

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Simple Test to Obtain Rheological and Strength Properties of Asphalt Binders at Low Temperatures

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Abstract:

Selecting asphalt binders that resist cracking at low temperatures represents a critical requirement when building asphalt pavements in cold regions. Low-temperature cracking resistance of binders is evaluated using rheological properties, such as creep stiffness and m-value, as well as fracture properties, such as failure stress and failure strain. The rheological properties are obtained using the Bending Beam Rheometer (BBR) and the fracture properties using the Direct Tension Tester (DTT), respectively. Many agencies use only the BBR creep test to grade asphalt binders, due to the high cost of the DTT instrument and complex sample preparation and to the erroneous assumption that creep properties dictate asphalt binder cracking resistance. Recently, a new strength test was developed at University of Minnesota to measure fracture properties of binders using a modified BBR, called BBR-Pro. In this paper, the idea of using the BBR strength test to obtain relevant rheological properties is investigated. The goal is to perform one single test to obtain both creep and strength properties of binders. First, the assumption of linear viscoelasticity (LVE) is verified for different loading rates. Then, both analytical and numerical method are used to obtain the creep compliance from the BBR strength test data. The results show that the analytical and numerical method are equivalent for obtaining creep compliance, while the numerical method is better than the analytical method for obtaining m-value. The analysis indicates that both methods are valid only within the duration of the strength test. By reducing the loading rate to increase the duration of the strength test, it is found that the strength data can be successfully used to predict the rheological properties (creep stiffness and m-value) of asphalt binders.

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Innovations and developments in bitumen composition analysis

Jeramie Adams, Joe Rovani, Ryan Boysen, Michael Elwardany, Jean-Pascal Planche

Western Research Institute

Abstract:

The analysis of bitumen composition has always been a challenge because of the complexity and nature of bitumen molecules forming a continuum of associating chemical molecules. The separation by molecule families with similar features, saturates, aromatics, resins and asphaltenes (SARA) became the norm. However, SARA separation was developed mainly for straight run bitumens, and not to account for current changes in refining streams, blends and modification processes. Recently the Western Research Institute invented a new separation combining chromatography with solubility called SAR-AD™ that separates saturates, aromatics and resins by liquid chromatography, and asphaltenes by solubility in solvents with increasing polarity. This technique provides eight fractions specifically reporting to the four generic ones. This technique is used to characterize a wide variety of binders from around the world, produced using various processes, and allows for obtaining strong correlations between the fractions, the physical properties and aging levels of the bitumens. Recent studies were devoted to better understand the chemical make-up of these fractions, using model compounds to identify molecular classes in the separation. Key compound features cause molecules to report to the chromatographic saturates, aromatics and resins fractions. The saturates fraction was shown to contain saturated hydrocarbons ranging from linear to cyclic species containing naphthenic rings; the aromatics separation produces three different fractions based upon the number of fused aromatic rings; and the resins fraction contains molecules influenced by heteroatoms and functional groups. The size, geometry, and location of aliphatic side chains result in steric hindrance causing molecules to report to different fractions. Similarly, functional groups with heteroatoms can change where the molecules report. Further developments are being made towards a second-generation of the SAR-AD instrument based on multi-dimensional separations and advanced detection techniques. Applications include the identification of additives, special refining processes, and aging. Examples were obtained from samples provided by WRI led Industry consortium's partners.

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Innovations in analysis of rejuvenators in blends using RAP as part of Infravation projects

Jean-Pascal Planche[1], Ryan Boysen[1], Emmanuel Chailleux[2], Simon Pouget[3], Laurent Porot[4], Christopher Williams[5], Eric Cochran[5], Davide Lo Presti[6]

[1]Western Research Institute, [2]IFSTTAR, [3]Eiffage, [4]Kraton Chemical, [5]Iowa State University, [6]University of Nottingham

Abstract:

