Assessment of Concrete Deformation and Failure Behavior during a Standard Fire Test and a Controlled Heating Rate Test

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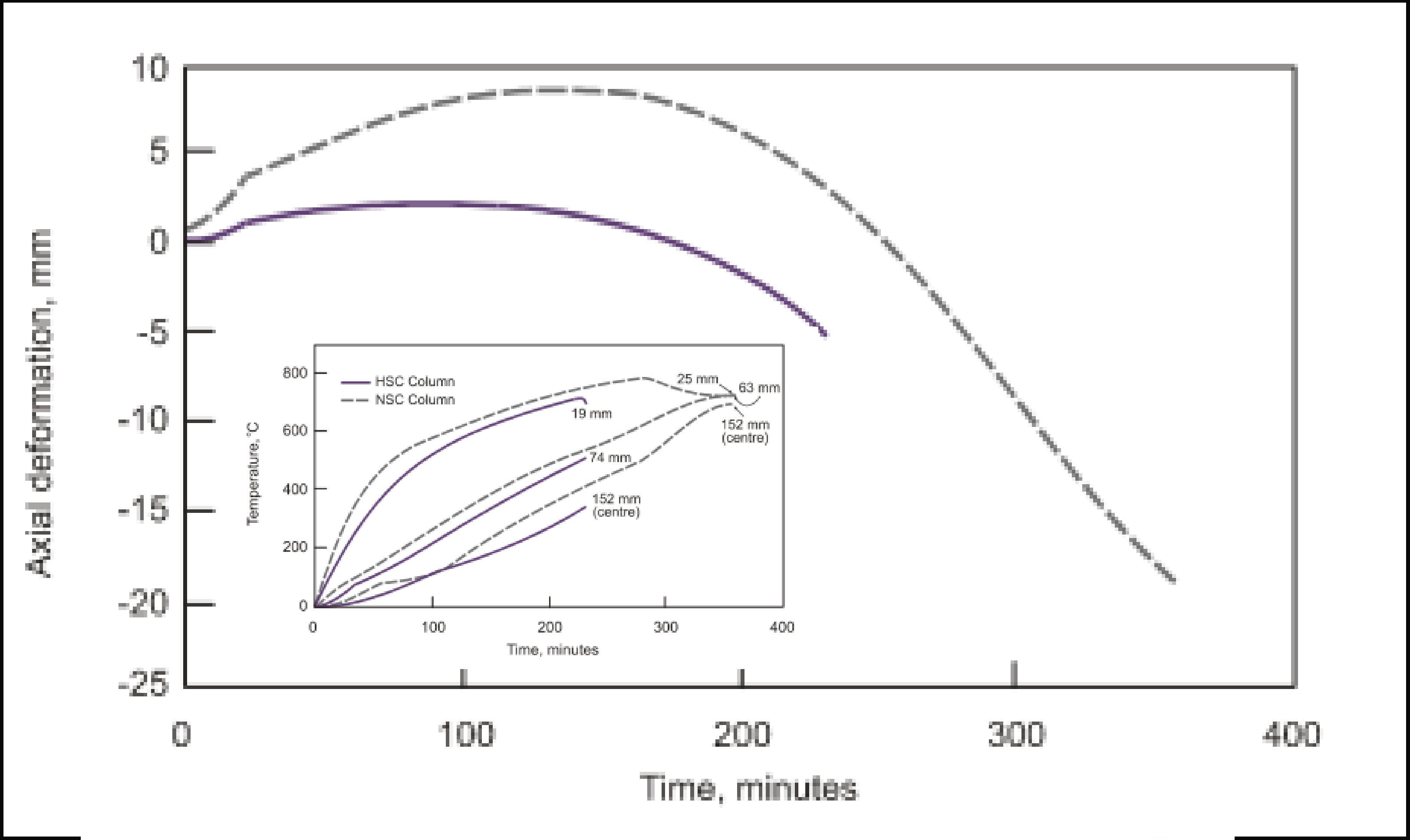
Normal and High Strength Concrete Column Behavior



Kodur, V.K.R. Fire resistance design guidelines for high strength concrete columns. NRCC-46116 or ASCE/SFPE Specialty Conference of Design Structures for Fire and JFPE, Baltimore, MD, October 2003, pp. 1-11

