Bond Behavior of Epoxy-Coated Reinforcing Bars in Non-Proprietary Ultra-High Performance Concrete

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Outline

- What is Ultra-High Performance Concrete (UHPC)?
- Objectives of study
- Research
- Findings

UHPC

- Advanced construction material
- Very high early compressive strength (often > 20 ksi)
- High tensile strength (> 1 ksi)
- 1-3% by volume of steel fibers (most often 2%)
- Contains no coarse aggregate
- Low water-to-cementitious material ratio (*w*/*cm* < 0.22)
- Very workable – Spread = 8-10 in.

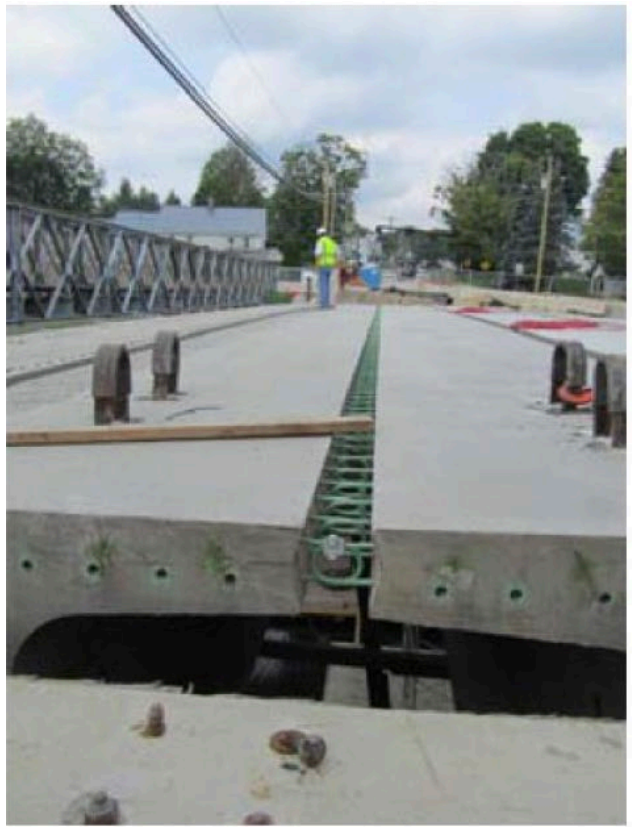
Spread Test

Mold

Spread

Two of the advantages of UHPC

- Develop reinforcing steel with very short embedment lengths
- Bridge-deck closure strips can be very narrow with UHPC



Bridge-Deck closure strips (Source: Castine, 2017; New York State DOT)

Existing knowledge

- Most knowledge based on proprietary UHPC mixtures = $$
- Existing design approaches for bond strength in UHPC based on pullout tests – this test method is not recommended for determining bond strength

Objectives of study

- Develop non-proprietary UHPC
- Perform realistic bond tests for use in design to determine effect of bar size, cover, splice length, spacing, and surface properties of reinforcing steel
- Develop design recommendations for splice length in non-proprietary UHPC