A new approach to evaluate an aged binder rejuvenation based on both chemical and rheological tests was pioneered as part of Infravation's AlterPave and BioRePavation projects. This paper focuses of results obtained under BioRePavation where blends of bio-rejuvenators with virgin binder and Reclaimed Asphalt Pavement (RAP) were made and evaluated both in the laboratory and in a field Demonstrator at the IFSTTAR accelerated loading facility. The chemical analytical tests of Infrared Spectroscopy (IR) and Saturates Aromatics Resins and Asphaltene Determinator (SAR-AD™) developed by the Western Research Institute (WRI) were performed to evaluate the rejuvenation of the binder blends. Low temperature rheologic tests including ΔTc, a parameter related to binder relaxation, were performed to evaluate possible rejuvenation of the physical properties, using the Dynamic Shear Rheometer. Blends were artificially aged in the lab via RTFO and extended PAV accelerated aging to test the likely longevity of pavements made with these rejuvenator, RAP, and binder combinations. Additionally, a new micro-sampling device and concept also developed by WRI under a contract with the FHWA, was utilized to sample test sections that were made using some of the RAP+Virgin Binder+Rejuvenator blends. The extracted and recovered binder from the field was evaluated via IR and rheology to demonstrate that laboratory blend performance was approximating field performance. Aging severity of the sampled sections was also evaluated.

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Innovative approach to evaluate the oxidative ageing resistance of bituminous binders

Jeramie Adams[1], Michael Elwardany[1], Jean-Pascal Planche[1], Laurence Lapalu[2], Soenke Schroeder[3], Mouhamad Mouazen[2]

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Abstract:

A methodology, based on the use of specially-designed long-term aging protocols, was developed in order to discriminate binder formulations with respect to their resistance to oxidative ageing. The conditioning involved two protocols, an extended PAV under standard temperature and pressure conditions, for durations up to 72 hours, and a precision oven test developed by the Western Research Institute (WRI) under a contract with the Federal Highway Administration. This oven aging test ages 100 micrometer thick films at 70□C for a duration up to 84 days, to ensure no oxygen diffusion effect. The methodology uses indicators from infrared spectroscopy and rheology to fit an advanced oxidation kinetics model also developed by WRI with the FHWA: this oxidation model allows to obtain rate constants for the first (fast) and secondary (slow/constant) reactions, and determine if various additives are showing an effect on which phase of the chemical oxidative aging reaction. The methodology heavily relied on changes in rheological behavior with an emphasis on the low-temperature end of the spectrum, to determine if the modifiers reduce the low temperature cracking potential through the determination of the ΔTc, Glover-Rowe Parameter, Rheological Index, and crossover frequency and temperature. These cracking indicators are getting more attention in the asphalt community, particularly in North America. The DSR-4mm was used to conduct the low temperature measurements in lieu of the bending beam rheometer. The study also involved thermal analysis as low-temperature thermal events such as the binder glass transition are known to evolve upon ageing. Overall, the impact of binder formulation on oxidative aging resistance was clearly observed and confirmed through this multi-technique approach which allowed to differentiate various binders and show the efficiency of modification systems with respect to given oxidation indicators. Results discerned between additives that may chemically retard oxidation from additives with merely softening effect.

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Use of plant derived sterols as an age retarding additive for bitumen and asphalt mixtures

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Abstract:

Rejuvenating additives for bitumen and bituminous mixtures is subject of much current research to facilitate the use of greater levels of aged bitumen in form of RAP and/or RAS. The additives are typically petroleum or plant derived oils that function as softening agents for aged bitumen and therefore reduce high and low temperature stiffness properties but do not reverse the aging of the bitumen. More importantly these additives do not significantly alter the rate at which treated, aged bitumen (RAP) is impacted by subsequent aging. Our research has shown that plant (phytosterols) can significantly retard the aging of virgin bitumen and can slow down the rate at which aged bitumen when treated with sterols undergoes additional aging. The sterol additive mainly acts to reduce the rate at which bitumen relaxation properties degrade with aging. Because as bitumen ages it becomes more m-controlled the ability of an additive to retard the rate at which bitumen relaxation degrades results in bitumen with a longer service time to failure. The economic benefits of extending the aging time of binder is obvious for long term performance. The use of higher RAP levels is also possible because the age retarding impact of sterol results in RAP binder aging at a slower rate compared to other additives. Sterol also acts to reduce the rate at which high temperature stiffness properties increase due to aging. The rate at which low temperature stiffness properties increase is the least affected property. Test sections in Wisconsin and Iowa have been constructed. Additional laboratory testing has shown that surface applications with emulsion containing sterol reduce the aging rate of the bitumen in the mixture surface compared to no treatment or emulsion treatment without sterol