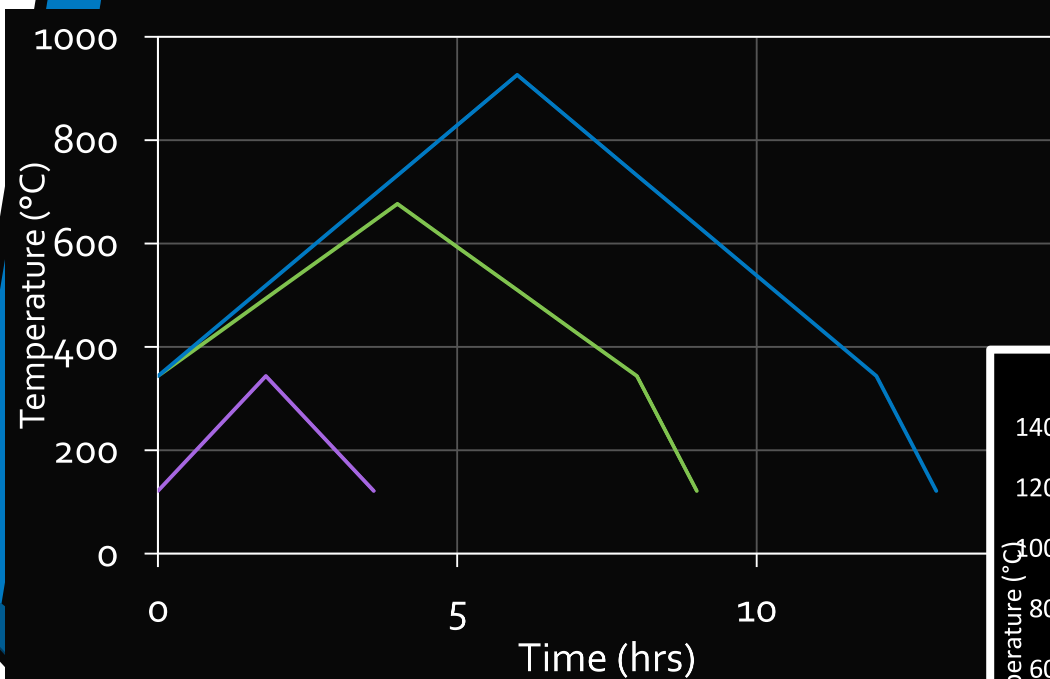
Observations from Column Fire Testing

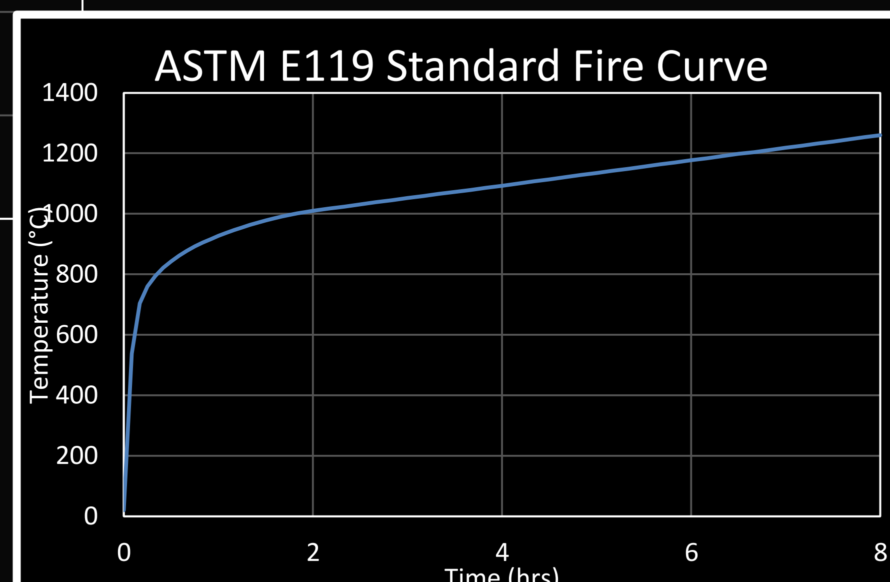
- The failure of the RC column is governed by the strength of the concrete
    - Concrete carries an increasing portion of the applied column load as the steel temperature increases resulting in yielding and decreasing strength.
    - The concrete strength also decreases with temperature

- The fire resistance decreases with increasing load intensity (loss of strength is higher in HSC than in NSC).

Motivation

- How comparable are concrete behaviors observed from simulated controlled heating rate fire tests to that of concrete behavior in standard fire tests?



