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Binder blending estimation method in hot mix asphalt with reclaimed asphalt

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Abstract

Current road construction technologies includes the use of recycled materials increasingly. High quality of hot mix asphalt with high content of reclaimed asphalt pavement (RAP) requires the use of virgin binder or rejuvenator agent additive. The phenomenon of blending of binder from RAP with virgin binder has not been fully investigated. This paper discuses procedure which allow asses blending level between virgin binder and binder film in RAP. In this paper there is presented the preliminary tests results of the research concerning binder blending estimation. Degree of partial blending was estimated based on the rheological tests such as complex modulus and phase angle conducted in Dynamic Shear Rheometer. The Multiple Stress Creep Recovery test method was used to examine how virgin binder blends with polymer modified RAP binder.

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Keywords: Reclaimed asphalt pavement – RAP; Hot mix asphalt, Blending; Virgin binder; DSR rheometer; MSCR

1. Introduction

Currently the use of recycled materials for road construction are increasing due to the ecological reasons and preserve natural resources. The hot mixed asphalt (HMA) is a material which can be recycled in 100% and could be totally reuse to construct new asphalt layers in flexible pavements [1]. Now, there is a tendency to use RAP for HMA in amount as much as possible. There are many technological solution to produce asphalt mixture with RAP addition such as bypass and double drum production into asphalt plant or production in construction site such as remixing and foamed asphalt [2]. Recycled asphalt pavements material properties depend on its original properties

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such as type of aggregate and binder and on deterioration of the service properties resulting from aging and weather condition. RAP properties also depend on milling asphalt pavement process. Obtaining appropriate properties of new asphalt mixtures contains high percent of RAP requires the application a new softer binder (usually called virgin binder) or special additive – rejuvenators to refresh aged binder from RAP. Moreover during asphalt mixes process design the correction of aggregate gradation which is achieved by adding selected fraction of virgin aggregate may be required. Information about the binder content in RAP is also important but depends on the extraction method [3].

The problem of blending degree between virgin binder and RAP binder is still unresolved. Previous studies have shown that virgin binder and RAP binder blends only partially [4, 5]. There is also no clear answer whether and how the partial blending of the binder film affects the properties of HMA. There is need to develop the method allows easily determine how two binders mix each other.

This paper shows results of using one of the laboratory method based on the method proposed by the Carpenter and Wolosick (1980) [4]. This method allows to assess the degree of binders miscibility based on the gradual extraction of binders from aggregate.

2. Binder miscibility

During HMA with high content of RAP (more than 30%) is designed, influence of aged RAP binder on HMA properties should be take into consideration. Improvement of aged binder properties is obtained e.g. by adding softer virgin binder during HMA production process.

Theoretically, it is assumed that the parameters of the equal binder are resulting from parameters of virgin binder and from aged RAP binder. In fact this equal binders are only partial blended. Previous studies shown that virgin binder additive makes new binder film covering RAP aged binder surface. During the mixing process friction and shear forces and diffusion phenomenon caused mutual penetration both binder films [6, 7]. In the asphalt film covering RAP there are formed the zones with different properties (Fig. 1.). Hypothetically, in extremely unfavorable case, only virgin binder creates a new layer covering the RAP and there is possible no interaction between these binders.

