engineering proceedings

MDPI

Abstract

Bituminous interlayers thermomechanical behaviour under small shear strain loading cycles with 2T3C apparatus: Hollow Cylinder and Digital Image Correlation†

Thien Nhan Tran *, Salvatore Mangiafico, Cédric Sauzéat, Hervé Di Benedetto

University of Lyon/ENTPE, LTDS (CNRS 5513), France
* Correspondence: thiennhan.tran@entpe.fr
† Presented at the 1st International Online Conference on Infrastructure, 07-09 June 2022

Keywords: bituminous mixture, interface, shear loading, DIC technology

1. Introduction: A road/airport pavement is a multi-layered structure generally composed of several layers of bituminous materials, cement-bound materials on unbound granular materials. In the design phase, the different bituminous layers are considered perfectly bonded and therefore expected to work as a unique structure throughout the service life of the pavement. However, due to environmental, traffic and/or material-related conditions, the quality of the bond varies in time. The layers in the structure tend to work more and more independently with degrading bonding capacity, which induces a reduction of the pavement life. Therefore, the mechanical behavior of the interface between bituminous layers has been recently studied with original approaches. There were tests developed to focus on the interface study, for example Ancona shear testing research and analysis device at the Marche Polytechnic University [1-3], the shear-torque fatigue testing device at the University of Limoges [4-5] and other tests [6]. Most of the studies on this topic present several limits. One or few loading configurations can be applied to the sample (for example, pure shear of the interface) and studies focus only on the interface strength. Moreover, stress and strain fields within the sample are not homogenous, therefore not allowing investigating the intrinsic mechanical behaviour of the interface. In this study, the 2T3C ("Torsion, Traction/Compression sur Cylindre Creux" in French, Torsion, Traction/Compression on Hollow Cylinder) apparatus developed at ENTPE is used to investigate the behaviour of a bituminous interface under shear loading and small strain cycles.

2. 2T3C apparatus: The device consists of different basic parts: (1) a servo-hydraulic press capable of imposing axial and shear loading (cyclic or monotonic) on a hollow cylindrical specimen, equipped with a thermal chamber controlling the temperature; (2) four cameras gathered by pairs used to perform digital image correlation (DIC) analysis, in order to determine the three-dimensional strain field in upper and lower layers and calculate the relative displacements at the interface between different layers; (3) several displacement sensors around the specimen to control its global deformation: one pair of noncontact sensors to control displacements in the vertical direction, and another pair to control torsional displacement. The sample has a total height of 125 mm, an outer radius of 86 mm and an inner radius of 61 mm. The small thickness of the cylindrical wall of the sample allows considering quasi-homogeneous strain and stress fields.

3. Material and experimental procedure: The sample tested in this study is composed of two different bituminous layers (classically used in France as base and surface layers) with an interface in between made of a tack coat (bitumen emulsion). The sample was cored from a slab produced by successive compaction of the two layers using a wheel compactor. The sample was tested at 0°C, 10°C, 20°C, 30°C and 40°C by applying sinusoidal torsion at 5 different frequencies, 0.01, 0.03, 0.1, 0.3 and 1Hz. The global shear strain amplitude applied was 200µm/m, while normal stress was maintained at 0MPa during the test. The two pairs of cameras were placed in two opposite sides of the sample and each camera took 50 photos per loading cycle (but 35 photos per loading cycle at the loading frequency of 1Hz). A specific analysis [7,8] was developed at ENTPE to compute the strains in both layers and the displacement gap at the interface.

4. Results: The complex shear moduli $G_{\theta z}^*$ of the two bituminous mixtures (upper and lower layers) were obtained. Since Time Temperature Superposition Principle is validated for them, master

Citation: Tran, T. N.; Mangiafico, S.; Sauzéat, C.; Di Benedetto, H. Bituminous interlayers thermomechanical behaviour under small shear strain loading cycles with 2T3C apparatus: Hollow Cylinder and Digital Image Correlation. *Eng. Proc.* **2021**, *3*, x. https://doi.org/10.3390/xxxxx

Published: date

curves are plotted at 20°C (Fig.1a for the norm and Fig.1b for the phase angle). Corresponding shift factors are plotted on Fig.1c. As the two mixtures, also the interface show a viscoelastic behaviour. Its complex shear stiffness $K_{\theta z}^*$, defined as the ratio of shear stress amplitude over the torsional displacement amplitude at the interface, could then be determined. This interface parameter exhibits similar evolution with temperature and frequency as the viscoelastic parameter $G_{\theta z}^*$. It is then possible to plot its master curves (norm and phase angle), which are also shown on Fig.1.