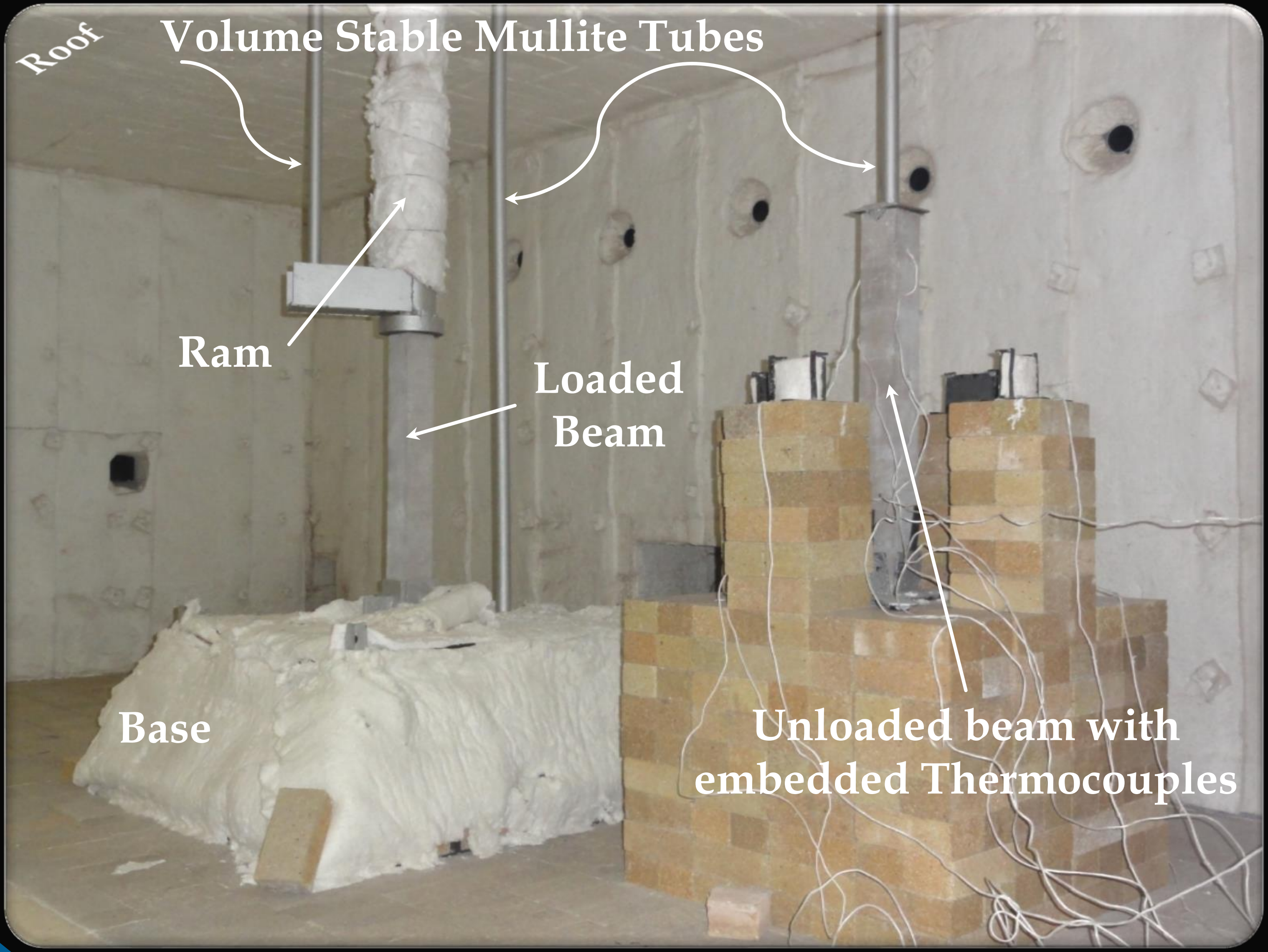


Concrete Mix	NSC	HSC	VHSC
Limestone Coarse Aggregate (kg/m^3)	1032	785	787
Limestone Fine Aggregate (kg/m^3)	795	880	859
Limestone Intermediate Aggregate (kg/m^3)	-	349	288
Type 1 Cement (kg/m^3)	203	259	262
Slag Cement (kg/m^3)	110	146	141
Mid-Range Water Reducer (Super P) (L)	0.95	1.2	1.2
Water (kg/m^3)	133	114.5	105
Water/Cementitious Materials Ratio	0.43	0.28	0.26
Compressive Strength (MPa)			
28 days	51.5	63.4	90.0
At Time of Testing	52.5	77.5	107

Specimens around 80-87% internal RH prior to testing
VHSC: conditioning at 45° C

Specimens: 100 mm by 100 mm cross section area (length 450 & 900 mm)