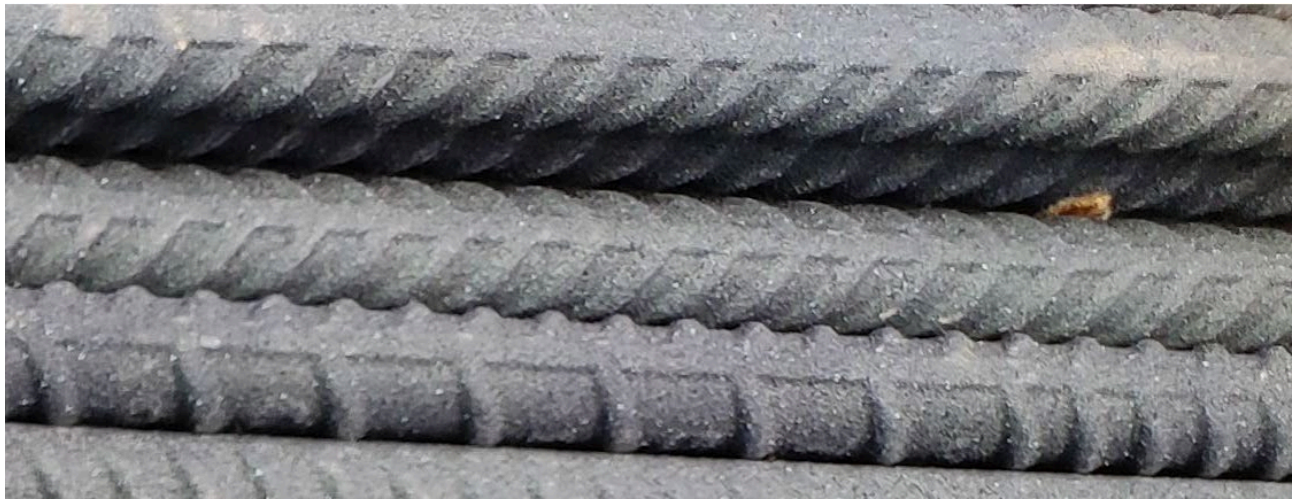
Research

Reinforcing steel – three types

Uncoated bars

Epoxy-coated bars

Textured epoxy-coated bars



Bottom line(s)

- UHPC can be made from local materials
- Admixtures play a big role in UHPC
- Bond strength in UHPC is two times that in conventional concrete, even at same compressive strength
- Bond strength in UHPC is independent of compressive strength
- Negative effects of epoxy coating are less in UHPC than in conventional concrete
- Textured epoxy-coated bars have same bond strength as uncoated bars

Non-proprietary UHPC

Material/Properties	Mix A	Mix B
Superplasticizers	Ia Ib	IIa IIb
Set Accelerator	None	IIc
w/cm ratio	0.183	0.183
Spread (in.)	10.75	9.75
Fiber Distribution	Not well-distributed	Well-distributed

