



Structural Design, Analysis, and Full-Scale Testing of Ultra-High Performance Concrete Girders

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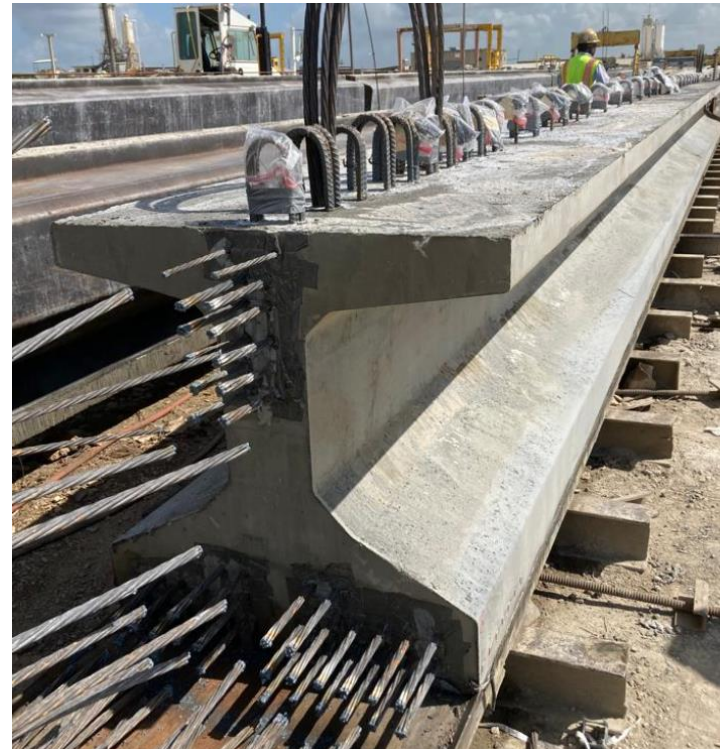


- Major Technical Objectives:

- Conduct *design feasibility study*
- Develop *a nonproprietary ultra-high performance concrete (UHPC) mixture design*
- Conduct *experiments to evaluate UHPC (material-level and full-scale)*



Tx34-1 Test Setup



Tx34-2 Girder after release of strands

Utilization of UHPC in Texas Precast Bridge Girders



Longer span
High prestress
Fewer girder lines
Long service life

Flexure Test
Shear Test

High early strength gain
>12 ksi at transfer (20 h),
15 ksi at 24 hours,
18 – 19 ksi at 28 days



Fabrication of UHPC Girder Specimen



Tx34-1 before transfer at precast plant

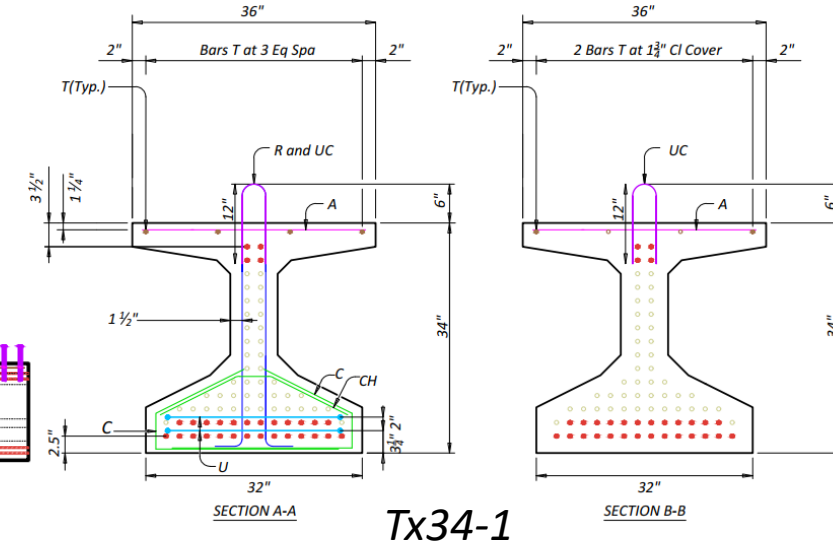
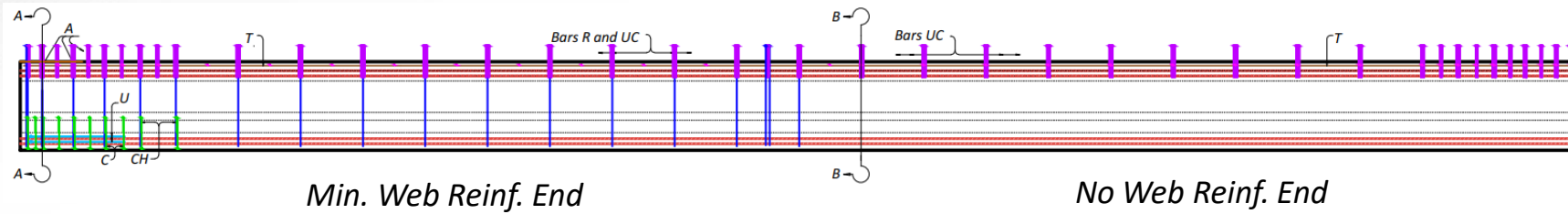
0.500 – 0.600 ksi