Test Setup

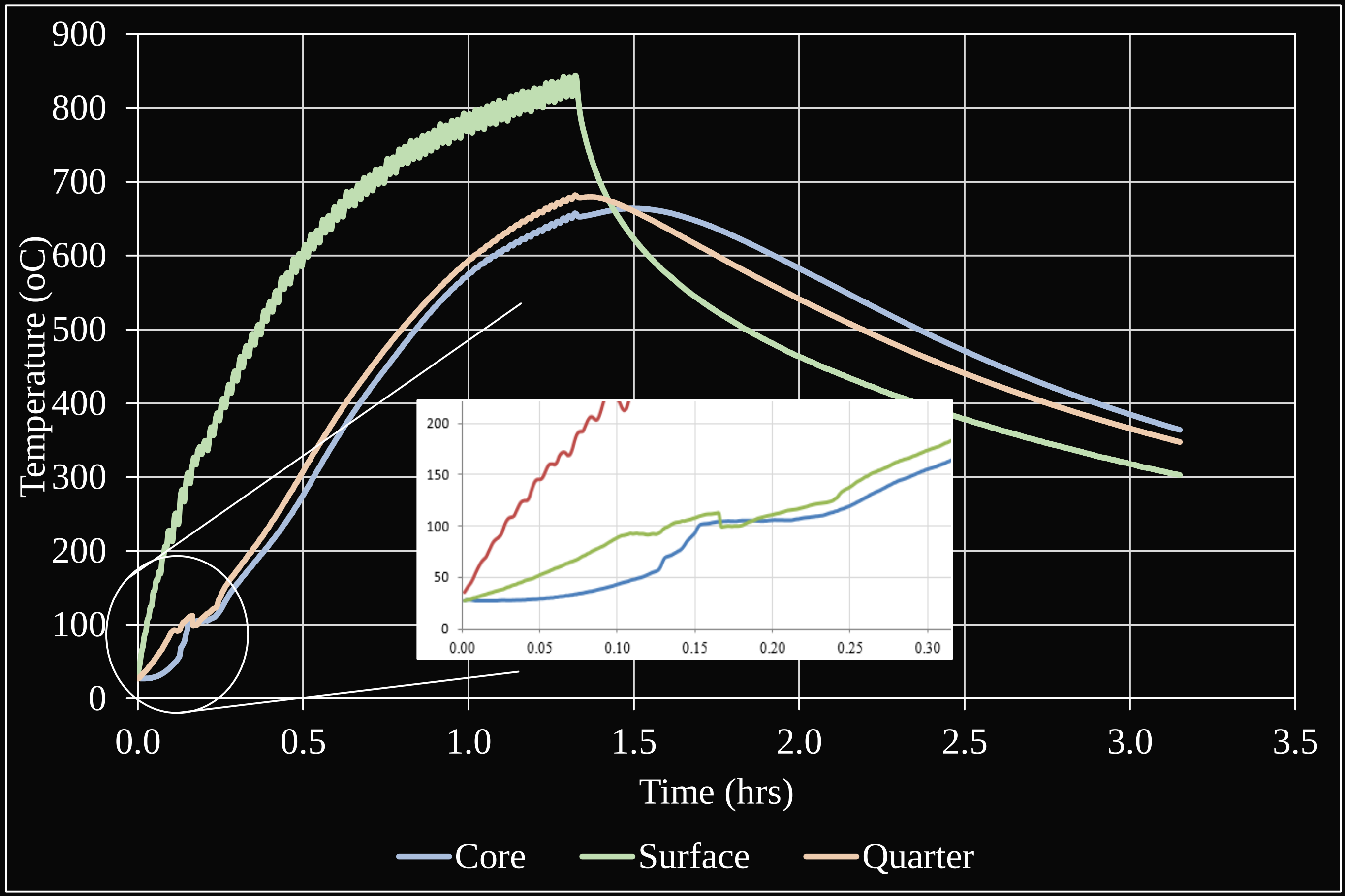

Roof
Volume Stable Mullite Tubes
Ram
Loaded Beam
Base
Unloaded beam with embedded Thermocouples

