Investigation of low temperature cracking through an improved thermal cracking model

Sofie E. Léon, Graduate Research Assistant

Glaucio H. Paulino, Professor

William G. Buttlar, Professor

University of Illinois at Urbana-Champaign

Civil and Environmental Engineering Department

July 18, 2009

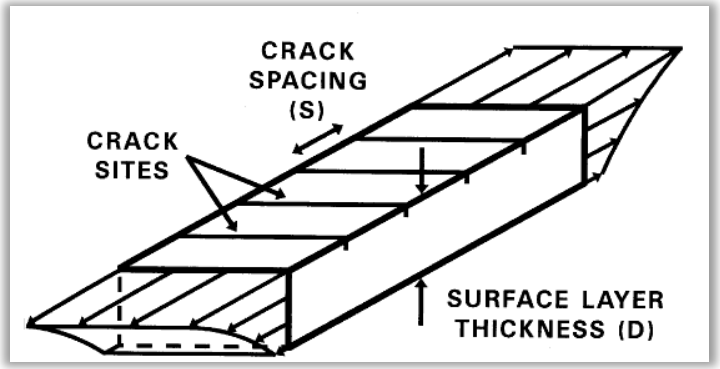
10TH US NATIONAL CONGRESS ON COMPUTATIONAL MECHANICS

Presentation Outline

- Thermal Cracking
- Thermal Cracking Prediction Models
- User Application: Visual LTC
- Demonstration
- Results
- Concluding Remarks

Thermal Cracking

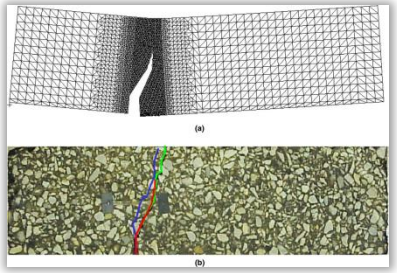
- Climatic events cause pavement to cool
- Thermally induced strain causes stresses in longitudinal direction
- Cracks form when stress exceeds material capacity



D. R. Hiltunen and R. Roque. "A Mechanics-Based Prediction Model for Thermal Cracking of Asphaltic Concrete Pavement." Asphalt Paving Technology: Proceedings - Association of Asphalt Paving Technologists Technical Sessions. 63 (1994): 81-108.