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Performance Bitumen Grades – Climatic Mapping Evaluation for Western Europe

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ExxonMobil

Abstract:

There is a growing trend worldwide to introduce a performance approach to select bitumen for roads construction. This strategy has been adopted in North America for several decades. The assessment of bitumen performances goes through determining properties based on rheological measurements. They characterize the viscoelastic behaviour of studied bitumen under well-defined testing conditions. The result is to provide specific temperatures at which bitumen undergoes noticeable physical modifications which describe and differentiate product grades according to dedicated standards. Conducting such determinations is of great interest when obtained temperatures can be compared to climatic conditions encounter by roads throughout the year, and particularly during summer and winter periods where pavements may be affected by different types of physical damages. When binder rheological performances match climatic road conditions, selected binder can be used. For paving bitumen grades, Europe is currently following harmonized standards based on utilization of empirical test methods, but trends are also to develop new specifications more-directly performance related. The objective of this paper is to (1) Present a climatic mapping of selected countries to screen typical high and low pavement temperatures in Western Europe. (2) Compare if observed rheological performances of paving bitumen grades used to build those roads are aligned with determined high and low pavement temperatures requirements.

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Correspondence between the state of aging of a PmB and its state in asphalt mix

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[1]COLAS CST, [2]NYNAS

Abstract:

PmB binders are well-known to improve AC mix characteristics and durability. But they often present a very complex evolution with time and temperature, which can have a significant effect on their characteristics. So it is unclear if the sample prepared for testing is in the same state as it is in the asphalt mix, even if the coating step has been simulated. On the other hand, in order to evaluate a binder of an asphalt mix a recovery steep is needed, which may also change the state of the binder. To get a comparison of the modified binder with a given and controlled thermal history to the one as it is in an asphalt mix is therefore almost impossible directly. This study presents detailed characteristics of three modified binders from industrial production facilities in different aging states : fresh, after RTFOT and after RTFOT+ PAV. Some of these binders are also extracted from an AC mix. Empirical binder tests are conducted and as well as a complete rheological binder characterisation. Three AC mixes produced with these binders are characterized from an asphalt mix rheological point of view. The behaviour of both the binders and the asphalt mixes is modelled according to the 2S2P1D model, and the best “correspondence” between the parameters determined on the binders at different aging states and those measured on AC mixes are sought. That helps to define a more adapted state to work on the binders. This will hopefully also shed some light on the relevance of some requirements based on the characterisation of recovered binders, and help indicate which aging and thermal history is the most relevant for possible future durability specifications.

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First step to the development of performance based criteria for bitumen resistance to low temperature cracking

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Abstract:

The existing standardized method for the determination of bitumen behaviour at low (negative) temperatures is based on bitumen prismatic beam bending – bending beam rheometer (BBR). However, BBR very often underestimates the performance of modified bitumens and needs approximately 15 g of bitumen for one specimen what may become a concern evaluating recovered and aged bitumens. A dynamic shear rheometer test with 4 mm parallel plates (4-mm DSR), introduced by Western Research Institute (WRI) in 2015, seems superior to other bitumen tests and methods dedicated to bitumen behaviour at low temperatures. However, WRI proposed limiting criteria for bitumen resistance to low temperature cracking (relaxation modulus (G) and apparent relaxation rate (mr) at a specific loading time of 60 s) are based on the BBR limits, which often fails in evaluating bitumen resistance to low temperature cracking. In addition, existing high precision DSRs allow direct measurements of relaxation modulus. Therefore, this paper focuses on the algorithm for the development of performance based criteria that appropriately evaluate bitumen resistance to low temperature cracking. Furthermore, first results – the severity of low temperature cracking in 26 road sections and lowest asphalt surface temperatures determined on the basis of nearest road weather stations – are given in this paper.