0.55 – 0.75 ksi

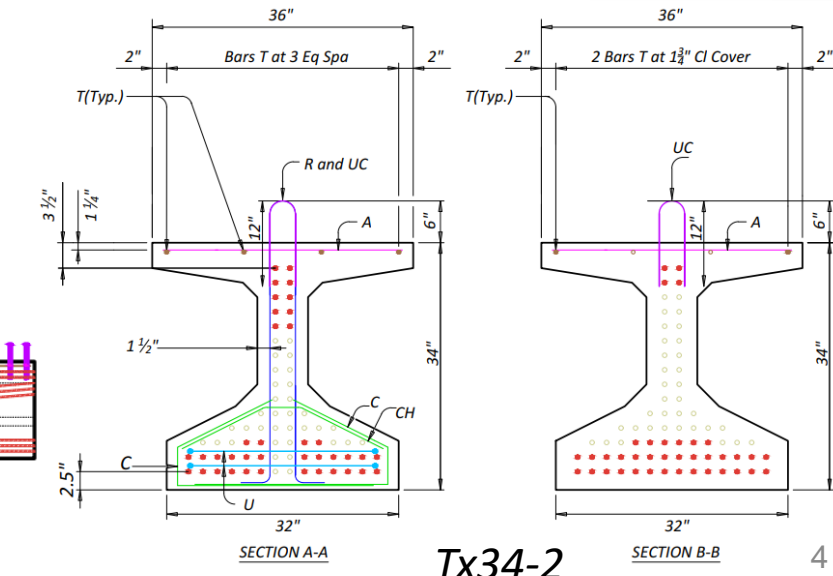
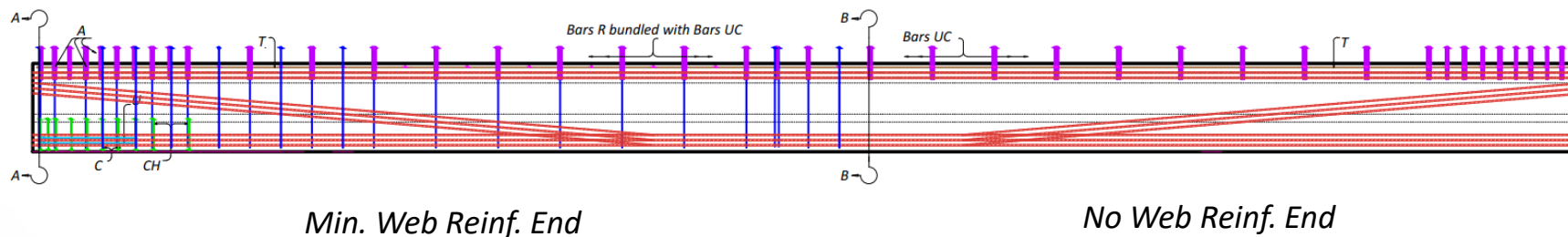
Tensile strength
2.00 – 2.12 ksi