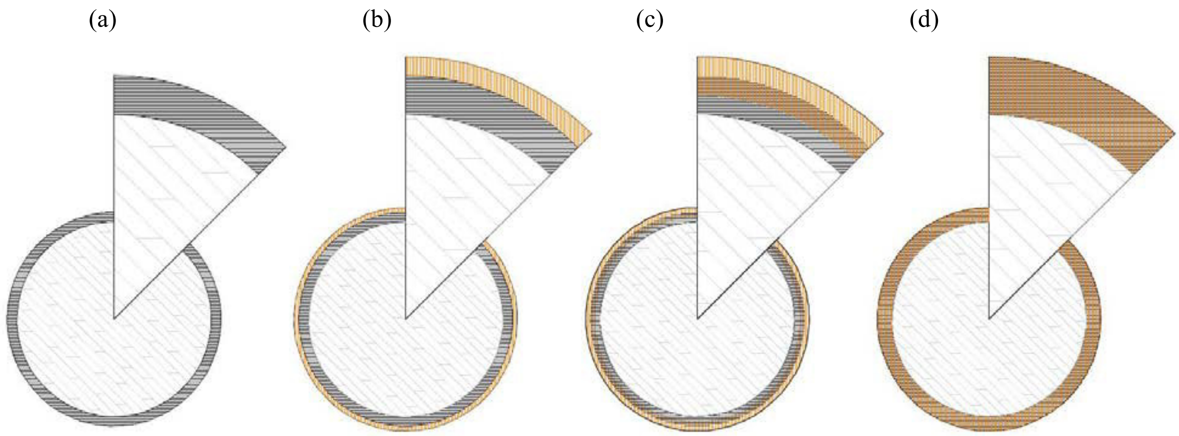

Fig. 1. Different stage of diffusion of binder film covering RAP: (a) RAP with only binder film; (b) RAP + virgin binder, no blending; (c) RAP + virgin binder, partial blending; (d) RAP + virgin binder, total blending

3. Objective

The objective of this preeliminary tests was identify miscibility opportunity of RAP aged binder and virgin binder. Effectiveness of multistep extraction method proposed by the Carpenter and Wolosick was adopted and verified.

4. Experimental procedure

4.1. Materials

In this study the asphalt mixture consisting of 100% RAP was used. RAP which was used in this tests came from SMA (stone mastic asphalt) wearing course . Basic properties of SMA RAP materials are shown in table 1.

Table 1. RAP properties

Property	Unit	Result
Binder penetration in 25°C	[0,1mm]	25
Binder softening point	[°C]	60
Soluble binder content	[%]	5,4
Content of aggregate < 0,063 mm	[%]	12,0
Content of aggregate from 0,063 to 2,0 mm	[%]	34,6
Content of aggregate > 2,0 mm	[%]	53,2

Virgin binder has a softening point by R&B test equal 38°C and penetration measured in 25°C equal 162,1 x 0,1 mm.

4.2. Specimen preparation

Asphalt mixture was prepared in laboratory mixer. The amount of 15000 gram of RAP and 300 gram of virgin binder was used. RAP was heated to temperature of 150°C before mixing. Virgin binder was accounted for 2% of total mixture (27% of total binder). The time of 60 s of mixing was used counted form adding the whole binder. Mixing temperature was adjusted to 150°C. After mixing process the asphalt mixture was spread on metal trays to facilitate subsequent granulation.

4.3. HMA extraction procedure

In this study multistep extraction method was applied. Before the extraction, asphalt mixture was heated to 100°C temperature and granulated for separate grains to allow solvent filtration through their surface. Then weighed specimen of mixture was placed onto the 1 mm sieve. The sieve with a mixture was immersed in the vessel filled by tetrachloroethylene solvent (Fig. 3. a.). After twenty seconds sieve was removed and after draining was immersed in next vessel with clear solvent. In total the HMA specimen was treated by solvent three times. Scheme of multistep extraction method was shown on Fig. 2.

