International Association of Chinese Infrastructure Professionals

Modeling of Asphalt Concrete's Tension-Compression Asymmetry Effects on Pavement Response

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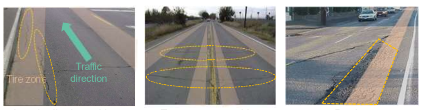
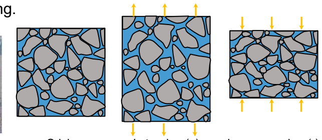
Introduction

- Due to the strong heterogeneity, asphalt concrete (AC) exhibits significant tension-compression (TC) asymmetry, i.e., much lower modulus in tension than in compression, especially at the high temperature.
- In conventional pavement design, only the compressive modulus is considered; the ignorance of the much lower tensile modulus may overestimate pavement's performance and thus lead to tensile failures.
- It is required to consider AC's TC asymmetry in pavement design.
- **Research Objective:** Develop a constitutive model to consider AC's TC asymmetry and further evaluate its effect on pavement response through numerical modeling.



Pavement distresses

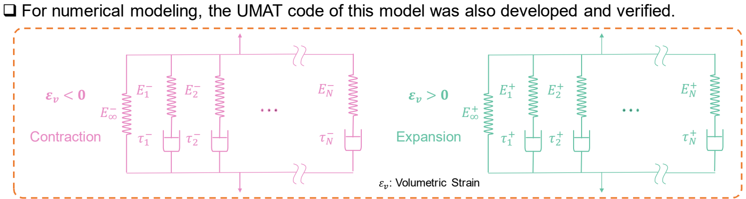


Tension-compression (TC) asymmetry

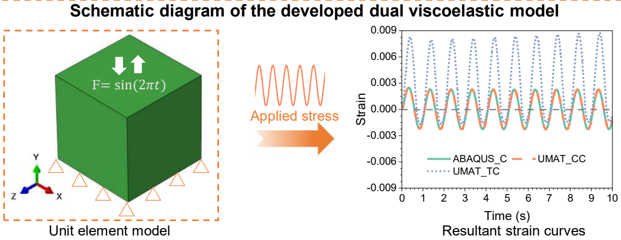
Model Development and Numerical Simulation

Dual Viscoelastic Constitutive Model

- A temperature-dependent dual viscoelastic model was formulated to consider AC's TC asymmetry.
- This model can switch between tensile and compressive moduli based on volumetric strain.
- For numerical modeling, the UMAT code of this model was also developed and verified.



Schematic diagram of the developed dual viscoelastic model



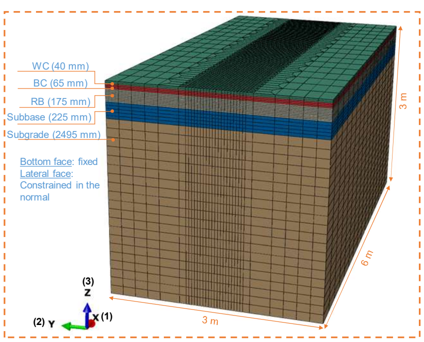
Unit element model

Resultant strain curves

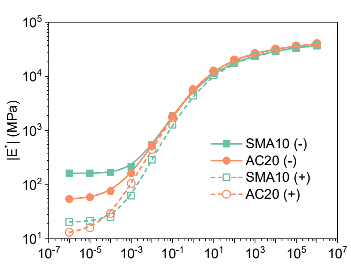
Model verification

Pavement Modeling

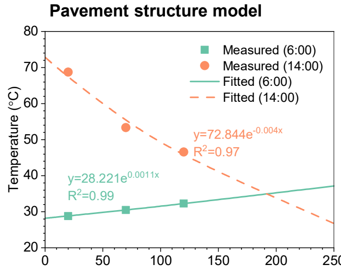
- Pavement model development
  - ✓ A typical pavement structure in HK
  - ✓ A dual-tire load was applied
- Two material cases for AC layers
  - ✓ UMAT_CC: consider compressive properties only (conventional)
  - ✓ UMAT_TC: consider tensile and compressive properties
- Simulation conditions
  - ✓ Two speeds: 20 and 80 km/h
  - ✓ Two temperature fields: high temperature (at 14:00) and low temperature (at 6:00) on a summer day.



