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Transportation Research Procedia 72 (2023) 3987–3994

Transportation Research Procedia

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Transport Research Arena (TRA) Conference

Volumetric view on asphalt mixture

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Abstract

An asphalt layer consists of stone aggregates, binder and air voids. The content of air voids (V_{min} and V_{max}), the voids filled with bitumen (VFB_{min} and VFB_{max}), the content of air voids in stone aggregates (VMA_{min} and VMA_{max}) and volume content of bitumen (VB_{min}) should be determined for each type of asphalt mixture. The volumetric properties of asphalt layer listed above are important parameters for assessing the properties of asphalt and are usually first presented in the requirements for produced asphalt mixtures and built in asphalt layers. Visualization of volumetric properties is important for understanding the composition of the produced asphalt mixture. The most appropriate is a triangular representation of the volumetric requirements for three main components of asphalt layer (stone, bitumen and air).

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Keywords: Volumetric representation; asphalt mixture; void content; bitumen content; voids in aggregate;

1. Introduction

From the perspective of quantity, asphalt is the second mostly used building material in the world. Asphalt mixtures are produced all over the world. In most countries in the world, requirements for asphalt mixtures production and requirements for laying asphalt are stricter than for concrete. Practically in whole world there are similar requirements for asphalt mixtures. Limits for the grading curve of stone aggregates exist in requirements in most countries. For laboratory prepared samples of asphalt and for asphalt pavements there are requirements for the content of air voids (V_{min} and V_{max}), the voids filled with bitumen (VFB_{min} and VFB_{max}), and the content of air voids in stone aggregates (VMA_{min} and VMA_{max}). In most requirements there is a demand for mass content of bitumen (B_{min}), but logically there should be the demand for volume content of bitumen (VB_{min}) instead. The volumetric properties of asphalt mixtures

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Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference
10.1016/j.trpro.2023.11.478

listed above are important parameters for assessing the properties of asphalt. Volumetric properties (content of air voids, air voids filled with bitumen, the content of air voids in stone aggregates and volume content of bitumen) are usually first presented in the requirements for produced asphalt mixtures and asphalt layers. Bitumen is the most important component of asphalt mixture and bitumen properties have the biggest influence on the asphalt properties. Many times people working with asphalt are not aware that volume percent of bitumen is what counts and not mass percent. Even when asphalt mixture is designed in the volume percent of components, volumetric properties are not always taken in account (Roberts et al. (2002)). Superpave asphalt mixture design is mostly oriented towards rheology of bitumen, granulometry of stone aggregates and air void design (Kennedy et al. (1994) or Huber et al. (2016)). Of course for volumetric properties the most important are aggregate structures (Alshamshi (2006)) and mostly affects compacabilty of asphalt mixture (Tušar et al. (2015) or Tušar et al. (2020)).

2. Bitumen content and sieving curve of stone aggregates

2.1. Bitumen content

In typical technical specifications more often the minimal mass content of bitumen (B_{min}) and not the volumetric content (VB_{min}) are required, which does not seem logical. But, with application of equation 1 from European standard EN 131308-1 section 5.2.3, requirement for minimal mass content of bitumen is transformed to requirement for minimal volume content of bitumen:

$$\alpha = \frac{2.650}{\rho} \qquad (1)$$

Where ρ is the weighted mean of the particle density of the aggregates at the target grading, in mega grams per cubic meter (Mg/m3), determined according to EN 1097–6.

In table 1 are presented the corrected values of bitumen content for asphalt mixtures containing some typical types of stone aggregates. Table 1 presents real examples. one of the technical specifications requires minimal mass content of bitumen (B_{min}≥6.3 m. %). In the last column of the table 1 are corrected values of bitumen content, with taking in account α factor. Such corrections are not required if the bitumen content requirements are given in volume percentages.

Table 1. Bitumen content values and corrected bitumen content values for some types of aggregates

		Density of stone aggregate	Bitumen content	Corrected bitumen content
		ρ	B	B_{cor}
	Type of stone aggregate	Mg/m^3	m.-%	*m. %*
1	Limestone	2.700	6.3	6.4
2	Basalt	2.900	6.3	6.9
3	Steel slag	3.400	6.3	8.1
4	Limestone	2.700	6.2	6.3
5	Basalt	2.900	5.8	6.3
6	Steel slag	3.400	4.9	6.3

2.2. Sieving curve of stone aggregates

Volumetric view is rarely important for the grading curve of stone aggregates. Significant difference between mass and volumetric view can be found only in the cases where stone aggregate mixture consists from two different sources of stone with significant difference in density, for example when limestone is used for sand fractions and steel slag for gravel fractions.