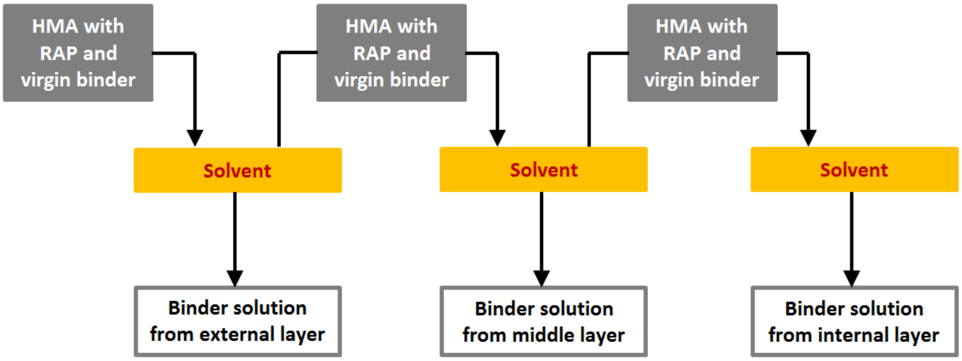

Fig. 2. Scheme of the multistep extraction process of HMA with RAP

From each of three vessels for extraction, about 1,5 liter of binder solution was obtained. Next the binder was recovered in rotavapor (Fig. 3.b.). From each layer about 50 gram of binder was recovered.

(a) (b)

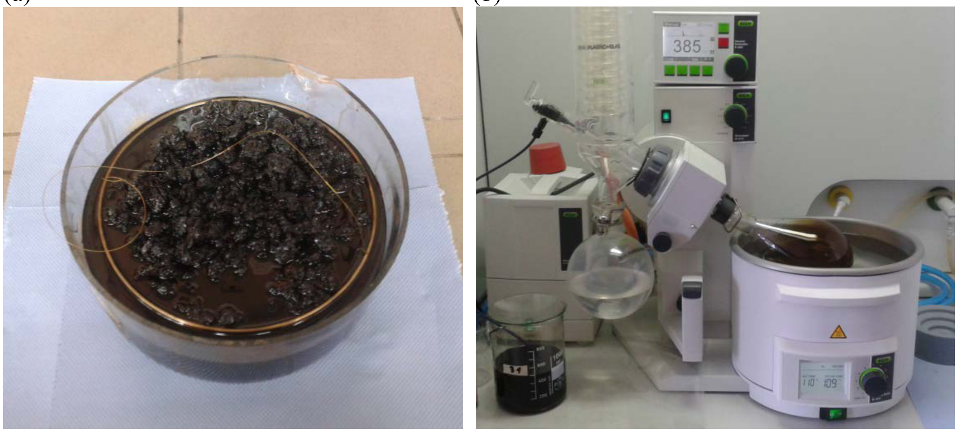

Fig. 3. Extraction and binder recovery: (a) HMA immersed in tetrachloroethylene solvent, (b) binder recovery in rotavapor

4.4. Rheological tests

To investigate the rheological parameters of recovered binder the Dynamic Shear Rheometer (DSR) was used. Six binder specimens have been studied. Three recovered binders from external, middle and internal layer of HMA with RAP. As a reference specimens the virgin binder 160/220 and RAP binder have been tested. Moreover specimen prepared in laboratory of recovered binder from RAP mixed with virgin binder was used to compare as a total (100%) blended binder.

5. Results

5.1. Phase angle and complex modulus

Phase angle and complex modulus were obtained from dynamic share tests in temperature range from 46°C to 82°C. Results of phase angle measurements were presented on Fig. 4. and the results of complex modulus measurements were shown on Fig. 5.

