Bench marking for Evaluating Fire Response of Materials and Structural Systems

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Outline

- What is Bench Marking?
- Why is it Important ?
- When it is Required ?
- Which Response Parameters?
- How it is done in other Areas?
- How can it be Applied?
  - Case Study – RC columns

Structural Fire Response

- Fire resistance
- Measure of the ability of a building element to resist a fire
  - Usually expressed in time as the duration during which a building element exhibits resistance with respect to:
    - Structural integrity
    - Stability
    - Temp transmission during a fire-resistance test
  - Performance of structural systems under fire conditions
    - Fire severity
    - Material properties
    - Structural parameters and member interactions
      - Load, restraint, member interactions
- Materials do not possess fire resistance

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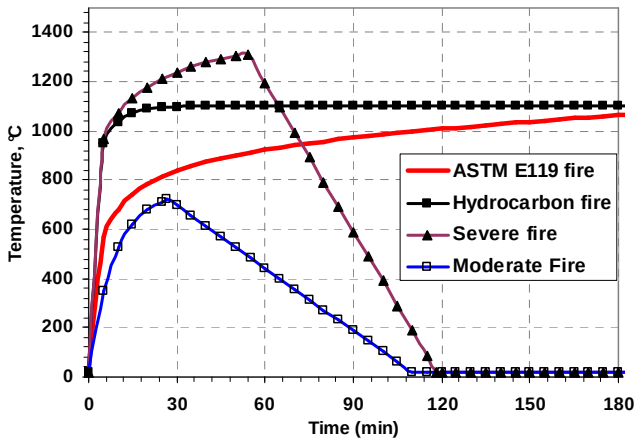
Fire Resistance Analysis
Fire Severity



Fire scenarios for compartment fires

- Fire load
- Occupancy
- Design features
- Type of building

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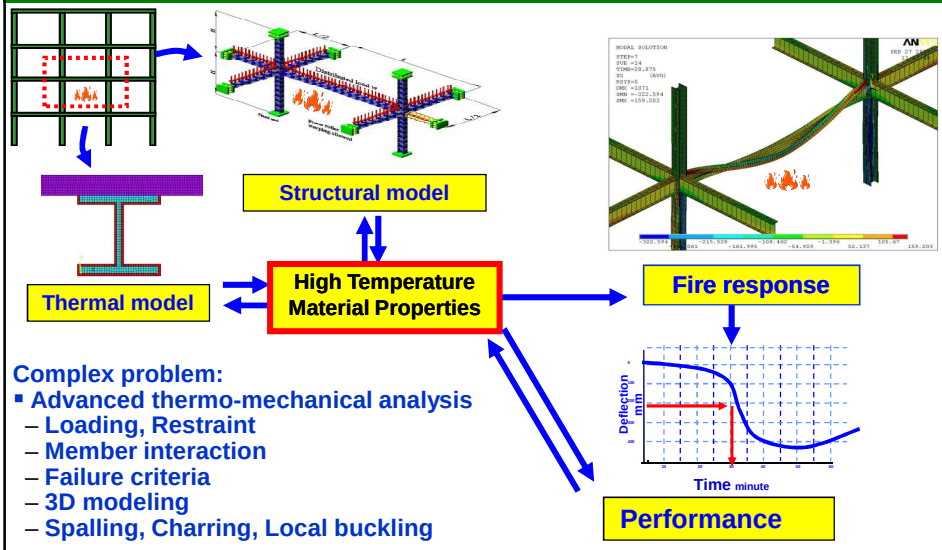
Fire Resistance Analysis
Structural Parameters & Interactions



Complex problem:
- Advanced thermo-mechanical analysis
  - Loading, Restraint
  - Member interaction
  - Failure criteria
  - 3D modeling
  - Spalling, Charring, Local buckling

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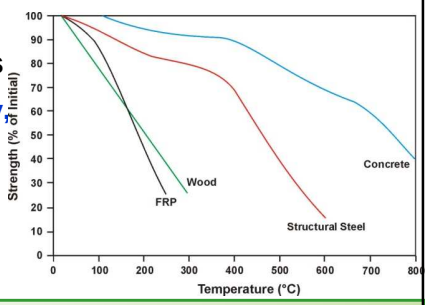
Fire Resistance Analysis - Materials

Structural performance depends on

- Properties of constituent materials
- Reliable high temperature properties are critical for realistic analysis
- No matter how complex numerical model is, improper material properties can give misleading answer
- Conventional construction materials
  - Concrete, steel (protected), masonry
  - Good FR properties
  - Limited Performance problems
  - Large Variation in H.T. properties



