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Applying a full-field measurement technique for studying the local deformation in reclaimed asphalt pavements

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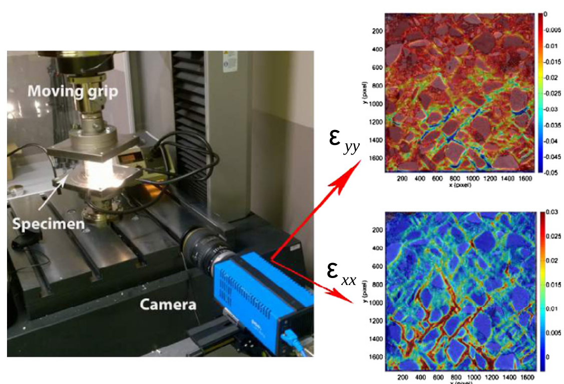
HIGHLIGHTS

- Reclaimed asphalt pavement samples were subjected to compression and recovery tests.
- Displacement and strain fields were measured using the grid method.
- The behavior of the samples was investigated at the binder and mixture scales.
- Local stiffening of the binder along the border of the RAP aggregates was observed.

GRAPHICAL ABSTRACT



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ABSTRACT

The proposed study focuses on the mechanical behavior of recycled asphalt mixtures using a full-field measurement technique, namely the grid method. For this purpose, cylindrical samples made of hot mix asphalt mixtures containing 0%, 20%, 40%, and 100% of RAP were prepared. Aggregates of different colors were selected in order to distinguish RAP and virgin aggregates. Compression tests were carried out on cylindrical samples. Displacement and strain fields were measured during these tests. The obtained results highlight the difference in behavior between samples both at the micro- and the macro-scales.

1. Introduction

Asphalt materials used as a coating for the road pavements are generally removed during the rehabilitation or reconstruction works. Once recovered and treated, these materials become Recycled Asphalt Pavement (RAP). RAP materials are generally composed of aggregates and aged asphalt binder. They can be used as an alternative of virgin materials. The use of RAP permits not only to decrease the construction cost of new roads, but also to contribute to the preservation of natural resources. The amount of RAP which is commonly used in hot recycled bituminous mixes is regulated by standards. It lies generally between 10% and 30%.

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Nowadays, a number of technologies are readily available to produce 100% RAP Hot Mixture Asphalts (HMA) [1]. Facing these emerging trend to increase the amount of RAP in asphalt mixes, questions are raised concerning the effect of RAP on the performance such mixtures. One of the major issues that affects directly the performance of HMA containing RAP is related to the blending efficiency between RAP and virgin materials. Indeed after the mechanical mixing process, some coarse aggregates remain coated with some aged binder and fine materials. They form a high viscosity shell that may acts together with RAP aggregates like a black rock [2]. Several studies have thus been undertaken to characterize the amount and nature of blending which forms the virgin and RAP materials. In this context, Rinaldini et al. [3] performed a multiscale study using electron microscopy and computer tomography (CT). The authors concluded that blending between two binders is not homogeneous within the sample. In addition, they observed the formation of microcracks in some areas of the inter-binder zone (zone between aged and virgin binders) and at the interface between virgin aggregates and aged binder. This may potentially constitute a line of weakness for cracks to propagate along.

In this context, it is clear that the investigation of the mechanical response of recycled mixture requires the use of suitable measurement tools which provide information at the same scale as that at which the aforementioned phenomena occurs. In recent years, full-field measurement techniques, particularly digital image correlation (DIC), have become popular for observing and characterizing the heterogeneities in various heterogeneous materials in particular composite materials [4]. Digital image correlation (DIC) is also increasingly used by the asphalt pavement community for the characterization and the analysis of local mechanical response of asphalt materials. The studies found in the literature addressing the application of DIC technique to study the mechanical behavior of asphalt mixtures can be categorized in the following scopes [5]: characterization of strain properties of asphalt microstructure [6–8]; investigation of cracks and damage distribution [9–11] and model validation [12,13].

