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2025 SPRING CONVENTION

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STICKY SITUATION: A CASE STUDY ON FRP AND HRA INTERACTION

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OUTLINE

I. Learning Objectives
II. Project Background
III. Fiber Reinforced Polymer Systems
IV. Hot Rubberized Asphalt Waterproofing Systems
V. A Sticky Situation and a Complicated Conversation
VI. Conclusions

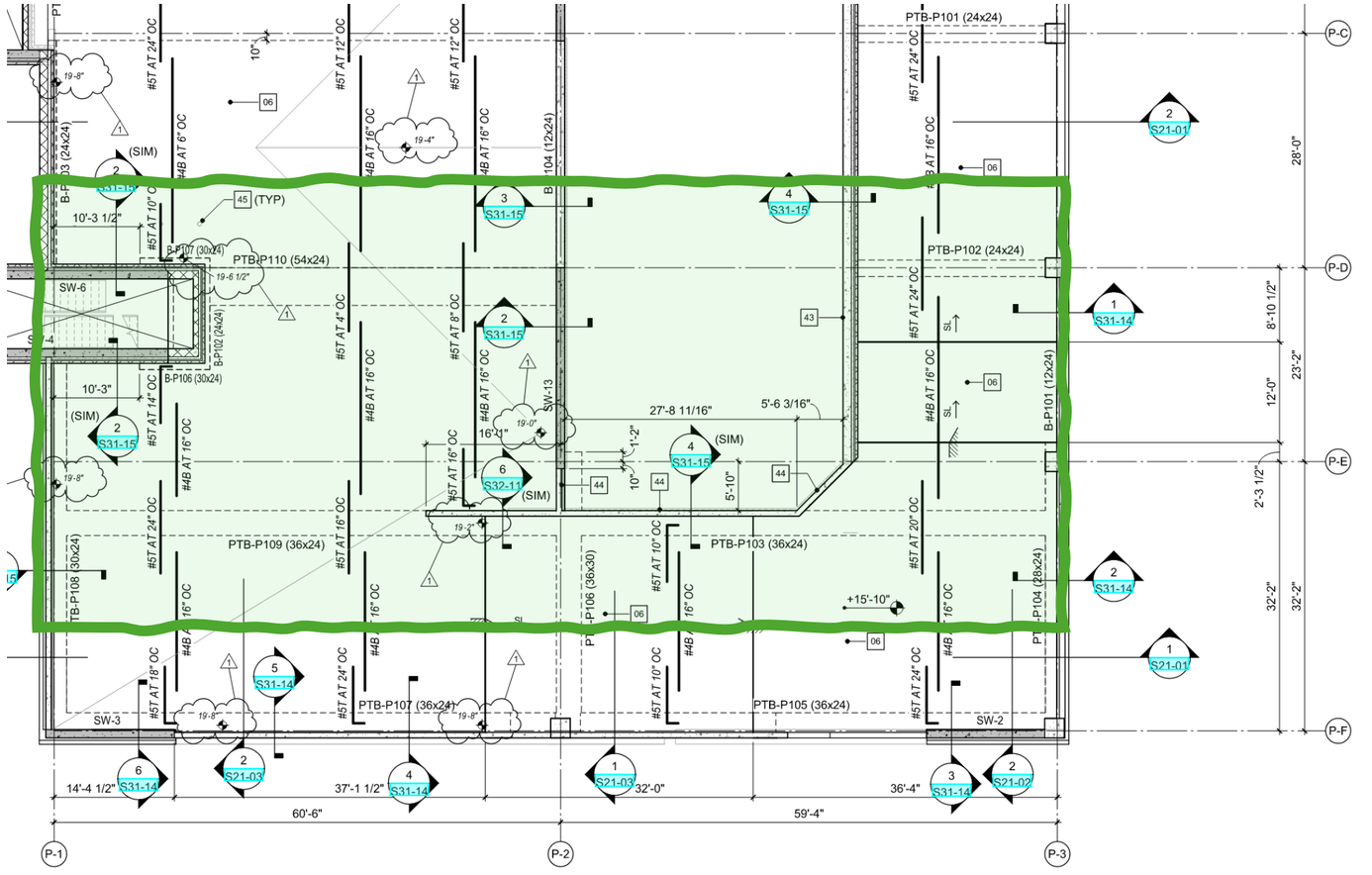
LEARNING OBJECTIVES

I. Review select ACI CODE-562 and ACI CODE-440.13 requirements for FRP systems.
II. Understand the importance and limitations of manufacturer's test data.
III. Examine the potential impact of nonstructural systems on structural elements.
IV. Explain the coordination process that led to the repair solution that was ultimately installed.

BACKGROUND

- Post-tensioned structure
- US East coast
- Non-seismic zone
- Required strengthening during construction

