Multiscale Characterisation and Quantification of Asphalt Binder Ageing Behaviour

Yongping Hu, University of Nottingham, yongping.hu@nottinggham.ac.uk
Gordon Airey, University of Nottingham, gordon.airey@nottinggham.ac.uk
Haopeng Wang, University of Nottingham, haopeng.wang@nottinggham.ac.uk
Lu Zhou, University of Nottingham, lu.zhou@nottinggham.ac.uk

International Association of Chinese Infrastructure Professionals

University of Nottingham
UK | CHINA | MALAYSIA

Introduction and Objective

- **Background**
  - Climate change accelerates the deterioration of pavement performance
  - Construction and maintenance of asphalt pavement contributes to climate change
  - Ageing of asphalt binders is one of the most important factors leading to pavement diseases
  - Understanding the ageing behaviour of asphalt binders is beneficial for recycling the waste resource

Disclose the performance evolution of asphalt binders in terms of ageing is challenging

- **Objective**
  - Evaluate the rheological and chemical properties of binders in terms of ageing
  - Propose novel ageing indices for asphalt binder
  - Correlate the chemical and rheological properties

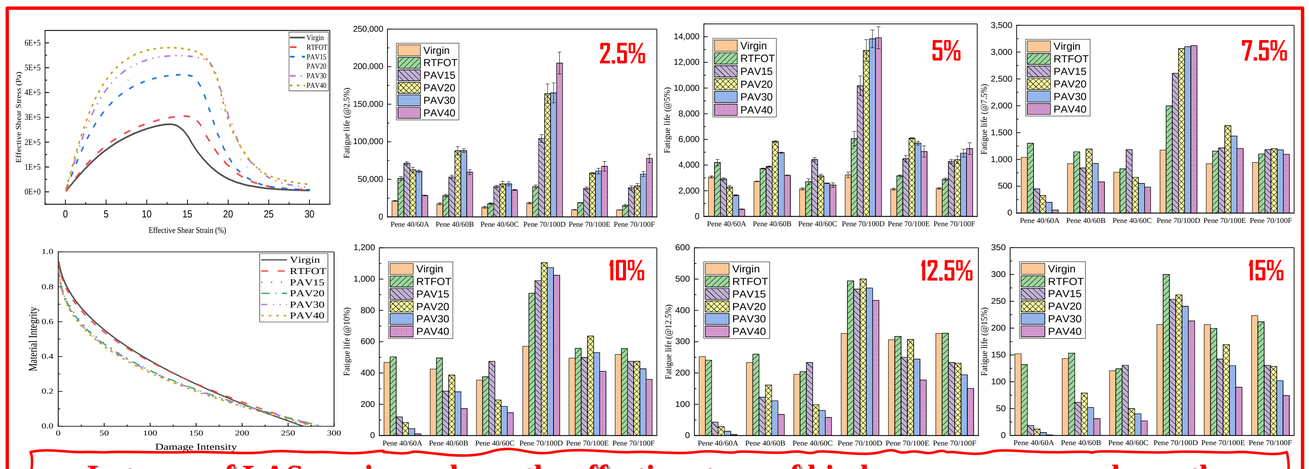
Climate change induced problems

Methodology

- **Materials**
  - Six asphalt binders with different PGs, chemical components and crude oils
- **Ageing procedures**
  - Standard RTFOT plus 15 hours, 20 hours, 30 hours and 40 hours PAV
- **Rheological and chemical tests**
  - Frequency sweep, time sweep, MSCR, LAS and BBR
  - FTIR for functional groups and TLC-FID for SARA properties