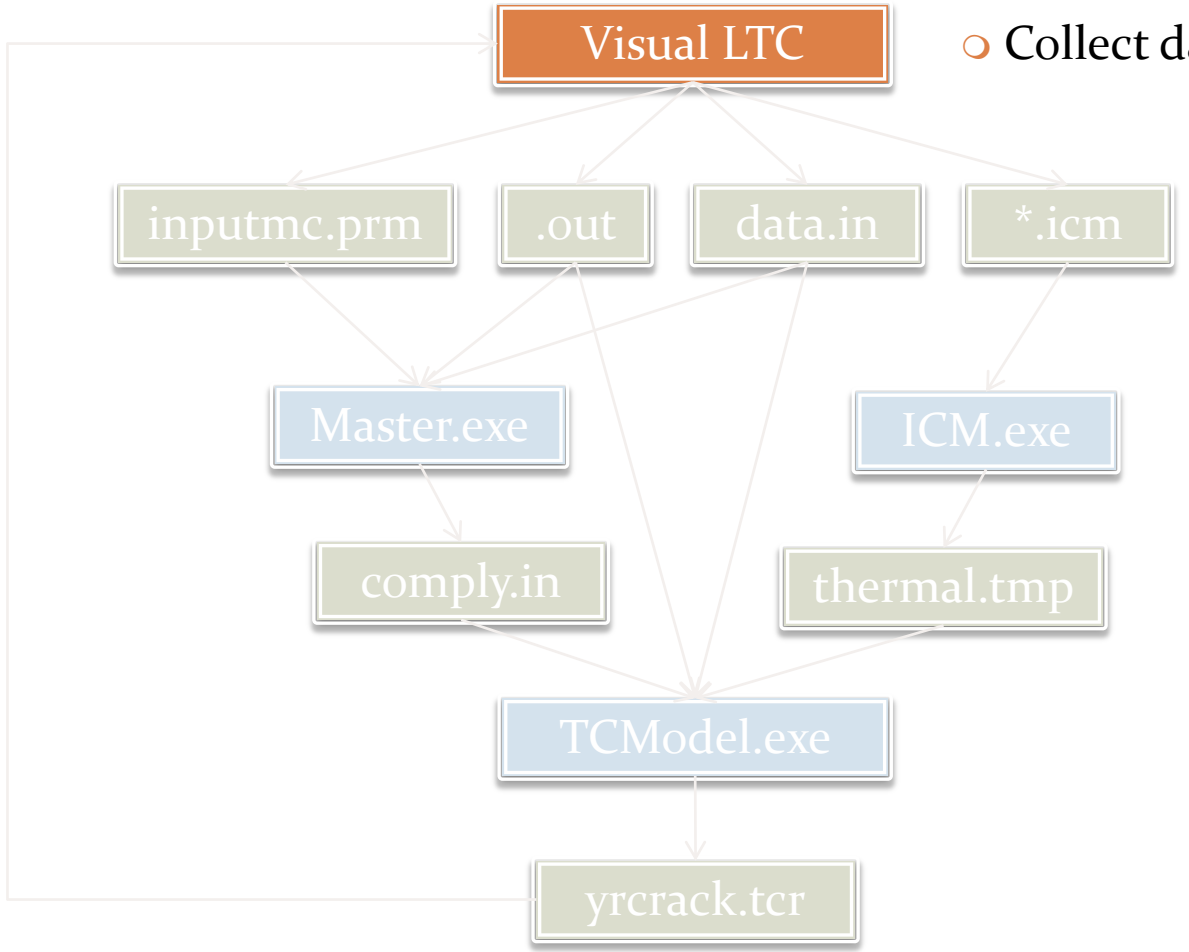
Visual LTC Analysis Tool

- User-friendly graphical user interface (GUI) to capture low temperature cracking characteristics of asphalt concrete
- Allows for quick yet sophisticated analysis for practical applications
- The first task of project to develop an improved thermal cracking prediction model



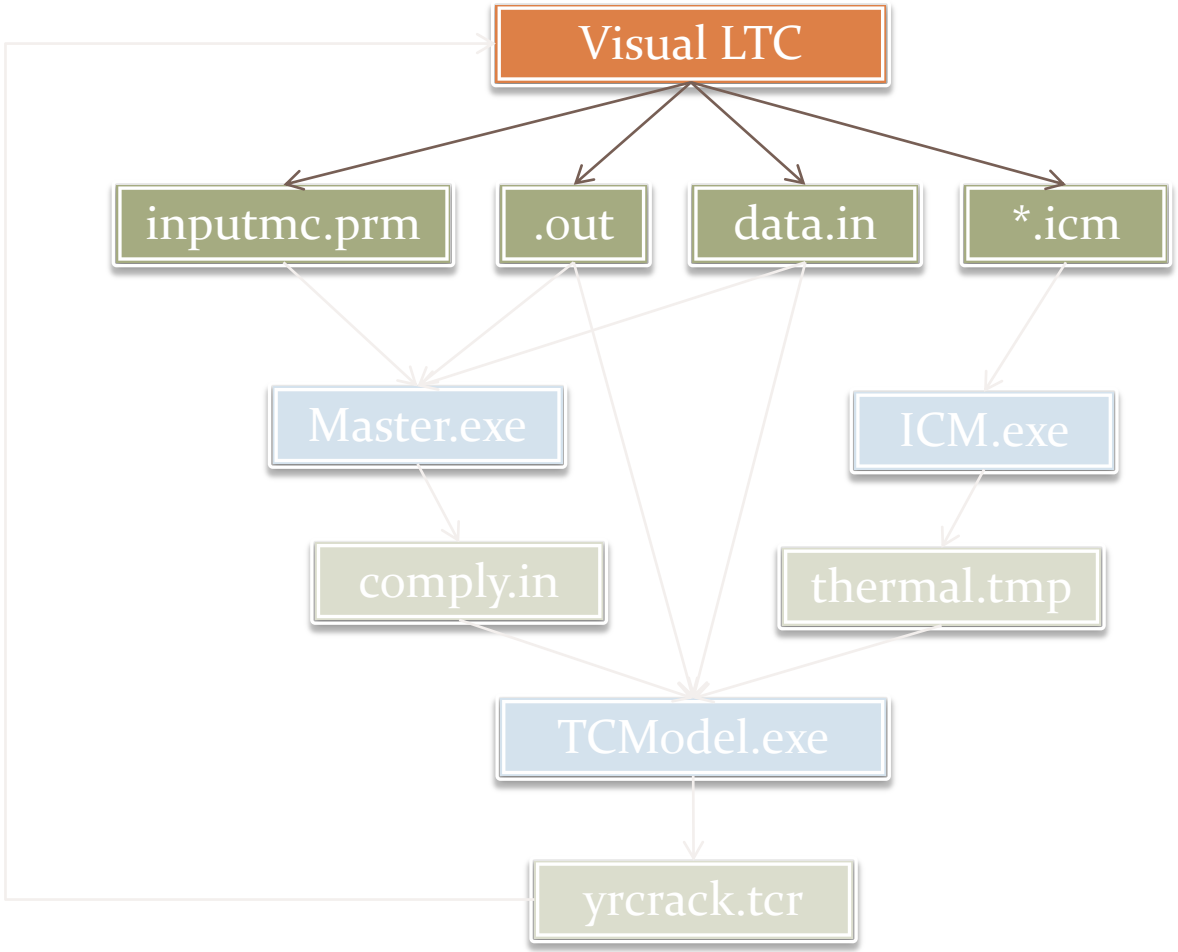
S. Song, G. H. Paulnio, W. G. Buttlar. "A Bilinear Cohesive Zone Model Tailored for Fracture of Asphalt Concrete Considering Viscoelastic Bulk Material." Engineering Fracture Mechanics. 73 (2006): 2829-2848.