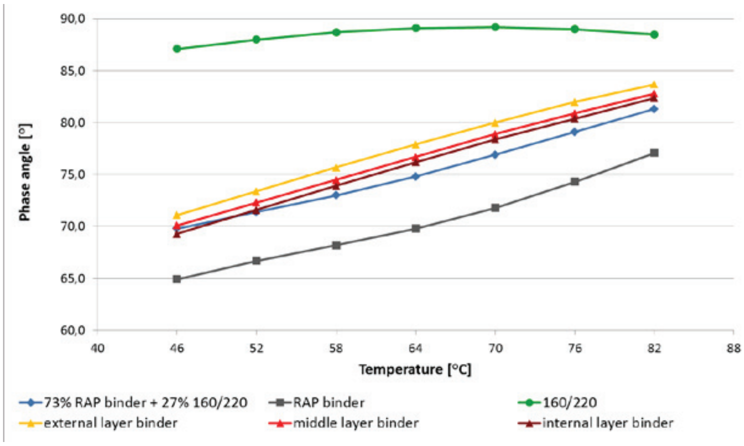

Fig. 4. Phase angle in function of temperature

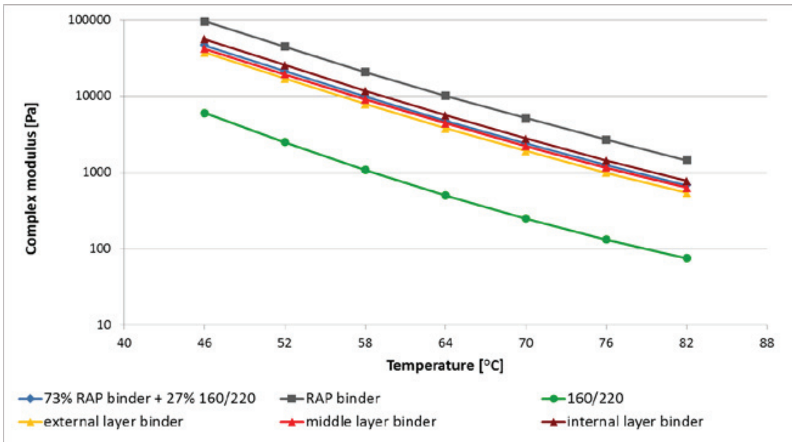

Fig. 5. Complex modulus in function of temperature

The high phase angle value can be observed for virgin binder in wide range of temperature. It was about 87 degrees at 46°C temperature and in higher temperatures increasing to 90 degrees which means that it is in a liquid state. The lowest phase angle was measured for RAP binder. Binders from three layers and 100% blended binder was placed between RAP binder and virgin binder curves. For all of binders layers results are placed above the total blended binder curve (73% RAP binder + 27% 160/220 binder). It can indicate that in each binder layer some of virgin binder was dissolve. The same dependence was obtained for the complex modulus results. The biggest value of complex modulus was obtained for PAP binder and the lowest value of complex modulus was obtained for virgin binder. Values of complex modulus for binders from each layers was placed between RAP binder and virgin binder curve and are located near the total blended binder curve.

5.2. Multiple Stress Creep Recovery test

Multiple Stress Creep Recovery test was conducted in 64°C temperature. For MSCR test two levels of stress: 0,1 kPa and 3,2 kPa was applied [8]. The MSCR curves obtained for tested binders were presented on Fig. 6 and Fig. 7 respectively for 0,1 kPa and 3,2 kPa stress. To better illustrate the differences between the samples logarithm scale for strain axis was used. The characteristic recovery shape of RAP binder curves can be observed. The recovery result indicate that RAP binder was modified by polymer. Virgin binder has no elastic behavior presented by no recovery. Layers binder curves are place near to the total blended binder curve. It is similar distribution of layer binder curves as in phase angle and complex modulus studies. Elastic recovery of recovered binders from each layers is lower than elastic recovery of clear RAP binder. This is caused by the various virgin binder content in each layer and the great content of virgin binder is in external layer and the lower is in the internal layer.

