EPRI Research Highlights

ACI 349-A

Together… Shaping the Future of Energy®

Monday April 31, 2025

Salvador Villalobos

Overview – High temperature expossure

- General overview
- Materials testing
- Structural testing
- Summary

Background and Current Knowledge

- Advanced reactors are likely to operate at higher temperatures.
- Elevated temperatures may cause: Cracking, spalling, and/or cement paste breakdown

- Ambient and operating (current limits)
  - 150 °F general
  - 200 °F for small areas as long as strength is 115% of 28 day f'c
  - Important to have testing and evaluation

- Testing and evaluation
  - Different materials in the concrete mix
  - Variation of aggregate size
  - Temperatures of 350°F, 500°F, 650°F, and 800°F
  - Evaluate the effects of changing materials for temperature exposures

EPRI report number 3002022614

Twelve Mix Designs

Mix	A	B	C	D	E	F	G	H	I	J	K	L
Cem	100%	65%	50%	65%	50%	65%	65%	65%	65%	65%	65%	24%
F.A.		35%		35%		35%	35%	35%	32%	32%	32%	24%
Slag			50%		50%							48%
S.F.									3%	3%	3%	4%
AGG	Gran	Gran	Gran	Gran	Gran	Gran+ Shale	TX- LS	FL-LS	Gran	FL-LS	FL-LS	FL-LS
	SCM effect			Smaller Agg.			LS-Modulus		S.F.	Smaller Agg.		Quat

Legend:

F.A- Fly Ash　Cem- Cement　S.F – Silica Fume　AGG- Aggregate

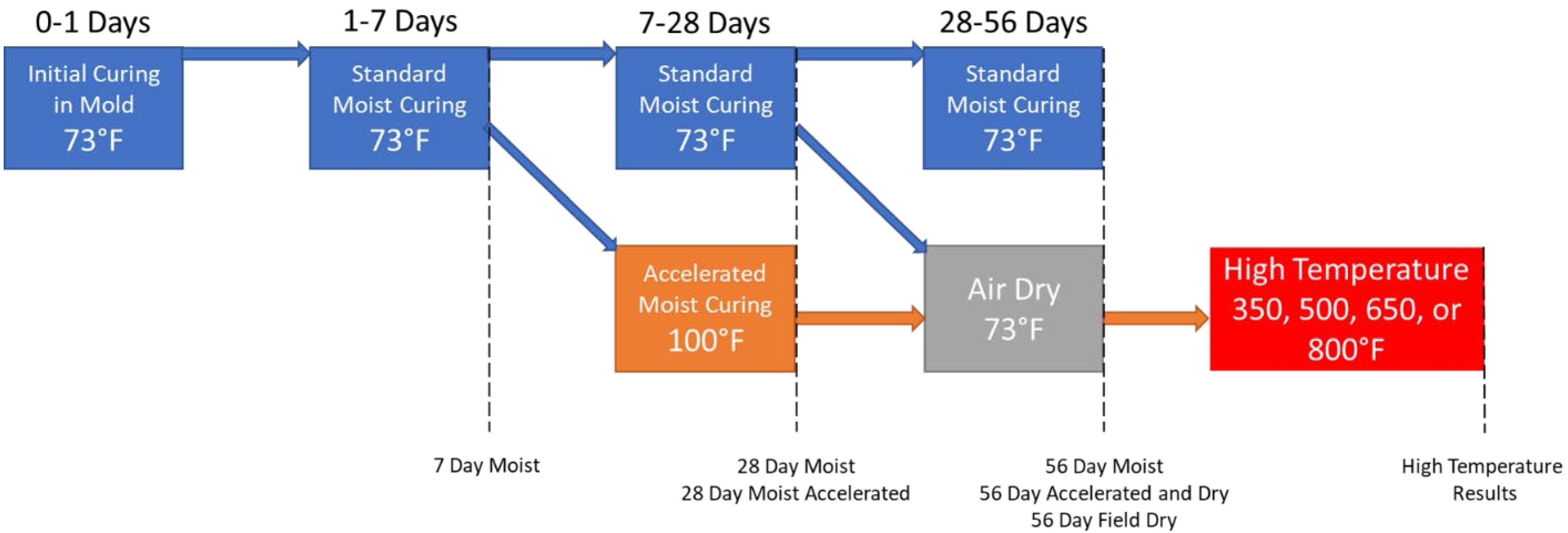
LS – Limestone　Gran - Granite

EPRI

Testing Regime

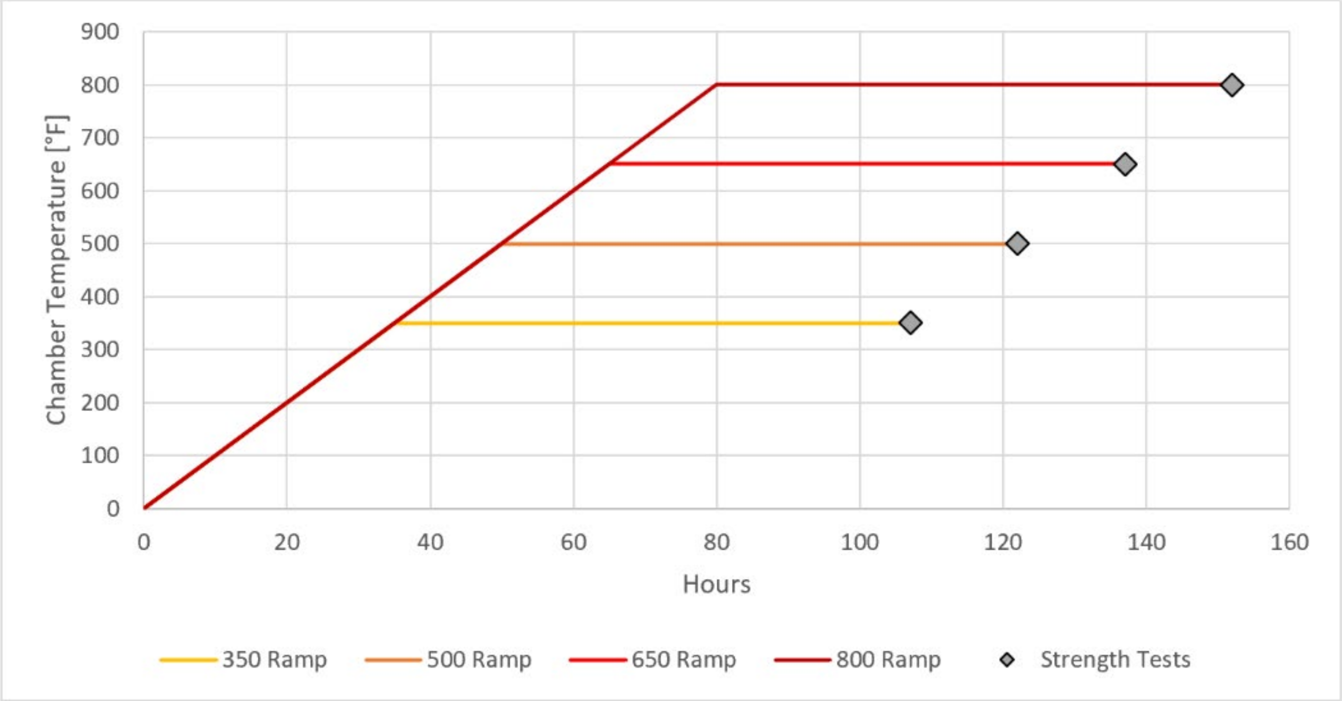
- Twelve different mixtures

A- Standard 28-day curing
B- Seven day Standard + 21 days accelerated (100 F)
C- Fifty six (56) day moist



