Asphalt Pavement Aging and Temperature Dependent Properties through a Functionally Graded Viscoelastic Model –II: Applications

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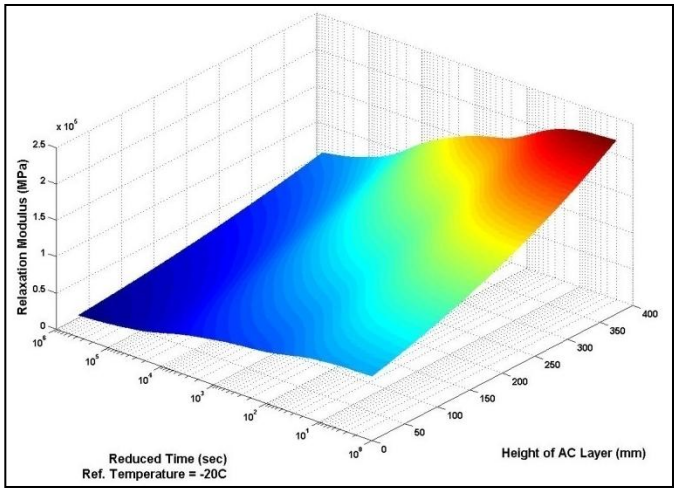
Outline

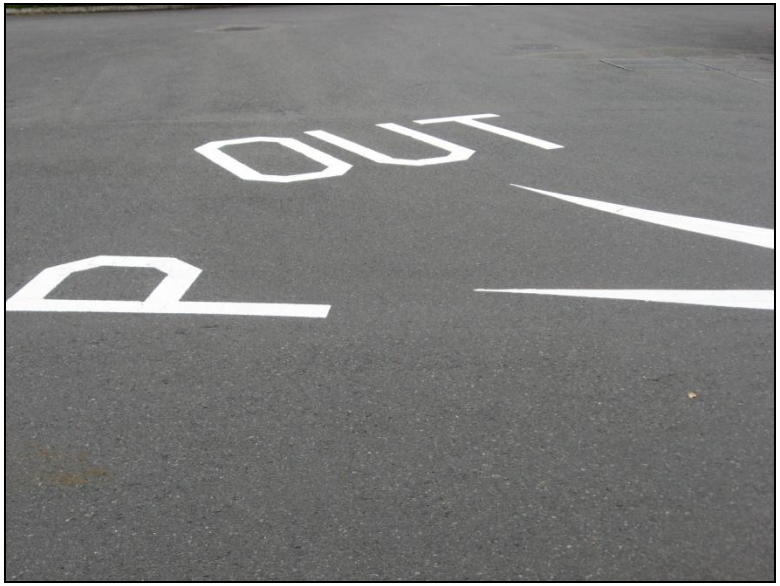
- Part – I
  - Graded Finite Elements
  - Viscoelasticity and FGMs
  - Finite Element Formulations
  - Verification
  - Concluding Remarks



- Part – II
  - Asphalt Pavements
  - Effect of Aging
  - Simulations
  - Concluding Remarks

Objectives

- Develop efficient and accurate simulation scheme for viscoelastic functionally graded materials (VFGMs)
- Correspondence Principle based formulation
- Application: Asphalt concrete pavements (Part II)

