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ASSESSMENT OF ADHESION BETWEEN BITUMINOUS BINDER AND MINERAL AGGREGATE USING DIGITAL IMAGE ANALYSIS

Jan Trejbal*, Tereza Valentová, Tereza Horová

Czech Technical University in Prague, Faculty of Civil Engineering, Thákurova 7, 166 29 Prague, Czech Republic

* corresponding author: jan.trejbal@fsv.cvut.cz

Abstract. Asphalt mixtures often fail due to a low adhesion of bituminous binder to mineral aggregate, which leads to surface coarse damages like potholes and fatigue cracking. To avoid this phenomenon, different types of adhesion promoters may be admixed into bituminous binder but a new question about their effectiveness arises. This paper presents two semi-automatic methods, which reliably replace the subjective assessment. Both of them use a digital image of asphalt mixtures as an input. The first is based on a gray level thresholding, while the second one on an entropy-based image segmentation. Asphalt mixtures composed from Zbraslav aggregate (fraction 8–16 mm), paving grade bitumen 50/70 and several types of adhesion promoters were made and subjected to the adhesion assessment. It was shown that aggregate grains coated by binder was equal to ca. 83–88 % in the case of reference binder, while that was increased by ca. 10–13 % if whatever adhesion promoters were used.

Keywords: Asphalt mixture, bituminous binder, adhesion promoters, adhesion assessment, interfacial interaction.

1. Introduction

In Europe, more than 90 % of roads are constructed from asphalt mixtures [1]. Over the past few decades, such a material has been partially replaced by concrete based on the cement matrix due to its better abrasive resistance and longer lifetime. Unfortunately, it has been shown recently that these road structures often fail due to issues connected with shrinkage cracking [2]. An attention of many engineers and researches is therefore drawn back to asphalt mixtures and efforts to improve this material are newly developed. The poor adhesion between bituminous binder and mineral aggregate is considered to be one of the most problematic issue, leading to a premature damage of the surface coarse. Mineral aggregates, especially those containing quartz-based granites, are typical for its affinity for water, much more than for binder. Once the asphalt mixture is exposed to water, this can easily penetrate between the two materials and thus acts as a separation, if binder to aggregate adhesion is too poor [3, 4]. Consequently, individual aggregate particles are stripped, i.e., the thin bituminous film is removed from their surface. This phenomenon is called "stripping" [5], resulting in road structure degradation like potholes and fatigue cracking, see Figure 1.

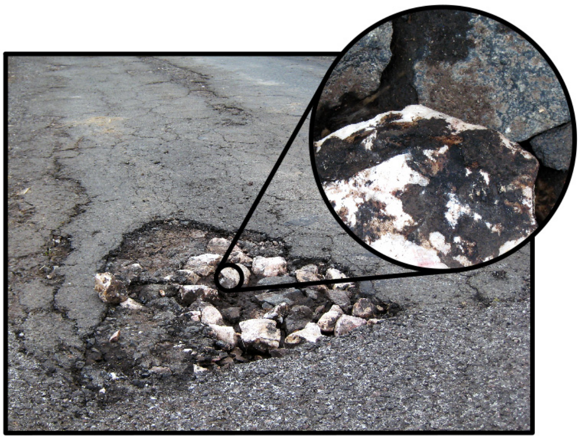

Figure 1. A pothole through the surface coarse of the asphalt structure road (road nr. 28110 between villages Jinolice and Javornice).

To reduce or avoid stripping, bituminous binder can be modified with adhesion promoters. The function of these synthetic compounds or those from natural resources is based on disruption of intermolecular interactions between water and aggregate surface [6].

In civil engineering practice, the interaction between the two materials is in most cases assessed as adhesion of the bituminous thin film to aggregate particles. Two observers evaluate the ratio between binder-coated and stripped areas visually on asphalt mixtures prepared in laboratory [7]. It is obvious that such approach cannot provide consistent and accurate data due to human factor. Therefore, some researchers developed semi-automatic methods. These are usually based on digital picturing of asphalt mixtures, while the ratio mentioned above is then assessed automatically. Most of such methods are based on classification of characteristic colors [8, 9].

Unfortunately, such an assessment is inaccurate or impracticable due to aggregate dark colors or light reflection from binder-coated aggregate surface. A digital camera is not capable to record such a contrast picture; the captured photo does not contain all shadows or brightness – the color spectrum is limited. In such cases, the software is not able to recognize the threshold between the two materials due to low information in the photo. Therefore, it is suitable rather for edges analysis based on brightness and shadows recognition [10]. To overcome this limit, the entropy-based image segmentation method can be used. Such a procedure provides much more accurate outcomes. Areas with high entropy are considered to belong to aggregate while low entropy areas represent the bituminous surface [11, 12].