Thermal Cracking Model Usage



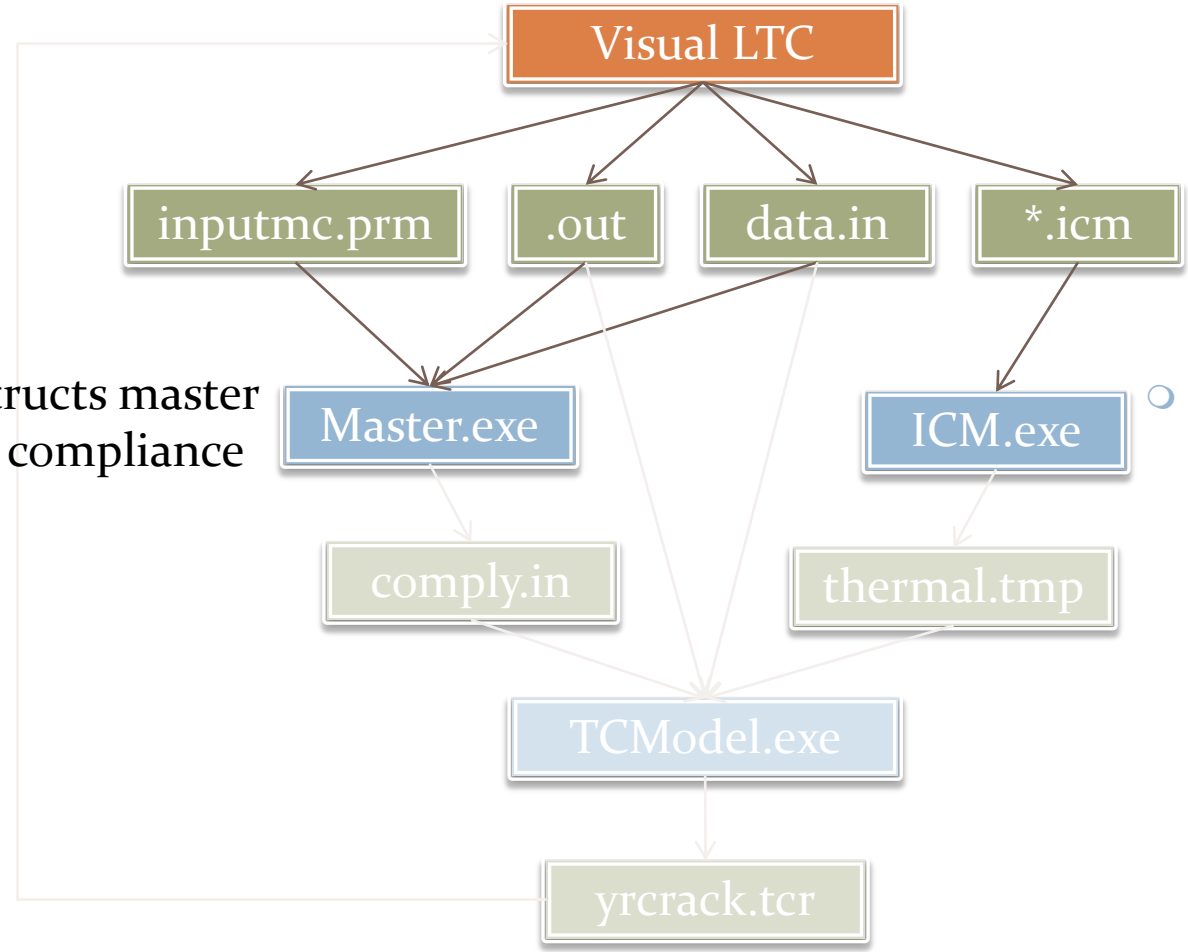
- Collect data from user

Thermal Cracking Model Usage



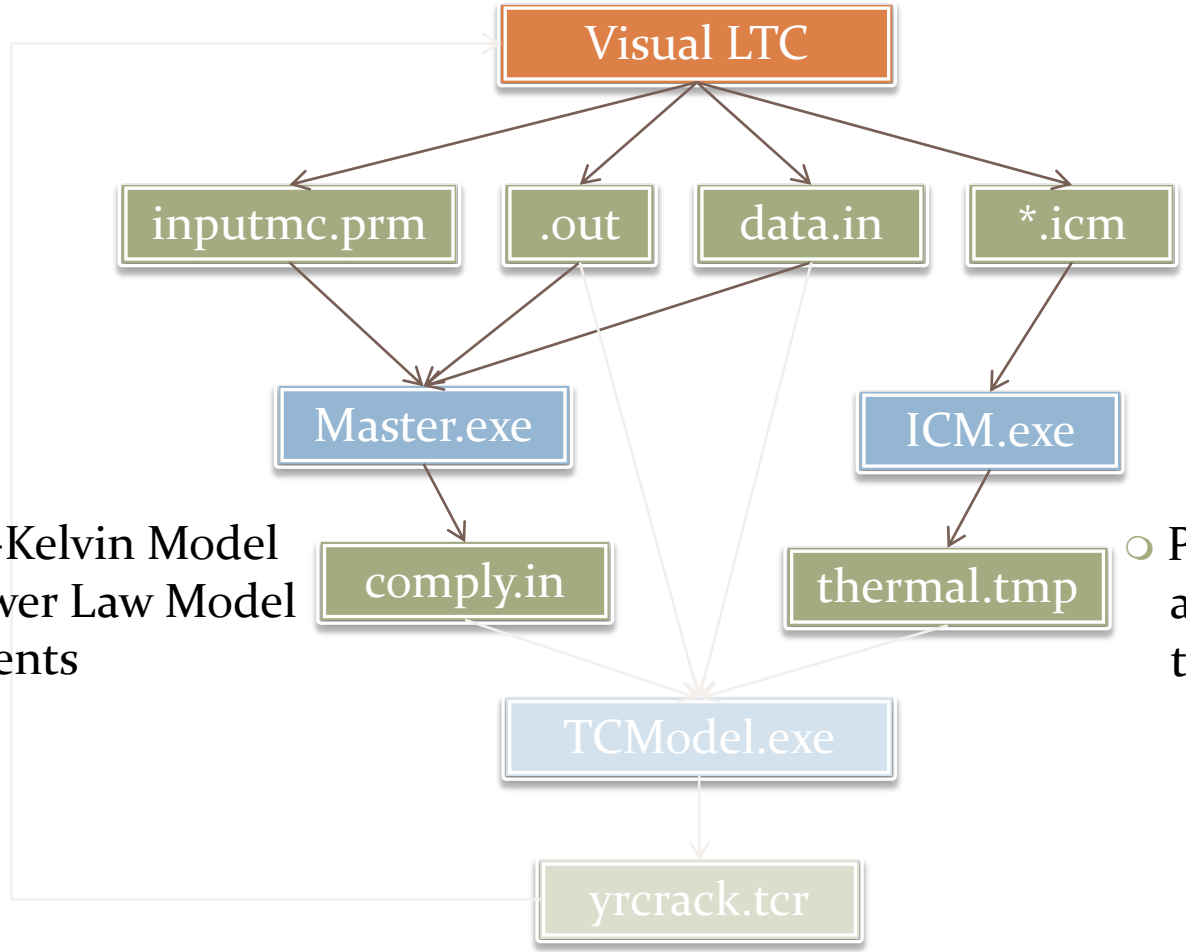