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GLOBE: an innovative technical solution to ensure waste free cold logistics of bituminous binders

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Abstract:

GLOBE is a French acronym for "Granulés pour la LOgistique des Bitumes d'Enrobage" literally meaning « Bituminous pelletsfor the logistic of coating binders ». This project supported by ADEME (French Environment & Energy Management Agency) focuses on the development of an innovative technical solution to ensure a logistic of bituminous binders from refineries to asphalt mix plants which is cold, waste free and thus cleaner and safer. The main challenge is to modify a material such as bitumen, usually handled hot in liquid form, in order to be able to produce a granular form of it, which stays stable over time. In order to do that, it is required to overcome in-depth its typical binder characteristics, especially its creep behavior and its exceptional adhesiveness properties. This implies to modify the rheology of the binders and to take into consideration the granulation technology. The final product should avoid agglomeration phenomena, while taking into account the mechanical and thermal stresses associated with the handling, storage and transport of the pellets. In addition, the characteristics of bitumen should be recovered after mixing and laying, namely, the adhesion to the aggregates to insure the cohesion of the granular skeleton and the mechanical characteristics to guarantee the transfer of the mechanical stresses within the asphalt material during the lifetime of the infrastructure. This project will also be subject to environmental monitoring, as it is important to check that the apparent gain is real throughout the entire life cycle. Key words: bitumen, pellets, rheological properties, granulation technology, ACV

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Methodology to evaluate oxidative ageing resistance of bitumen binders

Laurence LAPALU[1], Mouhamad MOUAZEN[1], Soenke SCHROEDER[2], Jeanne ZHU[1]

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Abstract:

A methodology, based on the use of PAV, developed in order to discriminate formulations in respect to their resistance to oxidative ageing will be presented. Statistical analysis of uncertainties will be discussed and different formulation ranked. The multi-criteria methodology developed allows to compare rapidly the impact of formulation on oxidative ageing resistance. For instance, it is demonstrated that standard bitumen base of the same grade can have different resistance to oxidative ageing. Other interesting results will be discussed during the presentation. Finally, this study evaluate the effect of binder oxidative ageing on asphalt mixes performances. It consists in comparing different asphalt mixes, changing only the used binder (standard bitumen, modified ones with polymers or other additives), keeping all other parameters constant. Ageing protocol and tests will be discussed. Clues about the ageing mechanisms and testing method will be discussed.

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Comparative analysis of the BBS and Mortar Pullout tests in the evaluation of adhesive properties and moisture damage in asphalt binders

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Abstract:

Facing the evolution of the problems caused by the deleterious effect of water on pavements, in recent years some researchers have been developing new tests for the experimental and analytical evaluation of this damage. The present work aims to compare the BBS (Binder Bond Strength) tests and an adaptation of the Mortar Adhesion test for the evaluation of the moisture damage in the adhesive properties of the bitumen/aggregate system. For this purpose, a PG 64-22 binder was modified with an SBS polymer, an adhesion agent (D.08 Dope) and the sap of Euphorbia Tirucalli (petroleum plant), in various contents. The adhesive properties and the moisture damage between the modified binders and a granite substrate were evaluated by the BBS tests, with the Positest AT-A equipment, and the Mortar Adhesion test, with the mortar pull-out equipment. The main difference between both tests is that the BBS equipment has hydraulic operation while de mortar pull out test is mechanically actuated. The tests were performed on dry and saturated conditioning of the samples, to quantify the damage caused by moisture. The results of the statistical treatment of the data showed that both tests, considering equal conditioning, were able to maintain the same trend of results. However, the magnitude of the values is higher in the BBS, once the rate of load application, being automated, is larger and more accurate. In the mortar pull out test the rate and accuracy are subject to the ability of the operator. It was observed that both tests showed similar repeatability. It can be concluded that the test performed by the mortar pull out equipment can be used as an alternative method to the BBS test, for the evaluation of adhesiveness and the moisture damage of asphalt binders.