Test Regime

- 10°F/hr
- Instrumented cylinder for reference



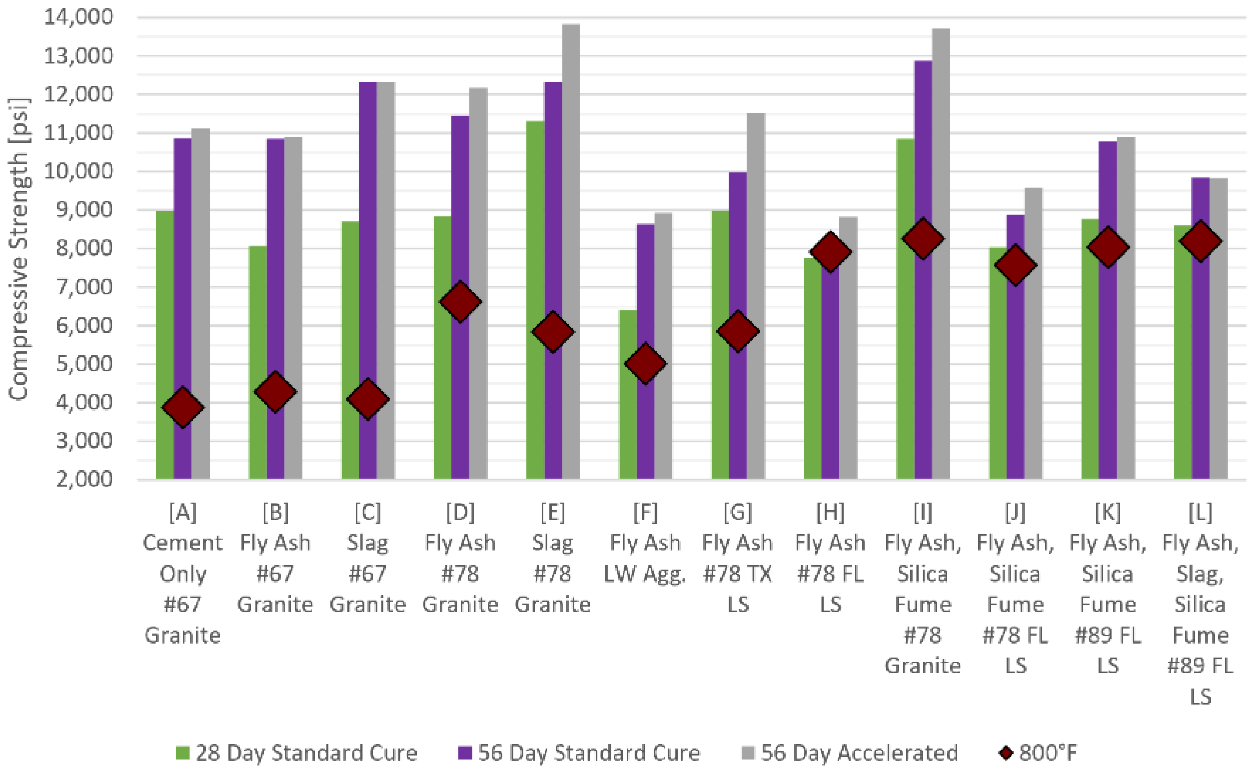
EPRI

Test Results

- 800 F is the highest exposure achieved

Limestone had lower initial strength but higher f'c retention

- 56 day accelerated curing was the highest compressive strength for all categories
- Smaller aggregate generally performed better
- FL limestone had better compressive strength retention – E compatibility



Summary

- The code indicates operational thresholds and indicates that through testing the mixtures can be qualified
- Literature review cites poor performance after 800°F
- This research evaluated 12 mixtures for
  - Differences in SCMs and max aggregate size
  - Three curing regimes
  - F'c retention
- Limestone that matches the modulus of elasticity of the paste has the best f'c retention and potentially have higher f'c than mixtures that had higher initial strength
- Aggregate size has some effect on f'c when exposed at high temperatures

Gaps

- Non-standard test methodology
  - Heated sample vs unheated sample
  - Rate of heating
  - Curing regime
- What is the operating and accident temperature for ARs