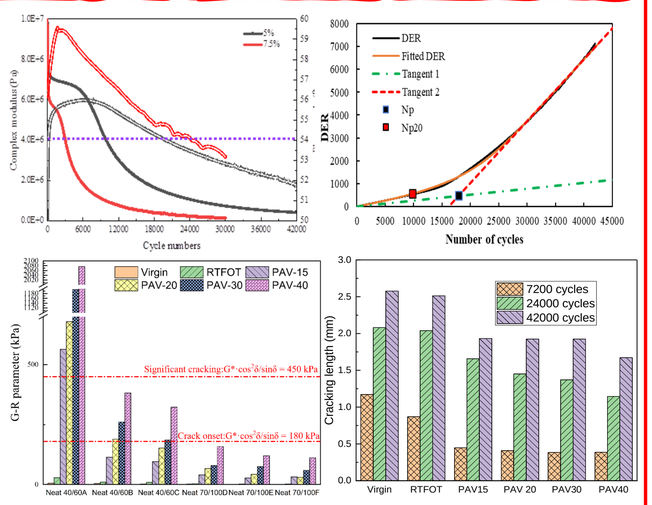
DSR BBR FTIR TLC-FID

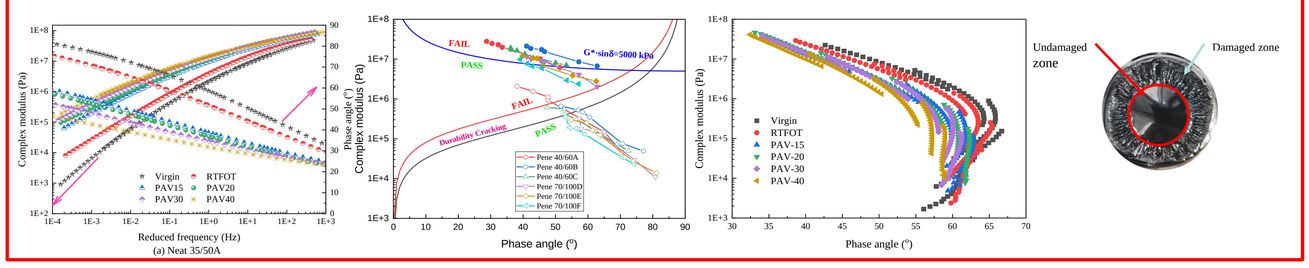
Fatigue Performance Characterisation



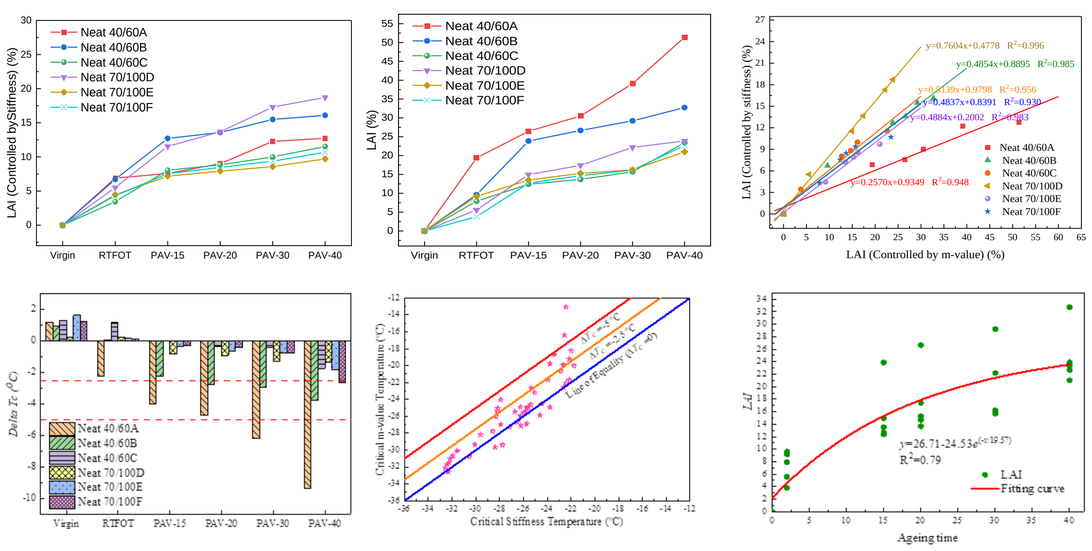
In terms of LAS, ageing reduces the effective stress of binders, moreover, prolongs the fatigue life of binders at low strain levels while reduces the fatigue life at high strain levels

- Based on 50% reduction of |G*|, ageing improves fatigue life of asphalt binders
- Based on peak value of phase angle, ageing improves fatigue life of asphalt binders
- Based on dissipated energy ratio, ageing improves fatigue life of asphalt binders
- Based on cracking length prediction, ageing improves fatigue life of asphalt binders
- Based on G-R parameter, ageing reduces fatigue life of asphalt binder
- ***Ageing does not necessarily reduces the fatigue performance of asphalt binder***



