First-year asphalt mixture results from a European in situ Ageing Consortium (EurIAC)

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ABSTRACT: Ageing of asphalt pavements is an inevitable phenomenon that reduces the overall lifespan of the road network. Typically, this process is simulated in the lab, however several climatic factors are often overlooked in such simulations. To evaluate the ageing effects more realistically, a network of universities in six Western-European countries was established in the summer of 2023. This paper reports the first-year results of in situ climatic conditioning and its effect on a reference asphalt mixture. Asphalt slabs were assessed for their mechanical performance via indirect tensile strength and resilient modulus. The findings depict slight differences between the participating labs concerning these properties, with the majority of them pointing to slightly increased modulus values ascribed to ageing. The extent of mix properties changes, yet in the early stages of long-term ageing, is still insignificant. Finally, a moderate positive correlation was found between the two asphalt mixture properties which can collectively explain the regional differences across Europe in the near future. Correlations with the changes at the binder level will also be considered as well as the linkage to the climatic history, as additional results will become available over extended time intervals.

1 INTRODUCTION

Ageing of asphalt mixture is one of the governing factors that affects the service life of pavements (Cavalli et al., 2018). Typically, bitumen is the binding medium of asphalt mixtures and due to its organic nature, it is prone to degradation under climatic conditioning (Pipintakos et al., 2024). Hence, considerable efforts have been made to simulate the in situ climatic conditions in the laboratory. A variety of ageing protocols persist at both binder (i.e. pressure ageing vessel) and mixture levels (i.e. ageing of loose or compacted asphalt mixtures), including testing under different temperatures and atmospheric conditions (Jacobs et al., 2023; Ma et al., 2022; Mirwald et al., 2020). However, most of these attempts are rather accelerated simulations of in situ conditions and the exact history of the climatic conditions, such as solar radiation, humidity and temperature, is challenging to be considered. Additionally, a few studies have investigated the influence of realistic field conditions with a primary focus on quantifying the effects of ageing gradients, air void percentage, and film thickness (Jing et al., 2021; Song et al., 2022; Zhang et al., 2022). Despite these efforts, a factor that is often missing for a thorough understanding and fair comparison of the effects of climatic conditions is the incorporation of a reference mixture into the experimental matrix, considering the different climatic regions.

Inspired by the paradigm of ongoing international efforts at a global scale (Adwani et al., 2023), current joint efforts in Europe, by means of a European in situ Ageing Consortium (EurIAC), try to elucidate these effects. This is realised by taking into account the specific climatic conditions, such as temperature, moisture, and UV/VIS history, among others, for a reference and local mixtures exposed to various climatic regions, assessed at different time intervals. The assessment of climatic data was performed on both binder and asphalt mixture levels, with an optimum future goal to link the changes in performance with the climatic data that will be recorded for a total duration of seven years in six European countries. Moreover, a European ageing model will be developed as an output of this collaborative work. This work reports on the first set of reference mixtures.

2 MATERIALS & METHODS

2.1 *Participating laboratories*

Six laboratories are participating in this study, as shown in

Table 1. Climate classifications according to Köppen system are also included, from which it can be seen that the majority of them are classified as temperate

oceanic climate (Cfb) regions, which is representative of a significant part of Europe (Beck et al., 2006).

Table 1: Overview of participating laboratories and their climate classification

Laboratory	Köppen Climate classification
University of Antwerp	Cfb
TU Delft	Cfb
EMPA	Cfb
TU Wien	Cfb/Dfb
University of Minho	Csb
Aristotle University of Thessaloniki	Bsk/Bsh

The results in this paper are anonymised, thus, the order of the labs in Table 1 does not necessarily correspond to the order of the graphs in the results section or to the images of the in situ slabs.

2.2 *Materials*

The reference mixture was a typical dense-graded asphalt concrete surface layer (hereafter referred as AC10) prepared with 5.8% (in total mixture) of 50/70 penetration grade binder, having a design air void content of 5.6%. The aggregates used for the mixture were porphyry (2/4, 4/6 and 6/10) limestone (0/2) and natural, round sand (0/1). Figure 1 shows the gradation of the AC10 surface mixture.

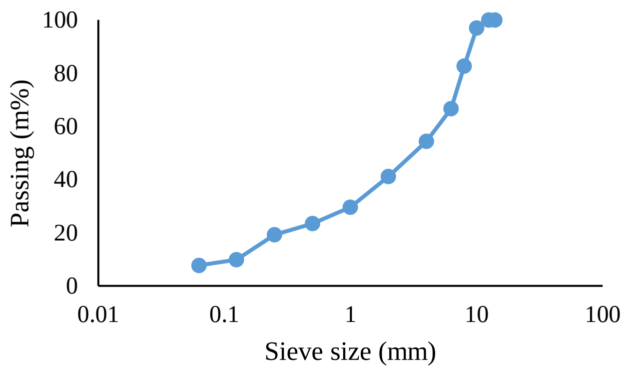


Figure 1: Gradation of the AC10 surface mixture

The mixture was produced in one of the laboratories in accordance with EN 12697-35 using an automatic mixer to avoid variations due to slightly different lab mixture production procedures, which could influence the results. Afterwards, the mixture was compacted in slabs of 60x40x5 cm as per EN 12697-33. Each laboratory received three slabs, having similar average air void contents, determined using the geometrical method. The slabs were placed outside on a flat surface in the summer of 2023 (between July and September), and were subjected to the local environmental conditions (no cover from precipitation or solar radiation) as shown in Figure 2.