w/cm ratio: water to cementitious materials ratio

Strength

- Compressive

Age (days)	Strength (ksi)	
	Mix A	Mix B
1	9.56	8.57
3	12.53	11.89
7	14.84	14.40

- Flexural

Age (days)	Peak Strength (ksi)	
	Mix A	Mix B
3	1.90	2.89
7	2.78	3.60

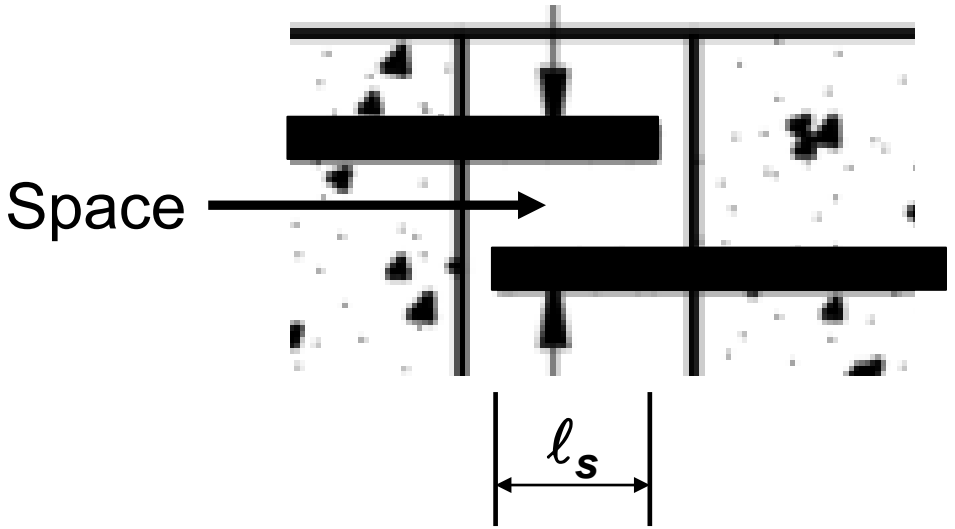
Bond tests

Non-contact splices

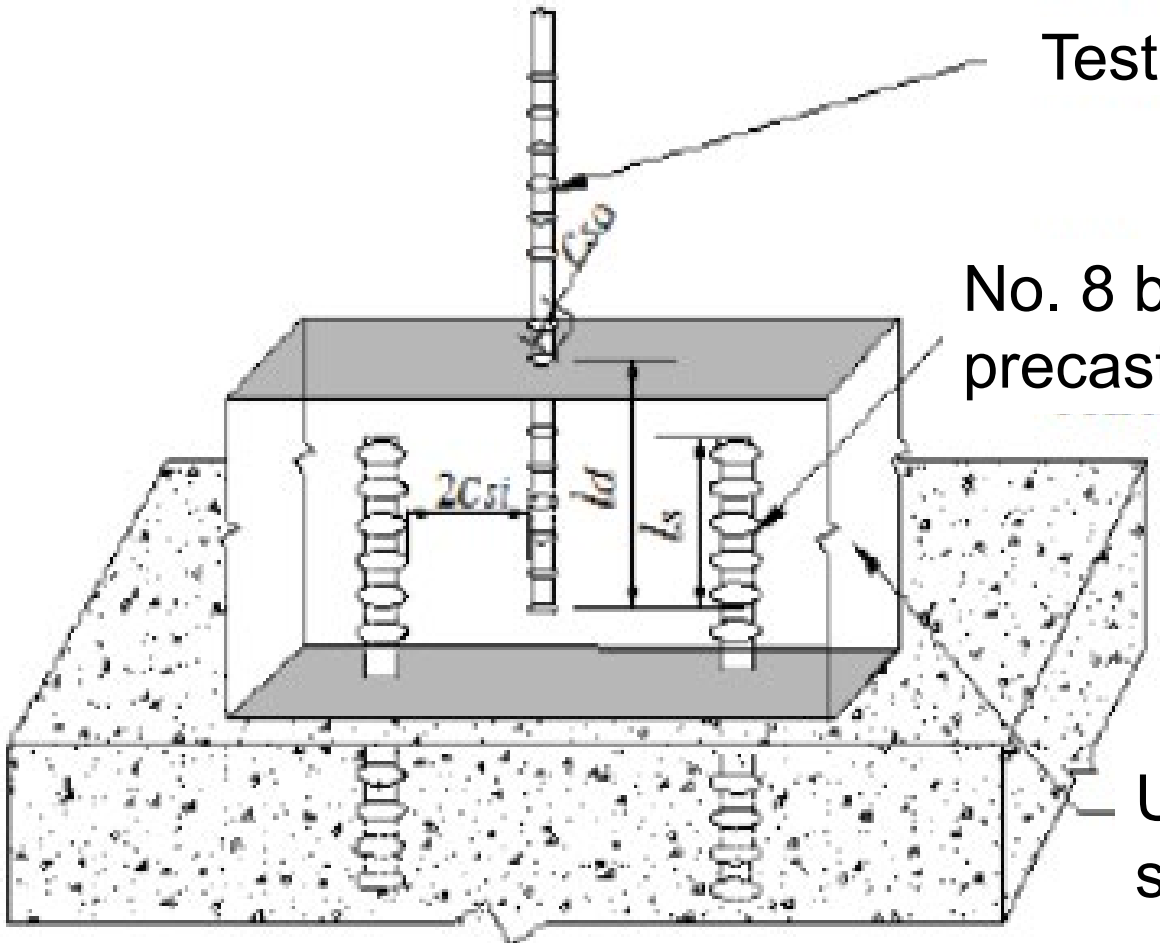
- Bars spliced by noncontact lap splices

  Space $\leq \ell_s/5$

  Space $\leq$ 6.0 in.



