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Effect of Ageing on Fatigue Properties of Sulphur Extended Asphalt Mixtures

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Introduction

Sulphur-Extended Asphalt

Sulphur extended asphalt mixtures have traditionally been used in order to enhance stiffness and thereby to produce base materials with more resistance to permanent deformation. In this work sulphur was added to the mixture in the form of pellets. The pellets are added to the hot asphalt mixture (aggregate and bitumen) during the mixing process (Figures 1&2). As the bitumen is extended by sulphur, bitumen content is usually reduced. However, with the increase in stiffness comes the possible reduction in the fatigue properties. Of particular concern was the sulphur modified mixture's susceptibility to ageing and its effect on fatigue properties.


Figure 1. Sulphur pellets


Figure 2. Mixer and fume extractor

Objective

The overall aim of this research study was to characterise the performance (in terms of stiffness and fatigue) of both a control and a sulphur modified mixture when subjected to age conditioning.

Experimental Procedure

Mixtures

- ❑control mix (20 mm DBM, 4.7% of conventional 40/60 pen bitumen by mass of total mixture);
- ❑sulphur modified mix (20 mm DBM, 30% modified sulphur pellets to 70% bitumen, blended with workability additive, by mass). The volume of total binder (i.e. bitumen and additives) was maintained equal to the volume of bitumen in the control mix.

Testing Procedure

- ❑Test Applying Indirect Tension to Cylindrical Specimens (IT-CY, BS EN 12697-26: 2004), was used to quickly assess the effect of ageing on stiffness and thus define a suitable age conditioning protocol for more fundamental testing (Figure 3).
- ❑ Two-Point Bending Test (2PB, BS EN 12697-26: 2004 & BS EN 12697-24: 2004) was used to perform both Dynamic Mechanical Analysis (DMA) and fatigue to widen the understanding of the effects of ageing on the mechanical and fatigue properties of control and sulphur modified mixtures (Figure 4).

