Thermo-mechanical properties of Hot Mix Asphalt containing high rates of Reclaimed Asphalt Pavement

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RÉSUMÉ. *Cette étude présente les performances thermomécaniques des enrobés bitumineux à chaud fabriqués avec l'agrégat d'enrobé (AE) conventionnel et régénéré. Six mélanges, contenant entre 40 et 70% d'AE, sont évalués et comparés avec une formule témoin (0% d'AE). Les performances à basse température sont mesurées à l'aide de l'essai de contrainte de traction uniaxiale (UTST) et de l'essai de retrait empêché sous contrainte thermique (TSRST). Les résultats mettent en évidence une température critique autour de -10 °C, car pour de valeurs supérieures à celle-ci les mélanges contenant d'AE présentent une résistance plus importante que celle de la formule témoin, mais pour les températures inférieures ce comportement est inversé. Cependant, l'utilisation d'un additive permet aux mélanges avec AE de récupérer partiellement les performances pour les températures inférieures à la valeur critique.*

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ABSTRACT. *This research presents the thermomechanical performances of hot mix asphalt (HMA) containing conventional and regenerated reclaimed asphalt pavement (RAP). Different mixtures containing 40 to 70% RAP are evaluated and compared to a control mix (without RAP). The performances at low temperature are measured through the Uniaxial Tension Stress Test (UTST) and the Thermal Stress Restrained Specimen Test (TSRST). The results put into evidence a critical temperature of about –10 °C such that above this temperature the mixtures containing RAP show higher strength than the control mixture and below this temperature, RAP mixtures exhibit lower performances than the control one. However, the use of an additive allows the RAP mixtures to partially recover properties at temperatures lower than the critical value.*

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MOTS-CLÉS : *enrobés bitumineux, essai de traction uniaxiale, essai de retrait empêché thermique, basse température, additif.*

KEY WORDS: *bituminous mixture, uniaxial tension test, thermal stress restrained test, low temperature, additive*

1. Introduction and background

The objective of this research work is to increase the rate of reclaimed asphalt pavement (RAP) in hot mix asphalt (HMA) without important loss of the thermomechanical performances by using an additive. An experimental laboratory program is developed involving two main steps: (i) composition and production of different mixtures with variable RAP content with and without the additive; (ii) testing of the thermo-mechanical properties of the mixes, especially at low temperatures. The material considered is a typical class-4 dense French asphalt known as grave-bitume (GB4). Information on the cracking resistance of RAP at low temperatures is relatively recent, and supposes a loss in performance [HUA 04, HAJ 09]. In order to compensate for performance loss in RAP mixtures, special binders and additives are introduced allowing an increase in RAP content. As a consequence, an increase in workability has been obtained [SIL 12, LOP 15). Moreover, the additives have enhanced the cracking resistance of RAP [LOP 11, LAR 15, POR 16].

2. Materials and test methods

Four different RAP contents are considered: 0 % (control mix); 40 %; 55 % and 70 %; the last three may contain or not an additive, which leads to seven different mixtures in total. Virgin aggregates come from massive rocks (sandstone quartzite), with a limestone filler; RAP aggregates are quartzite-eruptive. The penetration class of RAP binder is 10/20 and different grades of the virgin binder are used to ensure the same class (20/30) of the final binder for all the mixtures. For all the mixtures, the grading curve of the aggregates the final binder content (4.90 %) and the density are kept constant and in accordance with French standards. The additive employed (REGEFALT®) has the function of reducing the oxidized hydrocarbon components included in the RAP binder and to facilitate the interpenetration of the particles of old and new binders.

Two types of low temperature tests are performed using the equipment shown on Figure 1: the Uniaxial Tension Stress Test (UTST) at four different temperatures (+20 °C, +5 °C, -10 °C and -25 °C) and the Thermal Stress Restrained Specimen Test (TSRST) with an initial temperature of + 10 °C and a temperature gradient of -10 °C/h. For each condition, the tests have been repeated at least three times for repeatability sake.