Pullout tests

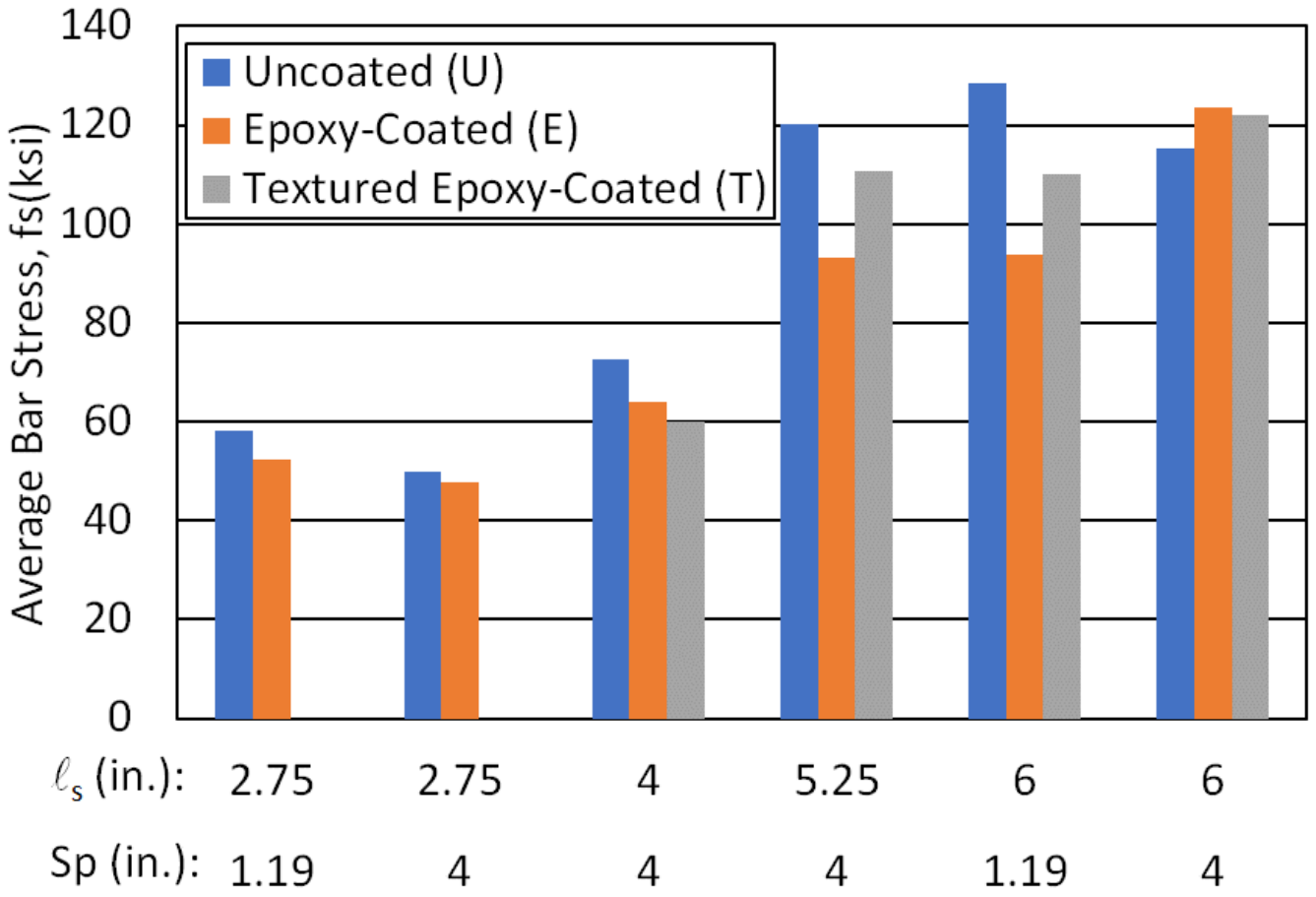


(Yuan and Graybeal 2014)