In figure 1 is presented example of weight and volume sieving curve of stone aggregates SMA 11 when we have filler and fraction 0/2 from limestone and other fractions (2/4, 4/8 and 8/11) from steel slag.

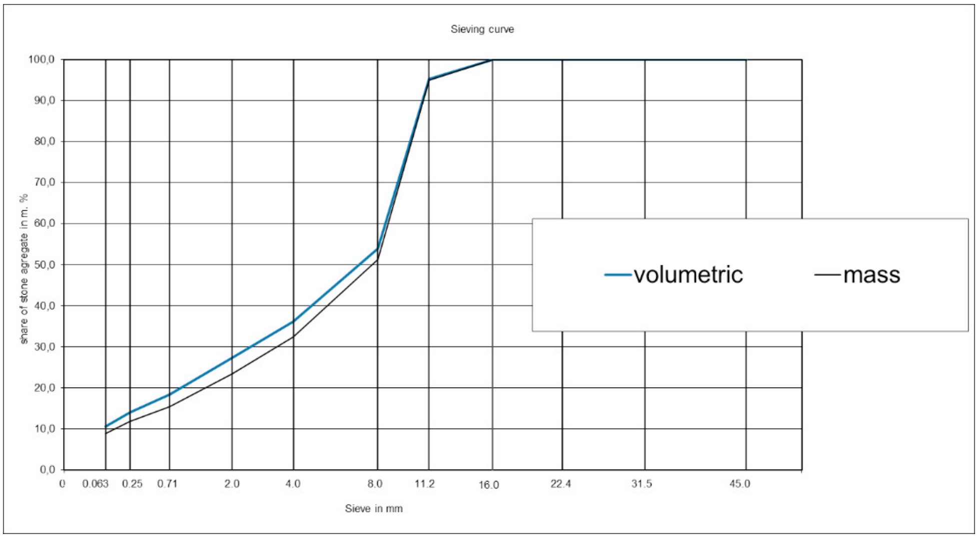

Fig. 1. Presentation of example of weight and volume sieving curve of stone aggregates SMA 11 when we have filler and fraction 0/2 from limestone and other fractions (2/4, 4/8 and 8/11) from steel slag.

From figure 1 it can be seen that visualization of volumetric composition can also be important for sieving cure presentation. Similar as for bitumen content differences are bigger if some of stone fractions has huge density.

3. Triangular representation

Visualization of volumetric properties is important for understanding the composition of the produced asphalt mixture and the built-in asphalt layer (Tušar et al. (2022)).

The most appropriate is a triangular representation of the volumetric requirements for three main components of asphalt mixtures (stone, bitumen and air). The triangular representation is therefore a valuable method to illustrate the volumetric requirements of technical specifications and standards. It was found that this kind of graphic presentation is also useful for asphalt mix design. In table 2 are requirements from technical specifications for asphalt mixture SMA 11.

Table 2 Requirements from technical specifications for asphalt mixture SMA 11

	Void content in for specimen compacted in laboratory	Bitumen content	Bitumen content in voids	Void content in asphalt layer
	V_{min}-V_{max}	B_{min}-B_{max}	VFB_{min}-VFB_{max}	V_{minL}-V_{maxL}
Asphalt mixture	v.-%	m.-%	v.-%	v.-%
SMA11	2.5–4.5	6.3–NA	75–88	1.5–7.5

In figure 2 is presented how triangular representation of three basic asphalt layer components look like. In the equilateral triangle presented in Fig. 2, it was assumed that the 100% content of the ‘stone’ is on the vertex, 100% content of ‘air’ is on the right side and 100% ‘bitumen’ content is on the left side.