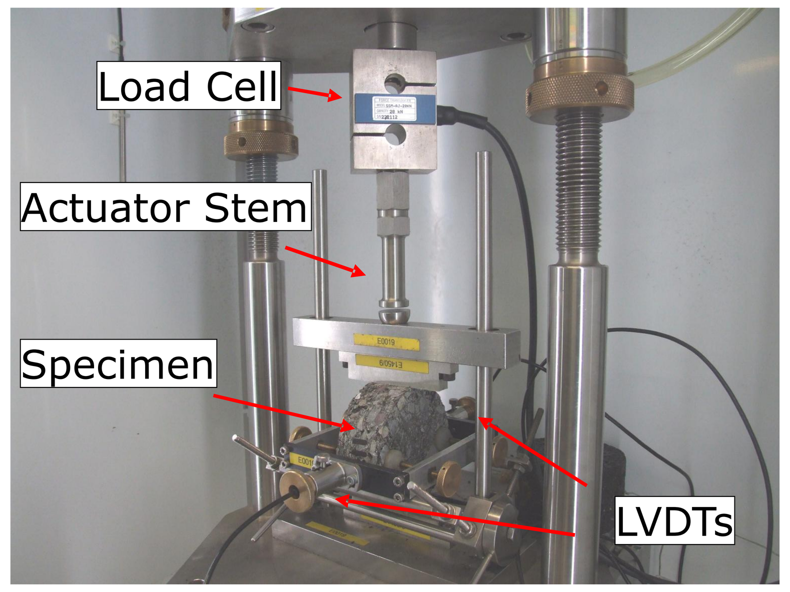

Figure 3. IT-CY apparatus

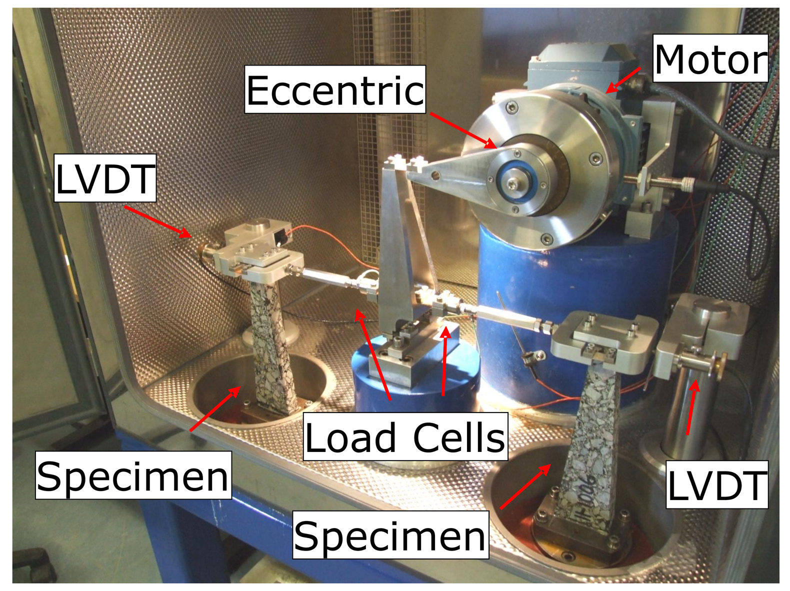

Figure 4. 2PB apparatus

Age Conditioning Protocol

Preliminary IT-CY Testing

Unconditioned stiffness was determined on the sulphur modified mixture at 20ºC (IT-CYu). The samples were then aged at 85ºC for a period of time of 24 hours per cycle. Then the conditioned IT-CY was determined for each conditioning cycle (IT-CYci). Stiffness ratio (IT-CYRatio,ci=IT-CYci/IT-CYu) was plotted against time (hours of conditioning) as depicted in Figure 5.

