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Influence of polymer modified binder content from RAP on stone mastic asphalt rutting resistance

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Abstract

Properties of hot mix asphalt with reclaimed asphalt pavement (RAP) mostly depends on RAP properties, especially RAP binder. It is assumed that binder from RAP is usually stiffer than virgin binder because of exploitation aging process. Use of RAP may cause stiffening of asphalt mix and improvement of rutting resistance. This paper demonstrates results of wheel tracking tests of stone mastic asphalt. Analyzed asphalt mixes were designed with six different content of RAP. Penetration and softening point of binder mix was determined and binder replacement factor for asphalt mixes was calculated. Analyses of wheel track tests with comparison to binder properties shown that increasing amount of modified binder from RPA occurs in increasing rutting resistance of asphalt mixes.

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Keywords: reclaimed asphalt pavement – RAP; stone mastic asphalt – SMA; wheel tracking; binder replacement; softening point

1. Introduction

The use of reclaimed asphalt pavements (RAP) as component of new hot asphalt mixes passes sustainable development polices and is environmentally friendly and compatible technology. Besides of ecological aspects the RAP additive has significant influence on asphalt mixtures properties [1]. Among many RAP properties as the

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granulation, mineralogical composition, binder type, content and properties they have a significant impact on the asphalt mixture features. The final properties of the mixture of virgin binder and binder derived from RAP can be calculated [2]. In addition it is possible to determine the rate of replacing virgin binder by binder form RAP called binder replacement factor [3]. This factor is use in some countries to control and characterize asphalt mixture containing RAP however, it may depend on the extraction method [4].

Now, there is a tendency to use RAP for HMA in amount as much as possible [5]. 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 [6].

2. Research scope and objectives

The aim of presented research was to determine the influence of content of binder derived from RAP on the functional properties of gap grade asphalt mixes. RAP binder parameters as softening point and penetration are included in the recycled asphalt mix design. Due to large amount of binder (usually about 5-7 percent) stone mastic asphalt (SMA) mixture was select to laboratory tests. This was to lead greater binder influence on investigated properties than in other types of asphalt mixtures [7]. The analyses have been focused on mixture of binder from RAP and virgin binder which were characterized by calculated softening point, penetration and binder replacement rate. Influence of different binder content from RAP in asphalt mix on rutting resistance has been shown in this paper. Wheel-tracking laboratory tests results were compared with properties of binders mixture derived from virgin binder and binder from RAP.

3. Materials

Six stone mastic asphalt mixes with six different RAP content (from 0% to 50% in increments of ten percentage) was designed. The gradation of all SMA mixtures were 11 mm.

For the right comparison, reference mixture and mixtures containing RAP were designed with similar grading curves, the same total binder content and air voids.

Grading curves of all mixes were shown on figure 1. For mixes with RAP content between 0 and 40 percent this assumption has been fulfilled. Because of high content of fine aggregate (from 0 mm to 2 mm) in RAP in the mixture contains 50 % RAP less air voids content can be observed.

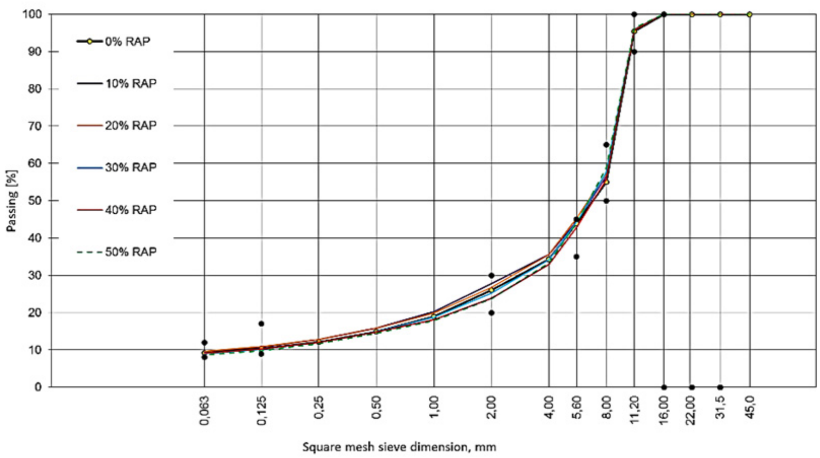

Fig. 1. Granulation curves of stone mastic asphalt.