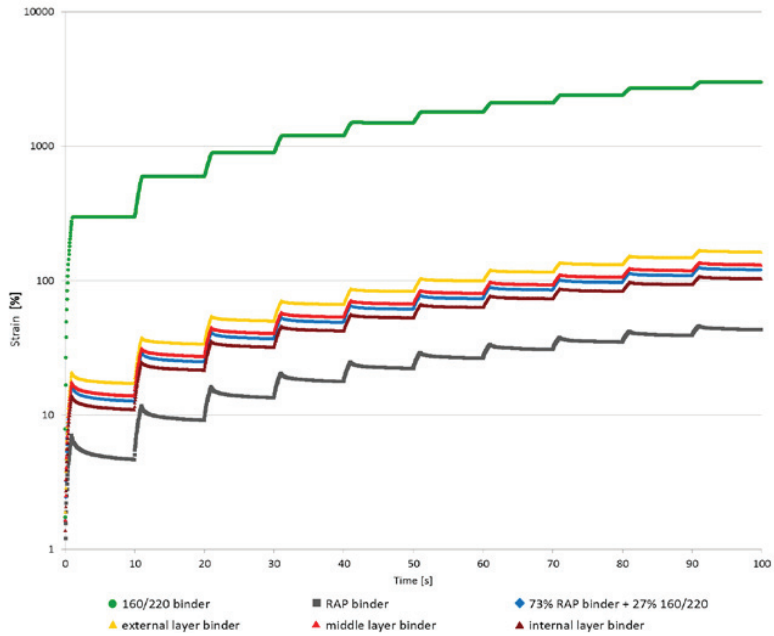

Fig. 6. MSCR curves for 0,1 kPa stress

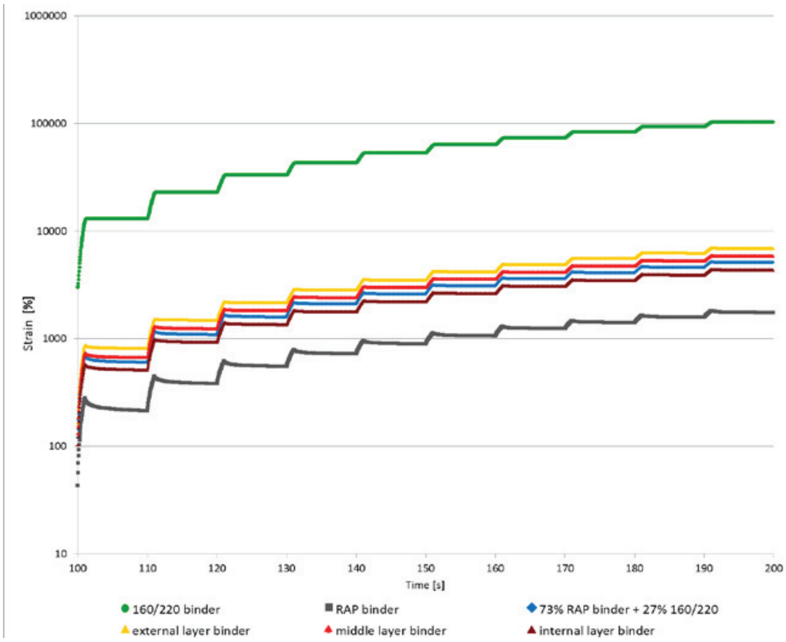

Fig. 7. MSCR curves for 3,2 kPa stress

Based on the results of multiple stress creep recovery test conducted at 3,2 kPa stress the recovery (R3,2) and the no-recoverable creep compliance (Jnr3,2) were calculated [9].

On Fig. 8 R3.2 to Jnr3.2 ratio curve has been presented. This empirical graph provides information about sufficient polymer content in binder [8, 9]. Binder from RAP is characterized by the best elastic properties from the analyzed binders group but the point corresponding to RAP binder is situated below the curve because the value of Jnr parameter. This fact indicates that polymer content in this binder is not sufficient.