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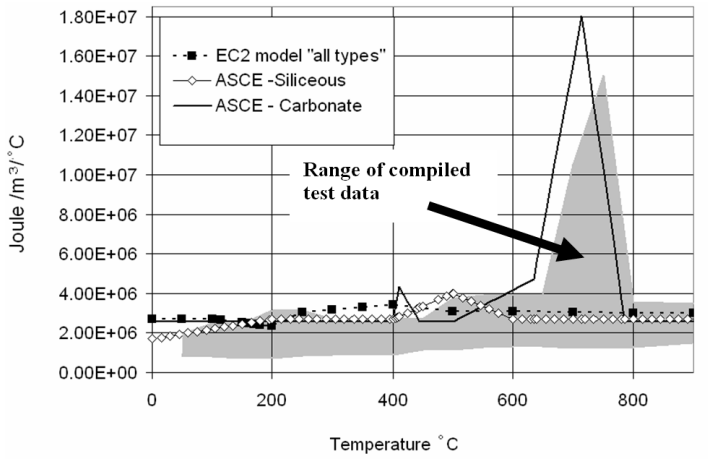
Knowledge Gaps - Material Characteristics

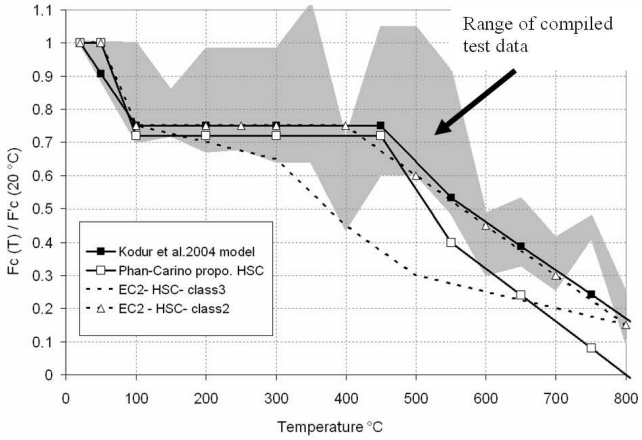
- **Properties @ Elevated Temp**
  - Thermal - conductivity, sp. heat, mass loss
  - Mechanical – stress-strain, elastic mod.
  - Deformation - expansion, creep, shrinkage
  - Material-specific properties
    - Concrete – bond, pore pressure, moisture migration
    - Steel – bond, local buckling
    - Wood – charring, moisture
    - Insulation – stickability (adhesion, cohesion), impact resistance
  - Properties - function of temperature
  - Constitutive models
  - Usually evaluated through tests
    - Small scale specimens (coupons)
    - Lower heating rates
    - Steady state conditions

Variability – NSC



Variations in test data for heat capacity of NSC

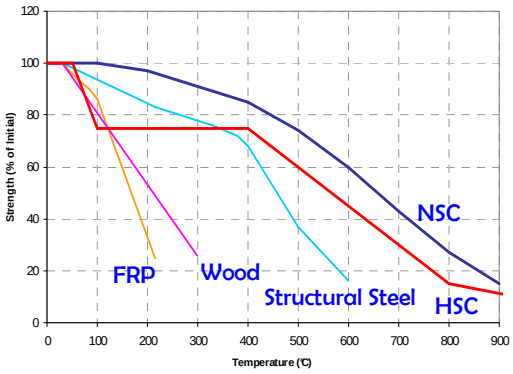
Variability – HSC



Variation of compressive strength with temperature for HSC

Variability- New Concretes

- New types of concrete – HSC, HPC, FRC, FAC
- Advantages
  - Superior strength
  - Higher stiffness
  - More durable
- Characteristics
  - Low w/c
  - Admixtures
  - Silica Fume
  - Dense/compact
  - Low permeability
  - Brittle
- Problems
  - Fire behavior is different
  - Faster degradation of strength & stiff
  - Fire induced spalling
- Current FR provisions may not be applicable



Variation of comp. strength with T for materials

Factors Influencing Fire Performance

- Compressive Strength
- Reinforcement Layout
- Moisture Content (RH)
- Concrete Density
- Fire Scenario
- Aggregate Type
- Load Intensity & Type
- Fiber Reinforcement
- 1-, 2-, 3-, 4-side Exposure
- Fire induced spalling
- Biaxial Bending

Fire Induced Spalling

- NSC – Minimal spalling
- HSC – Significant spalling
  - Pressure build-up - pore pressure
    - Moisture migration
  - Low permeability
  - Strong pressure gradients
  - Can be explosive
- Implications
  - Loss of C/S – fire resistance
  - Ext. damage – structure
  - Early spalling - safe evacuation
  - Cover – temp in rebar/ties
- No guidelines
  - ACI 318/216, CSA-A23.3, NBCC
- Need innovative solutions

NSC column HSC column

NSC and HSC Columns after Fire Resistance Tests

Thank You

Questions