2. Materials and methods

2.1. Mineral aggregate

Mineral aggregate Zbraslav (Czech Republic) composed of proterozoic spiliness and metaphrash was used for a production of asphalt mixtures. This was crushed to fraction of 8–16 mm. From the geological point of view, this rock is typical for its very fine grain and porous surface.

2.2. Bituminous binder

Standard paving grade bitumen 50/70 [13] was used at the alternatives – reference and modified with several different types of adhesion promoters. These were applied at amount of 0.2 or 0.3 % of the binder weight according to recommendation of their manufacturers. Composition of each asphalt mixture, differing in adhesion promoter type, is stated in Table 1, where the abbreviation MR indicates the reference mixture, while MA–MD belong to modified mixtures.

2.3. Asphalt mixture samples

Asphalt mixtures were prepared by procedures following the relevant technical standard [14]. Those were photographed in order to obtain basic input files for the digital image based analysis. A sample image is depicted in Figure 2.

2.4. Adhesion assessment

Two digital image based approaches were employed to assess the adhesion between aggregate and both reference and modified bituminous binder:

(1.) Gray level thersholding (GLT): this method is based on recognition of brightness and shadows on the digital image of asphalt mixtures. Areas which are brighter than dark bituminous binder are considered to be parts of stripped aggregate particles.

(2.) Entropy-based image segmentation (EIS): the principle of this method rests on a local entropy calculation in order to assess roughness of the texture. Areas with high entropy are considered to belong to aggregate while low entropy areas represent the bituminous surface.

Figure 2. A sample image of the asphalt mixture to be used for the adhesion assessment.

3. Results

The adhesion analysis of asphalt mixtures revealed that the surface area of the reference asphalt mixture (MR) reached on 88.0 % and almost 83.0 %, when assessed employing GLT and EIS method, respectively. The mixture was classified as "satisfactory" according to the relevant technical standard [14].

If an adhesion promoter is used (MA–MD), the coated area increased to 95.2–99.3 % (depending on method used). Verbal classification following the standard cited above was either “good” or even “excellent”. It is therefore clear that the effect of applied adhesion promoters is significantly positive. It can not be said which mixture reached on the best result due to slight difference between them. All results are summarized in Figure 3, where the verbal classification is also stated.

Figure 4 shows an original image of the reference asphalt mixture (MR), where stripped edges of aggregate grains are illustrated. These were exactly found by both methods used (GLT and EIS). This held true also for the mixture MB, which is depicted in Figure 5. It is also worth noting that the difference between the adhesion of MR and MA mixture is visible clearly.

The slight difference between results obtained using the two methods can be attributed to issues connected with dark and shiny surfaces of the aggregate grains. If these are rather dark, the software of the GLT method can define them as binder-coated. Therefore, such obtained results reached on better values than in case of the EIS method. The problematic image is shown in Figure 2, where the high contrast of whole mixture is presented.

4. Conclusions

The presented work was focused on adhesion assessment of bituminous binder to mineral aggregate using

Mixture	Aggregate	Fraction [mm]	Promoters	Amount [wt %]
MR			No promoters	0
MA			TTO-A	0.2
MB	Proterozoic spiliness, metaphrash	8-16	ValoJames	0.3
MC			Adhere	0.3
MD			AD-2	0.2

TABLE 1. Summarization and composition of asphalt mixtures used.

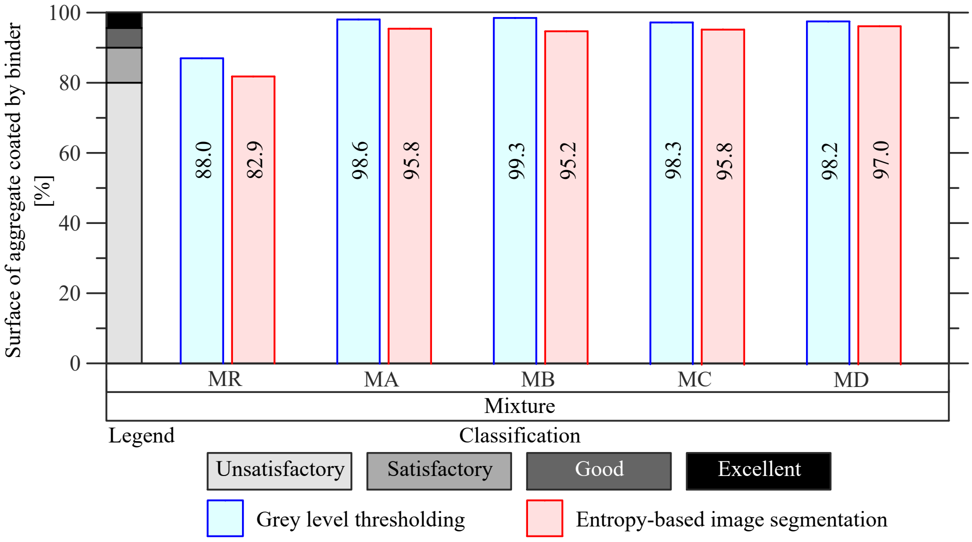

FIGURE 3. The surface of aggregate coated by binder.