BACKGROUND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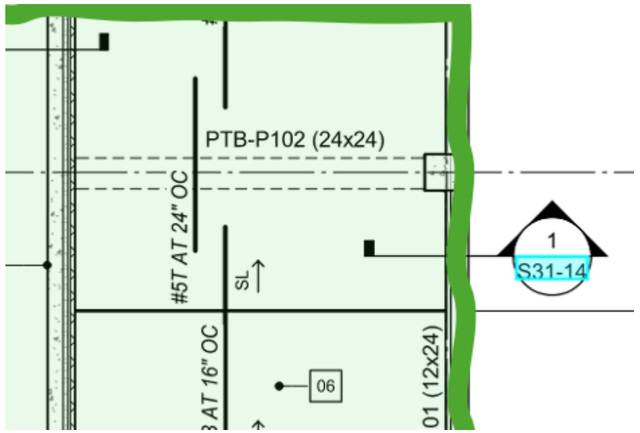
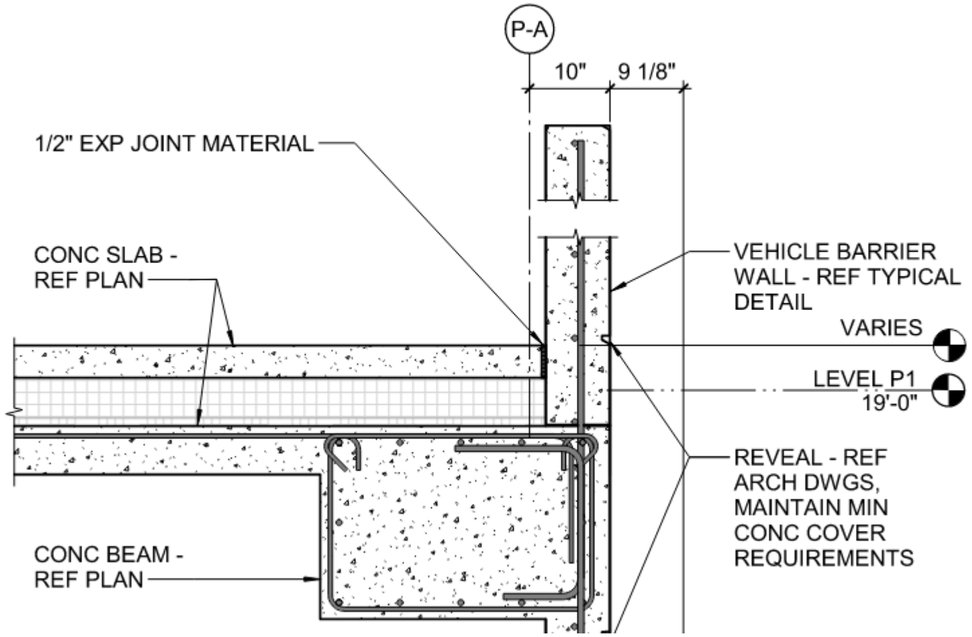
PTB-P102 (24x24)
PTB-P110 (54x24)
PTB-P109 (36x24)
PTB-P103 (36x24)
PTB-P107 (36x24)
PTB-P105 (36x24)
PTB-P108 (30x24)
PTB-P106 (36x30)
PTB-P104 (28x24)
B-P101 (12x24)
B-P102 (24x24)
B-P103 (24x24)
B-P104 (12x24)
B-P106 (30x24)
B-P107 (30x24)
SW-2
SW-3
SW-6
SW-13
#5T AT 24" OC
#5T AT 12" OC
#5T AT 16" OC
#5T AT 8" OC
#5T AT 4" OC
#5T AT 14" OC
#5T AT 10" OC
#5T AT 20" OC
#5T AT 18" OC
#4B AT 6" OC
#4B AT 16" OC
#4B AT 16" OC
(SIM)
(TYP)
10'-3 1/2"
10'-3"
27'-8 11/16"
5'-6 3/16"
16'-11"
5'-10"
+15'-10"
14'-4 1/2"
37'-1 1/2"
32'-0"
36'-4"
60'-6"
59'-4"
28'-0"
8'-10 1/2"
12'-0"
2'-3 1/2"
32'-2"
32'-2"
P-1
P-2
P-3
P-C
P-D
P-E
P-F

BACKGROUND

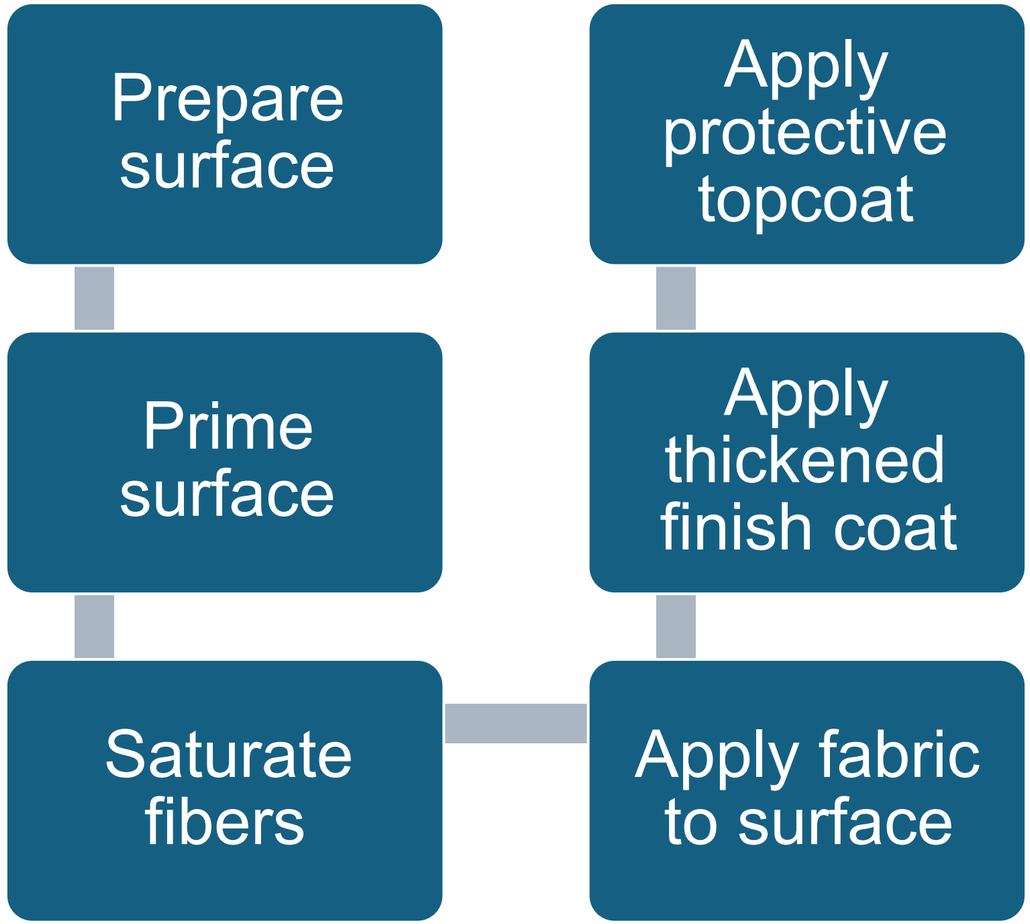

PTB-P102 (24x24)
#5T AT 24" OC
SL
1
S31-14
06


P-A
10"
9 1/8"
1/2" EXP JOINT MATERIAL
CONC SLAB - REF PLAN
VEHICLE BARRIER WALL - REF TYPICAL DETAIL
VARIES
LEVEL P1
19'-0"
REVEAL - REF ARCH DWGS, MAINTAIN MIN CONC COVER REQUIREMENTS
CONC BEAM - REF PLAN