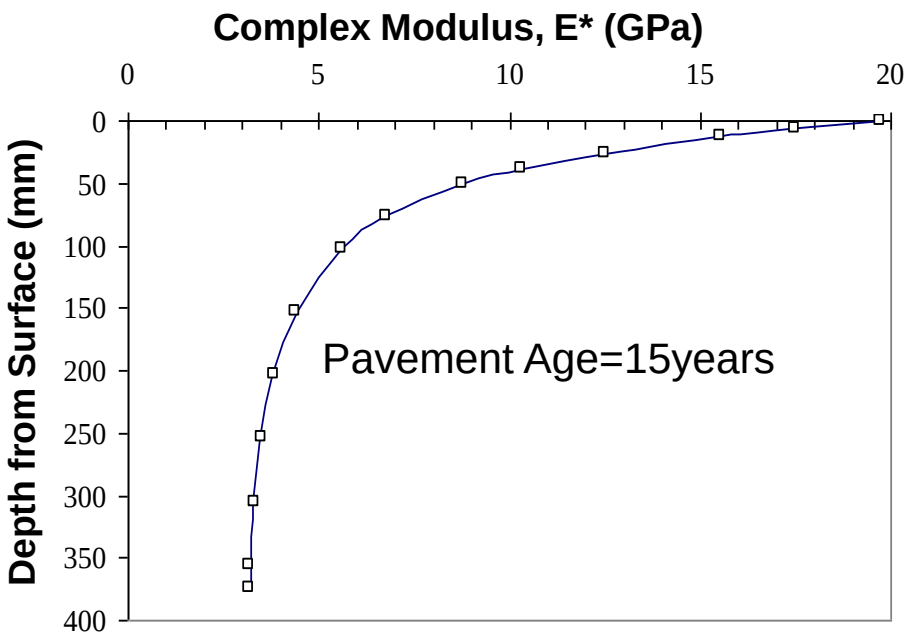


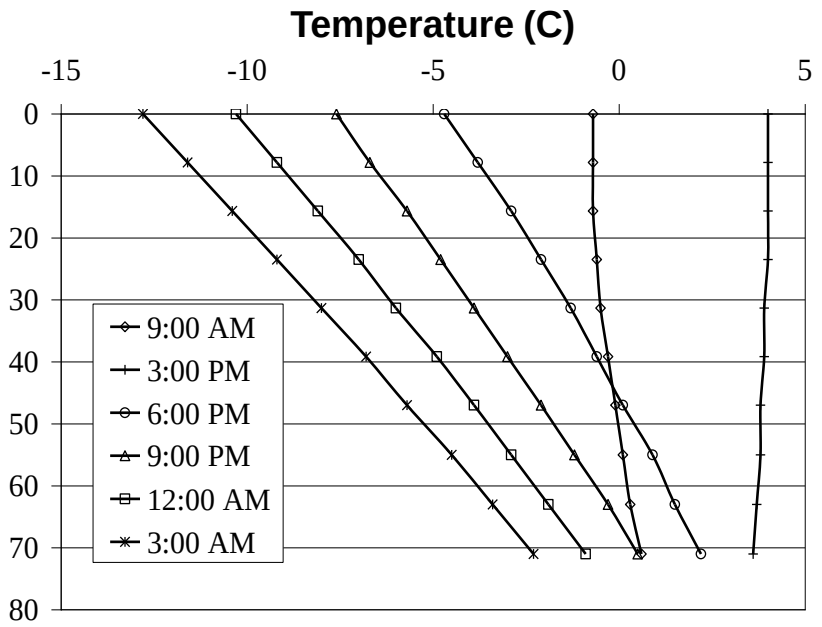
Asphalt Concrete

- Constituents:
  - Asphalt Binder
  - Aggregates
- Asphalt Binder:
  - Derived from Crude Oil
  - Many times modified with polymers to enhance properties
  - Undergoes oxidative aging (stiffening) with time
- Asphalt Concrete (Asphalt Mixture)
  - Large fraction produced as hot-mix asphalt (HMA)
  - Most common form of pavement surfacing material (96% of pavement surface in United States)

Pavements are GRADED Structures

- Sources:
  1. *Oxidative aging*
  2. *Temperature dependence of material properties*
  3. *Other sources (construction, additives etc.)*

