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PAVEMENT SUBBASE LAYERS FOR RECONSTRUCTION AND REPAIR OF LOWER CLASS ROADS

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Abstract

Today's construction industry is increasingly putting concepts such as sustainability, recycling, emission, and energy reduction at the forefront. This article follows the same path, looking at the design of new, recycled road subbase layers. These layers are almost 100 % composed of reclaimed asphalt, milled to the appropriate fraction. This reclaimed asphalt is either mixed with a suitable binder, heated to a low temperature or a combination of both effects occurs. The research described in this paper is partially related to the newly developed standard CSN 73 6147 Cold recycling of pavement structural layers [1]. The aim of the research is to economically and environmentally reuse even lower quality reclaimed asphalt, specifically in the subbase layer of pavements. Otherwise, this precious material is mainly used for the backfilling of roadsides.

Keywords: reclaimed asphalt, subbase layer, cold recycling, warm recycling, bitumen emulsion/cement bonding

1 Introduction

The use of reclaimed asphalt pavement (RAP) in hot mix asphalt (HMA) in the Czech Republic is increasing every year, as shown in figure 1. Unfortunately, this is still a lower percentage of usage of this economically and technologically suitable material for re-use in structural layers. A large proportion that is not suitable for use in HMA ends up as inferior material for sidewalk base courses, road shoulder backfills or as unpaved surfaces on lightly loaded private roads. This paper describes research on the design of mixtures for road subbase layers made of reclaimed asphalts, which, according to TP 210, are unusable for hot mix asphalt [2-4]. The research, including the procedures used and requirements for strength of specimens, was based on the newly published standard CSN 73 6147 following the former technical specifications TP 208 since the standard or technical regulation dealing with warm recycling described in following chapters does not currently exist in the Czech Republic [1, 5]. The aim of the research was to examine various samples of commonly used reclaimed asphalts and to design their easy, widely applicable and economically viable treatment for their further use as subbase layers of Czech pavements, especially less loaded and local roads.

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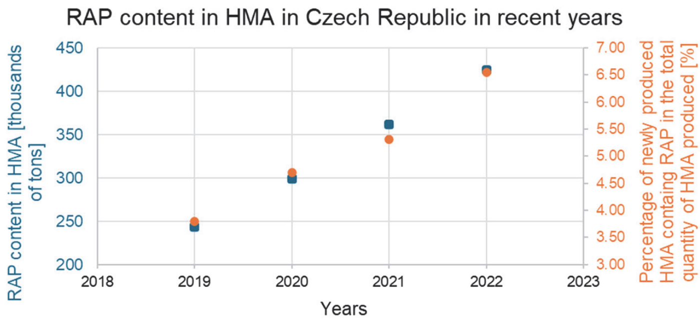

Figure 1 RAP content in HMA in the Czech Republic [6]

2 Mixtures design

In the first phase, a significant number of suitable test samples of the materials were collected. As the research focuses mainly on the subbase of second and third class roads, cooperation was established mainly with the road management and maintenance centres in the individual regions, which often manage this material. A total of 5 different types of commonly used reclaimed asphalts up to a maximum particle size of 32 mm or 45 mm were collected from these centres and the surrounding asphalt mixing plants. Apart from the maximum particle size and a water content of up to 5 % (to ensure good compactability under laboratory conditions), no other requirements were applied to the reclaimed asphalt [7].
In the second phase, standard tests were carried out on both the reclaimed asphalt itself (sieve analysis) and the extracted binder (bitumen binder content, penetration, softening point) to establish basic information on the samples taken. These tests confirmed the previously expected different origins and properties of the reclaimed asphalt, ensuring a wide range of choice between the materials used, from the lowest quality to very suitable reclaimed asphalts.
The third stage involved the actual design and production of the reclaimed asphalt subbase layers. A total of 9 test sets were created for each reclaimed asphalt tested. In the first stage, a series of reference reclaimed asphalt specimens were created at a laboratory temperature of + 30 °C. Then, in order to maximise the potential of the residual bitumen binder content in the reclaimed asphalt, 3 further sets of test specimens were created at 60 °C, 90 °C and 135 °C. The temperatures were chosen sensibly for the following reasons:

- 30 °C: reference temperature of the reclaimed asphalt under standard conditions,
- 60 °C: the softening point of the used bitumen binder in the reclaimed asphalt is normally reached or exceeded,
- 90 °C: the softening point of the bitumen binder is exceeded and no water evaporation from dosed bitumen emulsion occurs,
- 135 °C: heating temperature of the reclaimed asphalt pavement at the asphalt mixing plant when added to hot asphalt mixes.

