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Study of the influence of the mastic coating of reclaimed asphalt aggregates on the resilient modulus and long term behaviour with RLT tests.

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Abstract. Asphalt aggregates arise from the demolition of asphalt road layers. The ORRAP (Optimal Recycling of Reclaimed Asphalts in low-traffic Pavements) Project concerns the cold recycling of 100% Reclaimed Asphalts (RA) without binder addition in base and subbase layers of low-traffic roads. In this context, a test program was performed with Rhine Region materials to evaluate the impact of the mastic coating. A source of RA with 4.4% of bitumen is tested before (RAP) and after binder extraction (RAP-BE), then is compared to an unbound granular material (UGM) with a similar particle size distribution. Repeated Load Triaxial (RLT) tests were conducted to study the permanent and resilient behaviours. The results show that the RA before binder extraction and the UGM present similar permanent behaviours, while the aggregates without binder reveal low strains. Concerning the resilient phase, the reclaimed aggregates before and after extraction show similar levels of strains, but the resilient modulus of the UGM are significantly lower than those of the RA.

Keywords: Reclaimed asphalt aggregates, Mastic coating, Repeated load triaxial test, Mechanical behaviour.

1 Introduction

Many studies on recycling of asphalt aggregates have been carried out, in particular on the incorporation of Reclaimed Asphalts (RA) in hot asphalt mixtures [1, 2, 3], in warm processes by means of additives or foamed asphalts [4, 5], as well as in cold recycling with foamed or emulsion bitumen [6, 7]. However, the use without any addition, developed in Sweden [8], is still not widespread. In France, the cold strategy allows to reuse RA with high Polycyclic Aromatic Hydrocarbons (PAH) contents, rate up 500 mg/kg. The ORRAP (Optimal Recycling of Reclaimed Asphalts in low-traffic Pavements) Project concerns the cold recycling of 100% Reclaimed Asphalts (RA) without binder addition in base and subbase layers of low-traffic roads, instead of Unbound Granular Materials (UGM). In this framework, the effect of the mastic coating is studied, to measure the benefit of this recycling.

2 Material and test programme

2.1 Material characterisation

The tested Reclaimed Asphalts (RA) come from demolition of wearing courses of Rhine Region. This material is defined by 25 RA 0/14, according to the French Standard NF EN 13108-8 [9], where 25 is the maximum size of particles before binder extraction and 0/14 the grading of particles after binder extraction. The RA contain 4.4% of bitumen 10/20. This material is studied before and after binder extraction, then is compared to an Unbound Granular Material (UGM) with a similar particle size distribution (Fig. 1). The following Table 1 gives the main characteristics of the RA and the UGM. Unbound granular materials and asphalt mixtures represent the limits of the RA behaviour. Fig.1 displays the UGM 0/14 mm and the asphalt mixture 0/14 mm grading curves of the French Standards [10, 11]. The binder extraction releases fines, consequently the fines content (passing through the sieve 63 μm) is multiplied by four before and after extraction.

Table 1. Characteristics of the RA and the UGM.

| | RA before binder extraction | RA after binder extraction | UGM |
|--|-----------------------------|----------------------------|------|
| Grading (mm) | 25 AE 0/14 | 0/14 | 0/14 |
| Particle density (Mg/m^3) | 2.48 | 2.65 | 2.64 |
| Proctor maximum dry density (Mg/m^3) | 2.02 | 2.21 | 2.16 |
| Proctor optimum water content (%) | 5.86 | 5.31 | 7.60 |
| PAH content (mg/kg) | 298 | 0 | 0 |

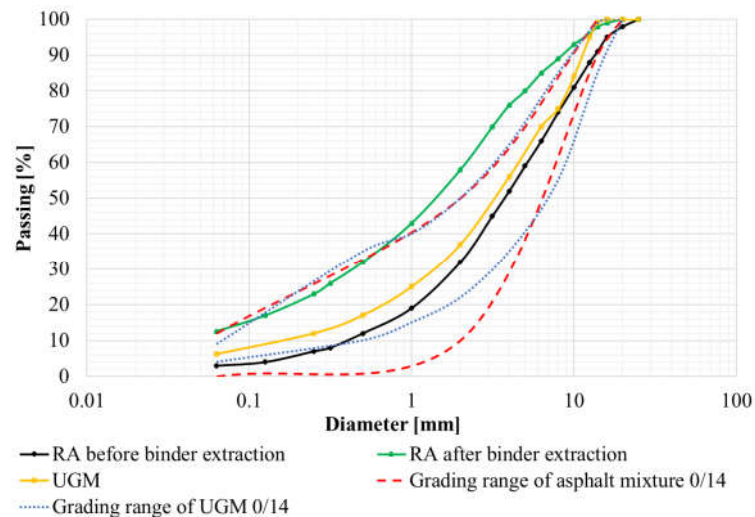


Fig. 1. Particle size distributions of the studied materials.