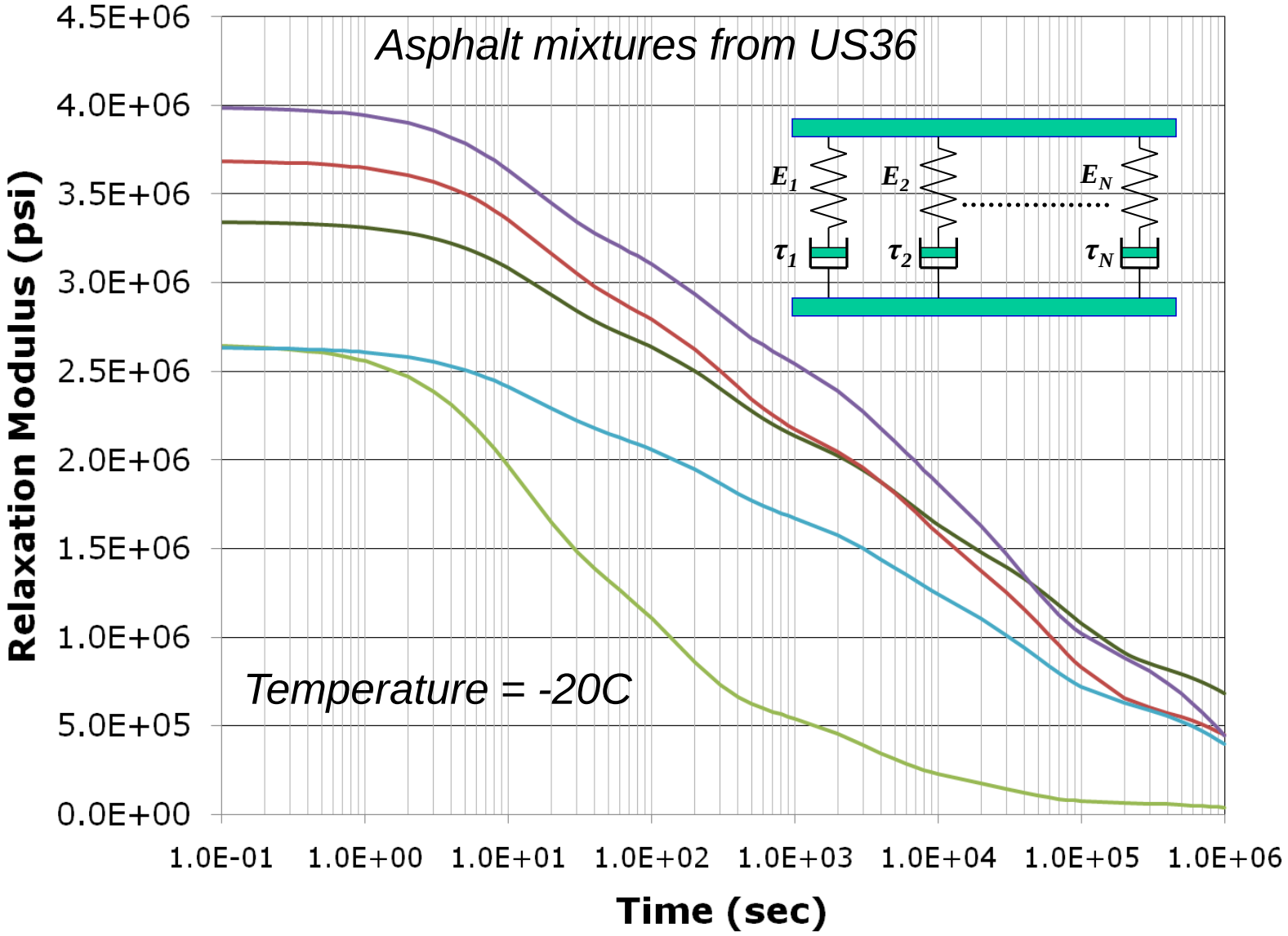




Aging gradient generated using "Global aging model" by Mirza and Witczak

Temperature profiles generated using "EICM" from AASHTO MEPDG

Asphalt Concrete is time-dependent (Viscoelastic)