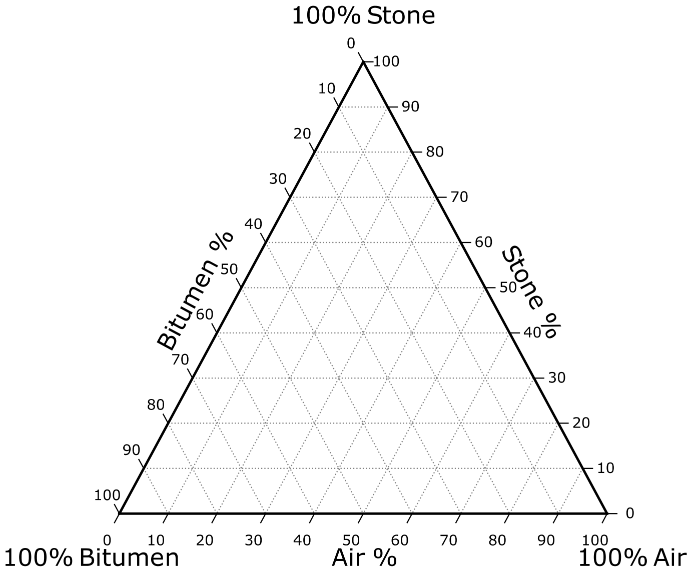

Fig. 2. Basic asphalt components represented by volume as a triangle.

Requirements from technical specifications for SMA 11 in Table 2 require the air void content for specimen compacted in laboratory to be from 2.5 to 4.5 v.- % and for asphalt layer to be from 1.5 to 7.5 v.- % . Fig. 3 shows the requirements for voids content for specimen compacted in laboratory designated with red lines.

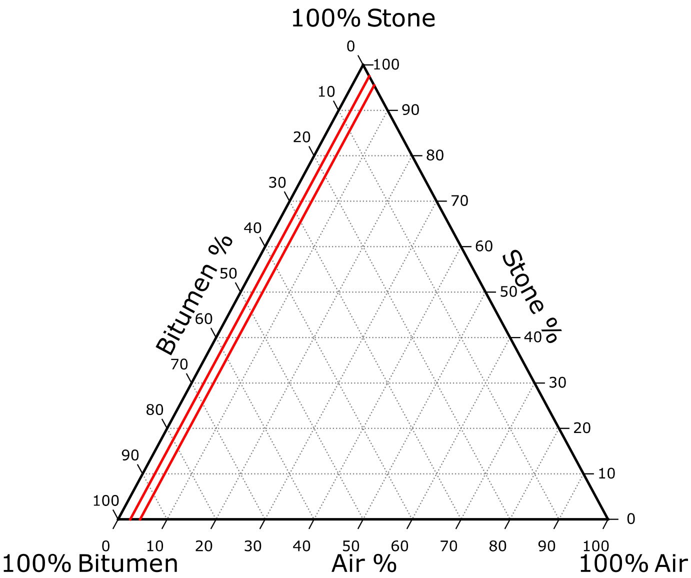

Fig. 3. Volumetric limits for air voids (red lines) for SMA 11specimen compacted in laboratory.

Many European specifications have requirements for voids in a stone aggregate filled with bitumen. A minimum of 75% and a maximum of 88% of voids should be filled with bitumen for SMA 11 in Table 2. The requirements for voids filled with bitumen for SMA 11 are designated with green lines in Fig. 4. This demand is graphically represented as a ratio between bitumen and air.

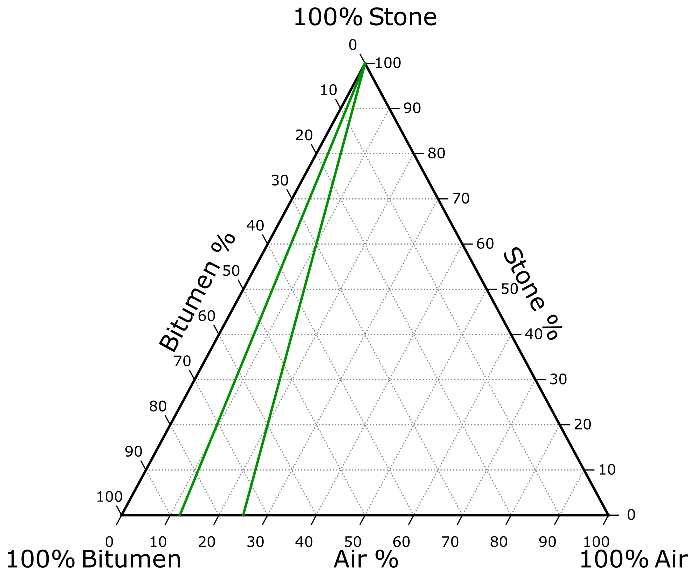

Fig. 4. Volumetric limits for voids filled with bitumen (green lines) for SMA 11specimen compacted in laboratory.