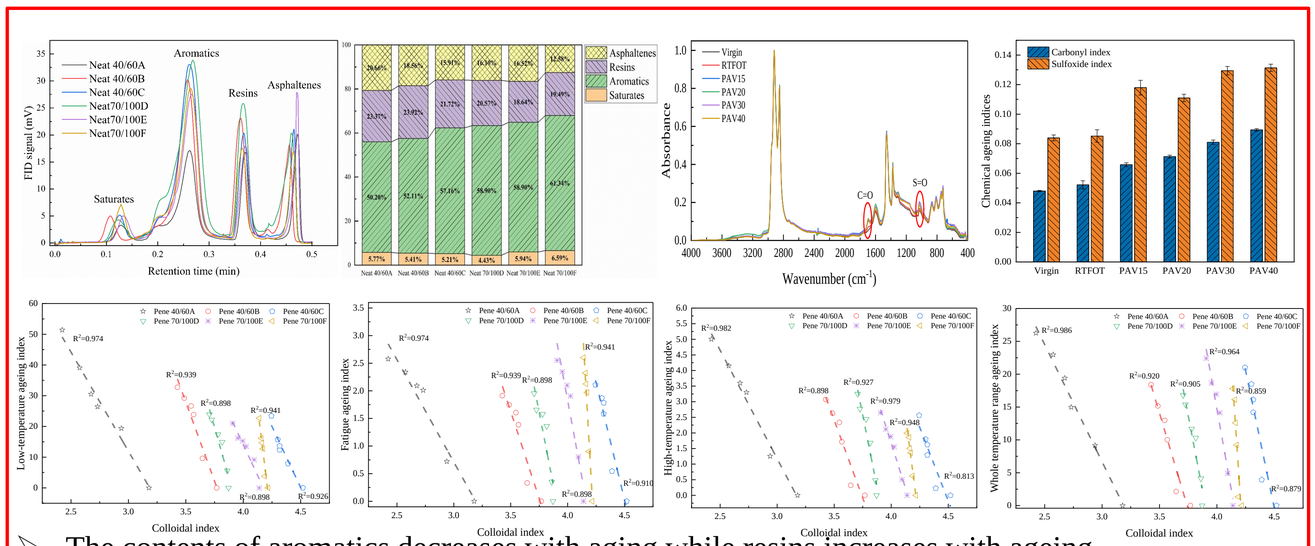


Low-temperature Performance Characterisation



- $T_{c,m}$ was recommended to employed in the low-temp ageing index
- ΔTc tends to be more negative with the increase of ageing levels
- -5 ℃ was recommended as the limit of ΔTc for the 40-hour PAV ageing

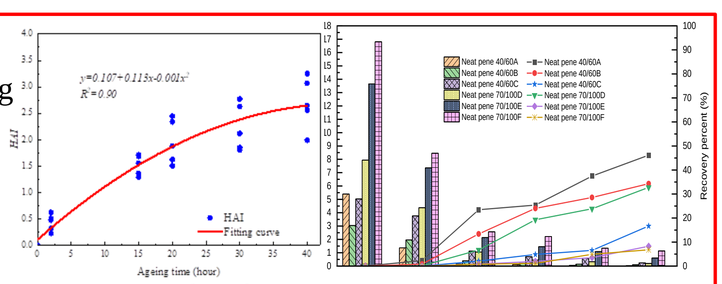
Chemical Properties Characterisation



- The contents of aromatics decreases with aging while resins increases with ageing
- The contents of saturates remain relatively stable with ageing while asphaltenes increases slightly
- Ageing leads to lower colloidal index of asphalt binders, meaning chemical system gets instable
- Carbonyl and sulfoxide indices increases with ageing

High-temperature Performance Characterisation

- Ageing lowers the strains
- The J_{nr} decreases with ageing while the $\%R$ increases
- Ageing improves the high-temperature performance of neat bitumen
- Ageing reduces the stress sensitivity of binders



$$J_{nr-slope} = \frac{J_{nr3.2} - J_{nr0.1}}{\tau_{3.2} - \tau_{0.1}} \times 100$$

$$HAI = \log\left(\frac{J_{nr3.2-virgin}}{J_{nr3.2-aged}} \times \frac{J_{nr-slope-virgin}}{J_{nr-slope-aged}}\right)$$

Conclusions

- The $T_{c,m}$ is more sensitive to ageing, indicating that the m-value always controls the thermal cracking process, also, ΔTc can be used as ageing indices in terms of low-temperature performance
- The high-temperature performance of asphalt binders can be improved by ageing
- Ageing does not necessarily reduce the fatigue performance of asphalt binders, on the contrary, ageing may be beneficial for the fatigue performance of asphalt binders
- Due to ageing, the contents of light components such as saturates and aromatics are decreased while those for heavy components such as resins and asphaltenes are increased
- The colloidal system tends to be instable due to ageing
- The proposed rheological based ageing indices have excellent correlation with chemical indices

Adaptive Infrastructure under Climate Change

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