For mixtures design mealaphyre coarse aggregate, limestone fine aggregate and lime filler were used. Binder derived from RAP was classified as corresponding to the polymer-modified bitumen (type PMB 45/80-55). That binder was classified based laboratory tests such as softening point, penetration and elastic recovery. Virgin binder was chosen from binders dedicated for SMA mixtures which are listed in Polish General Directorate for National Roads and Motorways specification WT-2 2014 [8]. The assumption of the research was to select virgin binder as more different as possible from binder form RAP. Base on that assumption as a virgin binder the 50/70 bitumen are used. The RAP which was used in analysis came from ten years stone mastic asphalt wearing course. Binders basic properties are shown in table 1.

Binder content in RAP is 5,9 %. The designing total binder content in mixtures is 6,5 % level.

Table 1. Virgin and RAP binder properties

Property	Method	Unit	RAP binder	Virgin binder
Penetration in 25°C	PN-EN 1426	[0,1mm]	51	59
Softening point temperature by R&B test	PN-EN 1427	[°C]	55,5	49,5
Elastic recovery	PN-EN 13398	[%]	75	12

4. Calculation of binders properties

To predict properties of asphalt mixes with recycled materials virgin binder and binder from RAP can be calculated. Resulting penetration and softening point of binders mixture can be determined by equations (1) and (2) in accordance to European Standard EN 13108-1:

$$\mathrm{a}\lg pen_1 + \mathrm{b}\lg pen_2 = (\mathrm{a}+\mathrm{b})\lg pen_{\mathrm{mix}} \quad [0{,}1\ \mathrm{mm}] \tag{1}$$

$$\mathrm{T_{R\&B\ mix}} = \mathrm{a} \times \mathrm{T_{R\&B\ 1}} + \mathrm{b} \times \mathrm{T_{R\&B\ 2}} \quad [^\circ\mathrm{C}] \tag{2}$$

In the first equation pen_1 is the penetration of binder recovered from RAP, pen_2 is the penetration of virgin binder and pen_{mix} is the calculated penetration of binders mixture. In the second equation $T_{R\&B\ 1}$ is the softening point temperature of RAP binder, $T_{R\&B\ 2}$ is the softening point temperature of virgin binder and $T_{R\&B\ mix}$ is calculated softening point temperature of asphalt mixture. In both equations a symbol is the percent of binder derived from RAP in mixture and b symbol is the percent of virgin binder in mixture. Both equation assume linear relationship of penetration or softening point between binder from RAP and virgin binder. In that equations total blending of both binders was assumed, but recent laboratory tests are showed that binder from RAP and virgin binder are not blending totally [9].

Additionally in this study binder replacement ratio is calculated. Binder replacement ratio express level of virgin binder replacing by binder from RAP in asphalt mixture. This ratio is especially useful for designing asphalt mixtures with high content of RAP. Giveing only percent of RAP content in asphalt mixture does not provide sufficient information about total binder content and binder quality in the mix. Today some of national road agencies specifie the both requirments of binder replacement level and maximum value of RAP content in the asphalt mix.

The binder replacement ratio can be calculated using equation (3) [3, 10]:

$$Binder\ replacement = \frac{(A \cdot B)}{C} \cdot 100\ [\%] \tag{3}$$

where A is the RAP binder content in RAP, B is the RAP content in mixture and C is Total binder content in mixture.

5. Wheel tracking tests

To investigate influence of content of binder derived from RAP on permanent deformation of stone mastic asphalt wheel-tracking test has been conducted. Wheel-tracking tests were carried out in accordance with European Standard PN-EN-12697-22, procedure A in air conditions. For each mixture the slabs with a length and width equal 305 millimeters and with 40 millimeters thickness was prepared by laboratory slab compactor. Asphalt mixture was produced in laboratory portable mixer. Reclaimed asphalt pavement was heated to 150°C and was added to hot aggregate mixture (200°C). Virgin binder was heated to 150°C and mixed with aggregate and RAP for 1 minute.

Compaction temperature was 135±5°C. After compaction and 48 hour rest, slab specimens were conditioned in 60°C temperature before test for at last 4 hours.

Fig. 2. SMA wheel tracking test

6. Results

Results of the binders mix softening point and penetration based on the equations (1) and (2) are shown on figures 3 and 4. Additionally on this graphs, calculated binder replacement rate are presented for tested mixtures.

