Chapter 7
Studying with a Full-Field Measurement Technique the Local Response of Asphalt Specimens Subjected to Freeze-Thaw Cycles

M. C. Teguedi, B. Blaysat, E. Toussaint, S. Moreira, S. Liandrat, and M. Grédiac

Abstract Asphalt is a strongly heterogeneous material, whose global thermo-mechanical behavior is generally studied at a large spatial scale. Observing the local strain fields which occur between aggregates and mastic (i.e., asphalt binder + filler) is however crucial to understand the phenomena that influence the global response of such materials, and then better design them. In this study, full-field measurements were used to investigate the difference in behavior between various types of asphalt containing Recycled Asphalt Pavement (RAP). We focused here on their response when they were subjected to freeze-thaw cycles. The local contraction/expansion of the specimens subjected to various cooling/heating phases was observed with the grid method. The strain distribution has been found to be very heterogeneous because of the difference in coefficient of thermal expansion between aggregates and mastic. The influence of the percentage of RAP on the global response of the specimen is observed and discussed.

Keywords Recycled Asphalt • Thermal contraction/expansion • Strain field • Freeze-thaw • Grid method • Digital image correlation

In cold regions, pavements suffer from the thermal cracking caused by the contraction and expansion of asphalt under temperature changes. The thermal behavior of asphalt at the macroscopic scale has been widely studied using testing devices such as the Asphalt Thermal Cracking Analyzer (ATCA) [1] and the Asphalt Concrete Cracking Device (ACCD) [2]. However, since low temperature damages are initiated in the internal structure of asphalt mixtures, understanding the thermal response of asphalt components (bitumen and aggregates) is of great practical importance to have a better understanding of the overall thermal response of pavements. The major problem is however to measure the local thermal response of these materials.

Full-field measurement techniques, which have now widely spread in experimental mechanics, are useful to have a better understanding of the asphalt behavior under thermal loadings. In recent years, these methods have become major tools to inspect and characterize the mechanical response of such materials. The main full-field measurement methods that are used by the pavement community are the digital image correlation (DIC) [3–5] and more recently the grid method (GM) [6, 7]. This last technique was used here because it exhibits a good compromise between spatial resolution and measurement resolution [8], which is crucial here, the material under investigation being highly heterogeneous. Till now, the application of such measurement techniques for the characterization of asphalt was limited to their mechanical response, and few emphasis has been placed on the investigation of their thermal response.

In this study, four Hot Mixtures Asphalt (HMA) specimens with 0%, 20%, 40% and 100% of RAP (Recycled Asphalt Pavement) content were considered. These materials were used in a previous study, which was devoted to the characterization of the effect of RAP on the local mechanical behavior of recycled asphalt pavements [6]. These RAP materials are composed of granite, basalt and gneiss. The virgin materials are constituted from limestone aggregates and a virgin bituminous binder. Freeze-thaw tests were carried out on these materials. They were performed in a climate chamber at a temperature range of [−10 °C 20 °C]. At the global scale, the specimens exhibited an anisotropic behavior along both the vertical and horizontal directions. The comparison of the global strain-temperature curves showed that the inclusion of 100% RAP resulted in an increase of the Coefficient of Thermal Contraction (CTC) of the specimen. Typical examples of the displacement fields

M.C. Teguedi • B. Blaysat • E. Toussaint • M. Grédiac (✉)
Université Clermont Auvergne, Institut Pascal, BP 10448, 63000, Clermont-Ferrand, France

CNRS, UMR 6602, Institut Pascal, 63171, Aubière, France
e-mail: michel.grediac@univ-bpclermont.fr

S. Moreira • S. Liandrat
Département Laboratoire de Clermont-Ferrand (CEREMA, DterCE), Clermont-Ferrand, France

L. Lamberti et al. (eds.), *Advancement of Optical Methods in Experimental Mechanics, Volume 3*,
Conference Proceedings of the Society for Experimental Mechanics Series, DOI 10.1007/978-3-319-63028-1_7