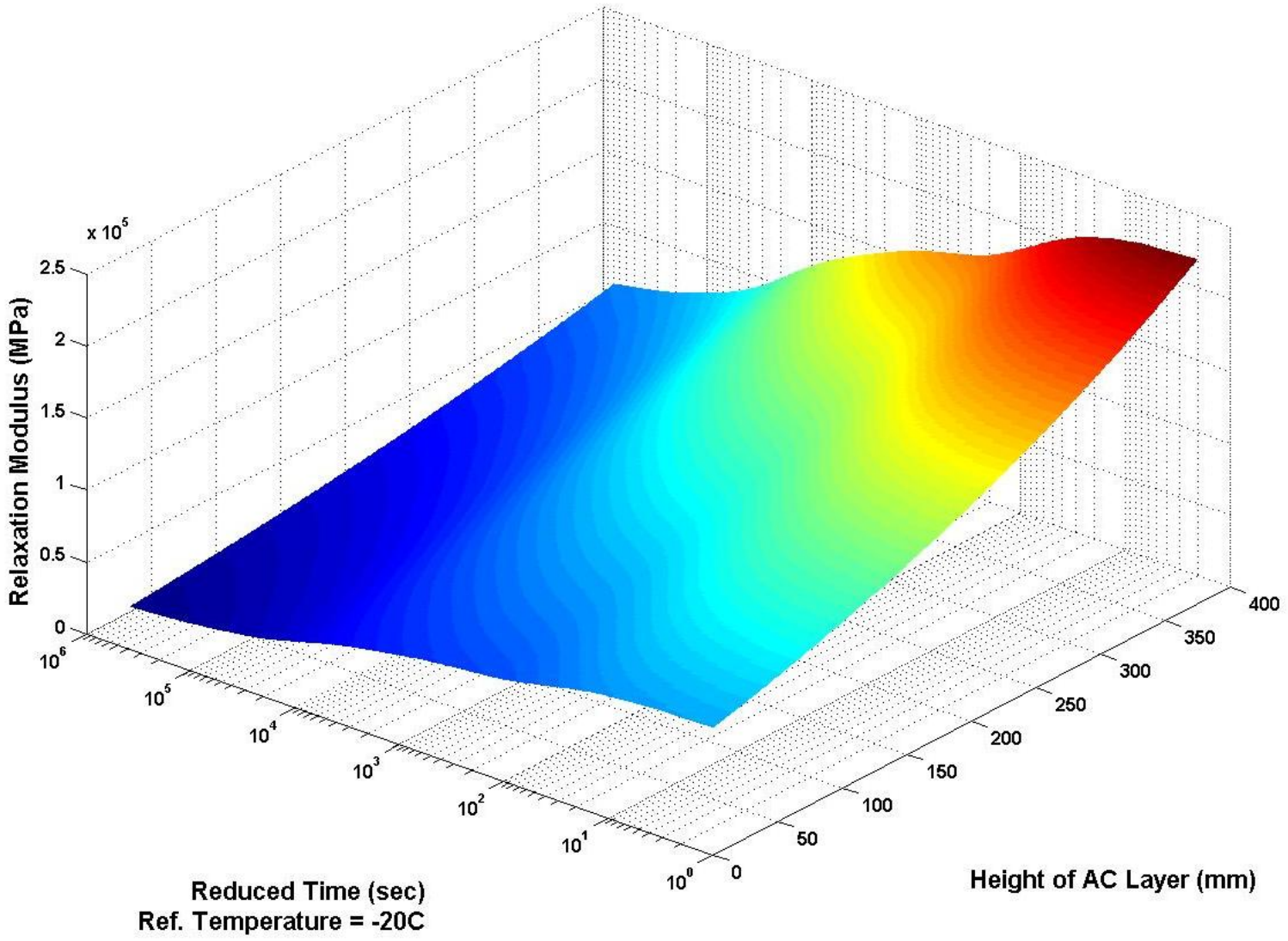


Pavement Section

- Simulation model based on Interstate highway located in Lincoln, Illinois (I-155)
- Full depth asphalt concrete pavement

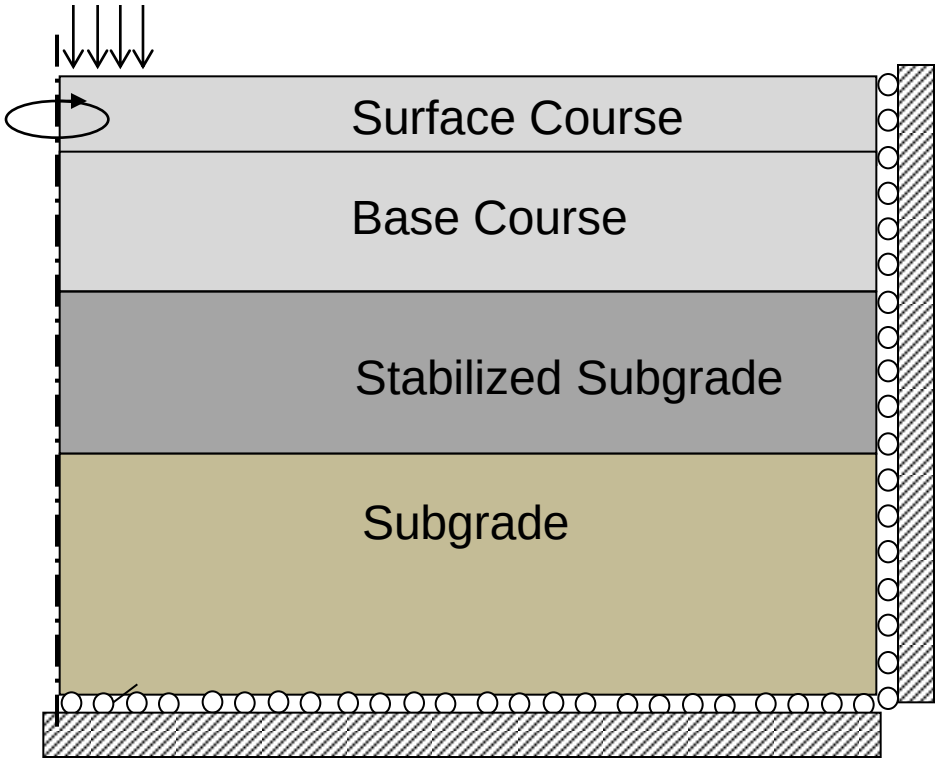
Effect of Aging on Material Response

- Data from Apeagyei et al. (2008)