However, the use of full-field measurement techniques for studying the mechanical behavior of asphalt materials is still modest compared to their application to other fields of experimental mechanics. Moreover, the obtained results often only allow qualitative analysis of phenomena without really characterizing from a quantitative point of view, these phenomena. This is related to the fact that DIC is not really suitable for detecting large strain gradients that take place in the narrow binder bands between aggregates. Besides, most of the studies were conducted using commercial packages, which have the drawback of not providing enough flexibility to the user to adapt the technique according to the specific asphalt testing requirements.

Recently, the grid method has been used to characterize the mechanical behavior of asphalt mixture in compression [14,15]. The results suggest that the grid method has a good ability to detect small strain amplitude (up to some hundreds of microstrain) with a spatial resolution which is often compatible with the strain gradients that take place in the narrow bands of binder.

This study aims at investigating the effect of RAP on the mechanical behavior of recycled asphalt mixtures using the grid method. For this purpose, cylindrical samples made of hot mix asphalt mixtures with different RAP contents were prepared. Aggregates of different colors were selected in order to distinguish RAP and virgin aggregates. Compression and recovery tests were carried out on cylindrical samples. The grid method was used to compute the displacement and strain fields on the front face of the tested samples during the test. These measurements were used to compare, at different scales, the change in behavior of asphalt when the amount of RAP increases.

2. Experimental set-up and methods

2.1. Material, samples and loading conditions

Four Hot Mixtures Asphalt (HMA) containing 0%, 20%, 40% and 100% of RAP were considered in this study. The mixtures were provided by Cerema Direction Territoriale Centre-Est, France. The RAP materials were recovered from the same source and composed of granite, basalt and gneiss. The virgin materials were constituted from limestone aggregates and a virgin bituminous binder (bitumen grade 50/70). The aggregates were selected according to their difference in color: black for recycled aggregates and white for virgin ones (see Fig. 1a). Hence, after the mixing process, the recycled material could easily be identified, and subsequently their mechanical response could be observed separately during the test (see Fig. 1b). The composition of the mixtures is given in Table 1. The tests were carried out on cylindrical-shaped samples featuring 80 mm in diameter and 90 mm in height. They were molded by compaction according to the standard [16]. The flat front face under study was obtained by cutting the cylindrical sample parallel to its axis (Figs. 1b and 2). The dimension of the surface under investigation for all samples is about 6.5 cm × 7 cm. Compression tests were performed in a temperature controlled room at 21 °C, with a displacement rate of 0.01 mm/s. Since the opposite faces of the samples were not perfectly parallel after the cutting process, a thin rubber sheet was placed between the sample sides and the compression plates to ensure a more uniform pressure on the upper face of the sample.

2.2. Displacement and strain measurement using the grid method

The basics of the grid method is to deduce the displacements field by observing a grid that is transferred beforehand onto the surface of the sample [17,18].

The first step consists in transferring a grid onto the surface under investigation (the front face of the samples in the current case) using the technique described in [19]. Grids of pitch $p = 0.2$ mm are first printed in advance on a thin polymeric sheet using a high-resolution printer (50,000 dpi). This sheet is then bonded on the sample surface using a thin white adhesive layer. Once the adhesive is polymerized, the polymeric sheet is peeled off and the ink grid pattern stays on the white adhesive layer. Indeed, the adhesion of the ink is higher with the adhesive than with the polymeric sheet. It is worth noting that the procedure of grid transferring described in [19] involves a curing phase of 40 h at 37 °C to accelerate polymerization. To prevent heat deterioration of the sample, the glue polymerization is carried out at room temperature (20 °C) for one week. The thickness of obtained layer is typically few tenths of mm. In view of the low layer thickness, it can be reasonably assumed that the grid perfectly follows the deformation of the sample surface.

The next step consists of acquiring images of the grid by a camera at different loading stages. The camera employed here featuring a 14-bit/2048 × 2048 pixel CCD sensor (CCD = charge-coupled device) and equipped with a 105 mm lens. The discretization is set to 5 pixels per grid pitch. During the test, the grid was illuminated using cold light source that provides a quasi-uniform lighting of the grid. The camera captured about 1.83 frames/s. It was checked that with this configuration and with the prescribed displacement rate equal to 0.01 mm/s, a temporal image averaging of 4 frames could be performed without inducing any blurring of the grid images. Such averaging is introduced for noise reduction purposes [20]. Finally these images were processed after testing using an in–house algorithm [17,18]. The code used in this study