2.2 Sampling

The specimens are compacted using a vibrocompression method in one layer, by applying a vertical load and a horizontal vibration. The cylindrical sample is 0.16 m diameter and 0.32 height. The Table 2 presents the characteristics of different specimens.

Table 2. Characteristics of specimens.

| | RA before binder extraction | RA after binder extraction | UGM |
|--|-----------------------------|----------------------------|-------|
| Compaction density (Mg/m^3) | 1.96 | 2.14 | 1.96 |
| Void content | 0.27 | 0.24 | 0.35 |
| Porosity (%) | 21.1 | 19.29 | 25.85 |
| Water content (%) | 3.9 | 3.3 | 3.9 |
| Number of specimens | 3 | 2 | 2 |

2.3 Triaxial apparatus

The sample is placed in a triaxial cell, and a constant confining pressure is applied with air. A hydraulic actuator is used to apply a cyclic axial load. The specimen is instrumented with three Hall effect displacement transducers: two axial and one radial.

2.4 Repeated Load Triaxial (RLT) tests

The sign conventions are:

- The stresses are positive in compression.
- The axial and radial strains are positive in contraction.
- A positive (negative) volumetric strain indicates a contracting (dilating) behaviour.

RLT test is one of the most reliable experiments to analyse the permanent and resilient behaviours of unbound granular materials. The test principle, defined by the French Standard EN 13286-7 [12], consists of applying a cyclic axial stress σ_1 and a constant confining pressure σ_3 . Eqs. (1) and (2) define the deviator stress q and the mean stress p . During the test, the axial strains ε_1 and the radial strains ε_3 are measured, then the deviatoric strains ε_q and the volumetric strains ε_v can be calculated (Eqs. (3) and (4)).

$$q = \sigma_1 - \sigma_3 \quad (1)$$

$$p = (\sigma_1 + 2 \sigma_3)/3 \quad (2)$$

$$\varepsilon_q = 2(\varepsilon_1 - \varepsilon_3)/3 \quad (3)$$

$$\varepsilon_v = \varepsilon_1 + 2 \varepsilon_3 \quad (4)$$

The test presents two phases:

- The conditioning phase: application of a high stress level ($\Delta q=340$ kPa and $\Delta p=113$ kPa) over 30 000 cycles at 2 Hz to stabilise the permanent strains.
- The resilient test: application of several stress paths over 100 cycles at 2 Hz to study the elastic strains. Fig. 2 presents the several stress paths.

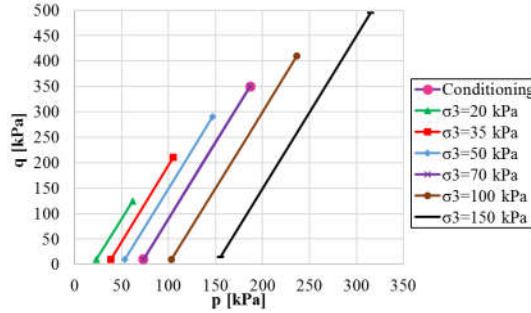


Fig. 2. Stress paths.

3 Experimental results and analysis

3.1 Conditioning phase

Fig. 3a and Fig. 3b show the evolution of axial and radial permanent strains. The RA before binder extraction and the UGM present similar permanent strains, particularly

for the axial strains. However, the permanent strains of RA after binder extraction are very low. The main explication is the fines content, in addition of the tested density and water content. The RA before and after extraction present respectively 3.0% and 12.6% of fines. According to Jing [13, 14], the quantity of fines has a significant benefit to rutting resistance, until a critical water content close to saturation. Indeed, before binder extraction the fines are trapped in the mastic coating, while after the extraction the fines are released and can reduce the rutting.