Figure 2: In situ slabs of all participating partners

2.3 *Experimental Methods*

2.3.1 *Coring*

Each participating partner is asked to drill four cores of 100 mm diameter at regular time intervals of 0.5, 1, 2, 3, 5, and 7 years. A minimum distance of 40 mm was maintained between the cores and the slab edges as well as between two cores to minimise the impact of ageing from the sides and of the other cores. In addition, each laboratory received four cores of 100 mm diameter, cored at the mixture-producing lab, which were tested to obtain reference results at zero months (0m), corresponding to short-term ageing. After coring, the specimens were dried to constant mass at room temperature and the mass alongside the dimensions of each specimen was measured.

2.3.2 *Resilient modulus*

The stiffness (resilient modulus) of the samples was assessed for 4 replicates per ageing time interval according to EN 12697-26, annex C (IT-CY) at 15 °C. The test was performed with a load rise time of 80 ms with a maximum allowable horizontal deformation of 6.5 µm. Further, two readings were obtained per replicate as proposed in the test standard. The average resilient modulus and corresponding standard deviation were determined for each laboratory based on these 8 measurements (4 samples, each tested in two directions).

2.3.3 *Indirect Tensile Strength*

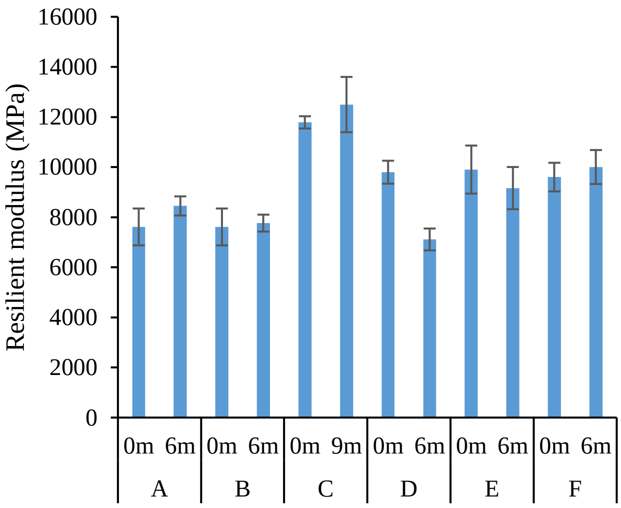
After the non-destructive stiffness test, the indirect tensile strength (ITS) was determined as per EN 12697-23 by applying a loading rate of 50 mm per minute at 15 °C. The peak load P, together with the average height H and diameter D, were used to calculate the ITS value according to Equation 1.

$$ITS = \frac{2P}{\pi DH} \quad (1)$$

3 RESULTS & DISCUSSION

3.1 *Resilient modulus*

The resilient modulus results obtained in different laboratories are presented in Figure 3. As shown in Figure 3, two measurements were made by the participating organisations, where 0m refers to results without in situ ageing and acts as the t=0 time interval, while 6m corresponds to in situ ageing at t=6 months. However, laboratory C performed the tests after 9 months instead of 6, whereas the values for 0m were similar for A and B since the mixture testing was performed at the same laboratory due to limitations of testing facilities. Samples after in situ ageing were shipped between these two labs.



In general, considering the standard deviations, the

Figure 3: Resilient modulus results for all labs and time intervals 0 and 6 months

differences between the average resilient modulus of the reference and aged mixtures after 6 months, were rather limited. Nevertheless, some differences can be observed. Laboratory C obtained a higher resilient modulus compared to all other labs. Further, the difference before and after 6 months of ageing was significant in laboratory D, with a drop in average resilient modulus of over 2500 MPa. The majority of the laboratories (A, B, C and F) showed a slight increase in average resilient modulus, as can be expected after in situ ageing.

3.2 *ITS*

Figure 4 shows the ITS results for labs A to E, since for laboratory F this test was not performed. Similarities between the resilient modulus and ITS results were noticed with some exceptions within the testing repeatability for labs A, B, and E. A significant drop in ITS after 6 months of ageing was recorded by laboratory D, corroborating with the resilient modulus results and clearly depicting a change in mixture performance. Based on these observations, it is likely that the properties of the drilled asphalt cores at t=0 differed significantly from the cores extracted at laboratory D after 6 months.