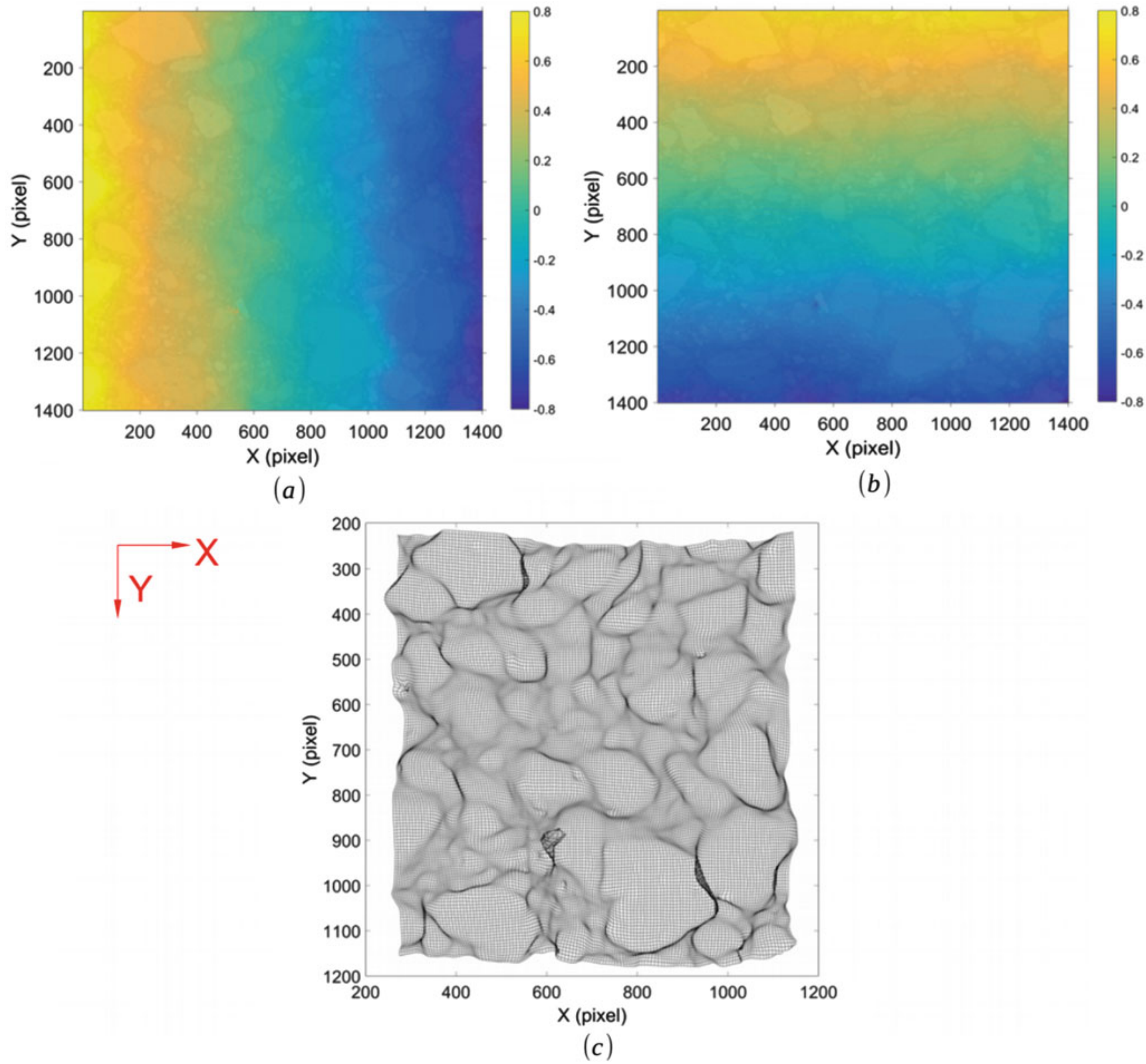

Fig. 7.1 Typical displacement fields for the 100% RAP specimen at T = −10 °C (in pixels, 1 pixel = 40 µm). (**a**) U_{xx}, 20% *RAP*. (**b**) U_{yy}, 20% *RAP*. (**c**) Magnified deformed mesh