Testing Procedure

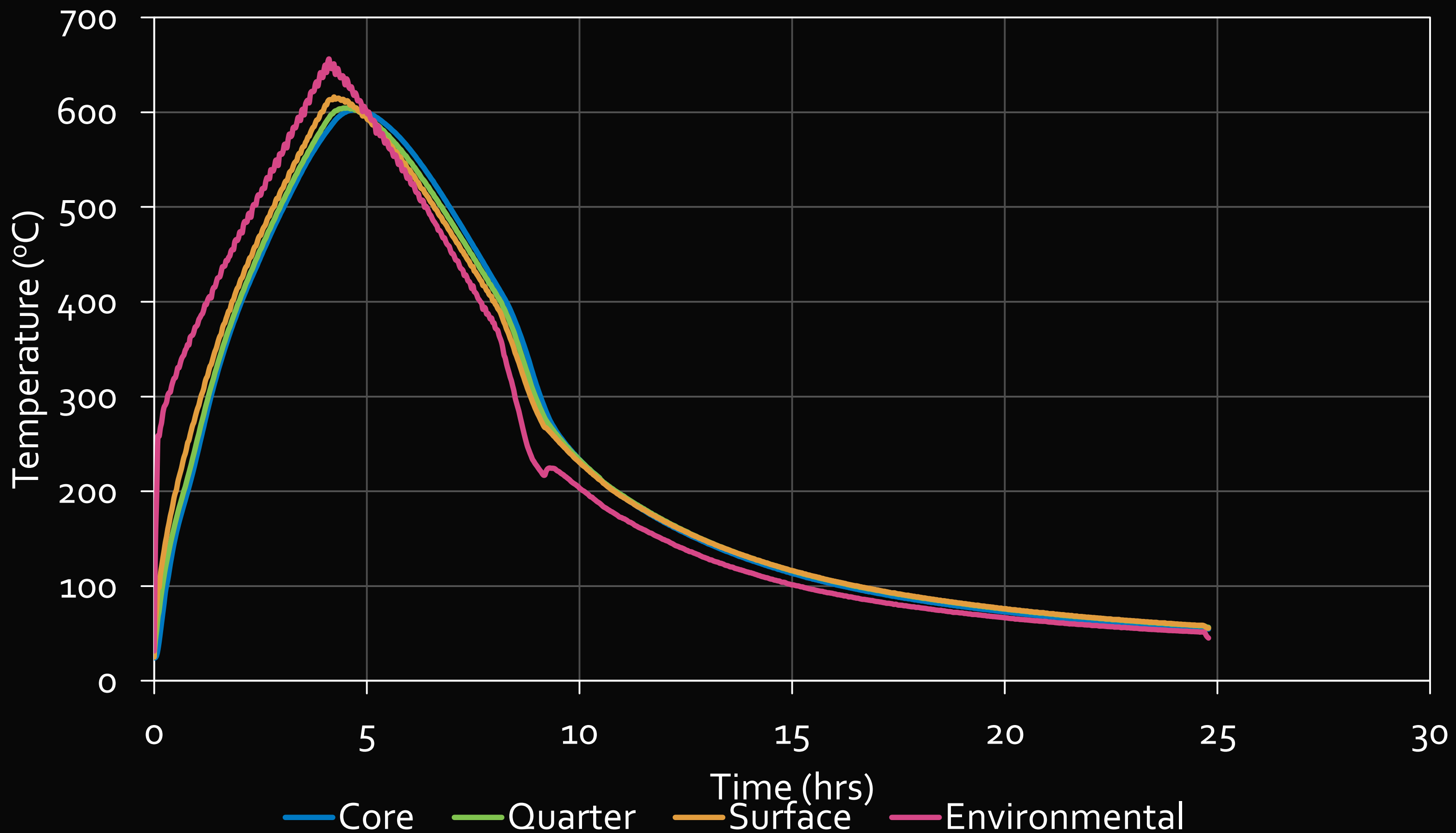
- Specimen Preparation
  - Loaded Prism
  - Free Expansion Prism
- Specimen Loaded to the Predetermined Load
- Thermal Profile Started
- Sustained Load During the Cooling Phase