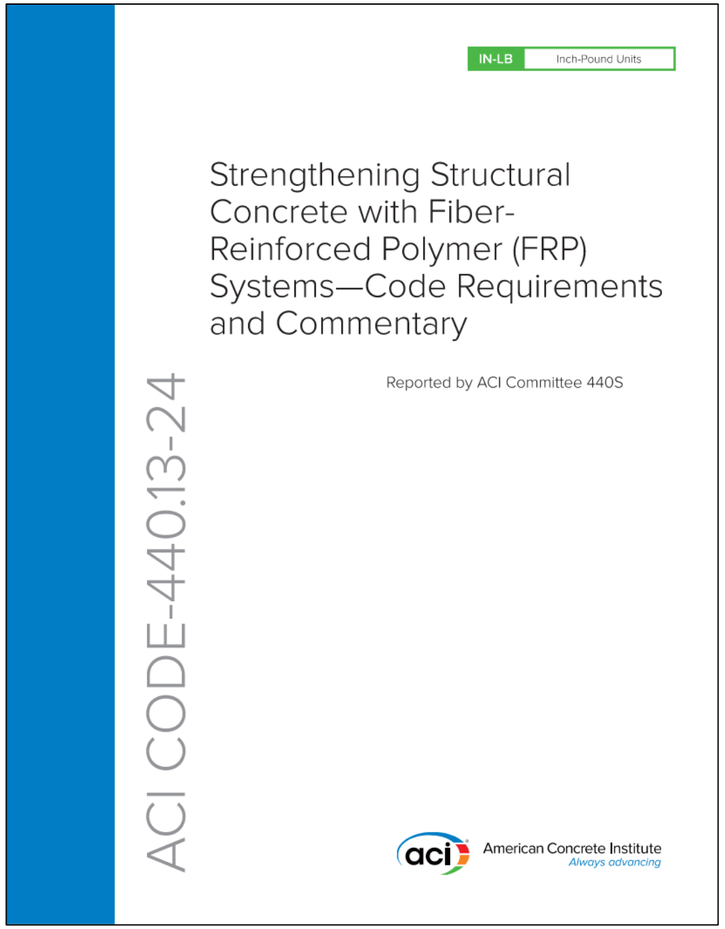
FIBER REINFORCED POLYMER (FRP) SYSTEMS

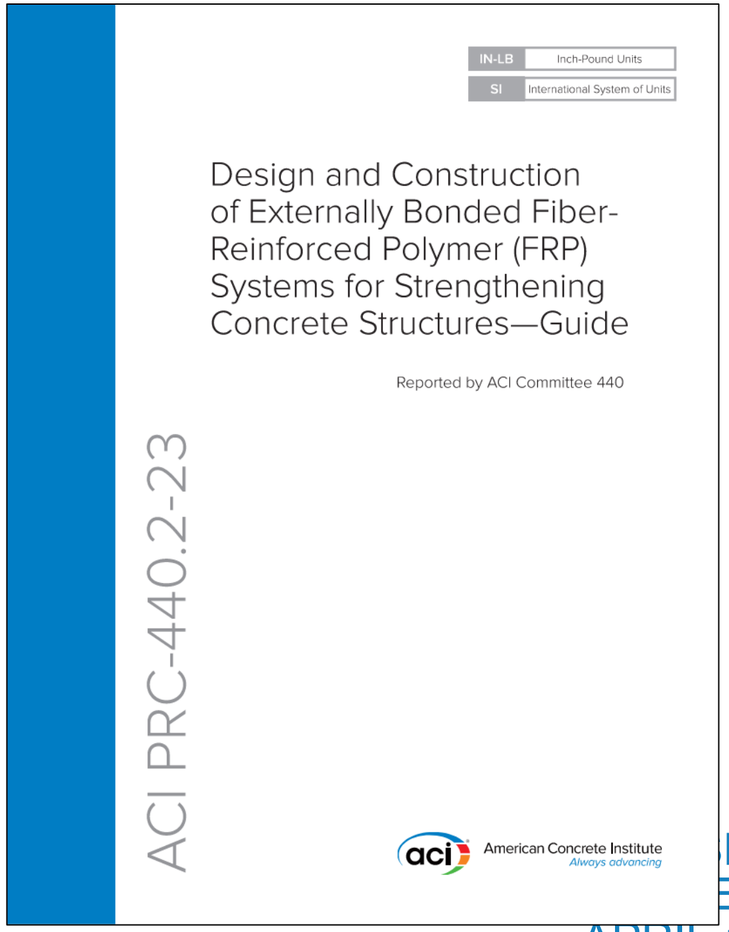
Composite material comprising a polymer matrix reinforced with fibers in the form of fabric, mat, strands, or any other fiber form

WET LAYUP APPLICATION

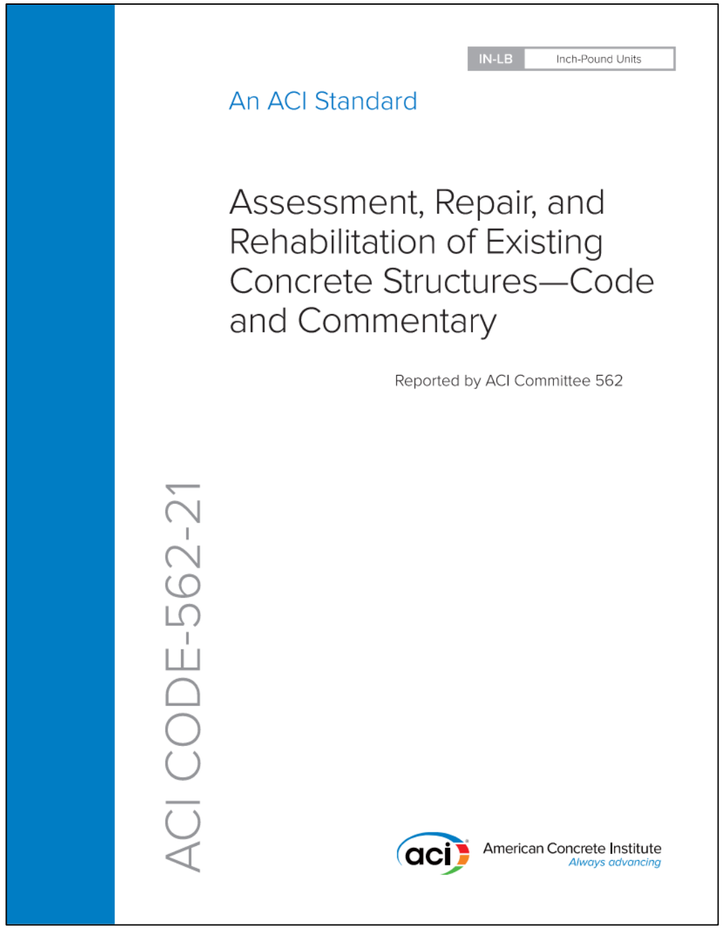


FRP DESIGN CODE AND GUIDES





EXTERNAL REINFORCEMENT



- ACI CODE-562-21 (5.5.2a):
  - $\phi R_n \geq 1.1D + 0.5L + 0.2S$
- ACI CODE-562-21(5.5.2b):
  - $\phi R_n \geq 1.1D + 0.75L$
- ACI CODE-562-21(5.5.3):
  - $\phi_{ex} R_{ex} \geq (0.9 \; or \; 1.2)D + 0.5L + 0.2S$