In the next stage, a small amount of binder – 1,5 % polymer modified cationic bitumen emulsion 60% (KAE C60 BP5) – was dosed into the reclaimed asphalt to improve the bond and strength characteristics of the layer. For this amount of emulsion, 4 sets of specimens were formed and compacted again at the abovementioned temperatures. The emulsion was always dosed at the standard mixing temperature of 60 °C. The last, ninth set of specimens was compacted only at a reference temperature of 30 °C and contained the addition of a binder in the form of 1,0 % CEM II 32,5 R Portland blended cement (CEM).

This set was specifically designed to investigate the effects of the cement binder primarily on the stiffness of the reclaimed asphalt, which contained the most aged binder [8, 9].
Finally, all the manufactured specimens (figure 2) were tested in an indirect tensile strength test. This was carried out on both saturated and dry bodies in accordance with CSN 73 6147 and both their minimum indirect tensile strength and the ratio of wet to dry strengths were monitored [1].

Figure 2 Test specimens after indirect tensile strength test

To produce the test specimens, a special compaction press was built because the Proctor modified impact compaction test, used for laboratory compaction of cylindrical specimens, is not suitable for elastic-plastic behaviour of reclaimed asphalt. A diagram of the mould and the compaction press itself are shown in figure 3.
Compaction was carried out using a manual hydraulic press, which ensured that the material was compacted evenly on both sides. The compaction force applied to the specimen was set at 88,5 kN ± 0,5 kN according to CSN 73 6147, which corresponds to a contact stress of 5 MPa in the compaction mould [1].

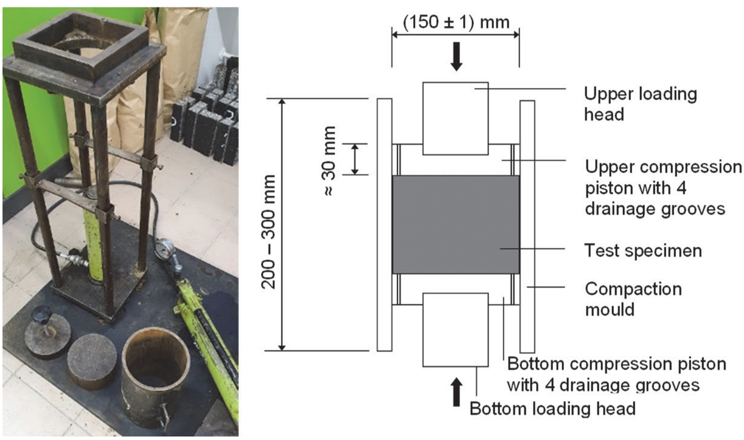

Figure 3 Manual hydraulic press and diagram of cylindrical mould with compacting pistons [1]

3 Results

This chapter presents selected results of both tests on bitumen binders extracted from reclaimed asphalts and tests carried out on the reclaimed asphalts themselves.

3.1 Bitumen binder tests

Tab. 1 shows the penetration and softening point values of the various bitumen binders extracted from the reclaimed asphalts and the amount of bitumen binder contained in the reclaimed asphalts. These values are used to evaluate the degree of ageing and the quality of the bitumen binder contained respectively the quality of the reclaimed asphalt itself.

Table 1 Softening point and penetration values of bitumen binders extracted from reclaimed asphalt.

	1	2	3	4	5
Softening point [°C]	61.8	67.9	85.9	60.8	62.5
Penetration [0,1 mm]	26.6	17.3	4.8	19.4	33.9
Bitumen content [%]	5.8	5.1	5.3	5.1	5.1

3.2 Sieve test analyses

The following figures, figure 4 and figure 5, shows the sieve test analyses performed on the used reclaimed asphalts, both before and after extraction of the binder, including the recommended grain size limits.