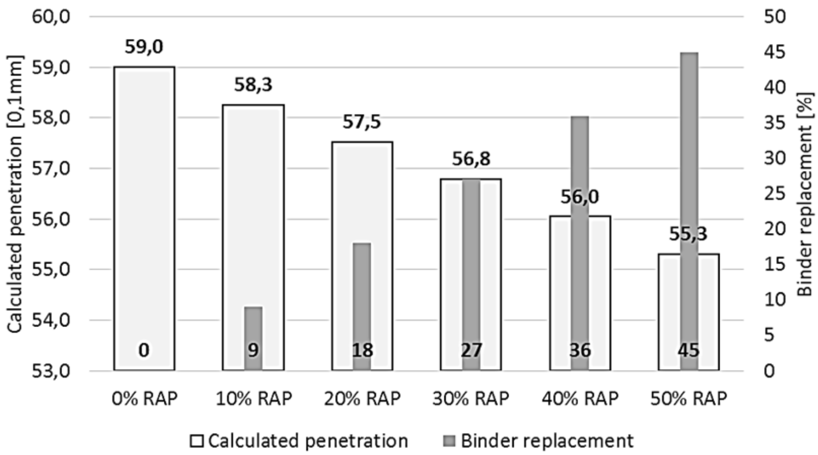

Fig. 3. Results of calculation of binder mixture penetration with reference to binder replacement rate

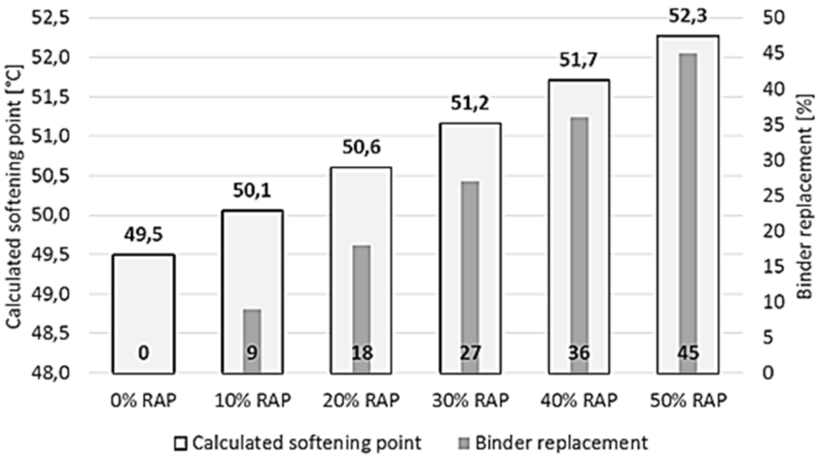

Fig. 4. Results of calculation of binder mixture softening point temperature with reference to binder replacement rate

Base on the obtained results it can be noticed that the softening point temperature of binder mixture is increasing proportional to RAP content while the penetration is decreasing. The difference between calculated softening point temperature for mixture with 0% of RAP and mixture contains 50% of RAP equal 2,8°C and the difference in penetration is 3,7 x 0,1 millimeter.

On figure 5 and 6 relationship between RAP content and proportional rut depth (PRD_{air}) and wheel-tracking slope (WTS_{air}) are shown. On both figures the binder replacement rate was also presented.

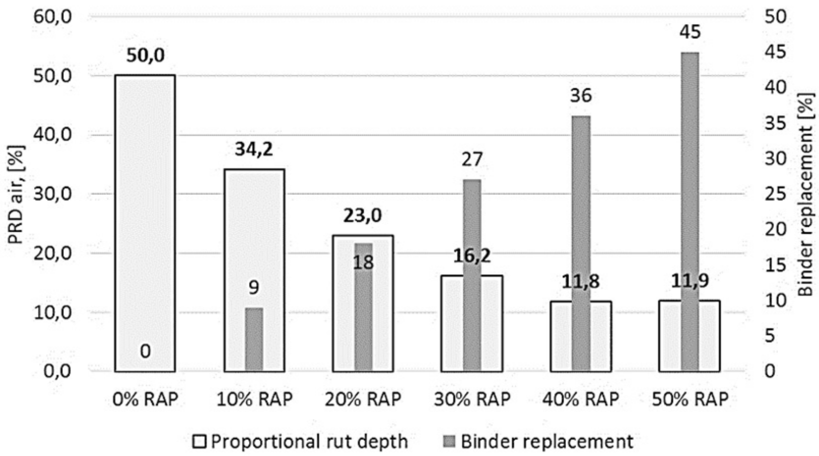

Fig. 5. Results of proportional rut depth (PRD_{air}) with reference to binder replacement rate

