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Particle clustering phenomena in hot asphalt mixtures with high content of reclaimed asphalt pavements

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HIGHLIGHTS

- Formation of RAP clusters was investigated.
- The specific surface to be coated with new bitumen is reduced as a result of clusters.
- RAP particles are coated with an active binder film that is covered by a more aged and stiffer binder crust.
- Formation of temperature dependent clusters was verified using ESEM and EDX.
- A clustering index was introduced as ratio between the modulus of a binder with clusters and without.

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ABSTRACT

One challenge in efficient recycling of asphalt concrete is the adherence of the reclaimed asphalt pavement (RAP) particles or clustering that inhibits fulfilling the aggregate gradation requirements. In order to investigate this phenomenon two types of mixtures containing virgin aggregates, bitumen and 50% and 90% RAP were investigated at different mixing temperatures. The formation of clusters in the mixture was verified using rheological properties (DSR) and imaging (ESEM, EDX). The virgin binder in the mixture was detected using imaging techniques by means of a titanium dioxide tracer and it was shown how the virgin binder surrounded the clusters of RAP depending on mixing temperature.

1. Introduction

Nowadays one can observe an increasing interest in producing high content reclaimed asphalt pavement (RAP) asphalt mixtures with similar properties as materials made of 100% virgin components. This is on the one hand economically viable due to the rising costs of bitumen and on the other hand triggered by the increasing awareness for producing sustainable road pavement materials. In Europe the amount of allowed RAP is regulated by national standards. For example, in Switzerland, the standard SN 640 431-1b-NA [1] allows using a maximum of 70% RAP in sub-base courses, 60% in base, and none in the hot mix surface courses. At the same time, recent research has shown that high RAP content mixtures can perform mechanically as well as those produced with all virgin materials [2]. Combining RAP with virgin materials introduces some unique challenges as the RAP materials contain aged bitumen and are therefore often considered as inactive "black rock". However, experience shows that "black rock" is not a priori inactive. Therefore, its aged bitumen should be ideally mobilized and the blending of old and new bitumen should be optimized so that it mixes with the virgin bitumen thereby reducing the amount of virgin bitumen needed.

In order to characterize this crucial blending process, various kinds of micro-characterization techniques have been used. Bowers et al. [3] have used gel permeation chromatography

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(GPC) and Fourier transform infra-red spectroscopy (FTIR) to analyze the blending of virgin binder with RAP binder using a staged extraction procedure. Their results indicate a certain degree of blending which is not uniform within all layers of the binder. More recently Mohajeri et al. [4] have used nano-indentation, nano-computed tomography (nano-CT) as well as scanning and optical microscopy for investigating the blending zone. Their results indicate that the two binder materials (old and virgin) could be identified mainly with nano-indentation due to the difference in their modulus values; however, detecting the interface between the two binders was difficult. Recent research by the authors using electron microscopy and computer tomography has shown that the blending is non uniform in the mixtures investigated; areas in the mixture were identified with a good degree of blending while in other areas no blending could be observed [5].

2. Objective and scope

Aged bitumen in hot RAP causes the RAP aggregates to stick together resulting in the clustering phenomena [6] and in turn inhibiting proper blending. Hence, the formation of clusters might have important consequences on the RAP mixture behavior and prevent the uniform distribution of the virgin binder, thus increasing the heterogeneity of the mixture. Moreover, the agglomeration of RAP particles changes the design grading curve and reduces the amount of small-size grains in the mixtures. This has an impact on the voids and on the quantity of virgin bitumen required for an adequate coating of the particles.

As a result, it is important to investigate the physical phenomena occurring during the mixing process, verifying and quantifying in particular the cluster formation in the mixture due to the addition of RAP. To this end, the clustering phenomenon on five types of engineered mixtures was investigated as discussed in detail in Section 3 exemplified by RAP content and mixing temperature.

The overall goals of the study are twofold:

(a) To learn how RAP blends and, if possible find evidence for clustering which, so far is a hypothesis and the basis of the definition of a clustering index.
(b) Find and compare methods to visualize clustering and investigate experimentally when and under what conditions clusters may form.