Requirements for minimum bitumen content can be also presented in the triangular volumetric representation. In most countries the limits for minimum bitumen content are set in mass percent for SMA mixtures. The minimum bitumen content in Table 2 is set to 6.3 m.-% for SMA 11. These values should be of course corrected for realistic densities of stone aggregates with the reference density of stone aggregates (2.650 Mg/m^3) from equation 1 in the asphalt mixture. The requirement for mass percentage is not constant in volumetric asphalt mixture design. The requirement for volume percentage of bitumen should be line parallel to right side of triangle, but the requirement for mass percentage of bitumen is line connecting the right corner of the triangle and the left side of the triangle.

For SMA 11 in Table 2 limits for minimum bitumen content are set to 6.3 m. -%. Assuming the densities of bitumen (1.01 Mg/m3) and stone aggregates (2.650 Mg/m3), we determined the line representing the volumetric requirement for the bitumen content. In the triangular volumetric representation this limit is depicted as the purple line in Fig. 5.

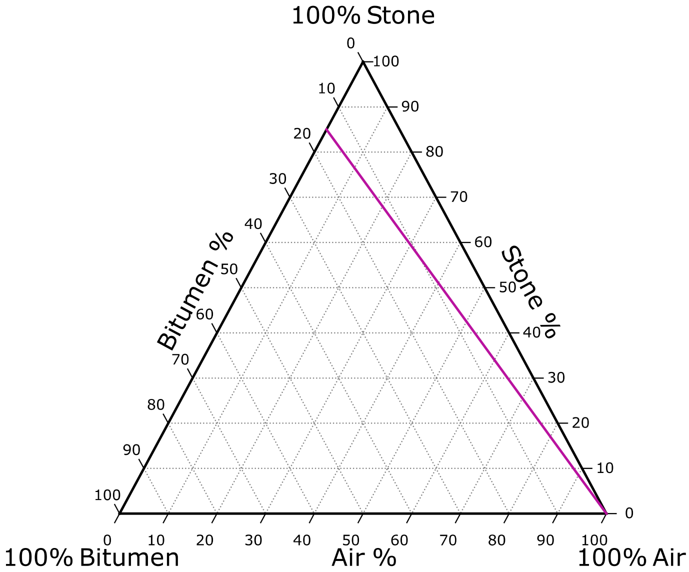

Fig. 5. Volumetric limits for bitumen content (purple line) for SMA 11specimen compacted in laboratory.

In Fig. 6 are presented all three requirements together. In right side (Fig 6.b) is enlarged green area where asphalt mixtures SMA 11 should appear.

a. b.

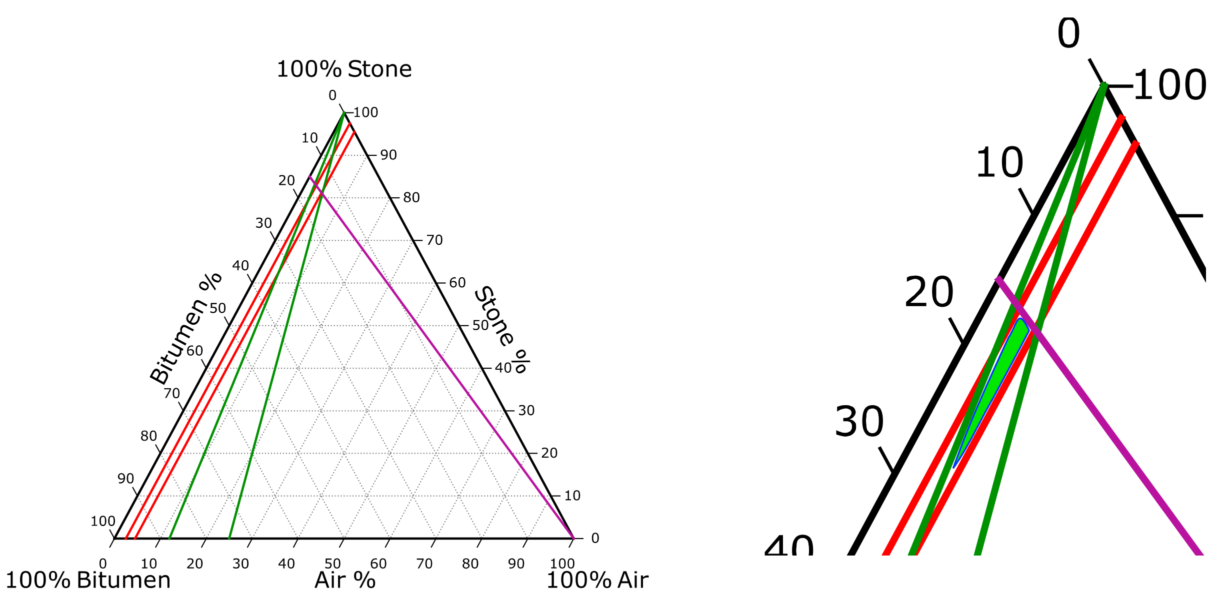

Fig. 6. Volumetric limits for air voids (red lines), voids filled with bitumen (green lines) and bitumen content (purple line) for SMA 11 specimen compacted in laboratory.