Specimen Failure at 740°C

Temperature Development in Standard Fire Test



Temperature Development in Controlled Heating Rate Test



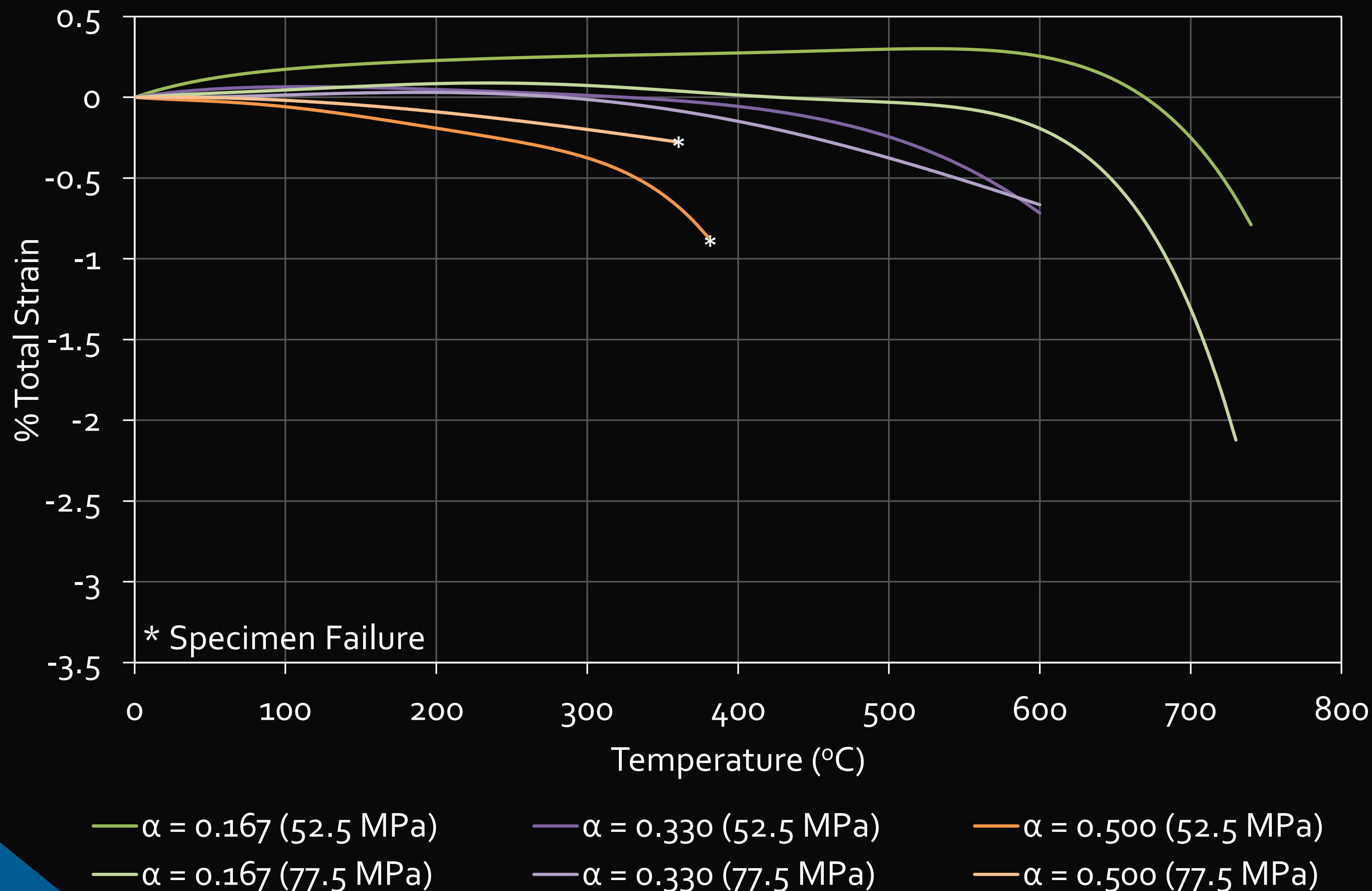
Total Deformation

- Total deformation of concrete is expressed as the sum of four strain components as follows:

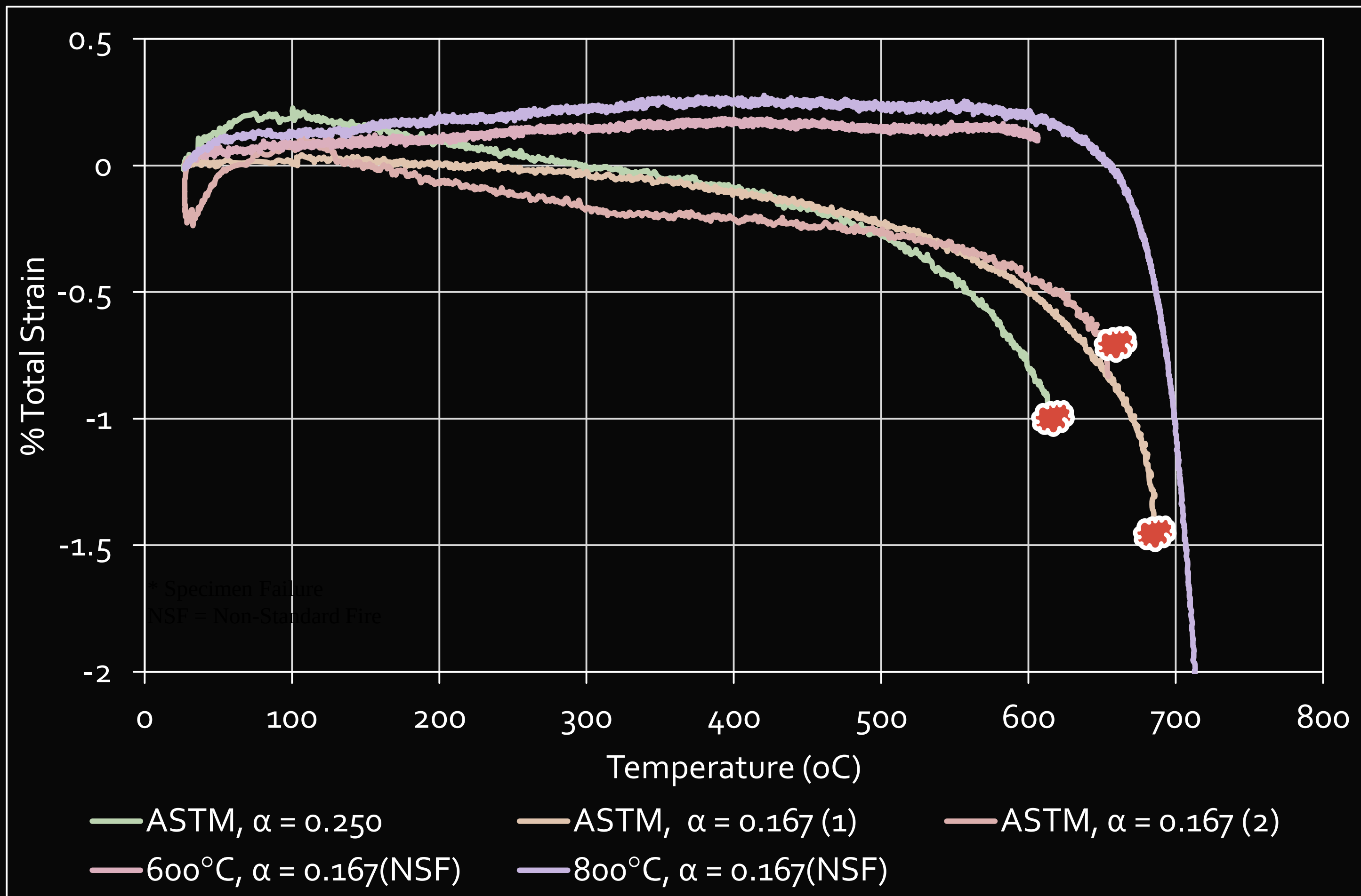
$$\varepsilon = \varepsilon_{th}(T) + \varepsilon_{t\sigma}(\sigma, T) + \varepsilon_{cr}(\sigma, T, t) + \varepsilon_{tr}(\sigma, T)$$

- Components of Total Strain
  - Thermal Strain (ε_{th})
  - Stress Related Strain ($\varepsilon_{t\sigma}$)
  - Creep Strain (ε_{cr})
  - Transient Strain (ε_{tr})

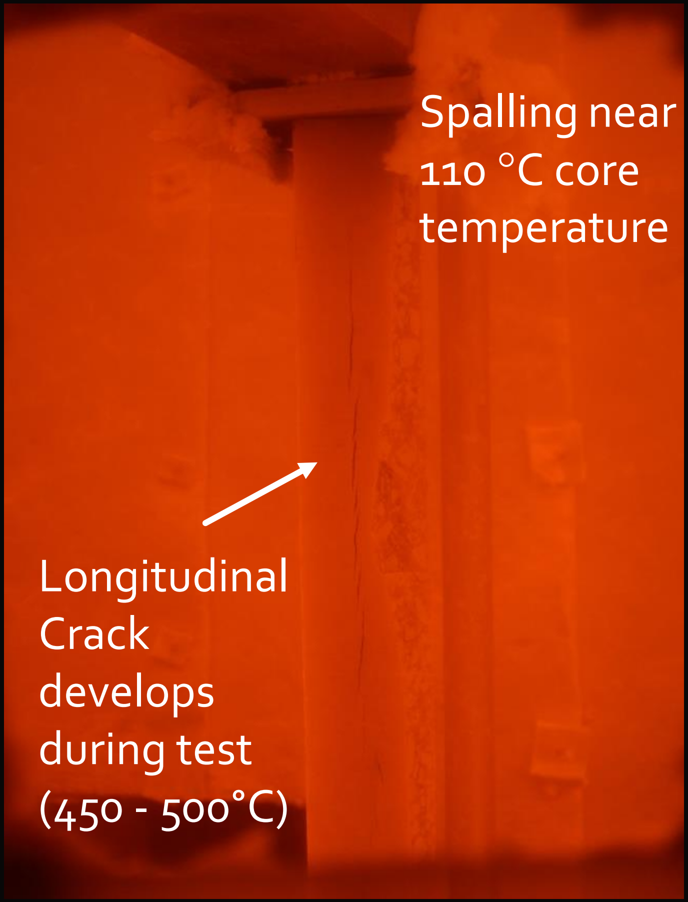
Total Strain Curves – Controlled Heating Rate