FIRE-RESISTANT DESIGN

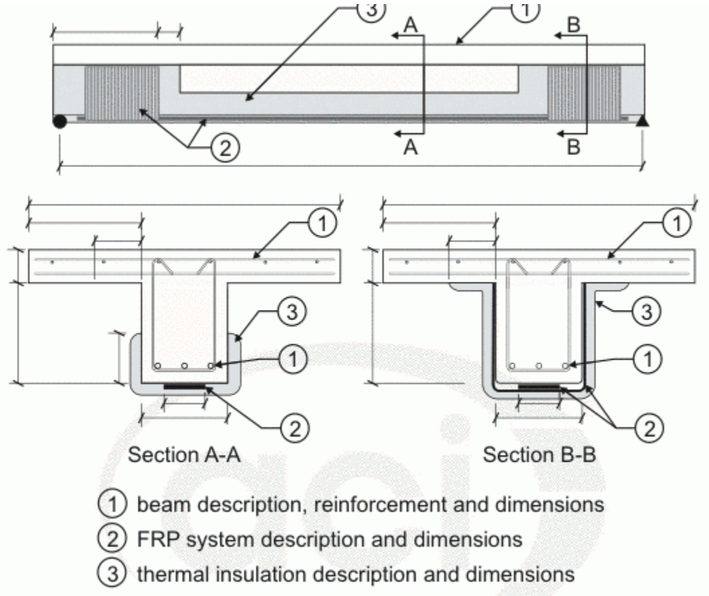
- International Building Code
  - Section 721 Prescriptive Fire Resistance
  - Section 722 Calculated Fire Resistance
- Design documented in approved sources
  - ASTM E119
  - UL 263
  - ISO 834

TABLE 721.1(1)—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[m]—continued

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hours	3 hours	2 hours	1 hour
4. Bonded or unbonded post-tensioned tendons in prestressed concrete[e, i]	4-1.1	Carbonate, lightweight, sand-lightweight and siliceous[f] aggregate concrete Unrestrained members:				
		Solid slabs[h]	—	2	$1^1/_2$	—
		Beams and girders[j]				
		8" wide		$4^1/_2$	$2^1/_2$	$1^3/_4$
		greater than 12" wide	3	$2^1/_2$	2	$1^1/_2$
	4-1.2	Carbonate, lightweight, sand-lightweight and siliceous aggregate Restrained members:[k]				
		Solid slabs[h]	$1^1/_4$	1	$^3/_4$	—
		Beams and girders[j]				
		8" wide	$2^1/_2$	2	$1^3/_4$	—
		greater than 12" wide	2	$1^3/_4$	$1^1/_2$	—
5. Reinforcing steel in reinforced concrete columns, beams girders and trusses	5-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete, members 12" or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.)	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^1/_2$
		Siliceous aggregate concrete, members 12" or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.)	2	$1^1/_2$	$1^1/_2$	$1^1/_2$
6. Reinforcing steel in reinforced concrete joists[l]	6-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete	$1^1/_4$	$1^1/_4$	1	$^3/_4$
	6-1.2	Siliceous aggregate concrete	$1^3/_4$	$1^1/_2$	1	$^3/_4$
7. Reinforcing and tie rods in floor and roof slabs[l]	7-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete	1	1	$^3/_4$	$^3/_4$
	7-1.2	Siliceous aggregate concrete	$1^1/_4$	1	1	$^3/_4$