Phase II will consist of Structural testing

BOND UNDER HIGH TEMPERATURE

THE UNIVERSITY OF KANSAS

Dr. Rémy Lequesne, PI

Bikash Giri

PURDUE UNIVERSITY

Dr. Akanshu Sharma, Co-PI

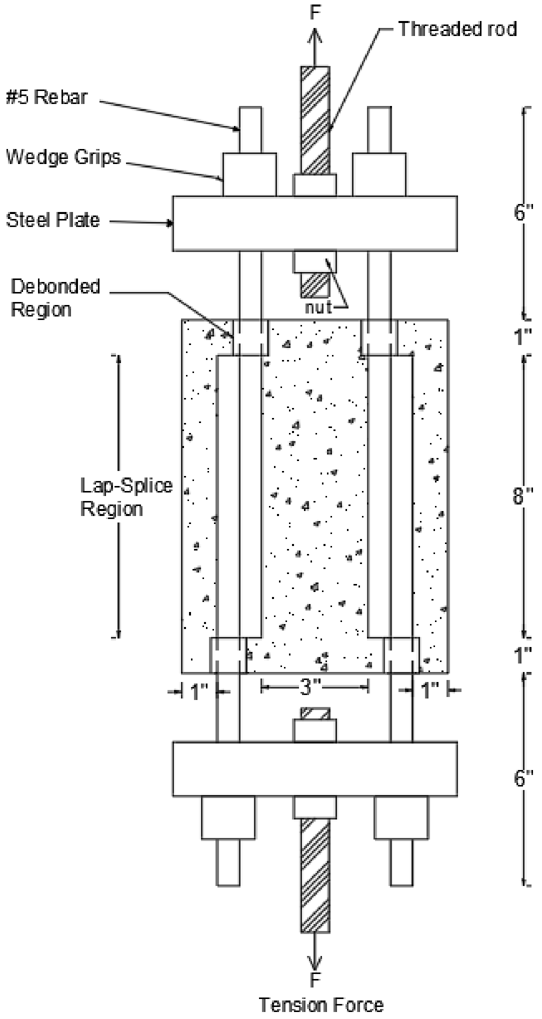
M. Fasih Rehman

EPRI

Project Aims

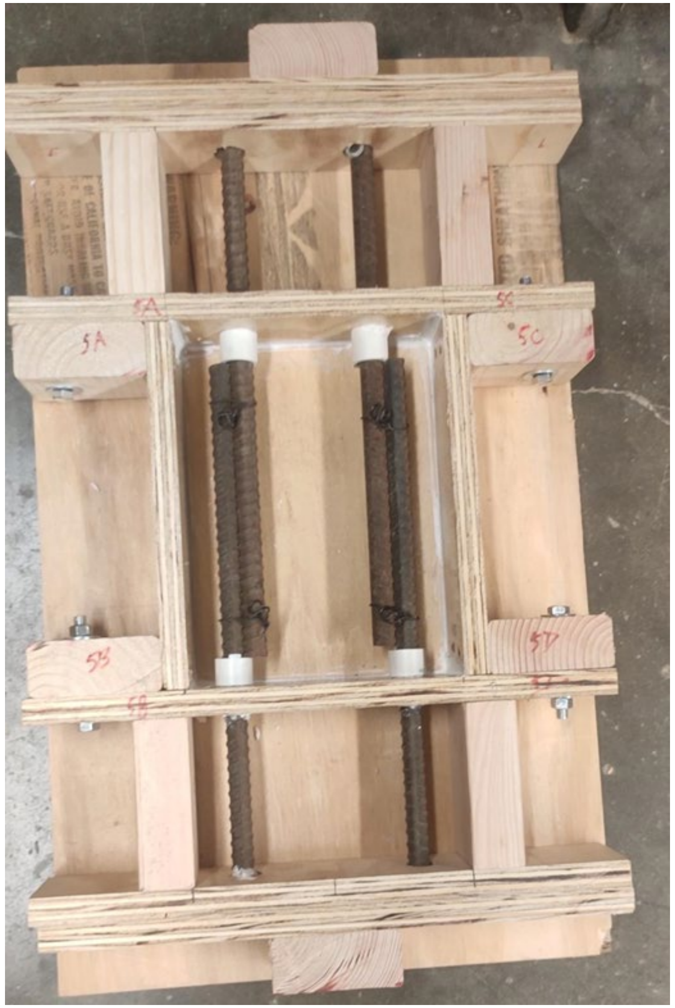
- Review literature and collect input from industry leaders to understand ANR design needs
- Experimentally/numerically investigate key variables related to high temperature effects on rebar-concrete bond to support ANR design
- Propose recommendations for design and modeling temperature effects on bond
- Report on temperature mitigation strategies to reduce exposure of concrete elements to high temperatures

Kansas: Small-Scale Lap Splice Tests



- About 2/3 of tests (14 of 44) are complete
- Variables of interest
  - Maximum Temperature
    - 200°C, 400°C, and 600°C
  - Number of cycles
    - 1, 3, 5
  - Heating rate
    - 2°C/min
    - 5°C/min