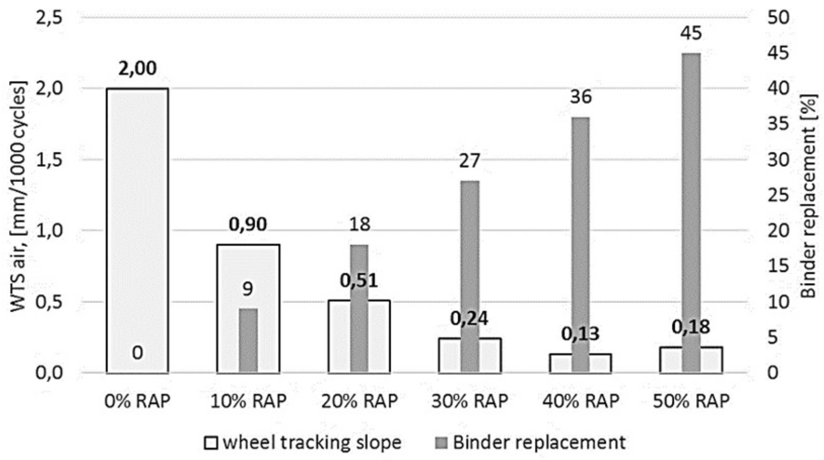

Fig. 6. Results of wheel tracking slope (WTS_{air}) with reference to binder replacement rate

Base on the obtained wheel track tests results it can be state that there are visible influence of RAP content and binders replacement factor on rutting resistance. It was found that if the RAP content is increasing and in particular content of binder from RAP increasing the proportional rut depth decreases. But this decrease is not linearity proportional to binder replacement rate. The fastest decrease of proportional rut depth occurs in the range of RAP content from 0% to 20%. For mixtures with higher content of RAP lower decrease of PRD_{air} value can be observed. Addition of 10% of RAP to the asphalt mix is causing approximately 32% reduction of proportional rut depth in relative to reference asphalt mixture while the wheel tracking slope is reduced twice. For asphalt mix with 50% content of RAP the proportional rut depth is five times lower than in reference mixture. In terms of wheel tracking slope the decrease is tenfold.

Proven influence of RAP content on rut resistance is mainly due to increasing of binder replacement rate. Polymer-modified binder derived from RAP causes in increasing of resistance to permanent deformation in stone mastic asphalt mixture. Tested stone mastic asphalt mixture was achieve maximum rut resistance for 40% RAP content and 36% binder replacement rate. Higher RAP content (50%) was influenced on decrease of air voids content and finally the rut resistance for this mixture is not comparable to the other.

7. Conclusions

Results of binders properties and laboratory tests are shown that calculated binder parameters are corresponding with asphalt mixes properties. Moreover improvement in rut resistance is not linearly proportional to calculated binder mix properties while clearly relationship between rutting resistance and increasing polymer modified binder content from RAP has been observed. It is also significant that equation which was describe in this study give correct results only for no-modified binder. If one of the binder (virgin nor RAP) is modified by polymer, calculated result may be used only as estimation. Moreover this equation are correct only if both binders are blending totally. Other laboratory tests show that during mixing process binder derived from RAP and virgin binder do not blended totally. Studies have proven the usefulness of binder replacement rate because this rate does not depend on binders properties so it is true for all types of mixtures of virgin binder and binder form RAP.
Based on the results presented in this paper the following detailed conclusions can be formulate:

- RAP binder properties are influencing on asphalt mixes rutting resistance.
- Partially replacement of virgin binder by polymer modified binder derived from RAP results in visible rut-resistance improvement.

- Binder replacement rate is an useful ratio to characterized the binders mixture in asphalt recycling technology.
- Calculated values of penetration and softening point temperature of binder mixture are corresponding with wheel-tracking test results.
- There is a need to develop binder mix estimating method, including binder miscibility which will be appropriate for modified binders.

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