The ITS values of laboratory C were slightly higher compared to others but not to the same extent as can be seen in the resilient modulus results. The similarities and trends observed between ITS and resilient modulus results led to a more in-depth exploration of the potential correlation between the two tests, which is elaborated in the next subsection.

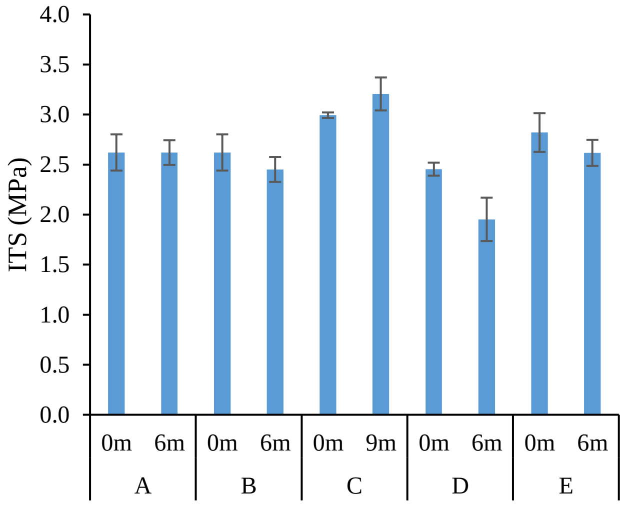


Figure 4: ITS results for labs A-E and time intervals 0 and 6 months

3.3 *Correlation between modulus and ITS*

Figure 5 displays the resilient modulus and ITS of the individual samples for laboratories A to E. This allows a visual assessment of the correlation between the two parameters and the variance in testing results. The dashed line is a linear trendline ($R^2 = 0.563$) that confirms a positive, though moderate, correlation be-

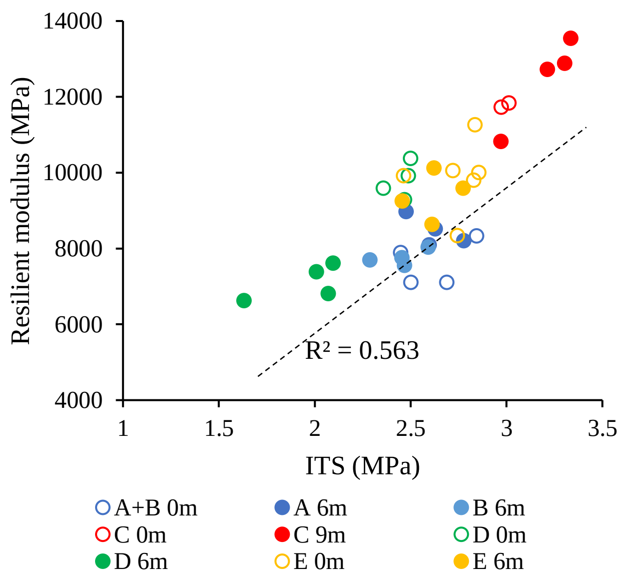


Figure 5: Resilient modulus vs ITS for labs A-E

tween the resilient modulus and ITS. However, the graph shows individual differences and trends for different labs that may be generated by the sample size and test type, which supports the use of both tests.

The first apparent observation from Figure 5 is that despite expectations, the correlation for the 0m results was not better. In the same graph, one can observe that laboratory C clearly distinguishes itself with relatively high values for ITS and resilient modulus, while maintaining increased ITS values after in situ ageing. On the other hand, labs D and E showed slightly decreased ITS and resilient modulus values after 6 months of in situ ageing. Finally, the results for labs A and B were similar before and after ageing. Therefore, it can be concluded that the trends are diverse and that future testing at multiple time intervals can help in establishing a clear relationship between the effects of ageing duration, climatic conditions, and mechanical performance.

4 CONCLUSIONS & RECOMMENDATIONS

This paper reports the results of the first-year in situ ageing at the asphalt mixture level of a collective effort of six European countries. The conclusions and recommendations are summarised herein.

- The effect of climatic conditions in different European regions is rather negligible for both ITS and resilient modulus after 6 months in situ.
- Four out of six participating laboratories showed a slight increase in resilient modulus, while the same increase was less obvious in the ITS results.
- Possible performance deviations at t=0 may have been introduced by testing device calibration errors.
- A moderate positive correlation exists between the ITS and resilient modulus results when accounting for both ageing time intervals.
- The differences between the asphalt specimens of the participating laboratories can be better highlighted via the correlation between ITS and resilient modulus.
- The consideration of both parameters to capture trends and understand testing deviations is crucial for the next in situ years.

During the forthcoming ageing time intervals of this project, the consortium will carefully assess possible testing device deviations and the origin of them. Moreover, correlations with the climatic data will be performed. Ongoing investigations of EurIAC will include extraction and recovery of bitumen at different depths for a chemo-mechanical evaluation of the ageing gradients in order to potentially link them with the mixture performance and the climatic data.

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