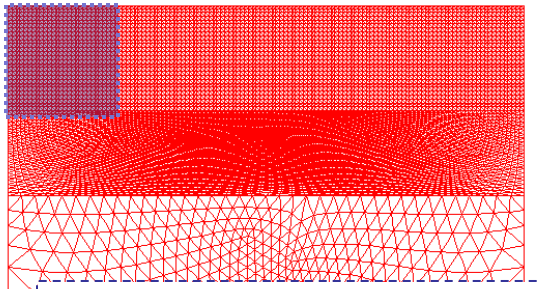
FE Model

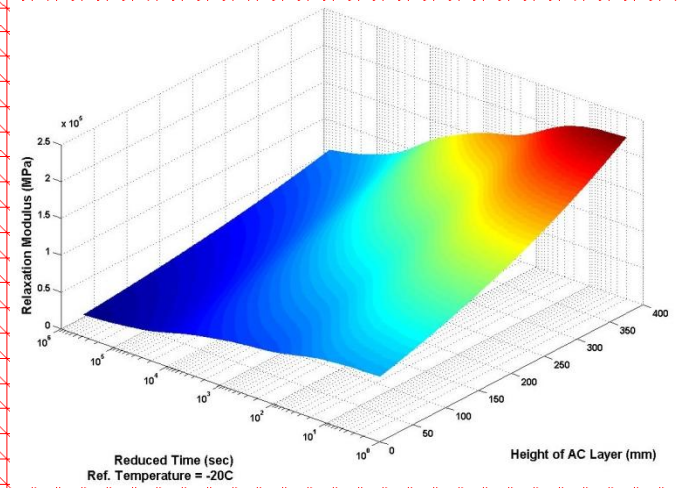
- Two-dimensional axi-symmetric conditions
- Single Tire load simulated (up to 1000-sec loading time)
- Two mesh refinement levels
  - Coarse mesh: Graded and Homogeneous simulations
  - Fine Mesh: Layered simulations