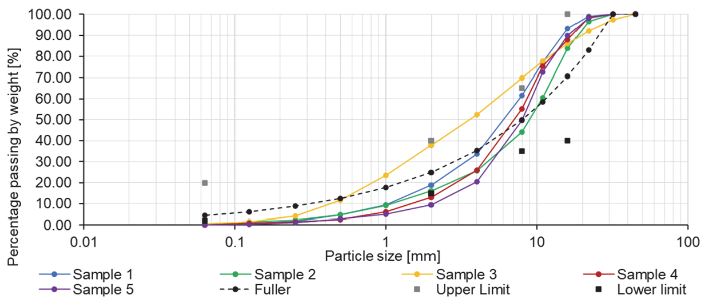

Figure 4 Sieve test analyses – reclaimed asphalts

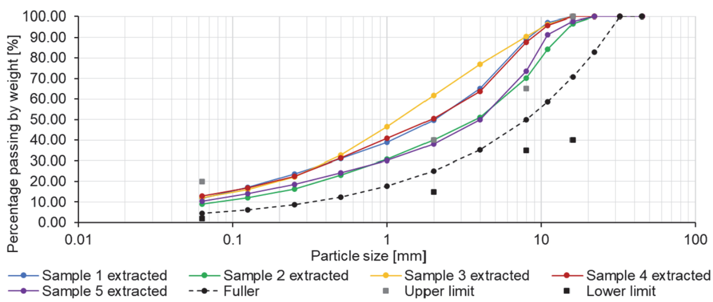

Figure 5 Sieve test analyses – reclaimed asphalts after extraction

3.3 Determination of indirect tensile strength and water resistance

The figure 6 shows results of the indirect tensile strength test. All test specimens used in the above-mentioned tests met the requirements of CSN 73 6147 for a mass (4700 g – 5000 g) and height (125 mm ± 20 mm) and were prepared and tested according to the relevant standard [1].

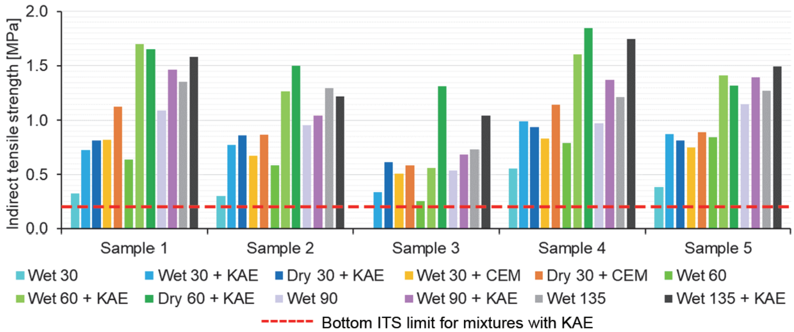

Figure 6 Indirect tensile strength – all values

4 Discussion

This chapter describes and evaluates the measured values presented in the “Results” chapter and compares them with the requirements of the relevant standards [1, 14]. This part is divided into several sections so that the subsections correspond to the content of the ‘Results’ chapter.

4.1 Bitumen binders and bitumen emulsion

First, the measured values of penetration and softening point by the ring & ball method were compared with the values specified in CSN 73 6141 Requirements for the use of reclaimed asphalt pavement in asphalt mixtures [10]. According to the requirements of the standard, the conditions for use in asphalt mixtures are fulfilled by 4 out of 5 tested reclaimed asphalts (under the conditions of their modification into reclaimed asphalt pavement, compliance with the prescribed granularity and compliance with the classification into quality grades ZAS T1 to ZAS T3) [11]. However, only samples 1 and 5 are sufficiently distant from the limit values required by the above-mentioned standard (penetration ≥ 15 p.u. and softening point ≤ 70 °C) and could probably be used to produce hot mix asphalt. The other samples are unsuitable for hot mix asphalt but can be used in road subbase layers.

A 1,5 % of polymer modified cationic bitumen emulsion 60% (KAE C60 BP5) was dosed into almost all designed subbase mixtures. This emulsion was chosen because of its frequent use, among others, at road management and maintenance centres in the Czech Republic. The amount of emulsion was chosen according to expert estimation, considering the economics of the designed mixtures. Changing the amount of bitumen emulsion added and changing the type of emulsion or binder in general are other options that are planned to be compared in follow-up research.