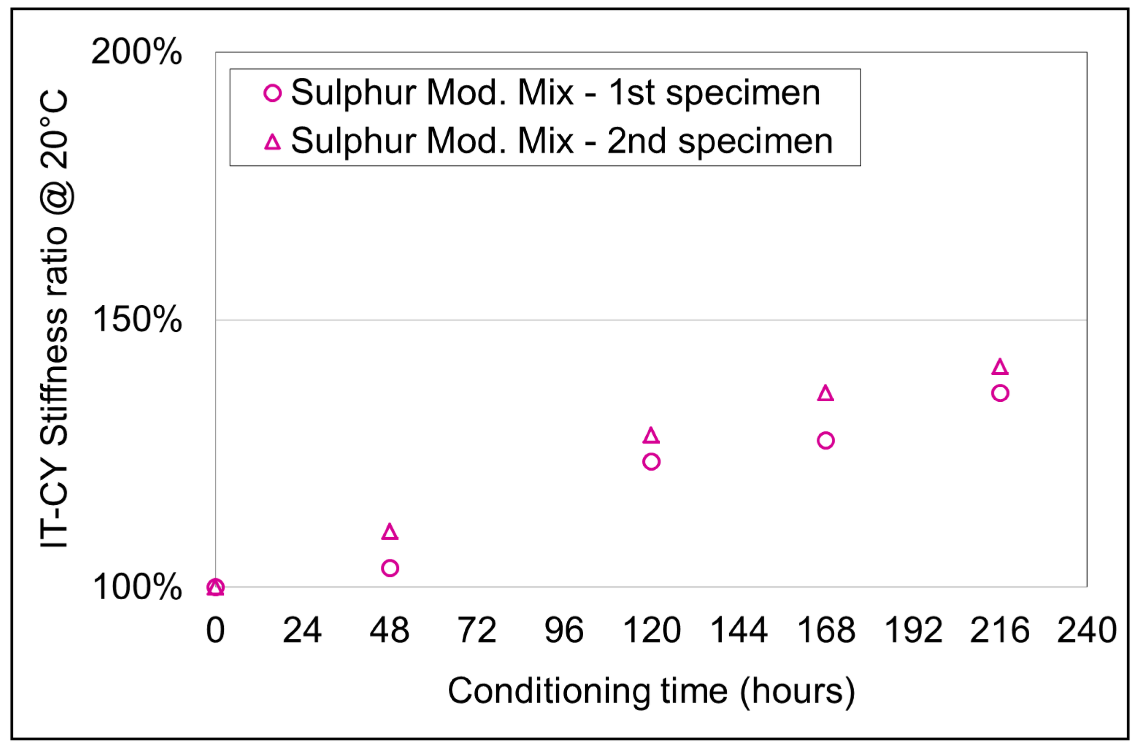

Figure 5. IT-CY ratio at 20ºC

Two-Point Bending Tests

Two sets of specimens for the control and the sulphur modified mixtures were selected. One set for each mixture was tested unconditioned whereas the remaining two sets were aged at 85ºC for 9 days. DMA (Figure 6) and fatigue (Figure 7) analysis were then undertaken and the results obtained on the conditioned and unconditioned specimens were compared. It can be seen from the results, that despite the stiffness gain, the fatigue properties of the sulphur modified mixture compare well with the fatigue properties of the control mixtures.