FEM Discretization

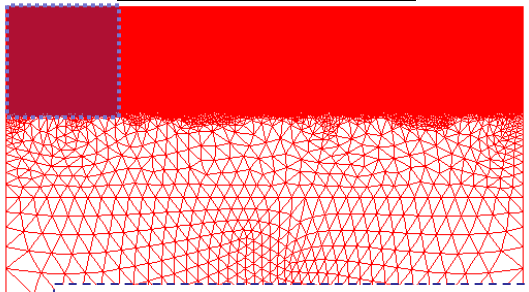
Coarse Mesh





72150 DOFs

Fine Mesh



6 Layers

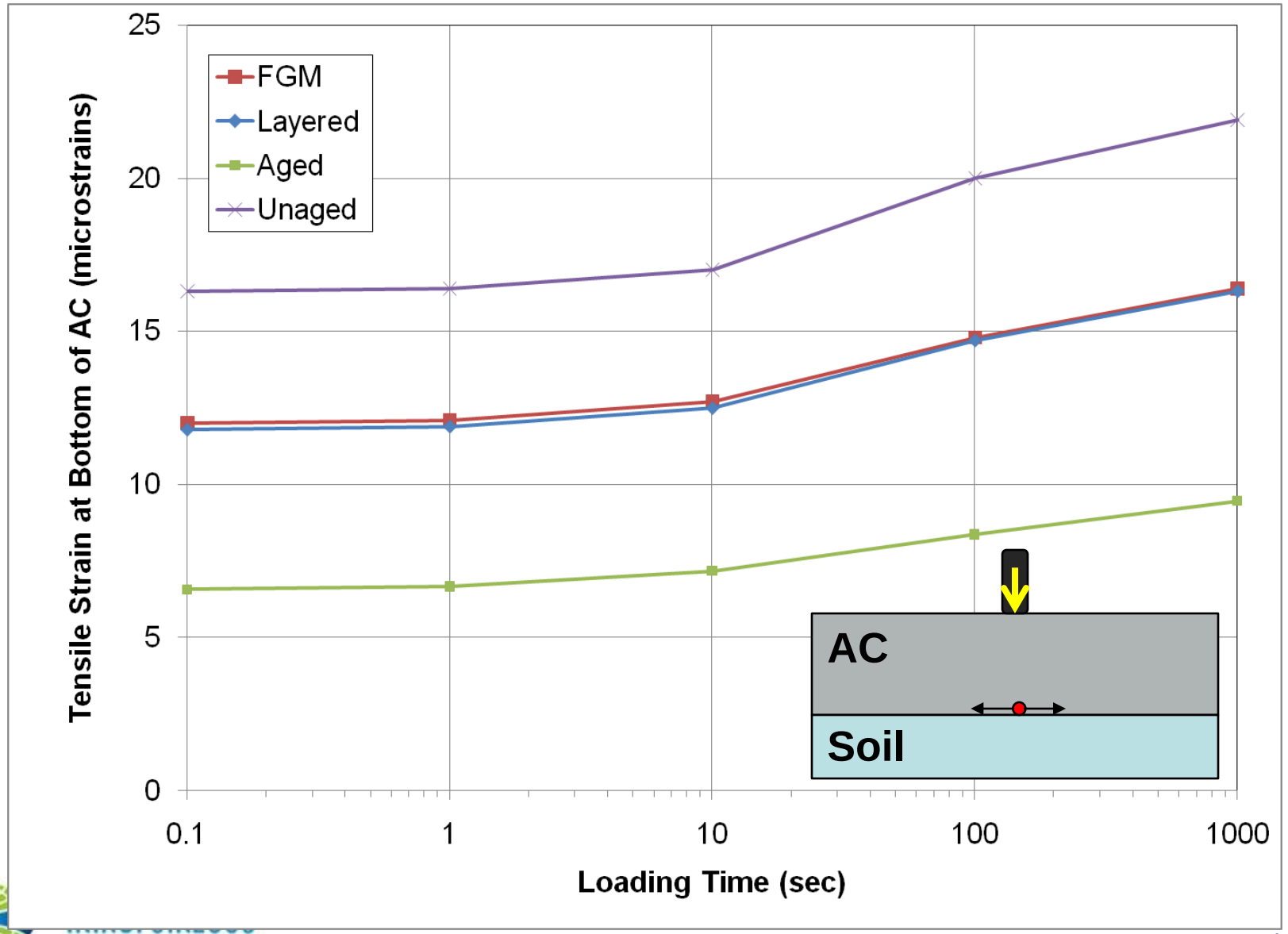
16 Layers

129060 DOFs

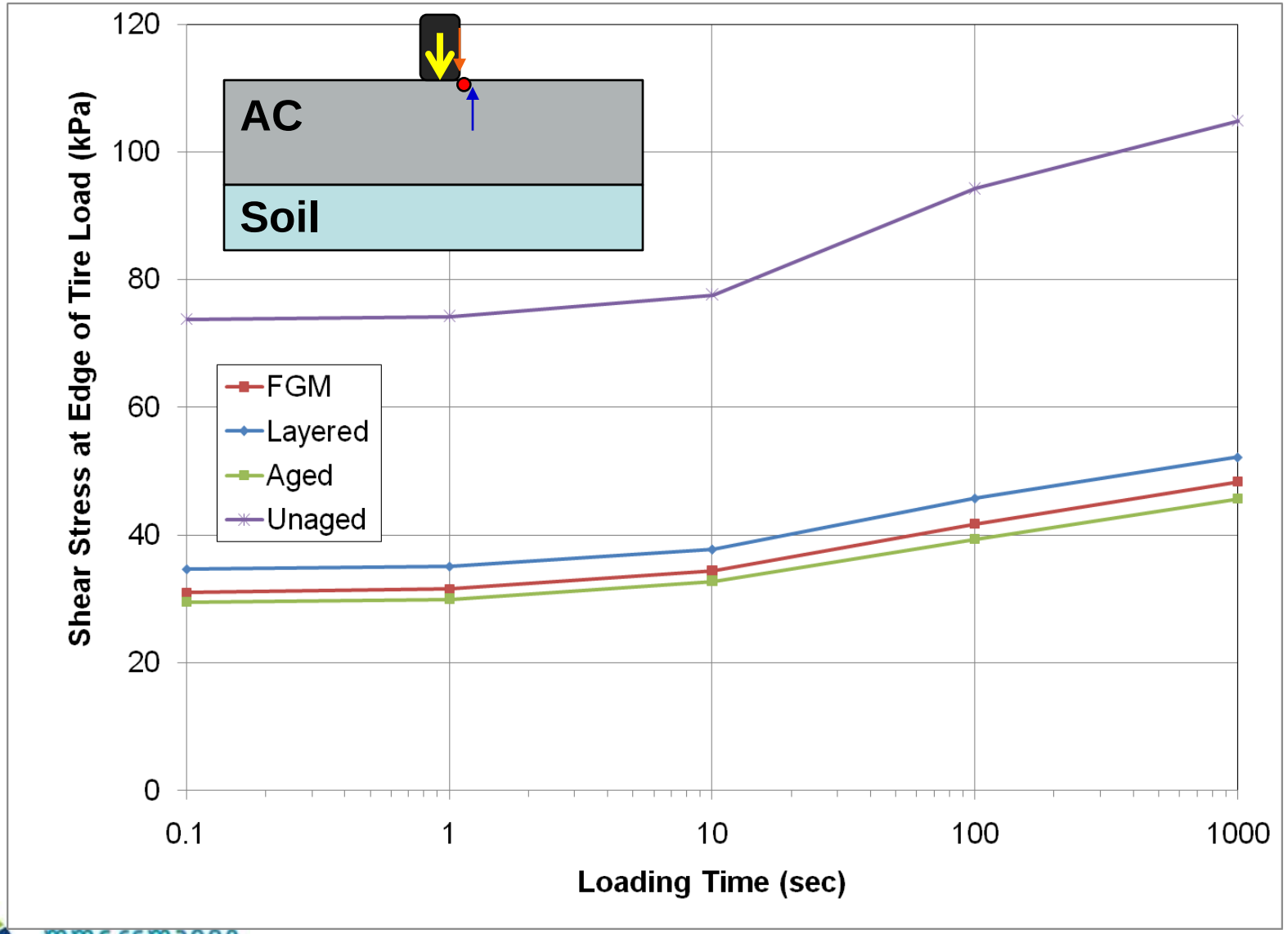
Simulation Results

- Material Distributions:
  - FGM
  - Layered
  - Aged
  - Unaged
- Pavement Responses:
  - Tensile strain at bottom of asphalt layer (to investigate cracking and fatigue)
  - Shear strain at wheel edge (longitudinal cracking/rutting)
- Comparison of FGM and Layered predictions
  - Compressive strain at interface of asphalt layers

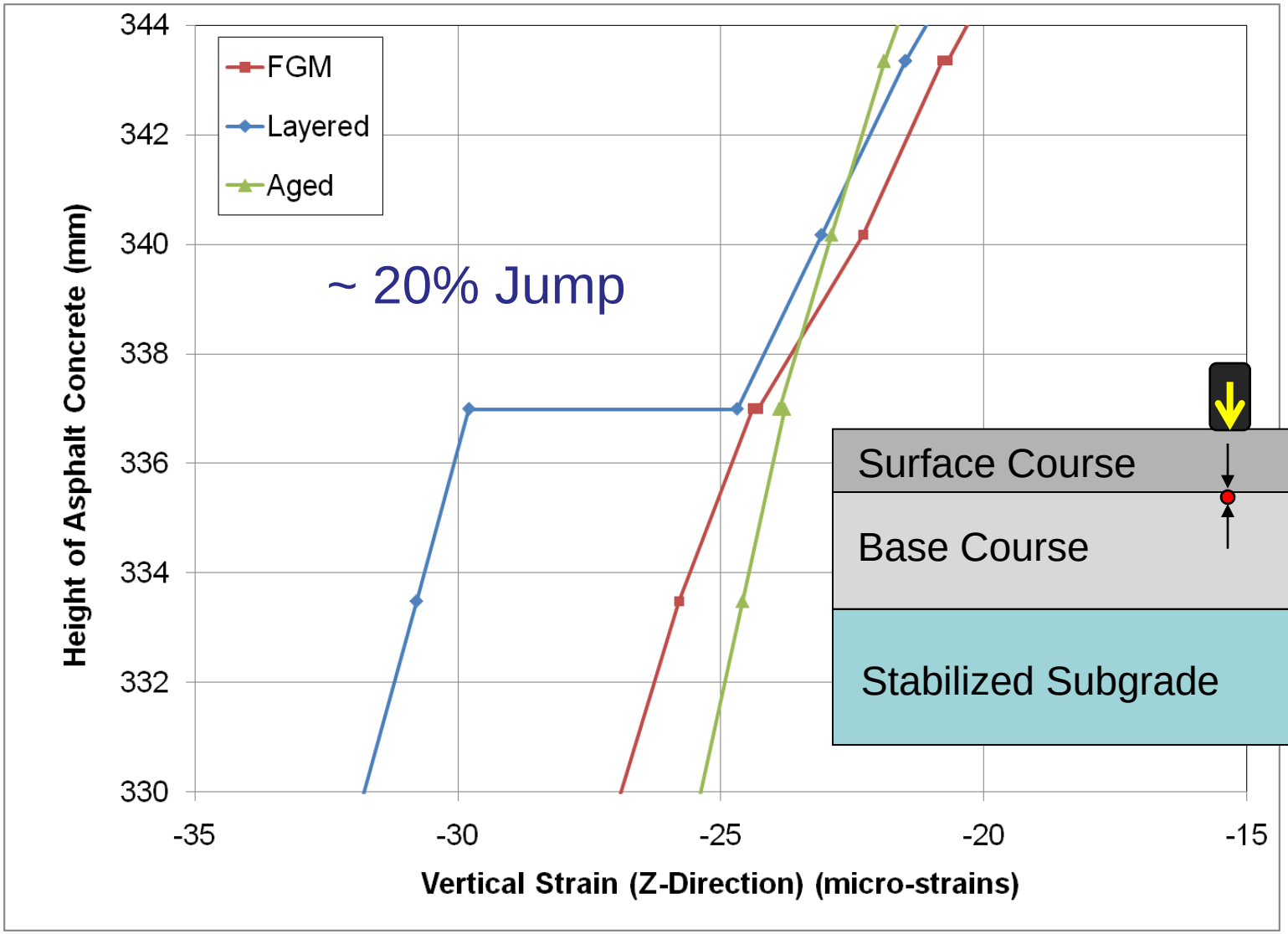
Simulation Results: Strain at Bottom of AC