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Test methods variability for Paving Bitumen grades - A statistical Approach

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Abstract:

European Standard EN 12591 describes the performance required for a number of properties of paving grade bitumen. It provides a framework which consists of specifications based upon empirical test methods such as penetration or ring and ball softening point. Each designated test method includes the operating conditions, the equipment requirements and precision statements. In spite of all the instructions and recommendations provided by the standard, it is not unusual to observe some dispersion for a same sample. This variability might even result in values out of the reproducibility and indicates that precision can be further improved. To address this concern, a Design of Experiments (DoE) was built and allowed to assess critical parameters with their contribution in the results variability. This paper describes the statistical approach used to highlight key testing parameters for penetration measurement through a Design of Experiments. The study was conducted with different bitumen grades of different production origins. Variables levels were defined within the authorized range in compliance with the standard. It allowed a better understanding of the main testing conditions and variables which may impact the test method precision. Keywords: bitumen, variability, penetration, Design of Experiments, testing parameters

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Effective methods to quantify the efficiency of the polymeric network in bitumen

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Kraton Polymers

Abstract:

Infrastructure around the world relies on material specifications that lead to the use of materials intended by engineers to deliver the desired performance. In the paving sector, softening point temperature, elastic recovery and penetration value are some of the most commonly used test methods to classify Polymer modified Bitumen (PmBs). The methods have been largely successful due to their simplicity and relative accuracy. For innovative technologies such as highly polymer modified bitumen, the goal of the modification is to provide a continuous elastomeric network able of resisting damage to a much greater extent than the traditional PmBs. The current test methods can be permissive and may allow the use of PmBs that lack a continuous polymeric network or materials, where the polymers has not been properly processed. This work discusses the use of test methods such as Multiple Stress Creep Recovery (MSCR) with an objective to allow for a far more accurate characterization of the state of the polymeric network in bitumen, and hence leading to a better quality PmB.

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Analysis of the influence of the chemical composition on the mechanical performance of asphalt binders

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Abstract:

Asphalt binders can be considered as the most important component of bituminous pavements, as they control the mechanical performance of these infrastructures during their service life. Thus, the understanding of the behavior of these materials will become crucial to design more durable road pavements. In this respect, the present paper focuses on the analysis of the influence of their chemical composition in the visco-elastic response offered by these materials under stress loading and against different service conditions. For this purpose, similar penetration grade asphalt binders, which came from different sources of crude oil and presenting different chemical composition, have been evaluated using Dynamic Shear Rheometer (DSR) and Dynamic Mechanical Analizer (DMA) tests at different temperatures and ageing conditions. The results obtained have demonstrated that the origin of the crude oil, and therefore the chemical composition of the binder, could play an important role in the mechanical performance of the final product, and thus in the durability of asphalt pavements.

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A Review of Recovered versus Unrecovered Asphalt Properties in Ontario

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Abstract:

Paving-grade asphalt binders are specified based on their properties in an original state following a specification such as the Performance Graded (PG) Asphalt Binder Specification. However, there has always been an interest in determining the properties of asphalt binder of in-place asphalt mixtures for research or forensic investigation purposes. With the increased use of reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS), many user agencies are also looking for ways to evaluate the properties of the blended asphalt binder (i.e. new binder and old binder from RAP or RAS) since this also has an impact on the asphalt pavement performance. One option is to conduct mixture performance testing. Another option, often selected by users because of its relative simplicity, is to conduct solvent extraction-recovery testing on the asphalt mixture and determine the physical properties of the recovered asphalt binder in accordance with a standard specification, usually the same specification by which the asphalt binder was originally verified. Although intuitive and relatively simple, using recovered asphalt binder properties, particularly in a specification, is not without some potential concerns. The Ontario Asphalt Pavement Council (OAPC) has partnered with the University of Waterloo's Center for Pavement and Transportation Technology (CPATT) to conduct a research study to provide a framework for evaluating asphalt binder properties in plant-produced asphalt mixes. The first objective of this research is to compare the physical properties of original asphalt binder to the properties of the same asphalt binder recovered from mix after plant production. The asphalt mixes include virgin and RAP mixes, produced with most PG grades used in Ontario, including polymer modified asphalts.