obtained for the 100% RAP specimen at T = −10 °C are shown in Fig. 7.1. These displacements correspond to a difference in temperature equal to ΔT = −30 °C. The displacement fields presented in Fig. 7.1a, b clearly illustrate the global contraction of the specimen along the vertical and horizontal direction. From these results, it is visible that the specimen shrinks toward its center. Another representation of the displacement fields is proposed in Fig. 7.1c. In this figure, the displacement fields are used to deform a regular mesh to help the reader figure out the deformation of the specimen. The pitch of the mesh is equal to 10 pixels and the displacement multiplied by 350 to give a clearer idea on the deformation of the specimen. This presentation is expressed in the deformed configuration. The overall contraction of the specimen towards its center is clearly visible. This contraction is mainly sustained by the mastic. Strain maps which are deduced from these displacement maps then enable us to characterize, among others, the in-situ coefficient of thermal expansion of the binder.

Finally, it can be concluded that the paper brings new information on the thermal contraction/expansion of asphalt materials at length scales ranging from binder to the mixture scales. In particular, it was possible to quantify the influence of the RAP on this response.

Full details on these experiments can be found in [9].

References

1. Stimilli, A., Canestrari, F., Teymourpour, P., Bahia, H.U.: Low-temperature mechanics of hot recycled mixtures through Asphalt Thermal Cracking Analyzer (ATCA). Constr. Build. Mater. **84**, 54–65 (2015)
2. Akentuna, M., Kim, S.S., Nazzal, M., Abbas, A.R., Arefin, M.S.: Study of the thermal stress development of asphalt mixtures using the Asphalt Concrete Cracking Device (ACCD). Constr. Build. Mater. **114**, 416–422 (2016)
3. Romeo, E.: Two-dimensional digital image correlation for asphalt mixture characterisation: interest and limitations. Road Mater. Pavement Des. **14**(4), 747–763 (2013)
4. Ktari, R., Millien, A., Fouchal, F., Pop, I.O., Petit, C.: Pavement interface damage behavior in tension monotonic loading. Constr. Build. Mater. **106**, 430–442 (2016)
5. Hill, B., Buttlar, W.G.: Evaluation of polymer modification in asphalt mixtures through digital image correlation and performance space diagrams. Constr. Build. Mater. **122**, 667–673 (2016)
6. Teguedi, M.C., Blaysat, B., Toussaint, E., Moreira, S., Liandrat, S., Grédiac, M.: Applying a full-field measurement technique for studying the local deformation in reclaimed asphalt pavements. Constr. Build. Mater. **121**, 547–558 (2016)
7. Teguedi, M.C., Toussaint, E., Blaysat, B., Moreira, S., Liandrat, S., Grédiac, M.: Studying the influence of the reclaimed asphalt pavement (RAP) on local deformation properties of asphalt mixtures. In: Zhu, Y., Zehnder, A.T. (eds.) Experimental and Applied Mechanics, pp. 159–163. Springer International Publishing (2017)
8. Grédiac, M., Blaysat, B., Sur, F.: A critical comparison of some metrological parameters characterizing local digital image correlation and grid method. In revision
9. Teguedi, M.C., Toussaint, E., Blaysat, B., Moreira, S., Liandrat, S., Grédiac, M.: Towards the local expansion and contraction measurement of recycled asphalt pavements (RAP) exposed to freeze-thaw cycles. Constr. Build. Mater. **154**, 438–450 (2017)

M. Grédiac 1989: PhD, University of Lyon, France; 1991–1997: Assistant professor, University of St-Etienne, France; 1997-date: professor, Université Clermont Auvergne, Clermont-Ferrand, France.