Following the penetration and softening point values measured for specimen no. 3, it was decided to create one set of test specimens using cement as a binder instead of bitumen emulsion. It is the cement that could be used for reclaimed asphalts in which the bitumen binder no longer performs the bonding function.

4.2 Sieve test analyses

The major problem concerning sieve test analysis is the influence of the temperature of the resulting mixture. In the case of cold recycling, which is the focus of this standard, the problem does not occur. If the temperature of the reclaimed asphalt is raised above the softening point, which was the focus of the research, the bonding between the particles is loosened and the sieve analysis of the cold reclaimed asphalt does not match the actual condition. For this reason, the average sieve analysis before (with binder content) and after extraction (without binder content) are shown in figure 7. It can be assumed that the actual sieve analysis for reclaimed asphalt heated to 60 °C would be somewhere close to this average of averages.

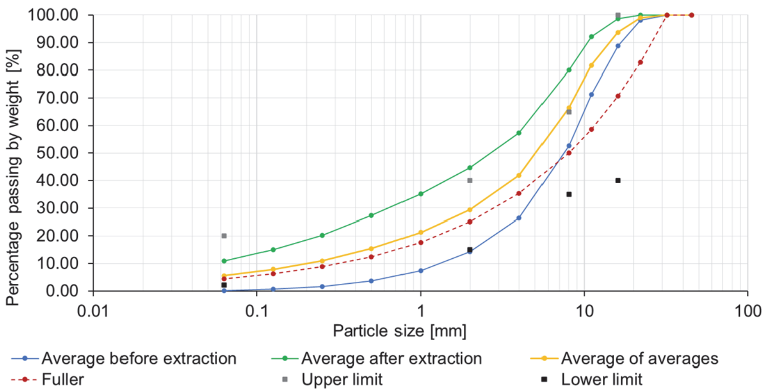

Figure 7 Sieve test analysis – average values.

4.3 Indirect tensile strength

Standard CSN 73 6147 requires 2 tests of the physical-mechanical properties to be performed on recycled bound mixtures – indirect tensile strength R_{it} after 7 days and minimum water resistance [1]. The required values are presented in Tab. 2.

Table 2 Requirements for physical-mechanical properties [1]

		Cement	Bitumen emulsion
All roads except highways	Indirect tensile strength R_{it} (7 days)	0.30 – 0.70 MPa	min. 0.2 MPa
	Minimal water resistance	75 % R_{it}	60 % R_{it}

The minimum limit of 0,2 MPa specified by the standard was exceeded by all samples without influence of temperature or type of bonding, except sample no. 3 at the laboratory temperature [1].

The most cost-effective and best quality option appears to be heating the reclaimed asphalt to a temperature around the softening point of the contained binder (approx. 60 °C) in combination with bonding by the cationic bitumen emulsion (1.5%). The average values of the indirect tensile strength R_{it} after 7 days were approximately about 1.6 MPa in the dry state and 1.5 MPa in the saturated state, which corresponds to approximately eight times the minimum required strength R_{it} [1]. Simultaneously, the indirect tensile strength doesn't increase with increasing temperature (or combined with the addition of emulsion).

This can be explained by the fact that while the binder in the reclaimed asphalt softens with increasing temperature, the emulsion reacts more rapidly with the reclaimed asphalt (or even the water in the emulsion evaporates immediately) and does not sufficiently coat and bonds the grains.
Due to the large number of specimens produced and the continuous acquisition of new results, some sets (at 90 and 135 °C), were tested for ITS only on saturated specimens as these specimens were expected to have lower strength than dry specimens. The missing dry samples will be tested for ITS in further research.

5 Conclusion

It has been found that combining reclaimed asphalt with bitumen emulsion and higher temperatures results in a subbase course with sufficient strength. By heating the mixture close to the binder softening point (±60 °C), the potential of the used reclaimed asphalt is increased several times. This type of subbase layer could save significant financial resources in the (re) construction of lower-class roads.

Acknowledgement

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