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Modification of bitumen with PE waste plastic

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Abstract:

Various kinds of plastics contribute to a considerable portion of global waste, on both land and in the oceans. This waste may be better managed if more uses are introduced for these plastics or their derivatives. The purpose of this study is to evaluate the use of waste plastics as bitumen modifiers. Waste plastics in the form of PE-pellet and PE-shredded were added by 5% mass of bitumen and the stability of the plastics in the bitumen was evaluated using stability test. The rheological properties of the waste plastic modified bitumen were evaluated by a Dynamic Shear Rheometer (DSR) in order to determine if the modification can contribute to desirable properties. Finally, Scanning Electron Microscopy (SEM) was used to determine the microstructural properties and how well the plastic blended with the bitumen. The results show that modification of 5% (by mass of bitumen) improved the high temperature resistance to deformation, which is an indicator of better rutting resistance. However, the thermal stability test results showed that both the PE-pellet and PE-shredded waste plastic are susceptible to phase separation.

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Identifying Surface Course Deterioration Using Viscous to Elastic Transition (VET) Temperatures

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Abstract:

Viscous to Elastic Transition (VET) temperature is the temperature at a phase angle value of 45 degrees. At this condition, the elastic component of the complex shear (stiffness) modulus of a bituminous material equates to the viscous component. The viscoelastic response of bitumen at this temperature is at equilibrium where neither elastic nor viscous elements will dominate the response. This paper makes use of the VET analysis to provide an indication of surface condition as a useful tool for monitoring deterioration of Thin Surface Course Systems (TSCS) produced using paving grade bitumens. The VET analysis shows that increased distress levels in the pavement correlated positively to an increase in the VET temperature and a decrease in the complex modulus at the VET temperature. Any increase in the VET temperatures and reduction in the associated complex modulus have been correlated to poor site conditions where surface cracks and/or material losses have been observed. The paper was able to positively differentiate between sites with "Major Fretting", "Minor Fretting" and "No Fretting". Core samples were collected from over 30 sites on the Strategic Road Network in England and the recovered binders were assessed for their rheological properties. Findings show that sites that were severely aged (penetration values ≤ 13 dmm) were fretted materials with evidence of surface cracks. The VET analysis developed in this paper can be used as a tool to monitor the current performance of surface course materials on the network. This can facilitate necessary actions, closer monitoring or preventative maintenance and asset management.

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Hybrid modification of bitumen with Crumb Tyre Rubber and thermoplastic copolymers

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Abstract:

Hybrid modification of bitumen with Crumb Tyre Rubber (CTR) and a thermoplastic polymer tries to take advantage of the complementary properties of the modifiers and to improve the storage stability at high temperatures as well. Aiming to this, in this paper Hybrid Systems (HSs) were formulated by the addition of a thermoplastic polymer (reactive or non-reactive) to a Crumb Tyre Rubber Modified Bitumen previously obtained. The resulting samples were submitted to a thermorheological analysis, technological characterisation, fluorescence microscopy and modulated differential scanning calorimetry. The obtained results point out a positive synergistic effect of the swollen thermoplastic polymer with non-dissolved Crumb Tyre Rubber (CTR) particles. In general, both in-service performance and storage stability result markedly improved because of the development of a multiphasic structure composed of non-dissolved CTR particles, a polymer-rich phase and an asphaltene rich-phase. The best results are obtained when the thermoplastic polymer contains reactive groups able to react with bitumen molecules. Keywords: Crumb Tyre Rubber, viscoelasticity, Reactive polymers.