- Input files

Thermal Cracking Model Usage



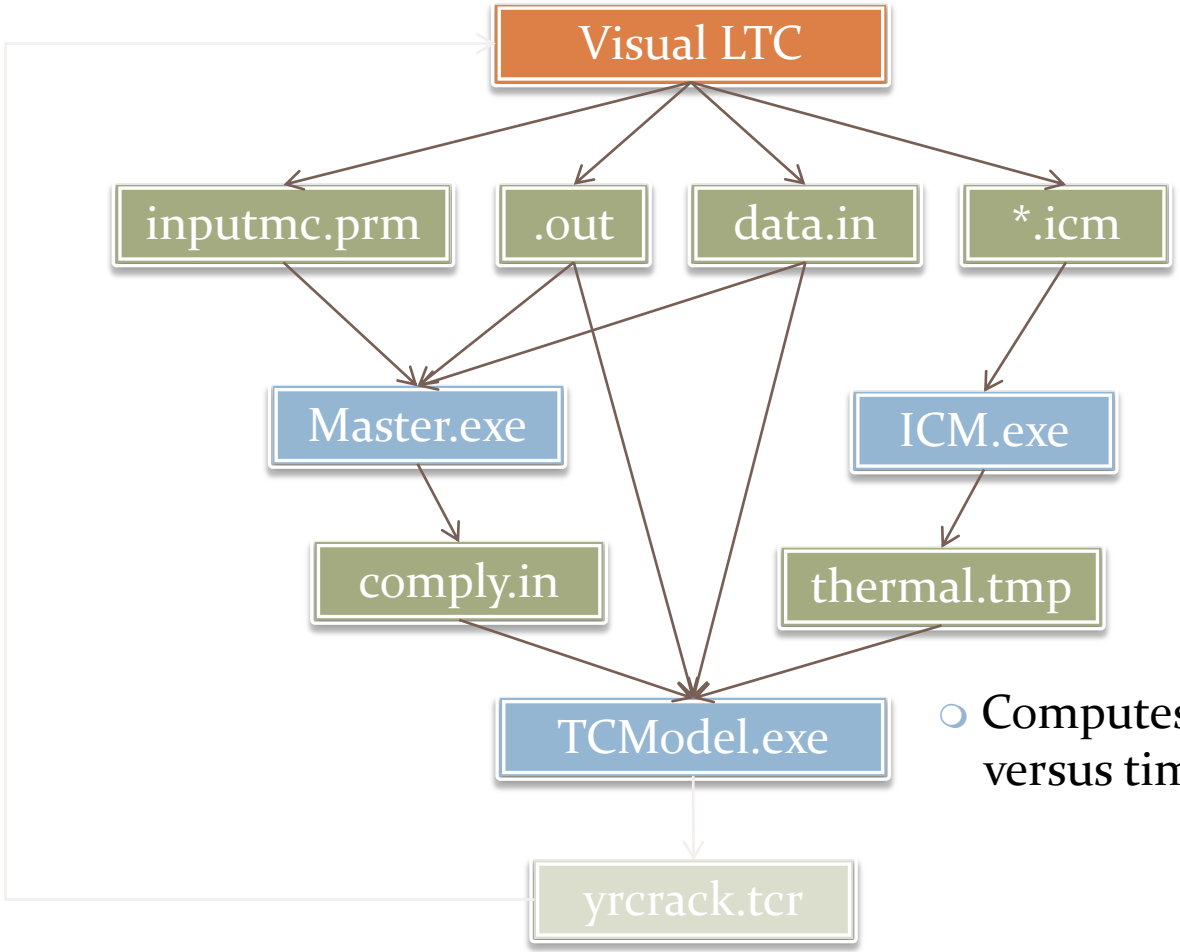
- Constructs master creep compliance curve
- Constructs temperature profile of pavement section