Table excerpted from IBC 2024

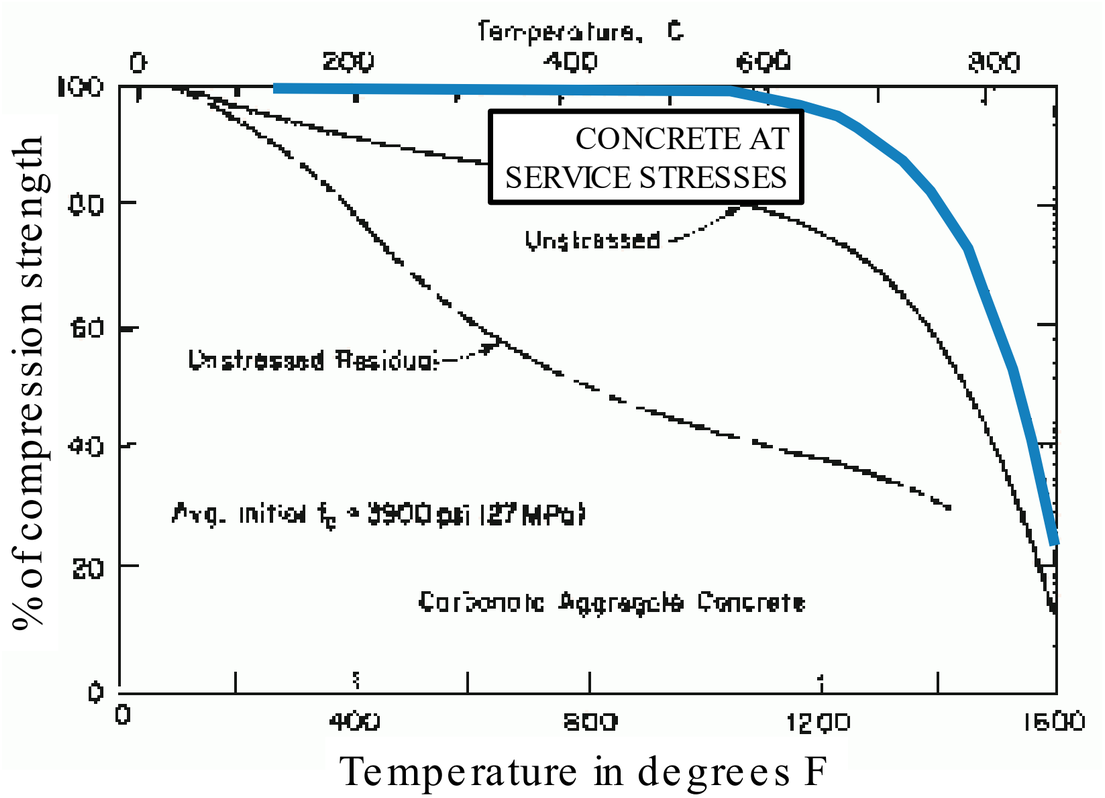
FIRE-RESISTANT DESIGN

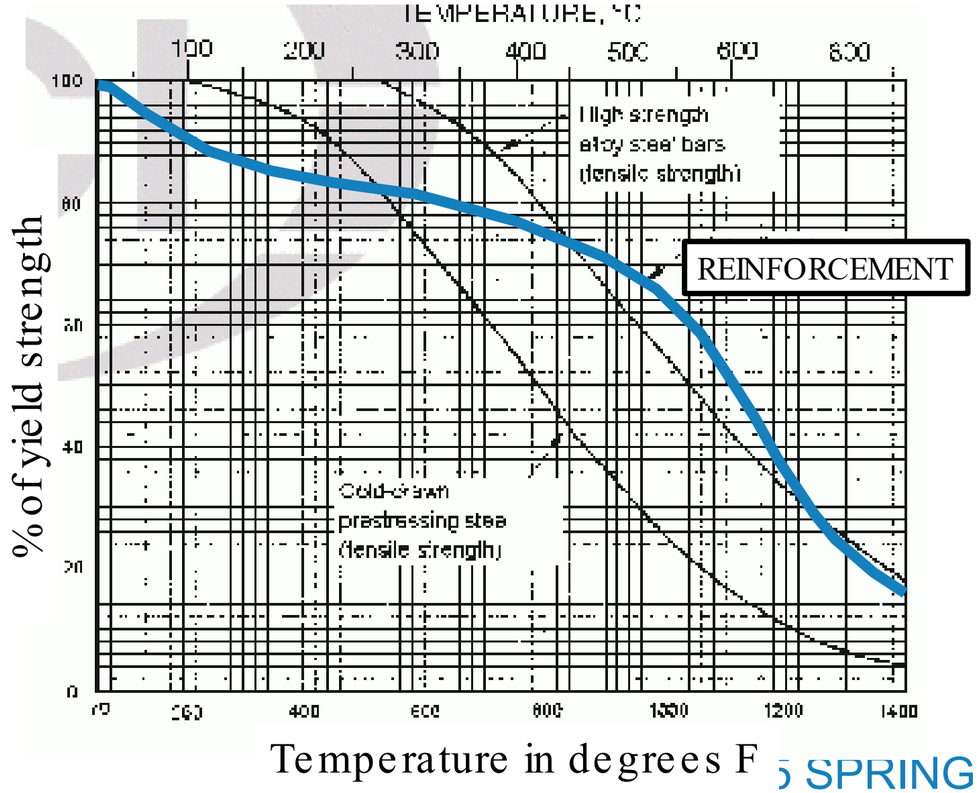


- Qualified fire protection systems based on testing
- Testing suggests concrete and steel performance are improved—not FRP