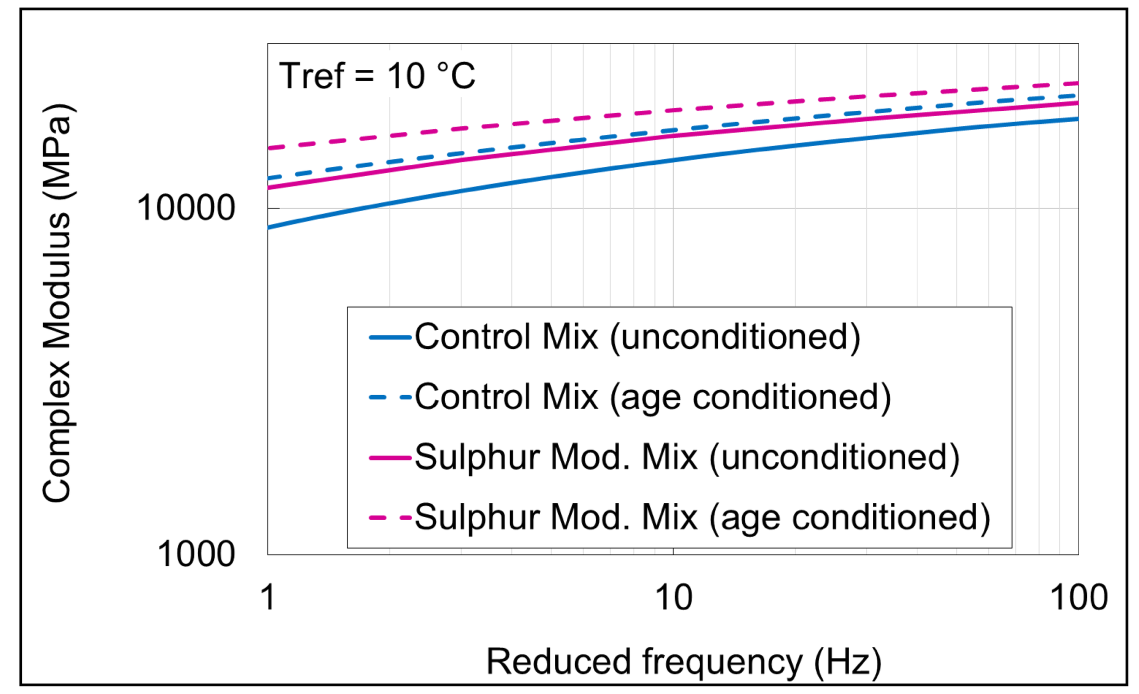

Figure 6. Age conditioning: complex modulus master curves

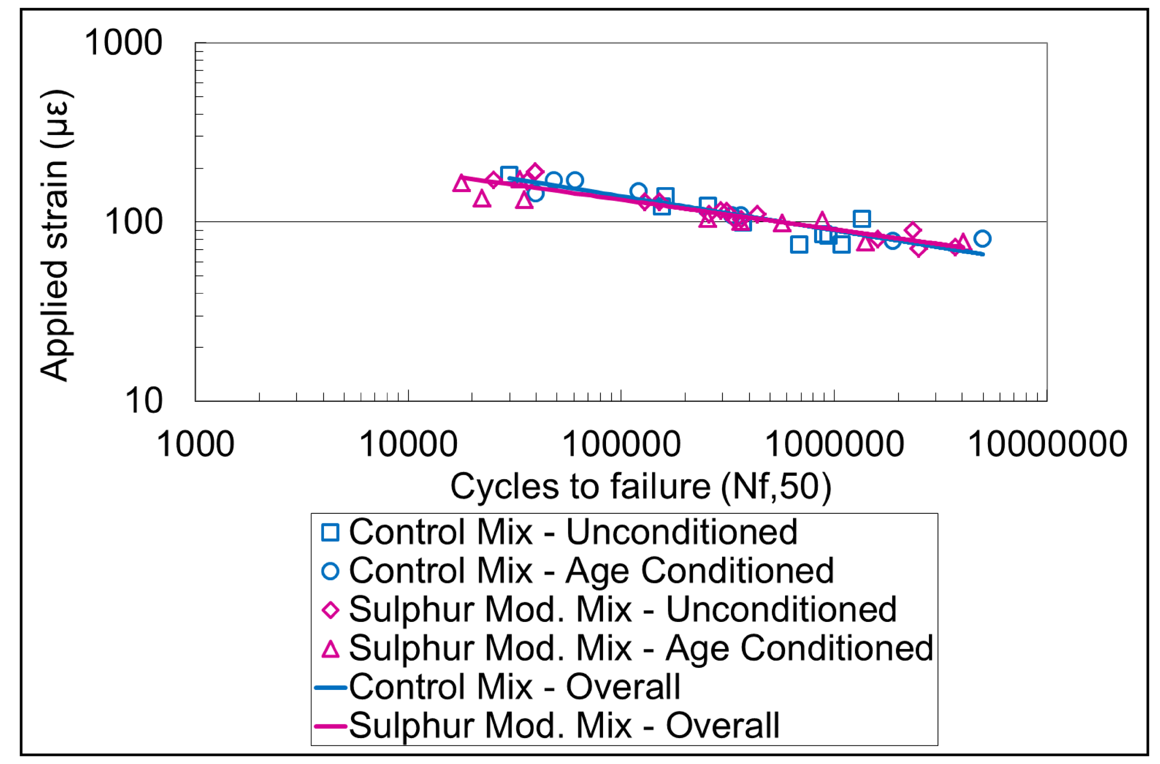

Figure 7. 2PB controlled strain fatigue tests at 10ºC and 25 Hz

Conclusions

- ❑ After 9 days of age conditioning the sulphur modified mixture, IT-CY carried out at 20ºC showed an increase in stiffness of approximately 40%.
- ❑ From the DMA results it can be concluded that the age conditioning protocol (temperature of 85ºC for 9 days) increases the properties of both the control and the sulphur modified mixtures in terms of stiffness.
- ❑ DMA, carried out on both mixtures after the age conditioning protocol, showed an increase in stiffness of approximately 20% for both mixtures tested at a lower temperature of 10ºC and a frequency of 25 Hz.
- ❑ The fatigue test results in terms of number of cycles to failure were not affected by the ageing process for the control as well as for the modified mixtures.
- ❑ The fatigue results of the two mixtures showed a very comparable performance in the laboratory.