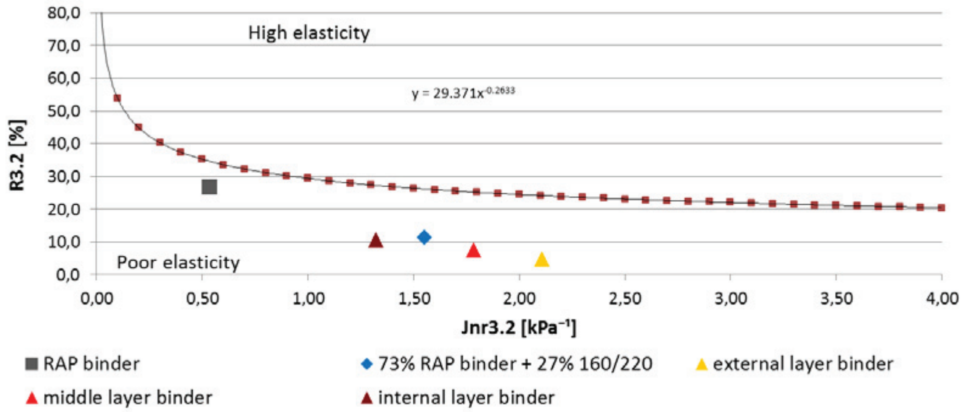

Fig. 8. Polymer modification curve

The 160/220 binder point is out of range of this graph because of high, out of scale value of no-recoverable creep compliance for this binder. Other binders points are located in poor elasticity zone (bellow the curve). The lowest modification level has been observed for binder from external layer. The highest modification level from each layers was obtained for internal layer binder. This results shows that RAP binder and virgin Binder do not blend totally during mixing process.

Comparison of recovery and no-recoverable creep compliance parameters was shown on Fig. 9a and Fig. 9b. On this charts difference between parameters for total blended binder and binder from each layer was presented. Slight Recovery difference for internal layer and total blended binder (about 5%) was observed. For external layer this difference is greater than 50%. Comparison of no-recoverable creep compliance shown that external layer binder is more flexible than total blended binder.

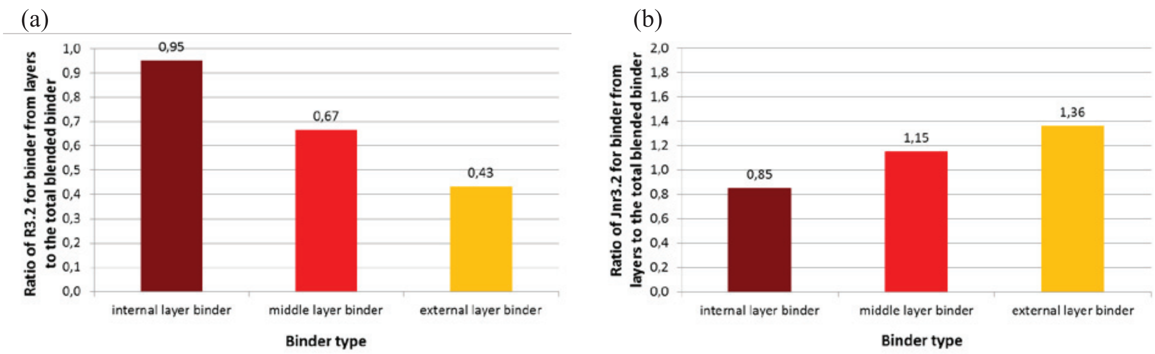

Fig. 9. Difference between total blended binder and binders from layers: (a) recovery R3,2; (b) no-recoverable creep compliance Jnr3,2

6. Conclusions

Results of laboratory tests are shown that during mixing process RAP binder and virgin binder do not blended totally. Used multistep extraction method have been found to be suitable and effective method to assess the blending levels of binder in HMA containing RAP. Studies have shown that in described production conditions of HMA, there is no complete blending between RAP binder and virgin binder.

MSCR test results are shown that virgin binder has influenced the binder film throughout its thickness, but depending on the distance from the binder film surface these changes was varied. The laboratory tests confirmed that the binder film in the HMA containing RAP is not homogeneous.

Studies have proven the usefulness of the MSCR test method for determining the binder properties in HMA with RAP, particularly in the case of polymer modified binders. This method allows to determine the degree of blending polymer modified binder with unmodified binder. Moreover this method gives the answer whether the level of modifier in a rejuvenate RAP binder is sufficient.

Based on the results presented in this paper the following detailed conclusions could be formulate:

- Multistep extraction is effective method to obtain samples for miscibility evaluation;
- MSCR tests is a useful method to binder blending assessment, especially if one of binders is polymer modified;
- During mixing process binders was only partial blend and properties of binder are various in binder film thickness;
- Additive of softer virgin binder allows to change properties of RAP binder but mainly on the external layer of RAP binder;

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