Simulation Results: Strain at Tire Edge



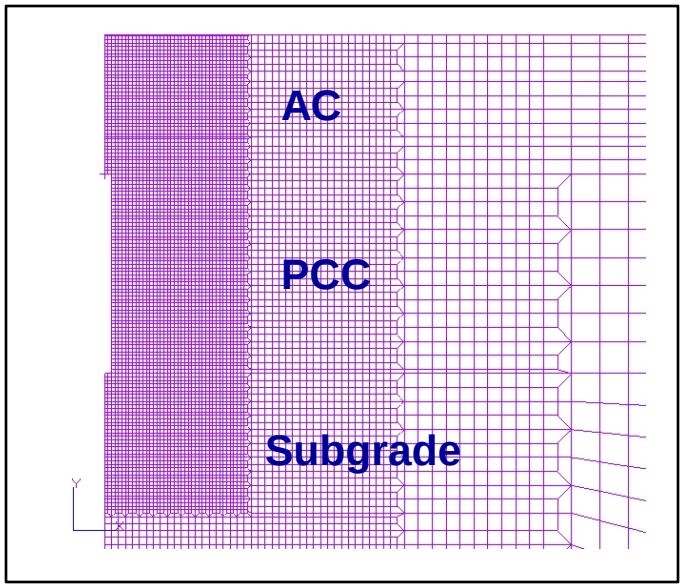
Simulation Results: FGM vs. Layered



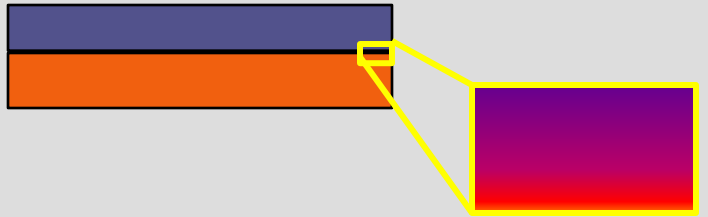
Concluding Remarks

- Consideration aging effect is important for obtaining reliable response of asphalt pavements
- Viscoelastic FGM analysis procedure developed herein provides an accurate and efficient way of analyzing asphalt pavements
- Layered approach may provide results with significant errors at the layer interfaces (especially stresses)
- Most severe response observed for this limited study was the shear strains at the edge of tire load.

Applications of Current and Proposed Research



Simulation of Transition Layers



Applications

Design of Viscoelastic FGMs

$$E(x,t) = E[ax + bExp[y],t]$$

Analysis of Graded Polymers, for example:

- Effects of UV radiation on polymer coatings
- Aerospace and automobile applications

Thank you for your attention!!

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