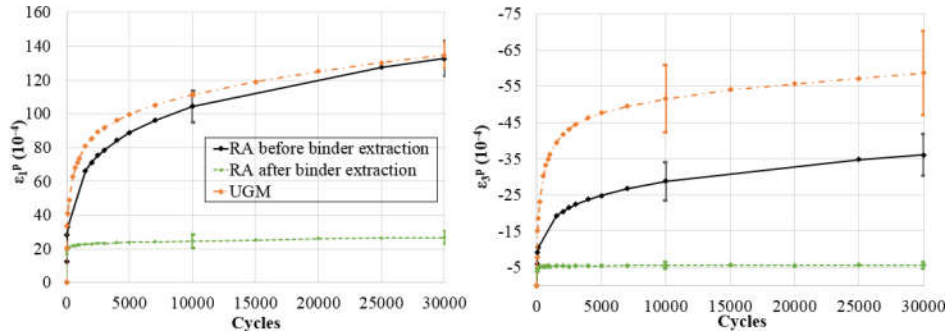


Fig. 3a. Evolution of axial permanent strains with standard deviation at cycles 10 000 and 30 000. **Fig. 3b.** Evolution of radial permanent strains with standard deviation at cycles 10 000 and 30 000.

3.2 Resilient test

For the sake of clarity, only maximum values of resilient strains are presented. Fig. 4a, Fig 4b and Fig. 4c display respectively the deviatoric and volumetric resilient strains as well as the resilient moduli. Eq. (5) defines the resilient modulus E_r .

$$E_r = \sigma_1^r / \epsilon_1^r \quad (5)$$

where σ_1^r is the axial resilient stress and ϵ_1^r the axial resilient strain.

Each material has a dilatant behaviour, except the RA at higher cell pressures. Thus, the higher confining pressure, the higher is resilient modulus. We notice that the UGM present high strains, while the RA before and after binder extraction have similar levels of strain. Finally, the resilient modulus of RA is significant, if we consider RA as an unbound granular material.

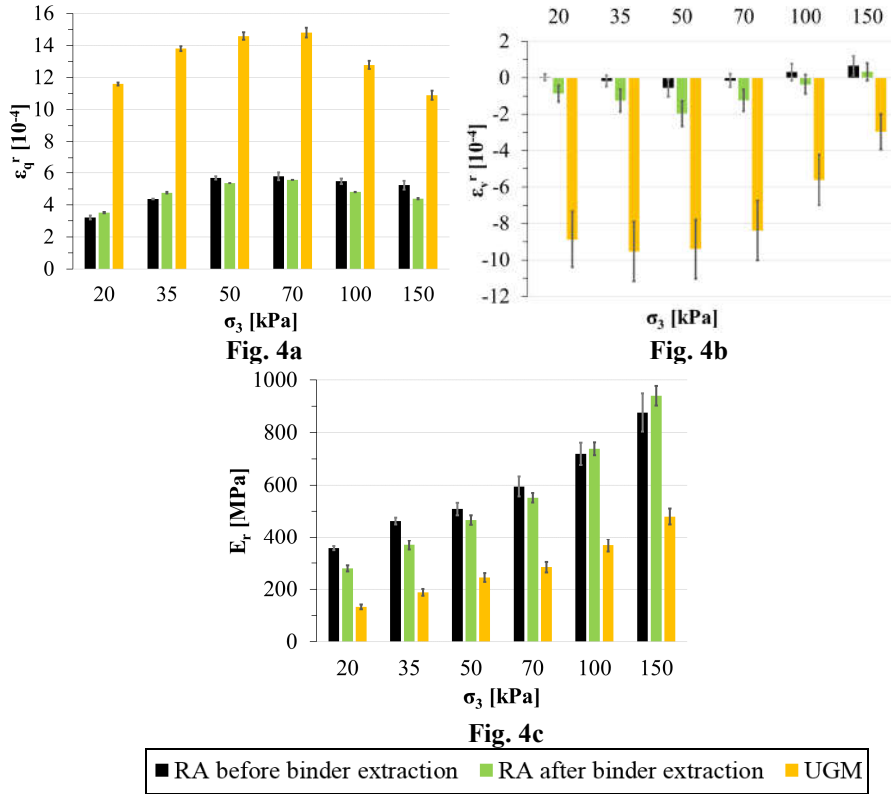


Fig. 4a. Resilient deviatoric strains. **Fig. 4b.** Resilient volumetric strains. **Fig. 4c.** Resilient modulus.

4 Conclusions

This paper reports some results of the study of a source of Reclaimed Asphalts (RA), with a high Polycyclic Aromatic Hydrocarbons (PAH) content. The difference between an unbound granular material and the RA is the smooth contact between the rigid particles. This contact has consequences on the permanent and resilient behaviours. First, the permanent strains of RA are high and outside specifications, according to the French Standard for Unbound Granular Materials (UGM) NF EN 13286-7 [12]. However, this conclusion is valid without curing, we can assume that mechanical performance improves over time. However, the RA present a higher level of resilient modulus than UGM. Consequently, these results confirm that the RA can be used instead of UGM, in base and subbase layers in low-traffic roads.

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