Total Strain Comparison
Standard Fire and Controlled Heating



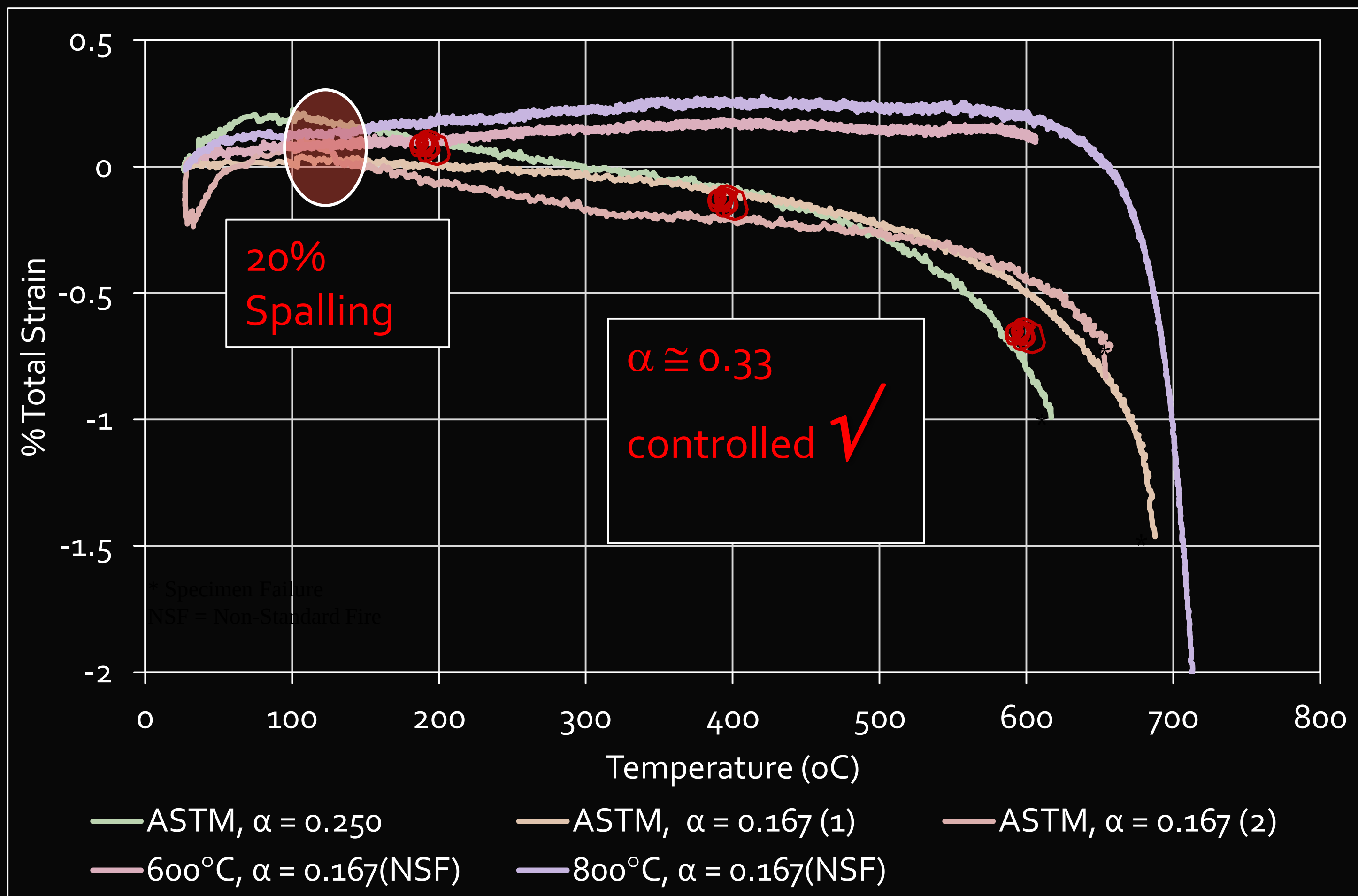
During and After Standard Fire Test



Specimen behavior similar at α = 0.167 and α = 0.25

Specimen Failure for initial load level α = 0.33

Total Strain Comparison
Standard Fire and Controlled Heating



Observations

- The deformation and failure behavior was similar for concrete prisms when load intensity and average core temperature was accounted for.

- Results indicated that deformations exceeding ≈ 1%, whether they occur during heating or cooling, are expected to cause an unstable ‘runaway’ failure.

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Thank you!