Figure excerpted from ACI PRC-440.10-21

RC STRENGTH AT HIGH TEMPERATURES

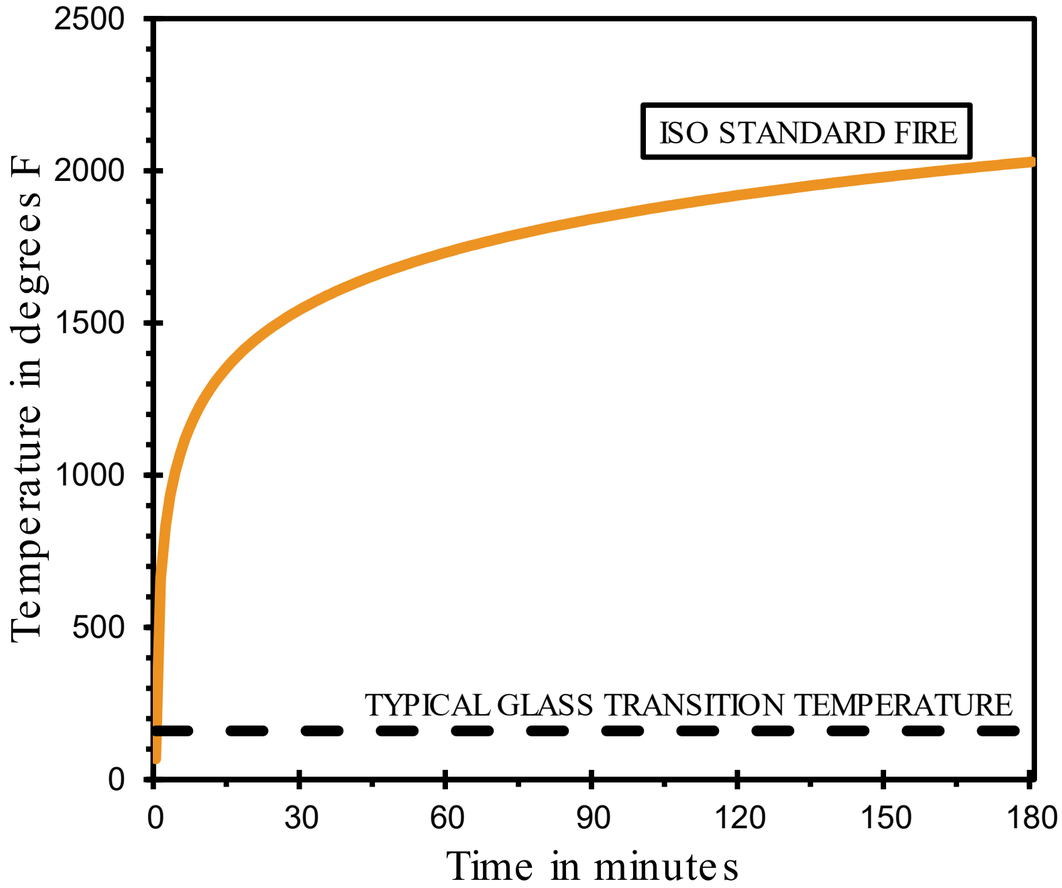




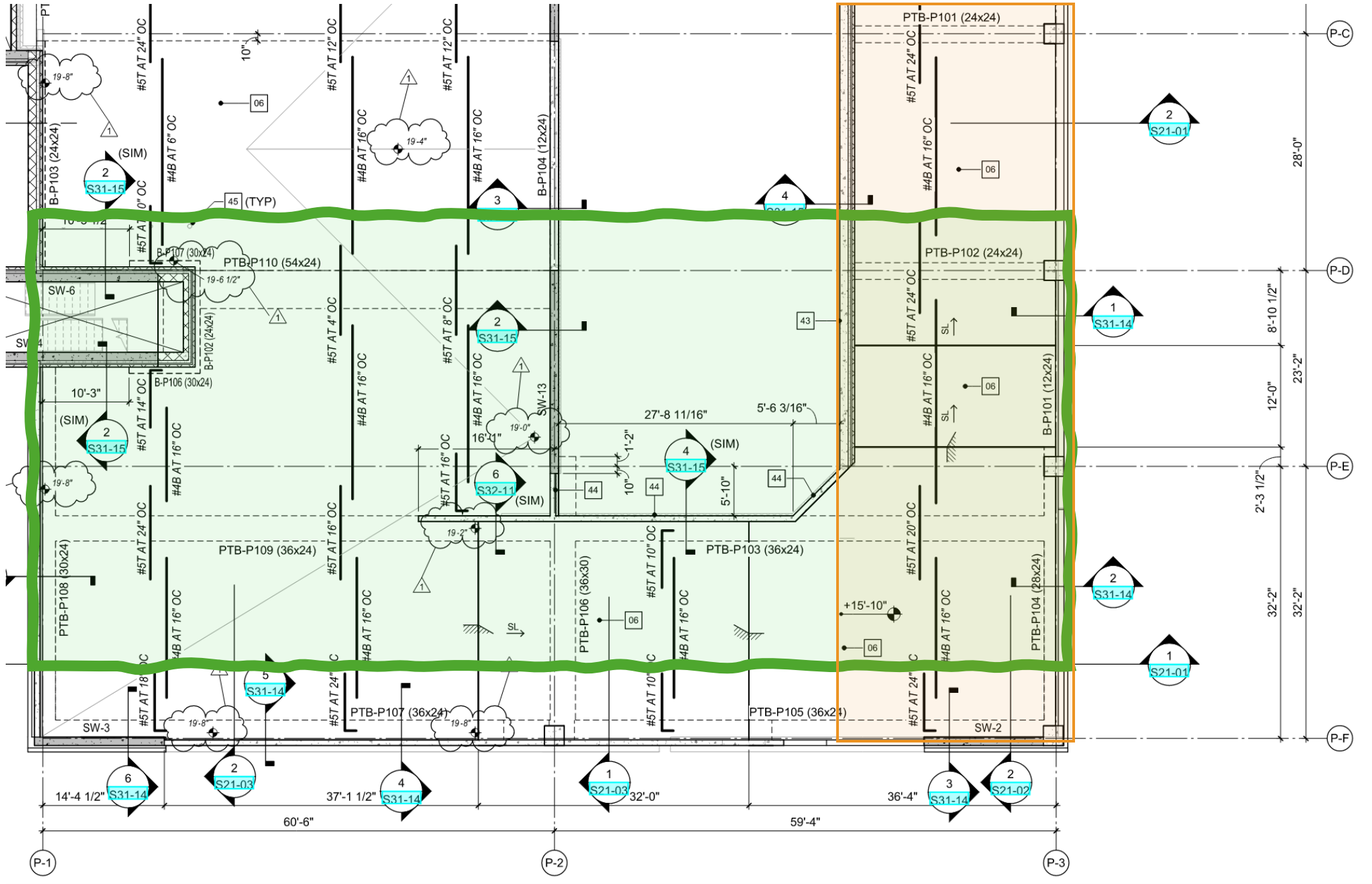
Images excerpted from ACI CODE216.114(19)

FRP FIRE PERFORMANCE

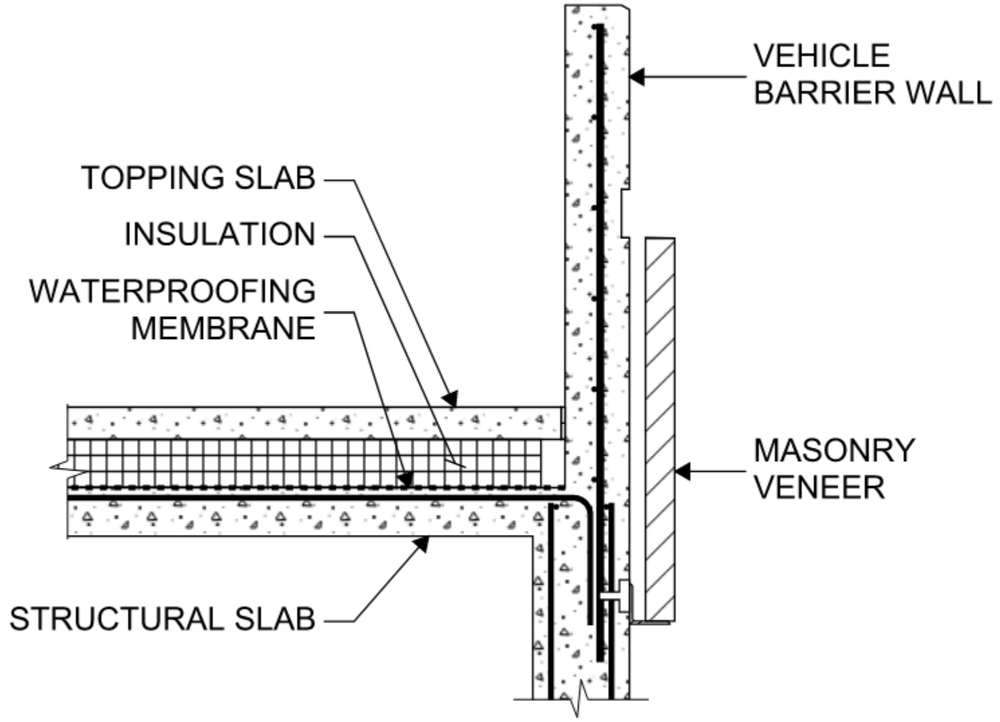
- FRP loses mechanical and bond properties under high thermal load
- FRP system likely damaged early in fire—even with fire protection
- External reinforcement *shall* be neglected

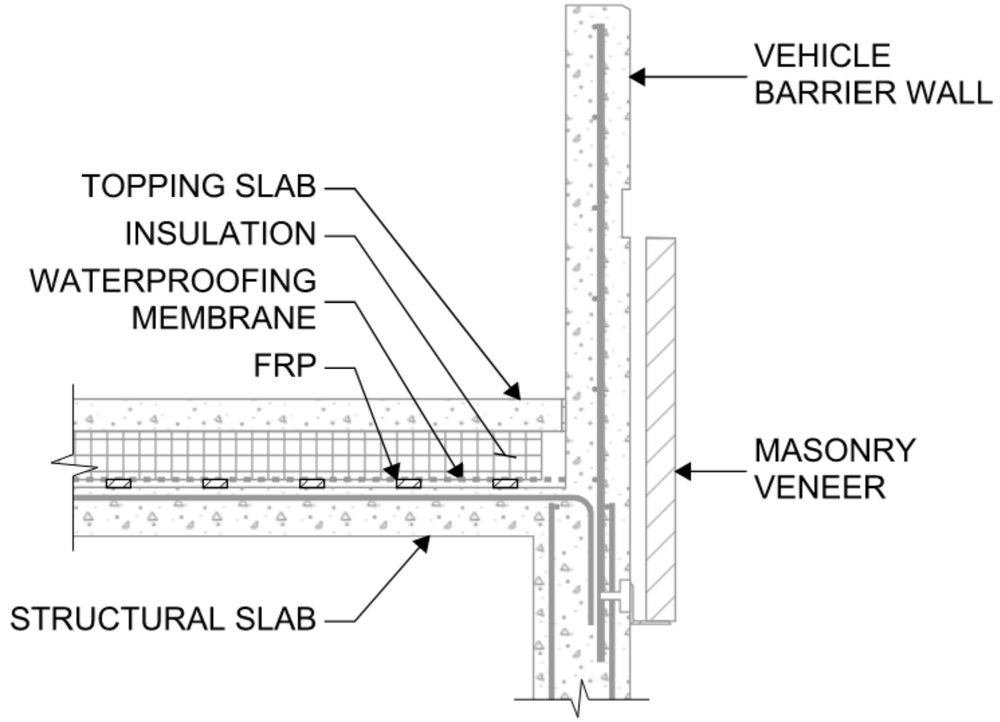


A STICKY SITUATION…



A STICKY SITUATION…





A STICKY SITUATION…

HOT RUBBERIZED ASPHALT (HRA)