Thermal Cracking Model Usage



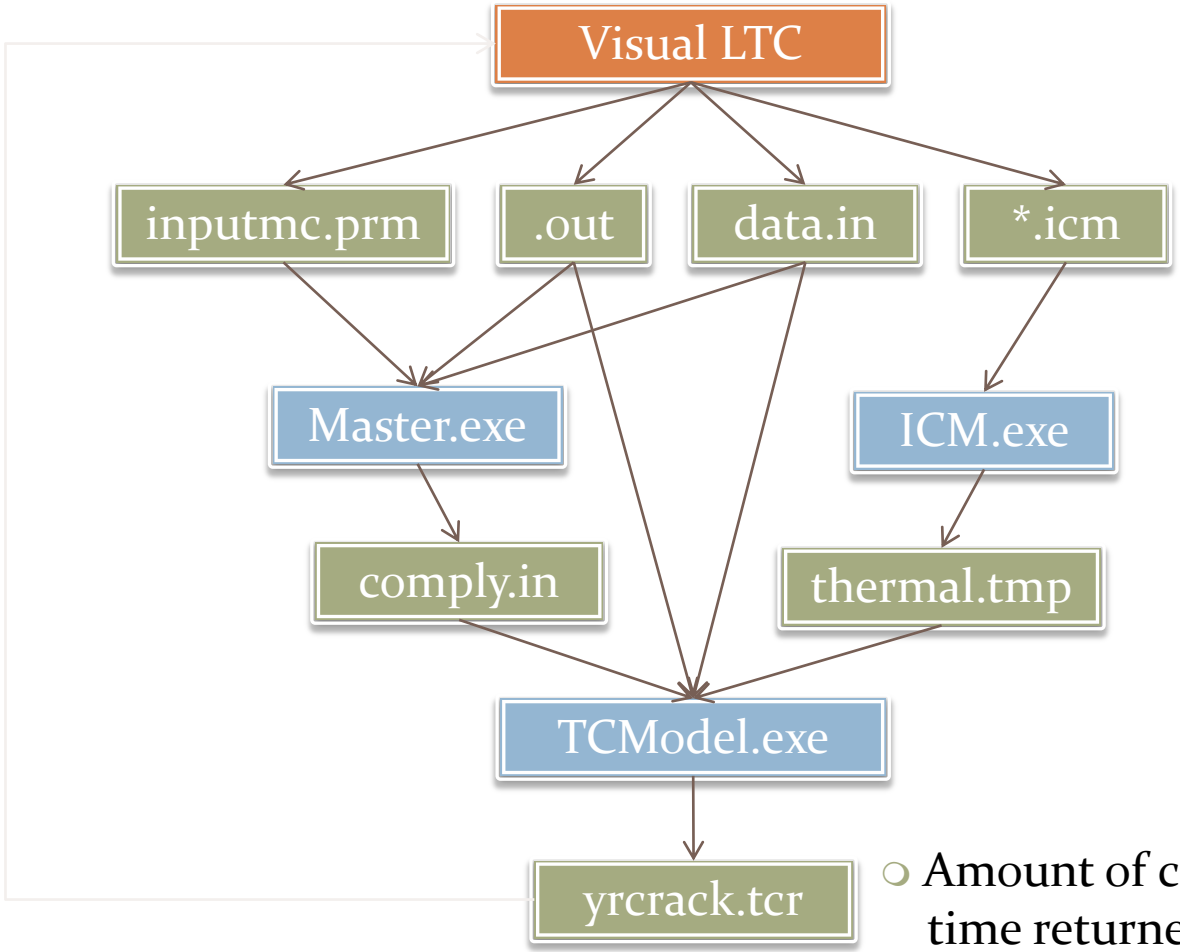
- Voight-Kelvin Model and Power Law Model coefficients
- Pavement temperatures at various depths with time