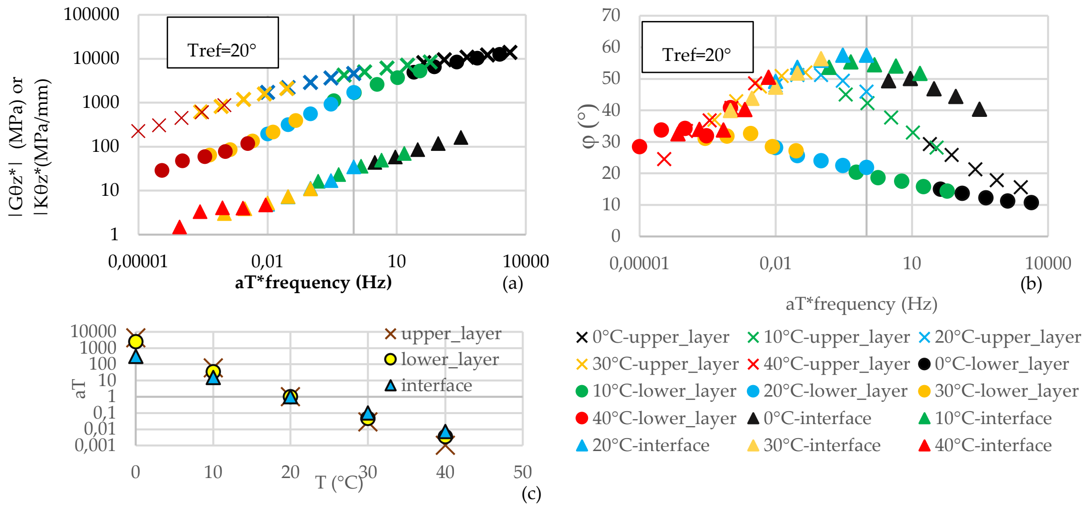

Figure 1: Master curves at 20°C and shift factors of complex shear moduli of upper and lower layer and complex shear stiffness of the interface (a, norm; b, phase angle; c, shift factors)

5. Discussion: The viscoelastic behavior of a multilayered sample composed of two mixtures, as well as their interface, was successfully investigated using the 2T3C apparatus. The DIC technology allows determining a displacement gap at the interface as low as 1-2µm. These results show the potential of the device and the carried-out analysis.

Author Contributions: Thien Nhan Tran: Conceptualization, Methodology, Formal analysis, Investigation, Writing. **Salvatore Mangiafico**: Conceptualization, Methodology, Supervision. **Cédric Sauzéat:** Conceptualization, Methodology, Supervision.

Acknowledgements: The authors acknowledge the company EIFFAGE for providing materials in this study

Conflicts of Interest: The authors declare no conflict of interest

References

1. F. Canestrari et al. *9 RILEM State-of-the-Art Reports Mechanical Testing of Interlayer Bonding in Asphalt Pavements (2013)*
2. F. Canestrari, Gilda Ferrotti, and Andrea Graziani. *Shear Failure Characterization of Time–Temperature Sensitive Interfaces*. Mechanics of Time-Dependent Materials, 2016, 20(3): pp.405-419
3. A. Graziani, F. Canestrari, F. Cardone, and G. Ferrotti. *Time–Temperature Superposition Principle for Interlayer Shear Strength of Bituminous Pavements*. Road Materials and Pavement Design, 2017, 18(March): pp. 12–25
4. D. Ragni, G. Ferrotti, C. Petit, and F. Canestrari. *Analysis of Shear-Torque Fatigue Test for Bituminous Pavement Interlayers*. Construction and Building Materials,2020, 254: 119309
5. D. Ragni, N. Sudarsanan, F. Canestrari, and Y. Richard Kim. *Investigation into Fatigue Life of Interface Bond between Asphalt Concrete Layers*. International Journal of Pavement Engineering, 2021, 0(0): 1–15
6. F. Canestrari et al, *Interlaboratory Test to Characterize the Cyclic Behavior of Bituminous Interlayers: An Overview of Testing Equipment and Protocols*, Proceedings of the RILEM International Symposium on Bituminous Materials (2022)
7. T. Attia, H. Di Benedetto, C. Sauzéat, S. Pouget, *3T2C HCA, a new hollow cylinder device using Digital Image Correlation to measure properties of interfaces between asphalt layers*, Construction and Building Materials, 2020, 247:118499
8. T. Attia, H. Di Benedetto, C. Sauzéat, S. Pouget, *Behaviour of an interface between pavement layers obtained using Digital Image Correlation*, Materials and structures, 2021, 54:38