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IMO and the Effect on Bitumen Quality

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Abstract:

The ultimate effect of the implementation of new IMO 2020 regulations on the use of fuel oil contain sulphur on the quality of bitumen is currently unknow. However, some interesting factors may be deduced from historical data and comments on the sulphur content of bitumens and the discussions be held at various industry meetings/conferences on this subject. IMO (International Maritime Organization) has been introducing rules to lower the use of high sulphur fuel oils (bunker fuel) over the past years. Data on sulphur in bitumen has been collected since the beginning of use in the late 1800's/early 1900's [1], even with a specification limit on sulphur content in one agency for a period of time in the first half of the twentieth century (introduced in 1915) [2]. This was contested in 1940 with the detailed review of physical and chemical properties developed by Lewis and Welborn [3]. Many heavy oils that have been used for good quality asphalt binders have had sulphur contents that tend to be towards the higher part of the range of in asphalt. As the market dynamics change refiners will face challenges regarding use of sour crudes and this will inevitability effect the asphalt binder supply. This paper presents some discussion of changes ongoing in the industry with refiners preparing for the IMO changes. The effects of sulphur on bitumen properties are discussed and the possible implementations to the asphalt industry.

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Towards advances in differentiating recycling agents: softening agents vs. rejuvenating agents

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Abstract:

The correct choice of recycling agent is probably the most important factor in a successful recycled asphalt pavement production, however, regarding variety of commercial product currently available, it is not an easy job. This paper represents a possible approach for differentiating softening agents from rejuvenating agents, which are capable of restoring not only the physical properties but also the chemical structure of an aged bitumen. For this purpose, seven different recycling agents, either softening or rejuvenating agent, were studied anonymously via different testing methods. The test methods consisted of conventional bitumen tests, Dynamic Shear Rheological (DSR) analysis, microscopic analysis, spectroscopic and chemical techniques using Infrared spectroscopy (IR) and Powder X-Ray Diffraction (PXRD) as for structural characterization. According to the results of this study, while all of the tested materials showed softening properties (through conventional tests) to different extents, not all of them could restore the chemical structure of aged bitumen too. This has was found by bitumen non-conventional tests including Atomic Force Microscopy (AFM), IR, and PXRD, which could provide apparent evidences showing the chemical and structural differences between the aged bitumens containing softening agents compared to those containing rejuvenating agents.

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GRIP ON BITUMEN: MAPPING THE CHANGES IN BITUMEN MARKET AND ITS IMPACT ON PERFORMANCE

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Abstract:

Major road networks in the Netherlands are made of asphalt concrete. These roads enable our economic and social activities by facilitating the movement of goods and people. Development and maintenance of the road network, by keeping it operational is crucial to the growth and competitiveness of the economy. In order to maintain high quality of these roads, while striving towards a more sustainable, circular society requires a thorough understanding of both the performance of asphalt concrete and its constituents. Bitumen is known to be the most important component that influences the performance and durability of asphalt. Composition of bitumen can vary depending on nature and source of the crude oil and its refining process. In recent years, bitumen market has changed significantly in terms of its quality and consistency. One aspect of this change is the unavailability of certain crude oil sources, which introduces a change in choice of crude oil source and often mixture of crude oils from multiple sources. Another aspect is that the refineries are in transitions due to economic and regulatory reasons. As a result, there is an inconsistency in crude source and quality of bitumen in the market. This change can influence both short and longterm performance of bitumen and asphalt. To address timely topics and to promote asphalt related innovations, a collaboration platform between asphalt industry, road authority and knowledge institutes is introduced in 2018 in the Netherlands. The program is called Asphalt- Impulse. All stakeholders work together towards a common goal: “Doubling the lifetime of asphalt pavements, halving the scatter in lifetime, halving the CO2- footprint with the same or lower production cost”. One of the projects within Asphalt-Impulse is called “Grip on Bitumen”. The project aims at a better insight and understanding the influence of refining methods, crude oil sources: in this way to map potential sources of change in bitumen market. It also aims to define additional performance indicator for bitumen that can better predict the functional properties of bitumen and asphalt. This paper summarizes the knowledge document developed within ‘Grip on bitumen’ and presents the aspects of bitumen manufacturing process, driving factors of the current change in bitumen market and its possible impact on asphalt and other industrial application.