Thermal Cracking Model Usage



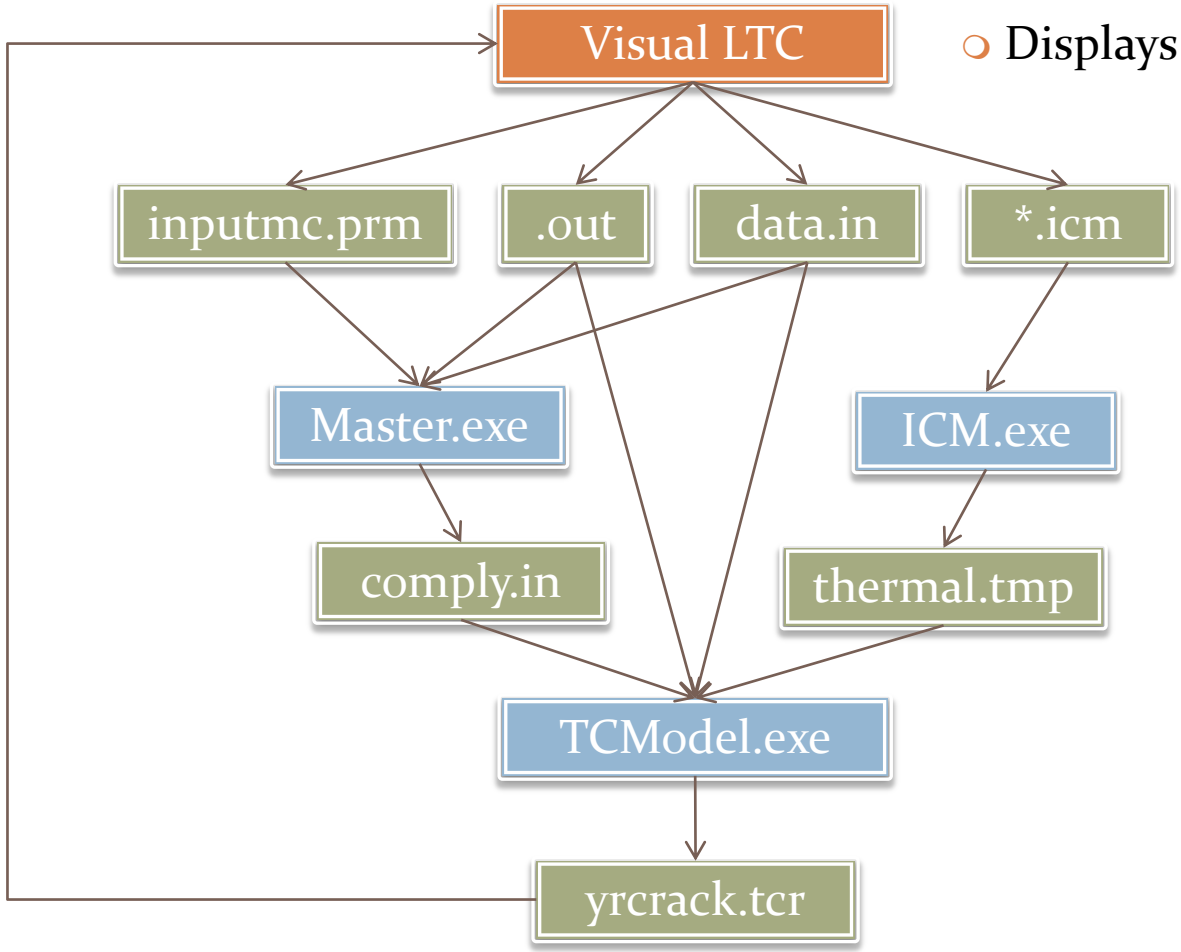
- Computes amount of cracking versus time

Thermal Cracking Model Usage

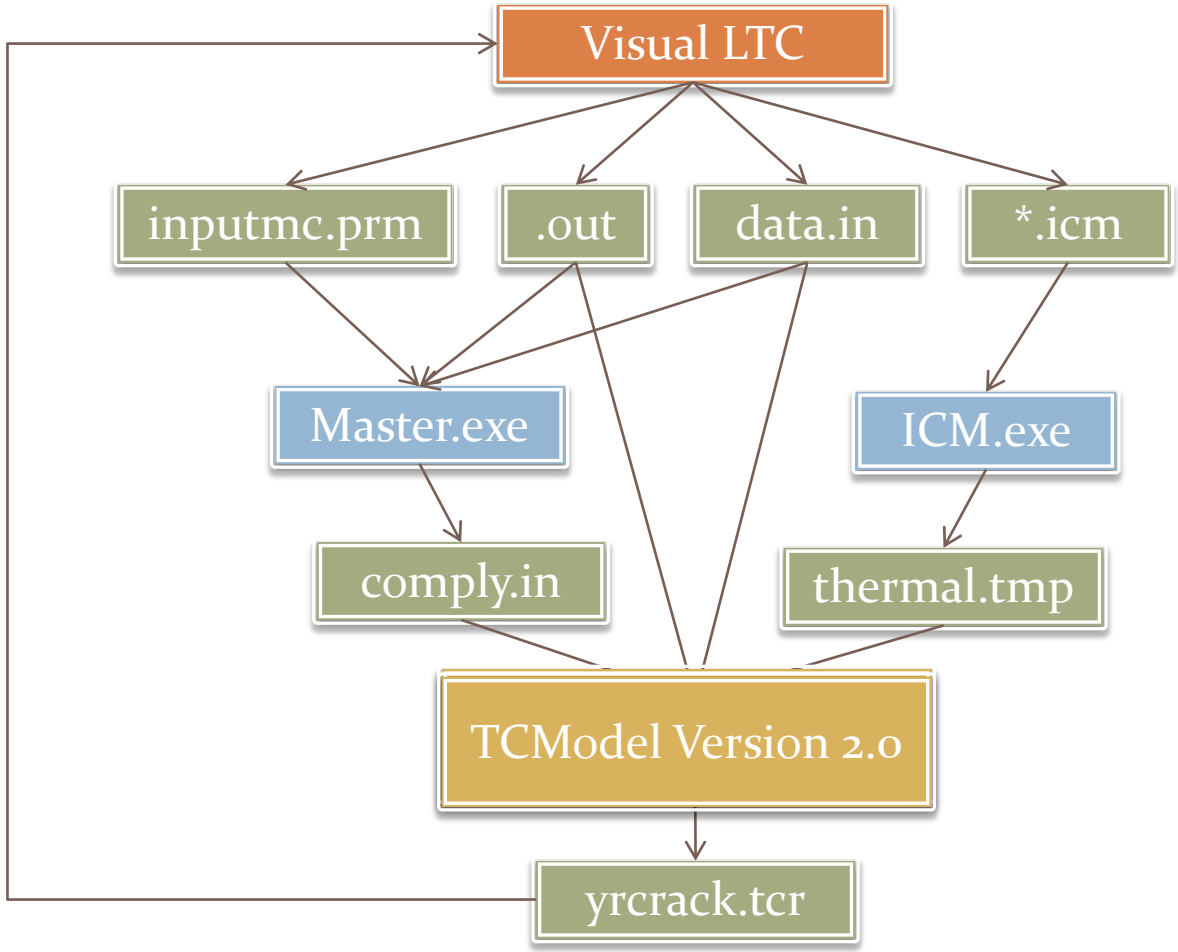


- Amount of cracking versus time returned to Visual LTC

Thermal Cracking Model Usage



Thermal Cracking Model Usage



TCModel vs. TCModel Version 2.0

TCModel[1]