4. Examples of real asphalt mixtures in triangular representation

Three real SMA 11 asphalt mixtures were taken from database and their volumetric properties are presented in table 3.

Table 3 Requirements from technical specifications for asphalt mixture SMA 11

	Void content in for specimen compacted in laboratory	Bitumen content (mass)	Bitumen content (volume)	Bitumen content in voids
	V	B	VB	VFB
Asphalt mixture	v.-%	m.-%	v.-%	v.-%
SMA11 a	4.0	6.7	16.3	80.4
SMA11 b	5.8	6.6	15.1	72.3
SMA11 c	3.0	6.5	15.0	83.2

Circles in figure 7 represent position of three real asphalt mixtures SMA 11 from Table 3. It can be seen that two asphalt mixtures lay inside requirement and sample SMA 11 b is outside requirements for void content and voids filled with bitumen.

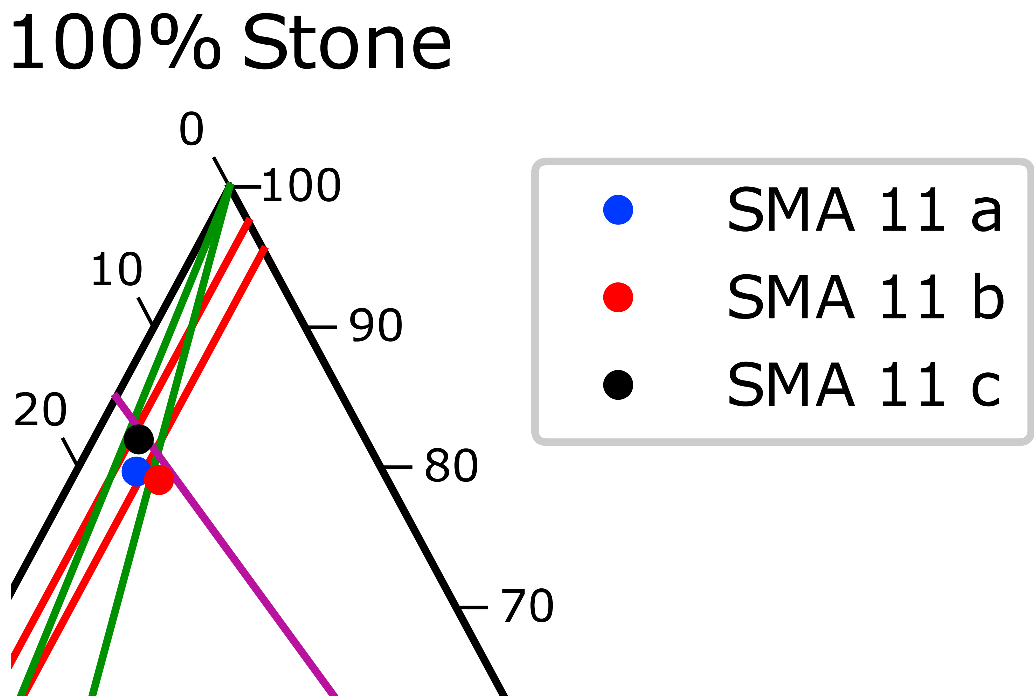

Fig. 7. Volumetric limits for bitumen content (purple line) for SMA 11specimen compacted in laboratory.

5. Conclusions

The main goal of this study was to demonstrate the applicability of graphical representations for asphalt mixture design. Visualisation of volumetric properties is important for the understanding of the composition of the asphalt mixtures. Three basic constituents of asphalt mixture (stone aggregates, air voids and bitumen content) are graphically represented by a triangular representation. This allows for a visual presentation of the true meaning of a particular requirement. For a demonstration, we used three real SMA 11 asphalt mixtures and proved that the triangular representation of requirements for volumetric properties of asphalt mixtures is the most useful way to represent the meaning of different volumetric requirements from specifications.

Acknowledgements

We are grateful to Kaja Tušar for her help in constructing the figures. The authors acknowledge the financial support from the Slovenian Research Agency (research core funding No. P1-0017 and No. P2-0273).

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