Kansas: Small-Scale Lap Splice Tests



Before concrete placement

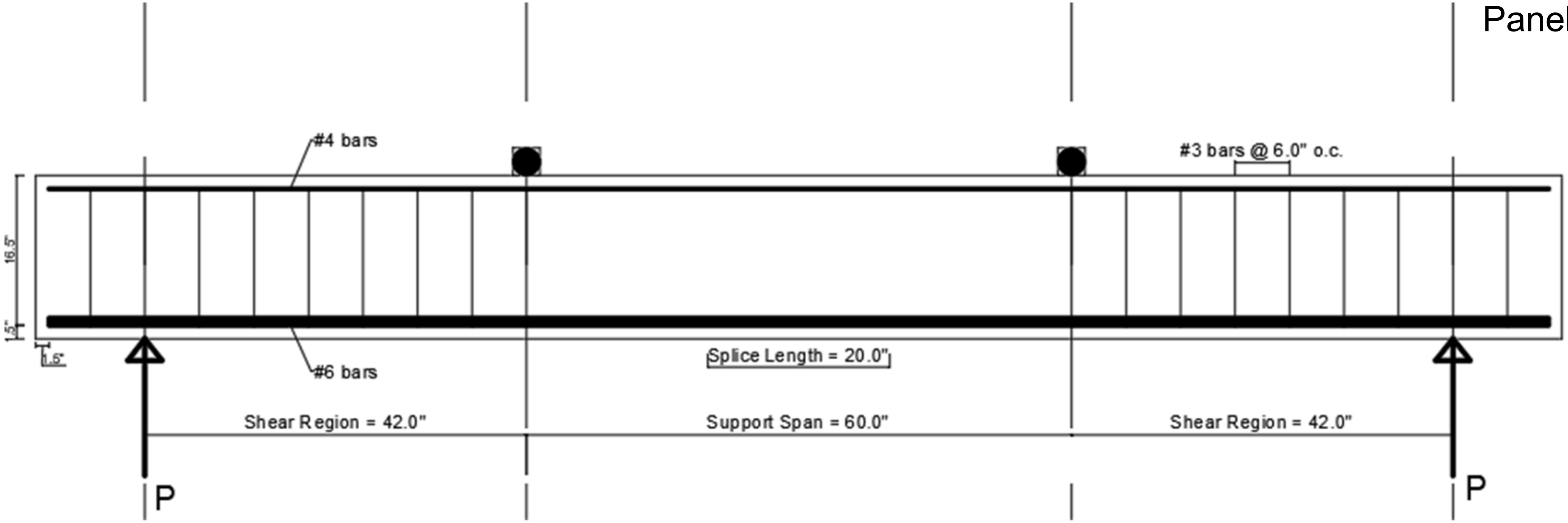
Inside kiln

Specimen after test

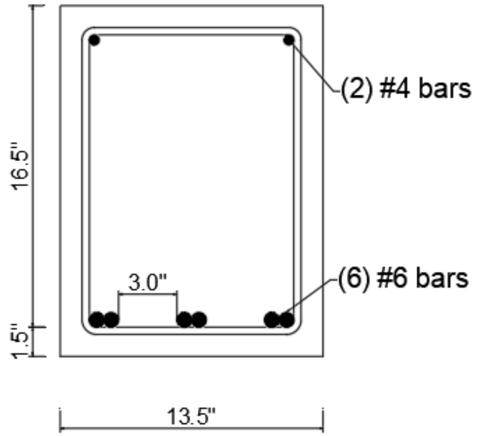
Kansas: Plans for Large-Scale Tests

- Variables of interest
  - Heating under loading
  - Testing while specimen is at high temperature