Pullout tests – No. 5 bars

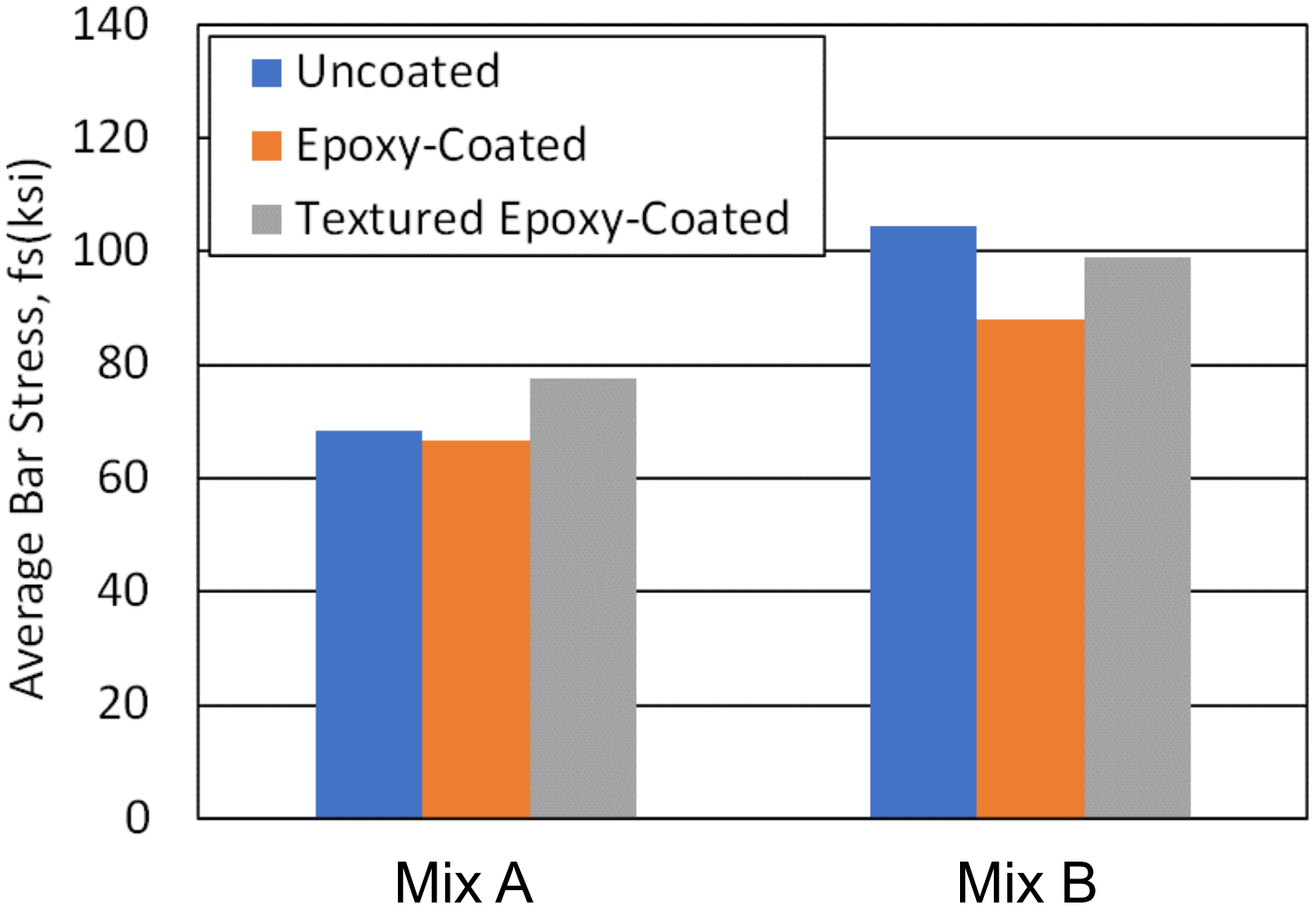
Pullout tests

- ℓ_s: Splice length