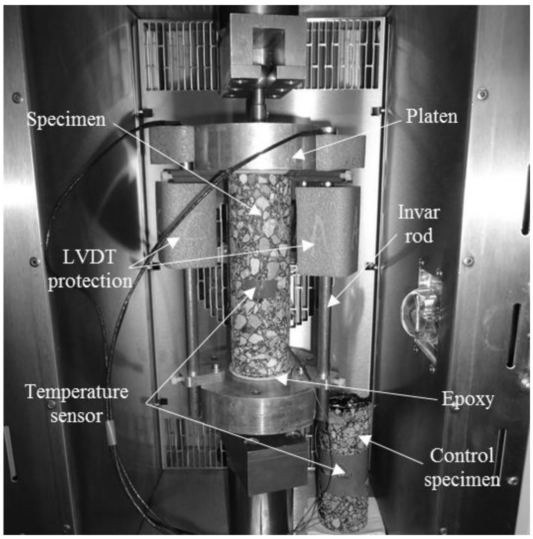

Figure 1. *Equipment for the low temperature tests in climate chamber.*

3. Uniaxial Tension Stress Test (UTST) results

In the following the mixtures will be identified by XR or XR'; X corresponding to the RAP content in percent, R and R' denote the absence and the presence of additive respectively. The tests are strain-rate controlled at 4,2 ± 0.8 10^{-6} s^{-1}. Typical stress-strain curves show two types of fracture (Figure 2): fragile fracture for low temperatures (- 25 °C ; - 10 °C) and ductile for higher ones (+ 5 °C ; + 20 °C). In the case of ductile fracture, the tensile strength β_t and the failure strain $\varepsilon_{failure}$ are taken at the maximum stress according to the standards.

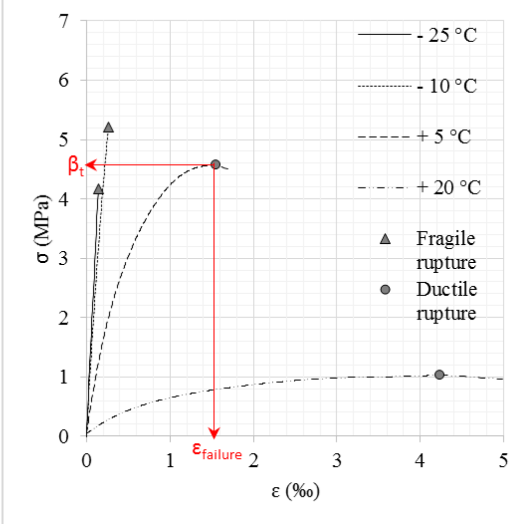

Figure 2. *Typical stress-strain response from UTST tests on 40R' mix (40 % RAP, no additive).*

The curves of the tensile stress versus the temperature (Figure 3 left) show that, compared to the control mix (0R) the RAP mixtures offer significant higher resistance for temperatures higher than -10 °C and slightly lower strength for temperatures less than -10 °C. The fragile-ductile transition temperature, corresponding to the maximum tensile strength reached, is deteriorated by the presence of RAP: from -15 °C for 0% RAP up to about 0 °C for 70% RAP. The additive enhances slightly the tensile strength of the mixes at low temperatures (about + 0,5 MPa at -25 °C). The failure strain differentiates the mixtures as the temperature increases (Figure 3 right): the higher the RAP content, the lower the failure strain due to the ageing of the binder; but at these positive temperatures the additive enhances significantly the failure tensile strain.