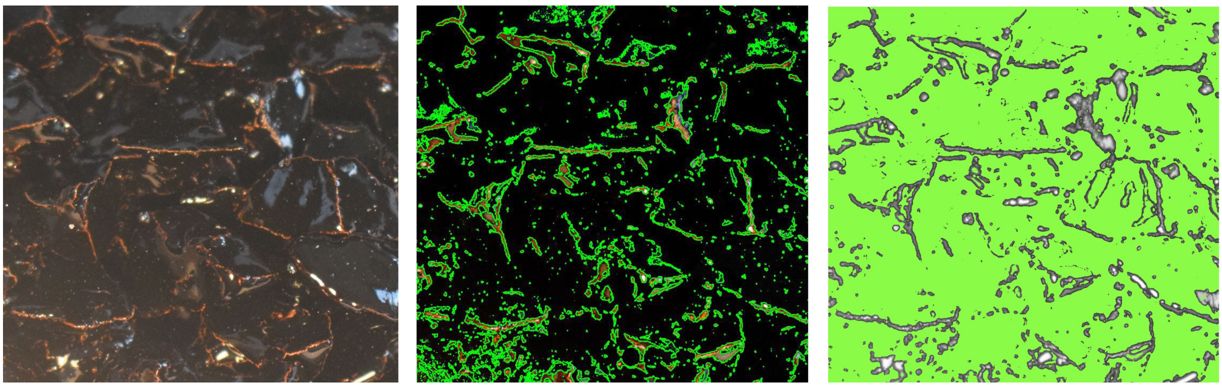

FIGURE 4. Coverage of Zbraslav aggregate with reference bituminous binder (MR), from left to right: an original image, GLT, and EIS results.

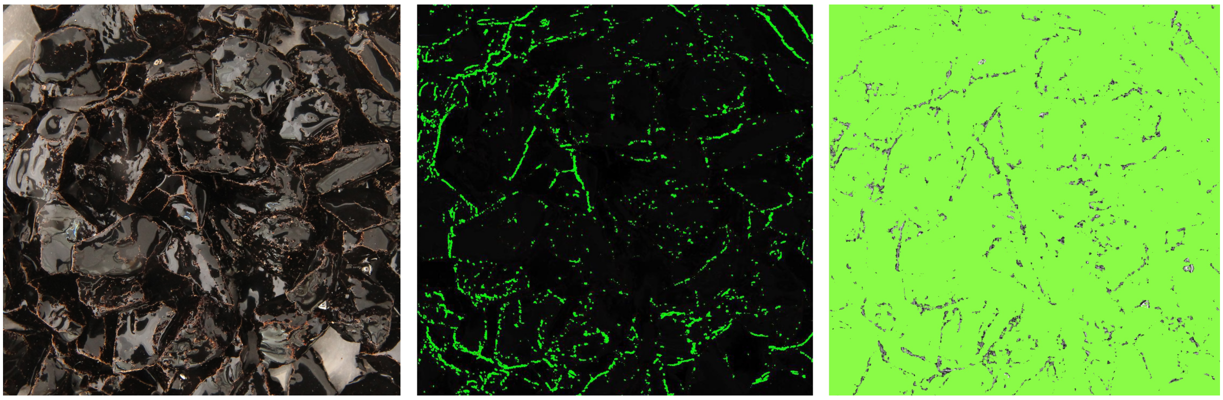

Figure 5. Coverage of Zbraslav aggregate with modified bituminous binder (MA), from left to right: an original image, GLT, and EIS results.

two different digital image based semi-automatic analyzes – a gray level thresholding (based on identification of aggregate areas brighter than dark bituminous binder) and an entropy based image segmentation (aggregate areas rougher than binder). Asphalt mixtures composed of paving grade bitumen 50/70, Zbraslav aggregate crushed at the fraction of 8-16 mm, and several types of adhesion promoters were made. Promoters were employed in trace amount – from 0.2 to 0.3 % of the binder weight, according to recommendation by their manufacturers. After finishing of the asphalt mixtures preparation, those were photographed in order to attain input files for the semi-automatic adhesion analysis. The findings were as follows:

- The aggregate area coated by reference binder was equal to ca. 83–88%, as assessed using both semi-automatic methods.
- If bitumen was modified by adhesion promoters, regardless to their type and amount, the adhesion was increased by ca. 10–13 %.
- The EIS method was considered to be more accurate than the GLT because of the issue connected with dark and shinny surfaces of asphalt mixtures. These provide misleading information for the image-based analysis.

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