- Sp: Bar spacing

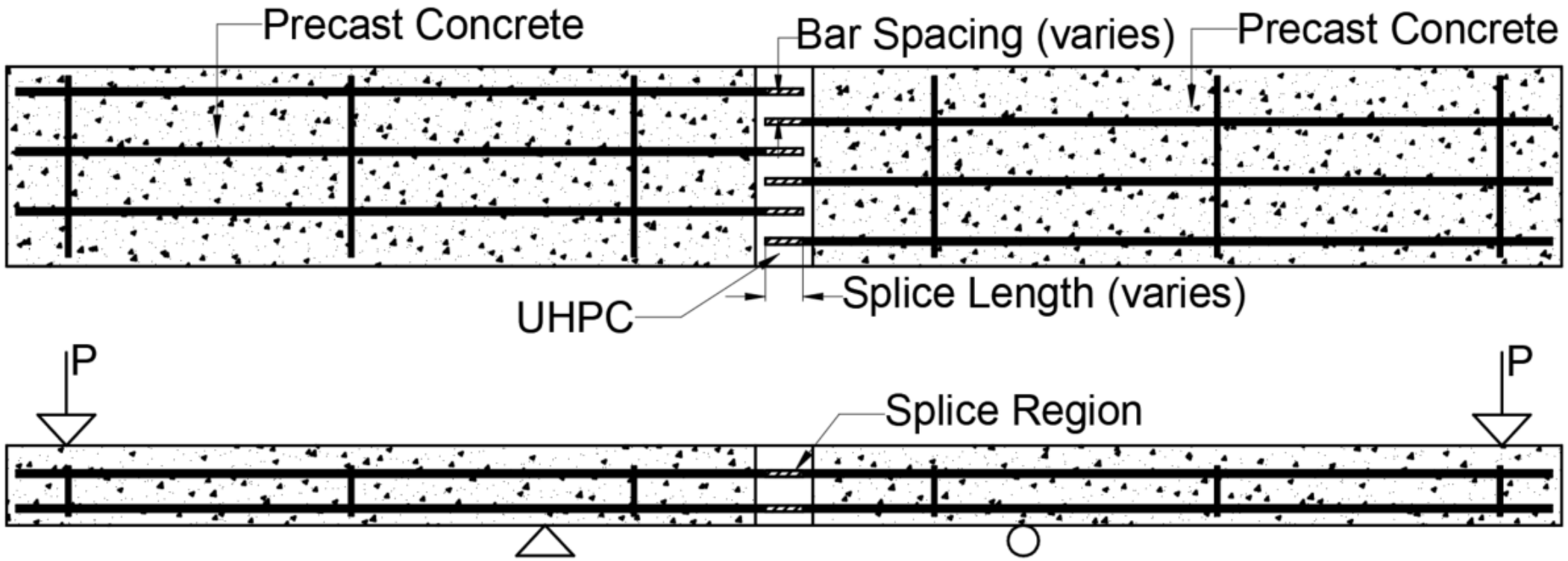


Beam-end tests – No. 5 bars, ℓ_s= 5 in.