Pavement structure model



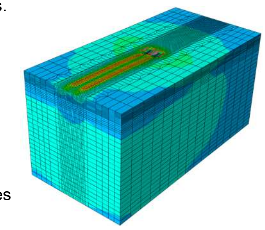
Properties in tension (+) and compression (-)



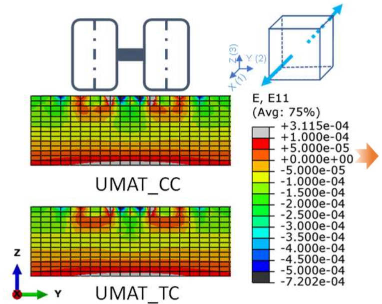
Temperature vs. pavement depth

Results & Findings

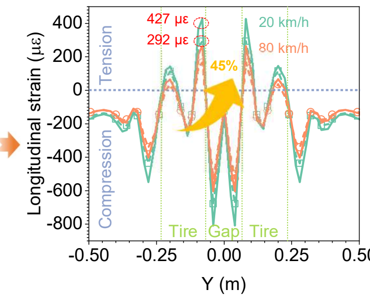
- AC's TC asymmetry mainly affects the response of AC layers.
- Model considering TC asymmetry at 20 km/h and high temperature (14:00)
  - ✓ 6% increase in maximum vertical deformation
  - ✓ 45% increase in longitudinal tensile strain (LE11)
  - ✓ 11% increase in transverse tensile strain (LE22)
- Vehicular speed and temperature effects
  - ✓ A lower vehicular speed or higher temperature field induces more effect of AC's TC asymmetry on asphalt pavement.



Longitudinal Strain (E11) at High Temperature (14:00)

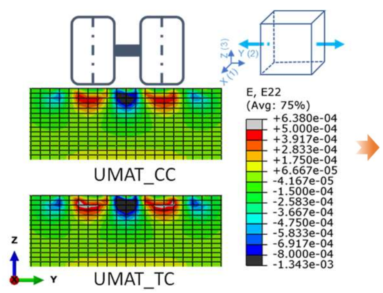


E11 distributions

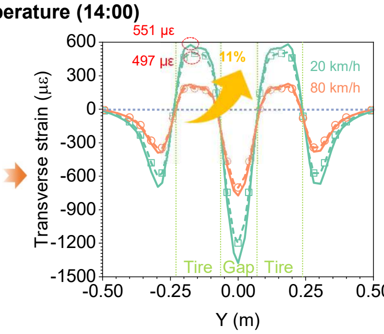


E11 on the pavement surface

Transverse Strain (E22) at High Temperature (14:00)

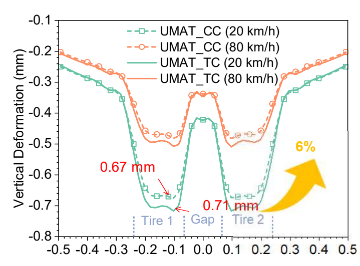


E22 distributions

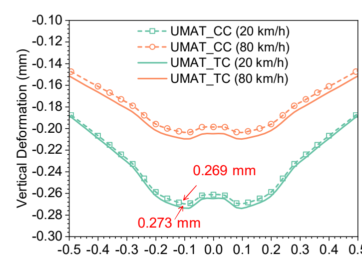


E22 on the top of BC layer

Temperature Effect



Vertical deformation at high temperature



Vertical deformation at low temperature

Conclusions

- The developed dual viscoelastic constitutive model can effectively capture AC's TC asymmetry, and the developed algorithm is for the first time to introduce AC's asymmetry into pavement's numerical modeling.
- Due to the much lower tensile modulus, considering AC's TC asymmetry can significantly increase the strains in asphalt layers and thus lead to distresses, such as rutting and cracking.
- A higher temperature or lower speed makes AC's TC asymmetry more significant and thus induces more effects on asphalt pavements.

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