- High-performing, well-proven waterproofing system for protected membrane applications on concrete substrates
- Blend of asphalt and rubber that creates seamless, self-healing membrane
- Requires heated application

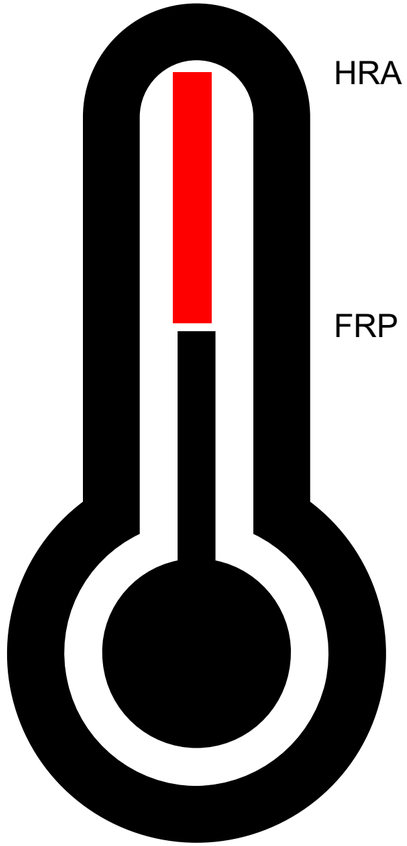
Assembly:

- 90 mil HRA
- Reinforcing fabric
- 125 mil HRA
- Protection course
- Acoustic mat
- Topping slab

HRA – FRP INTERACTION

- Epoxy used for bonding FRP is heat sensitive
- Glass transition temp between 140-180 deg F

- HRA is heated on site to 350-375 deg F
- Variable change in T between melter and surface



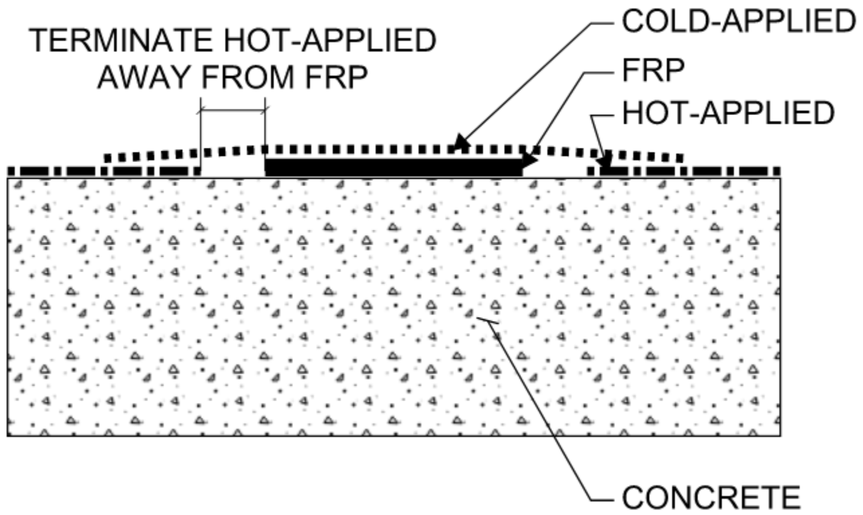
HRA APPLICATION TEMPERATURE

FRP GLASS TRANSITION TEMPERATURE

…AND A COMPLICATED CONVERSATION

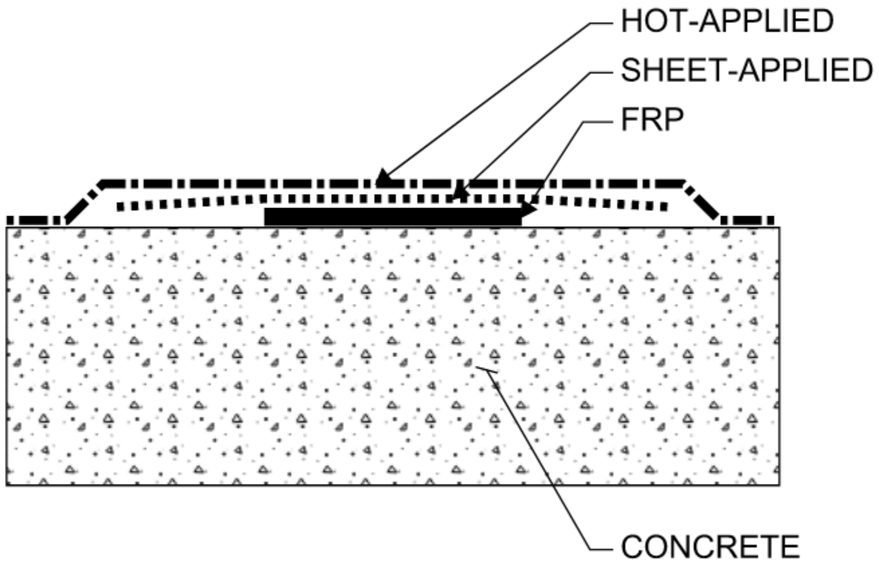
- Original project team sensitive to delays in construction schedule
- Direct HRA application to FRP not warrantable
- Waterproofing manufacturer stated they had previously-tested assemblies to consider

REPAIR OPTION 1



- Avoid applying heat to FRP
- Preferred option by the FRP manufacturer and the repair team