Beam-end tests



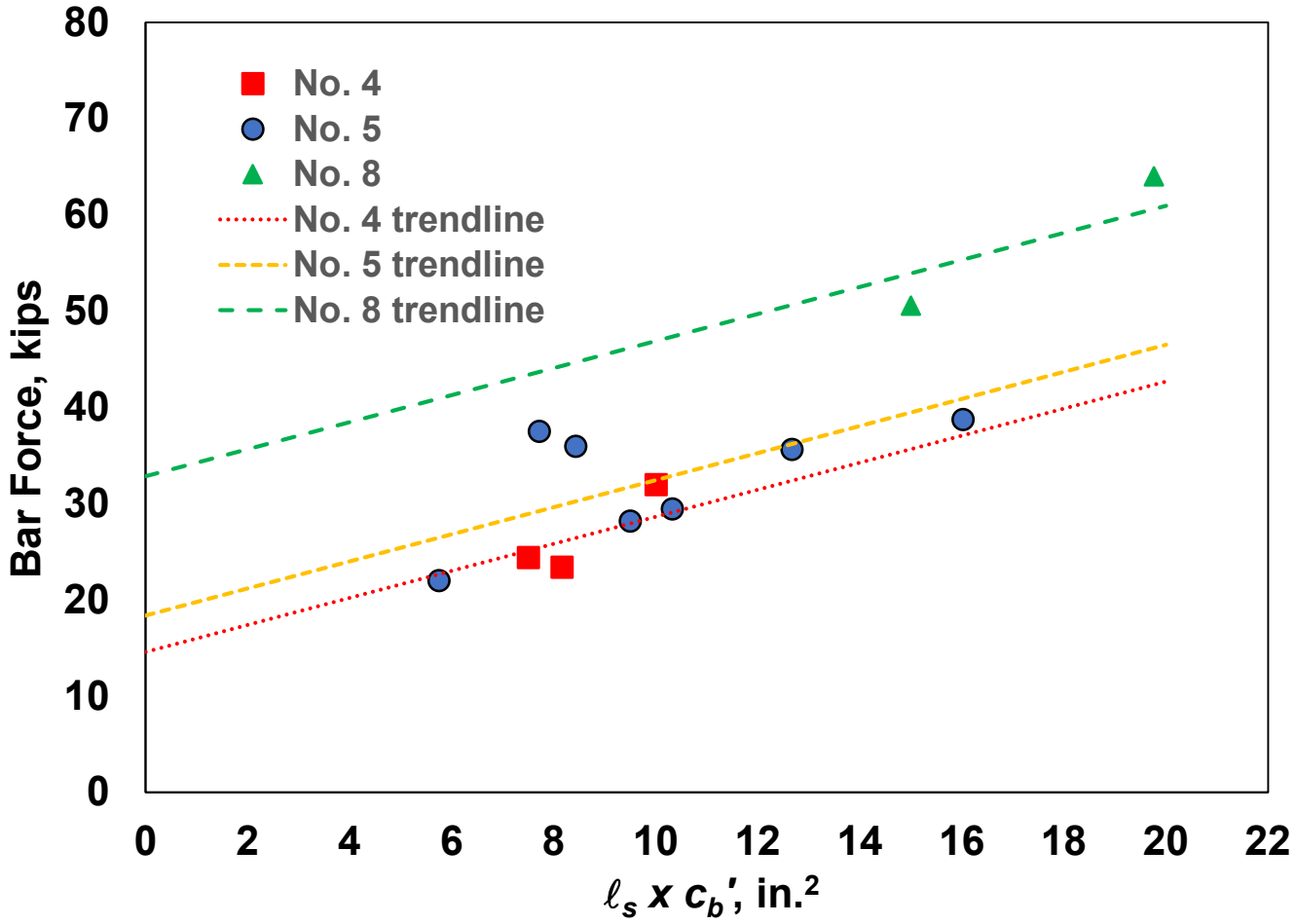
Splice tests



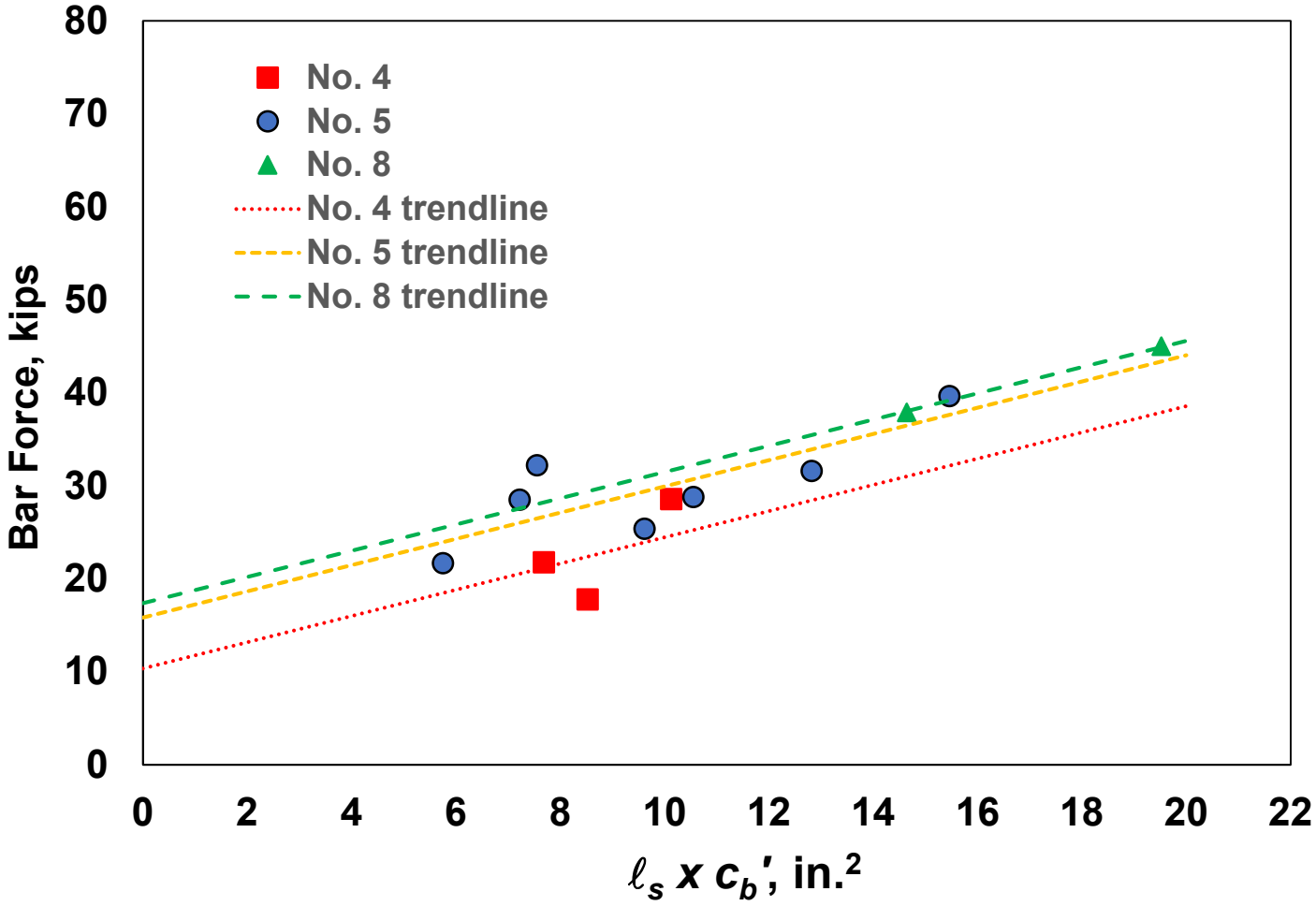
Beam-splice specimen with UHPC closure strip

Splice tests – No. 4, No. 5, and No. 8 bars

Splice test results - Uncoated bars



Splice test results - Epoxy-coated bars



Comparisons to spliced bars in conventional concrete – Use ACI Committee 408 database

- Uncoated: $f_{s\ test}/f_{s\ ACI\ 408} = 2.23$
- Epoxy-coated: $f_{s\ test}/f_{s\ ACI\ 408} = 1.94$
- Textured epoxy-coated: $f_{s\ test}/f_{s\ ACI\ 408} = 2.37$
- $f_{s\ Epoxy\text{-}coated}/f_{s\ Uncoated} = 0.87$ vs. < 0.7 in conventional concrete

Design: ℓ_s for epoxy-coated bars

$$\ell_s = \frac{A_b f_y - 13\sqrt{d_b}}{1.1 c_b'} \geq 6 d_b$$

c_b' = cover to center of bar being developed to nearest concrete surface

- Could be shortened with textured epoxy-coated bars

Summary of findings

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Questions?

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