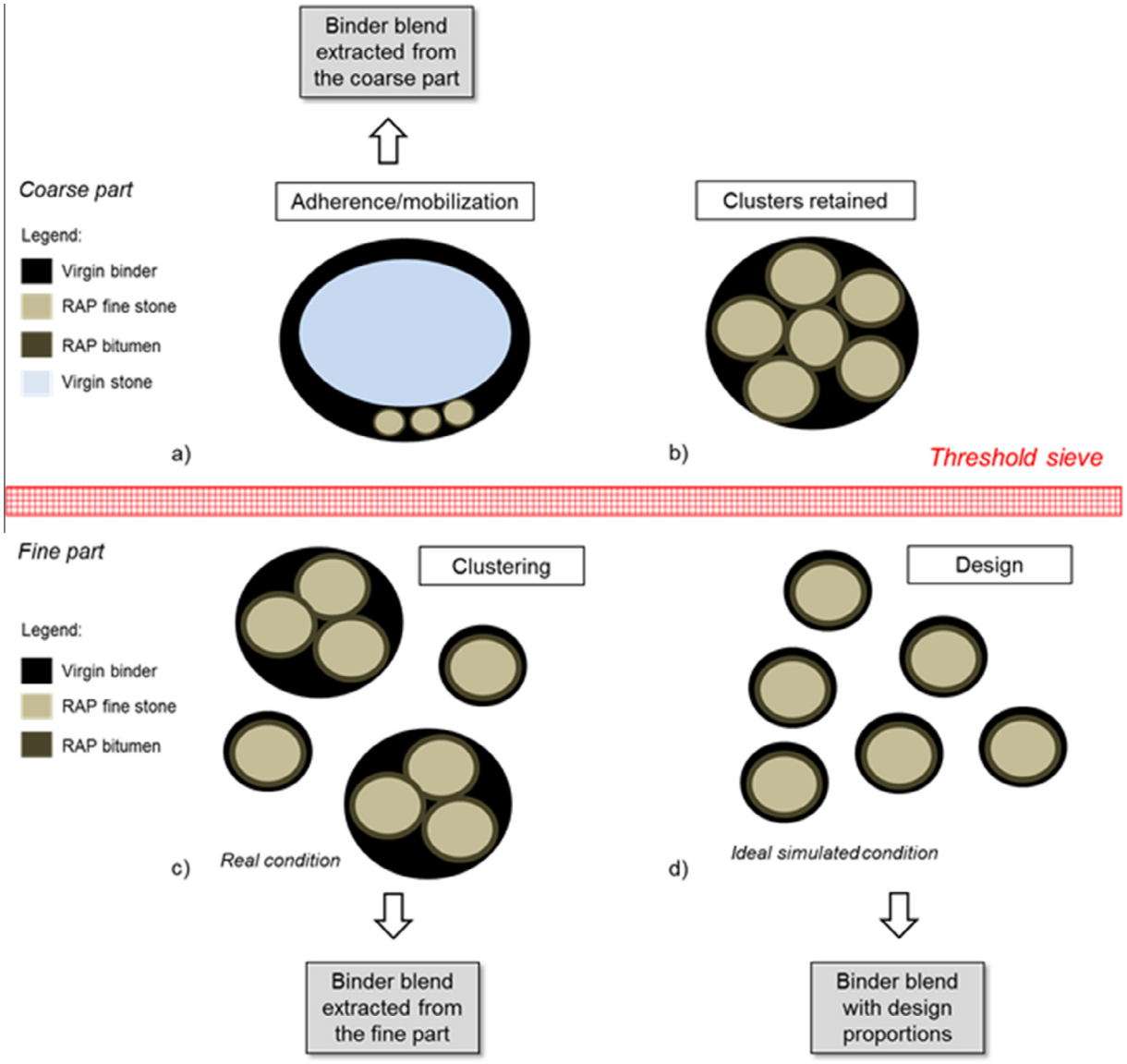

Fig. 1. Schematic representation of the different components: (a) RAP attached to coarse aggregates, (b) clusters of RAP retained above the threshold sieve, (c) clusters in the fine part and (d) design or ideal condition where every individual RAP particle is covered by RAP and virgin bitumen.