REPAIR OPTION 2



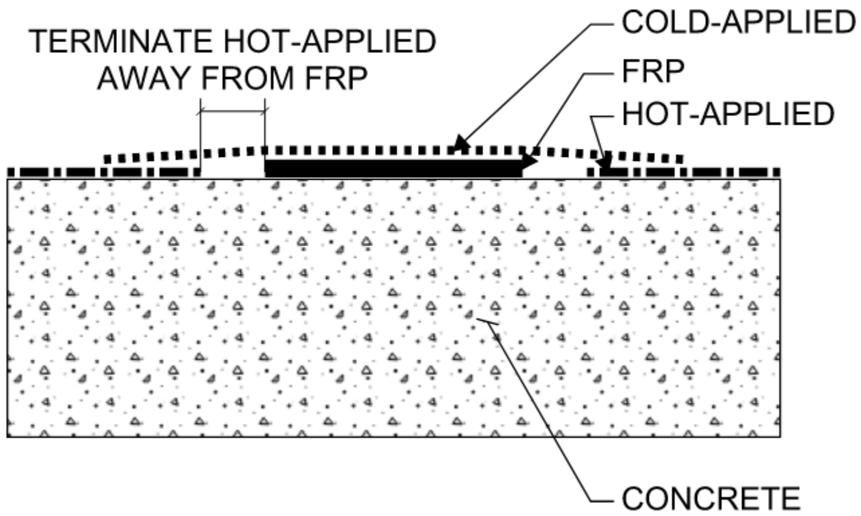
- Sheet-applied asphaltic membrane heat sink
- Reported testing limited temperatures to 180 degrees F
- Preferred option by waterproofing manufacturer and installer

…AND MORE COMPLICATED CONVERSATION

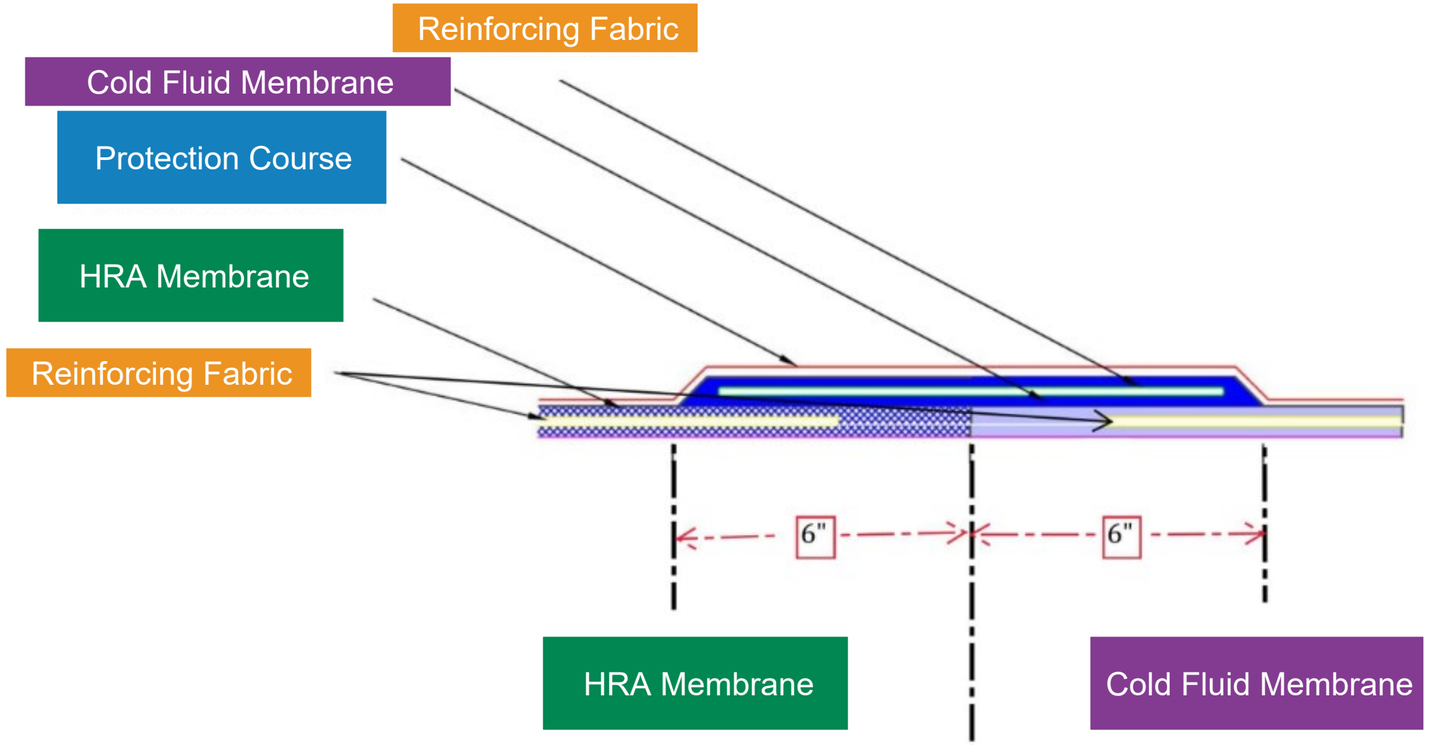
- Now what about the waterproofing warranty?
- Concern over epoxy/FRP below cold-applied product

- Long lines of communication and multiple interests
- Brought all parties together to discuss path forward

WHAT WAS INSTALLED



WHAT WAS INSTALLED



WHAT WAS INSTALLED

- Required enhanced trade coordination
- Resequencing of typical operations to avoid potential rework

CONCLUSIONS

- Unconventional design scenario may occur outside of normal load combinations
- Repair in new design may be small in scope but can have broad coordination impacts
- Test limitations may be institutional knowledge but not well publicized

Live Content Slide

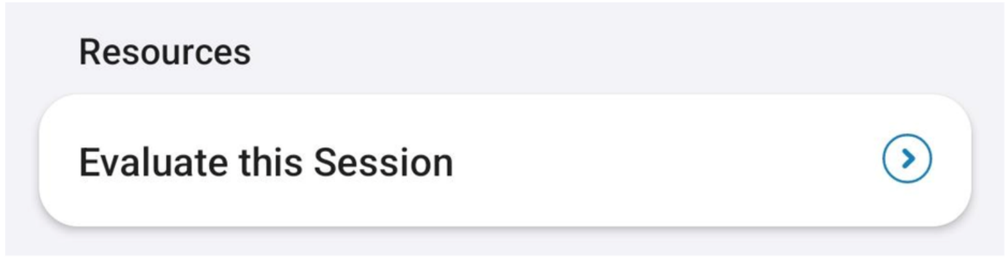
When playing as a slideshow, this slide will display live content

Poll: The key temperature for the FRP design in this case study was:

LEARNING OBJECTIVES

I. Review select ACI CODE-562 and ACI CODE-440.13 requirements for FRP systems.
II. Understand the importance and limitations of manufacturer's test data.
III. Examine the potential impact of nonstructural systems on structural elements.
IV. Explain the coordination process that led to the repair solution that was ultimately installed.

SESSIONEVALUATION



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ANY QUESTIONS?