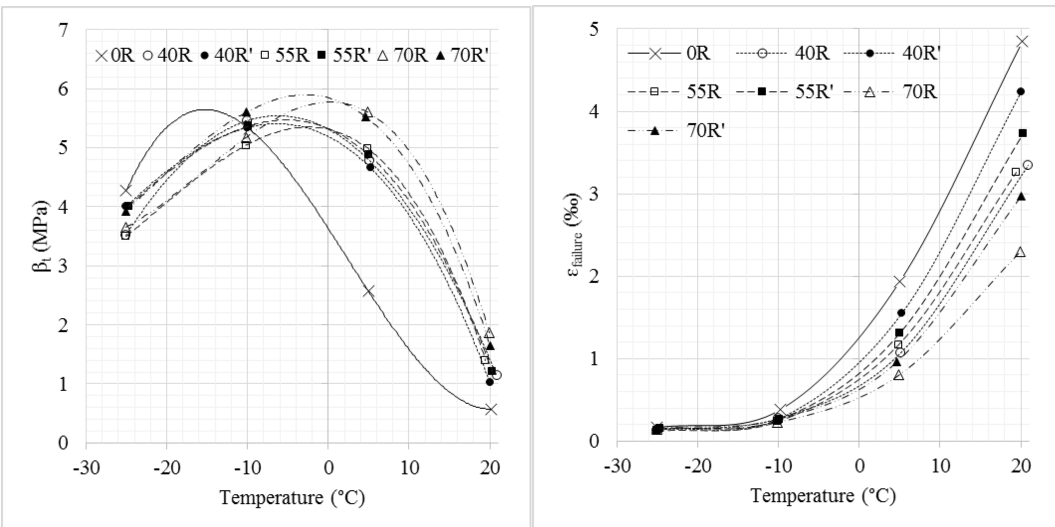

Figure 3. *Curves of tensile strength (left) and failure strain (right) versus temperature from UTST results.*

4. Thermal Stress Restrained Specimen Test (TSRST) results and conclusions

The TSRST simulates the thermal stress σ_{cry} produced in a longitudinally restrained pavement by an environmental temperature drop. The test results are characterized by the maximum stress reached $\sigma_{cry,failure}$ (cryogenic failure stress) and by the corresponding temperature $T_{failure}$. Moreover, a tensile strength reserve $\Delta\beta_t(T)$ at a given temperature T is defined as the difference between the tensile strength $\beta_t(T)$ and the cryogenic stress $\sigma_{cry}(T)$ derived respectively from UTST and TSRST tests. The tensile strength reserve corresponds to the allowable stress afforded to traffic when the pavement is submitted simultaneously to cryogenic stresses.

The results (Figure 4 left) show that for the mixtures containing RAP the cryogenic failure stress increase slightly with higher RAP content, but the mean value for all the RAP mixtures is similar to that of the control mixture. On the other hand, compared to the control mixture, the failure temperature of the RAP mixtures is deteriorated of about + 3 °C and is slightly enhanced by the additive. Compared to the control mixture, the tensile strength reserve (Figure 4 right) shows trends similar to the UTST results: greater strength reserve of RAP mixtures for temperatures higher than -10 °C and lower strength reserve for temperatures lower than -10 °C with a positive effect of the additive in this last temperature domain.

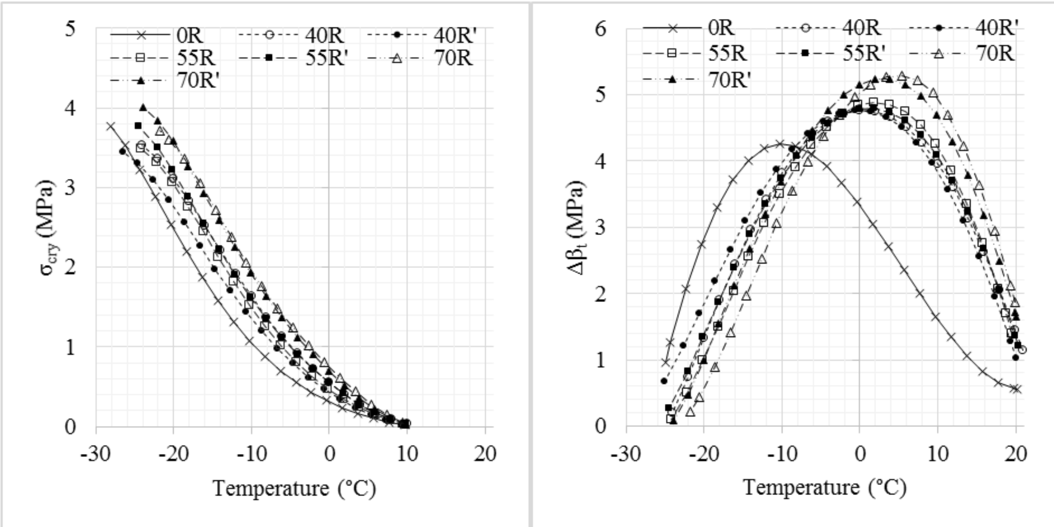

Figure 4. *TSRST results: cryogenic stress (left) and tensile strength reserve (right) vs temperature.*

As a conclusion, the mechanical performances measured on a set of bituminous mixtures with different RAP contents and the the introduction or not of an additive, have shown an increase of the tensile strength of the mixtures containing RAP at temperatures higher than a critical value of about -10 °C and a strength reduction at lower ones but this reduction is limited by using the additive.

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