- Stress Intensity Factor Model

$$K = \sigma(0.45 + 1.99C_0^{0.56})$$

Current crack length
Far-field stress at depth of crack
Stress Intensity Factor

- Fracture Model: Paris "Law"

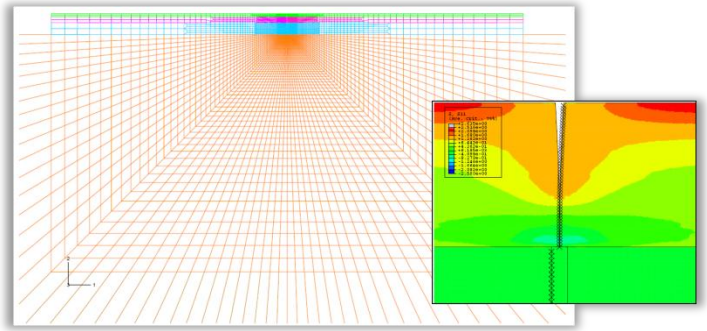
$$\Delta C = A(\Delta K)^n$$

Change in stress intensity factor
Fracture parameters
Change in crack depth

- Crack Amount Model
  - Amount of cracking is a function of the probability that the crack depth is equal to or greater the thickness of the surface layer

TCModel Version 2.0

- Finite Element Based Thermal Cracking Prediction Model with Cohesive Zone Modeling



Bilinear cohesive zone model[2]

[2] *S. Song, G. H. Paulnio, W. G. Buttlar. "A Bilinear Cohesive Zone Model Tailored for Fracture of Asphalt Concrete Considering Viscoelastic Bulk Material." Eng. Fracture Mech. 73 (2006): 2829-2848.*

[1] *D. R. Hiltunen and R. Roque. "A Mechanics-Based Prediction Model for Thermal Cracking of Asphaltic Concrete Pavement." Asphalt Paving Technology: Proceedings - Association of Asphalt Paving Technologists Technical Sessions. 63 (1994): 81-108.*

Visual LTC Development

- Written in C# under Microsoft's .NET Framework
- C# Language is intended for use to develop deployable software
  - Code can be executed locally and internet distributed
- Object oriented, garbage collection, exception handling
- .NET Framework supports building and running applications
  - Common Runtime Language: manages code at execution time
  - Class Library: object-oriented collection of reusable types

Visual LTC Data Storage

- Data to Store
  - Existing Projects from previous Visual LTC runs
  - Existing Asphalt Mixes from previous Visual LTC runs and default mixes
  - Climatic Data (downloaded from MEPDG website)

- Data Storage Requirements
  - Modifications to existing data and/or new data in one Visual LTC run should be available to user in subsequent runs

- Solution: Working Directory and Input Files
  - Practical for user because Visual LTC creates and checks input files automatically

Visual LTC User Types

- Similar to existing MEPDG layout
- User can easily switch between user types

Standard User

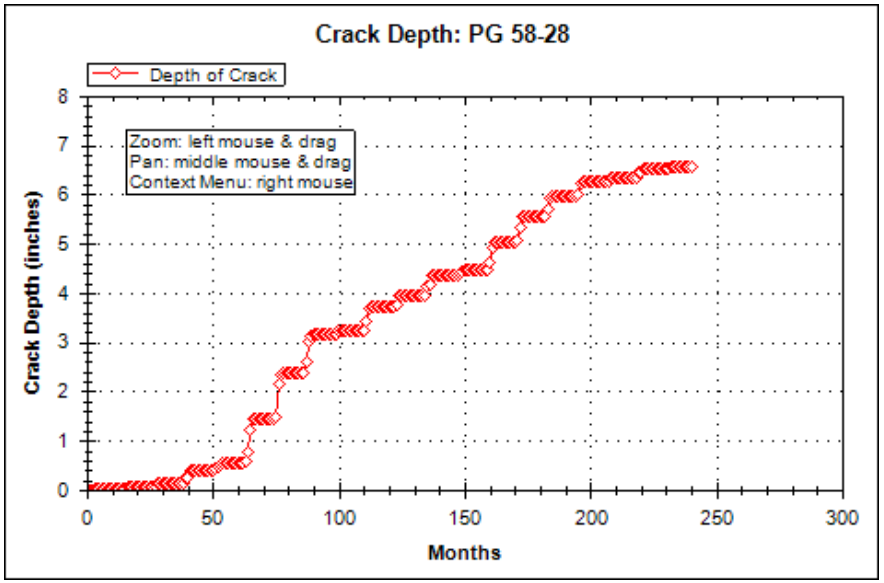
- Practitioners
- Access to all existing mixes
- Default mix properties can be viewed *but not changed*