Panel for heating specimen surface

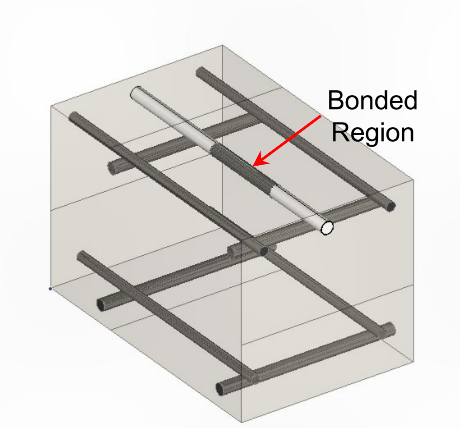


Elevation View

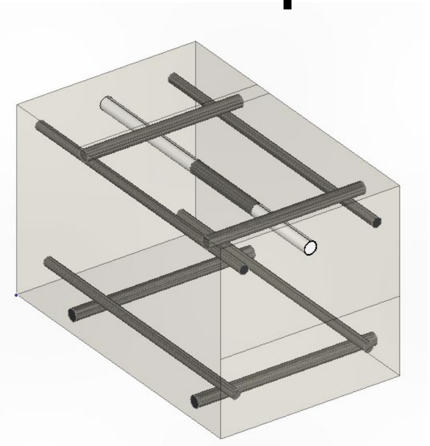


Cross section

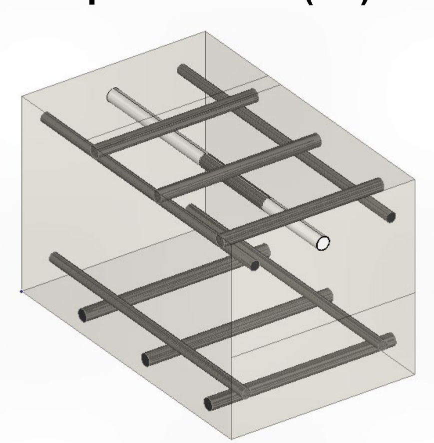
Purdue: Experimental Program



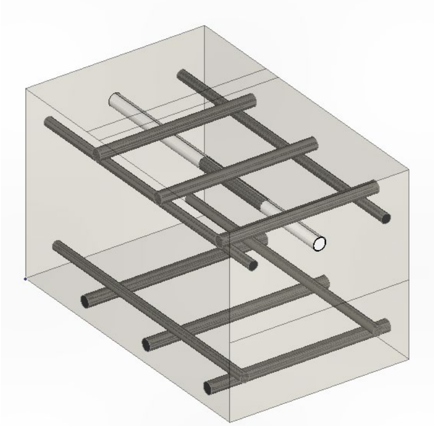
Specimens-1 (S1)



Specimens-2 (S2)



Specimens-3 (S3)



Specimens-4 (S4)

4 Specimens

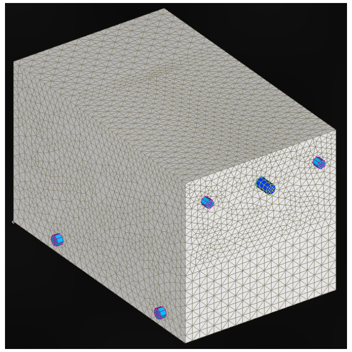
S1	$c\text{-}c_{min}$	0.75 in
	TR	0
S2	$c\text{-}c_{min}$	1.50 in
	TR	0
S3	$c\text{-}c_{min}$	1.50 in
	TR	1
S4	$c\text{-}c_{min}$	2.25 in
	TR	1
$c\text{-}c_{min}$: clear cover minimum TR: No. of transverse rebar in bonded region		

15 Replica per specimens

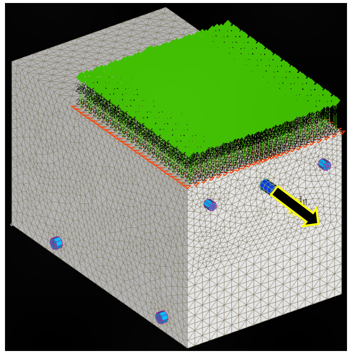
- Ambient temperature: 3 tests
  - 2 heating rates: 6 tests
  - 1 heating cycle: 3 tests
  - 3 heating cycle: 3 tests

Casted Specimens

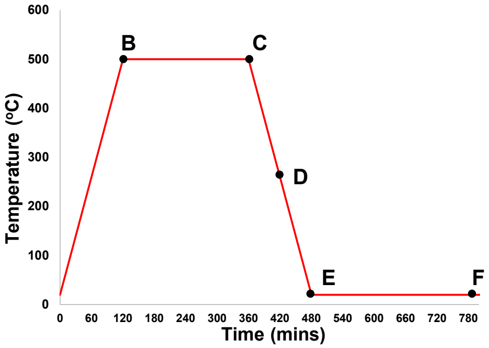
Purdue: Numerical Analysis



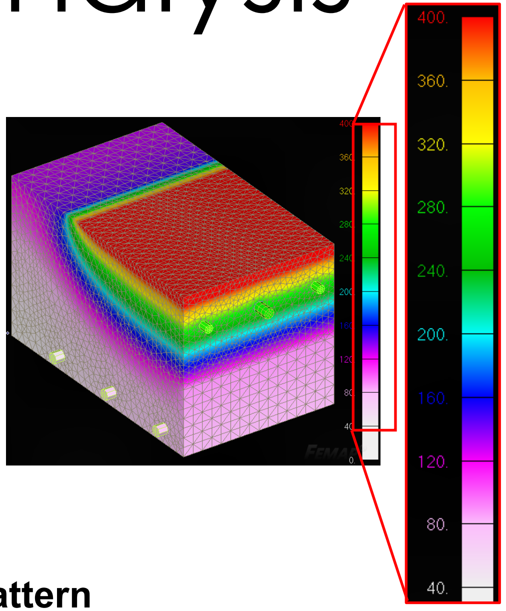
Numerical Model

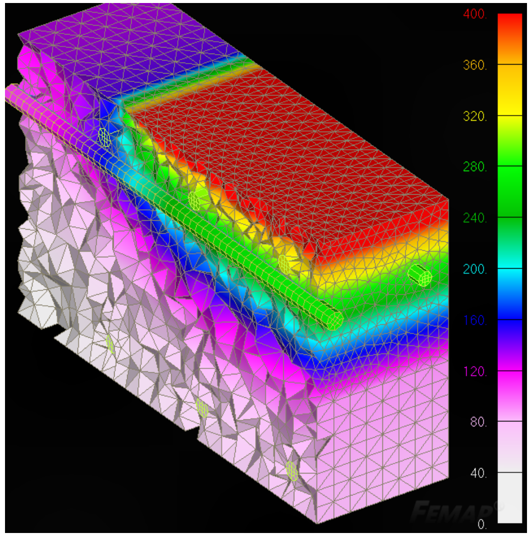


Sequential loading
Thermal
Mechanical



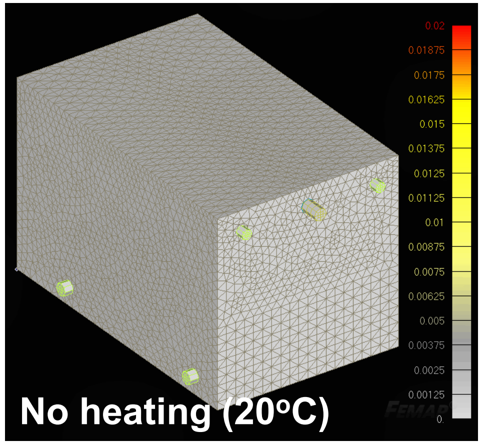
Thermal Cycle

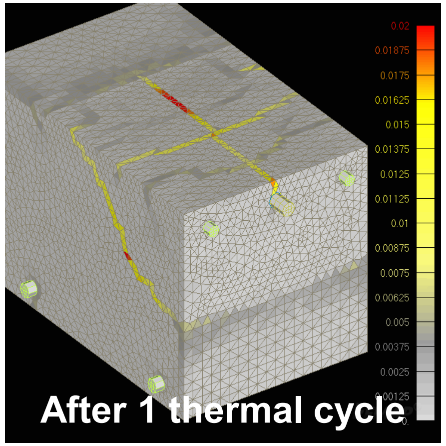


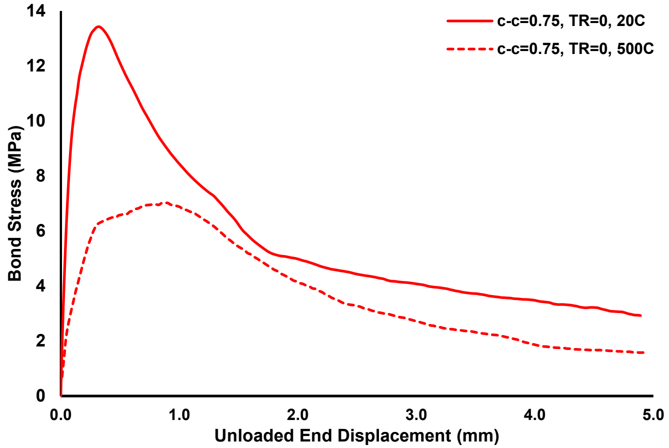


Temperature Profile at 'C'

Crack Pattern







Timeline

- Procurement largely complete
- Small-scale tests at Kansas and numerical modelling at Purdue continuing
- Spring/Summer 2024: Larger-scale testing at Kansas and Purdue
- Fall 2024/early 2025: analysis and reporting

TOGETHER…SHAPING THE FUTURE OF ENERGY®

www.epri.com