Advanced User

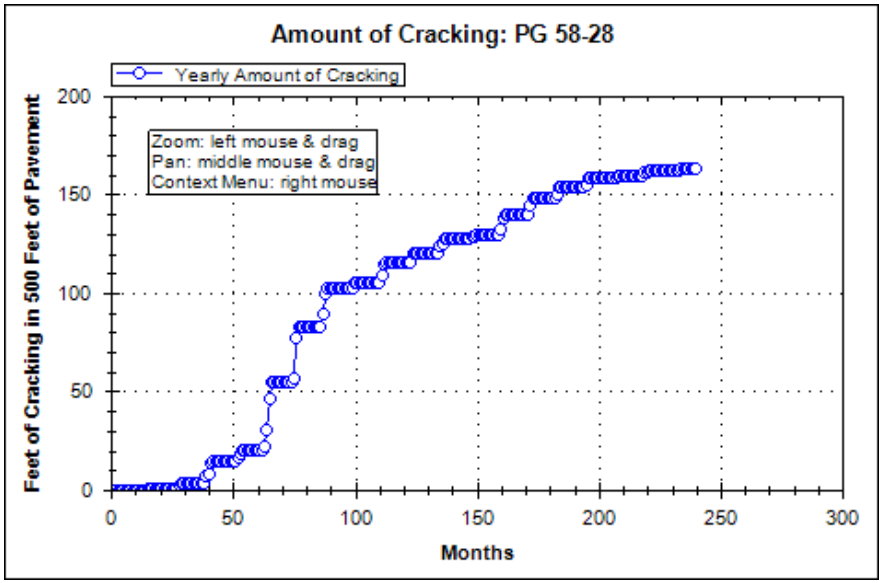
- Researchers/Developers
- Access to all existing mixes
- Default mix properties can be viewed *and changed*
- Modify existing mixes and add new mixes

Visual LTC Result Template

Crack depth with time



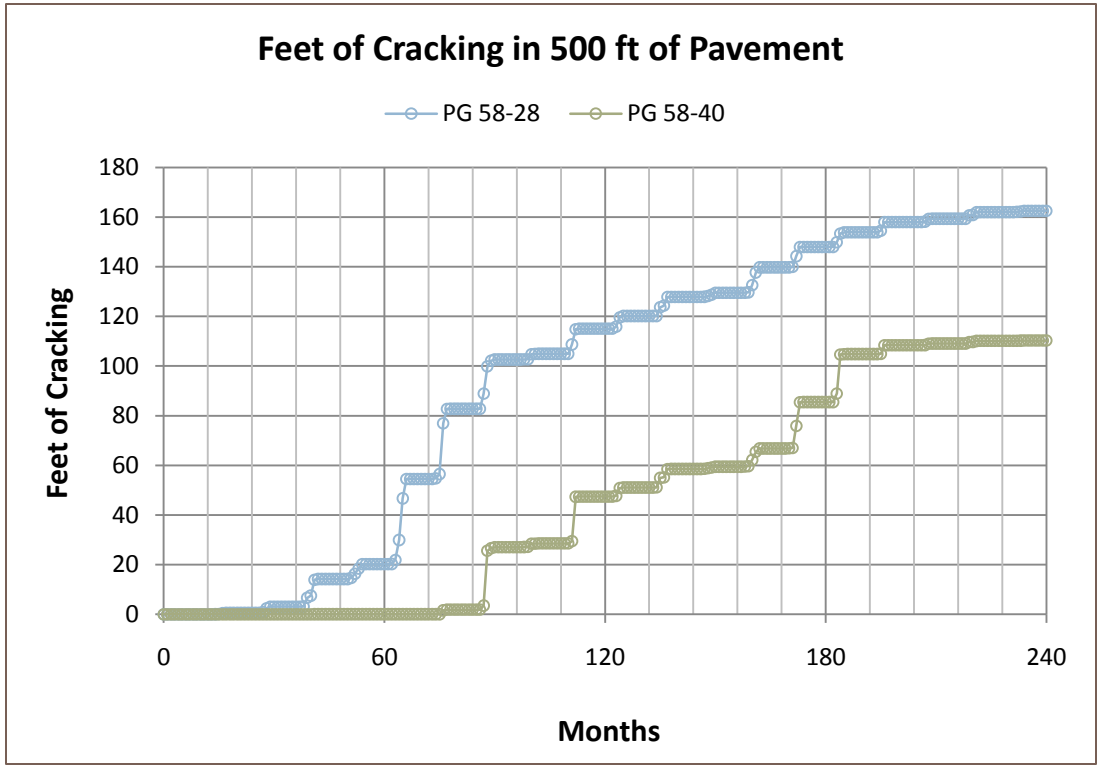
Amount of cracking with time



Demonstration

Thermal Cracking Prediction Results using Visual LTC

	Mn Road Cell 33	Mn Road Cell 35
Mix	PG 58-28	PG 58-40
Tensile Strength	722.2 psi	411.7 psi



Concluding Remarks

- Visual LTC integrates existing tools (Master, ICM, TCModel) for low temperature cracking analysis and design of asphalt pavements
- Provides accessibility to practitioners and researchers
- Relevant features of Visual LTC
  - User friendly
  - Expandable
  - Adaptable
- Work is in progress to develop a tailored nonlinear cohesive zone model to provide a more realistic model of fracture