Tx34 Girder Specimens: Eccentric and Draped Tendon Profiles

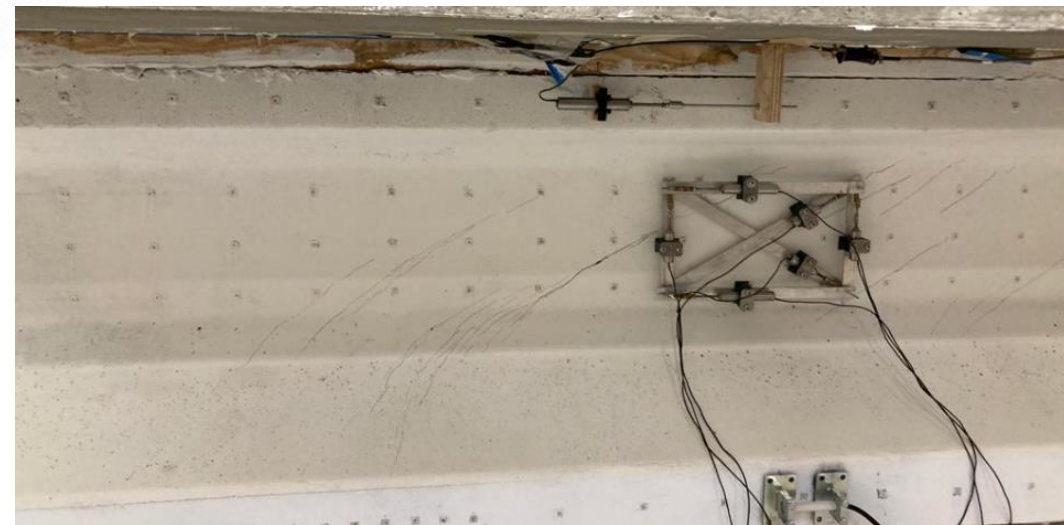
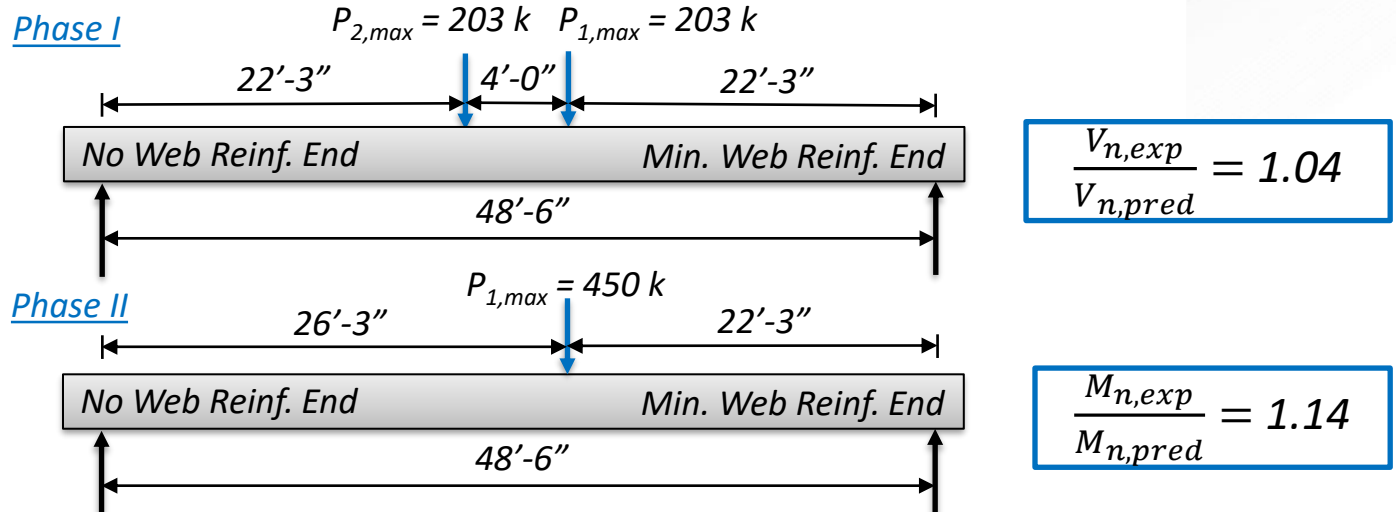
Parameter	Tx34-1
Prototype Span Length	77 ft
Specimen Length	48.5 ft
No. of Strands	30 total (all straight)



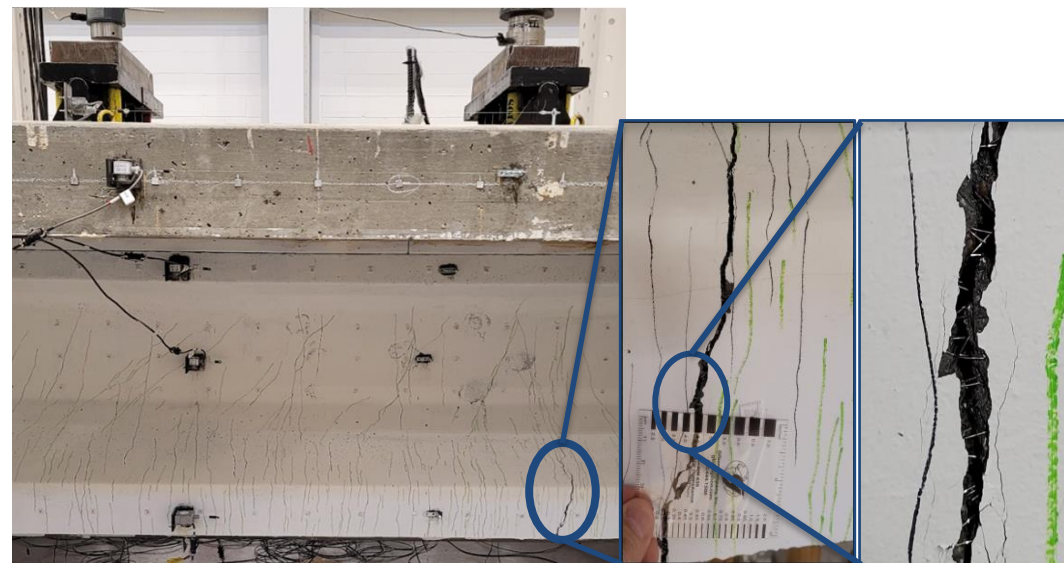
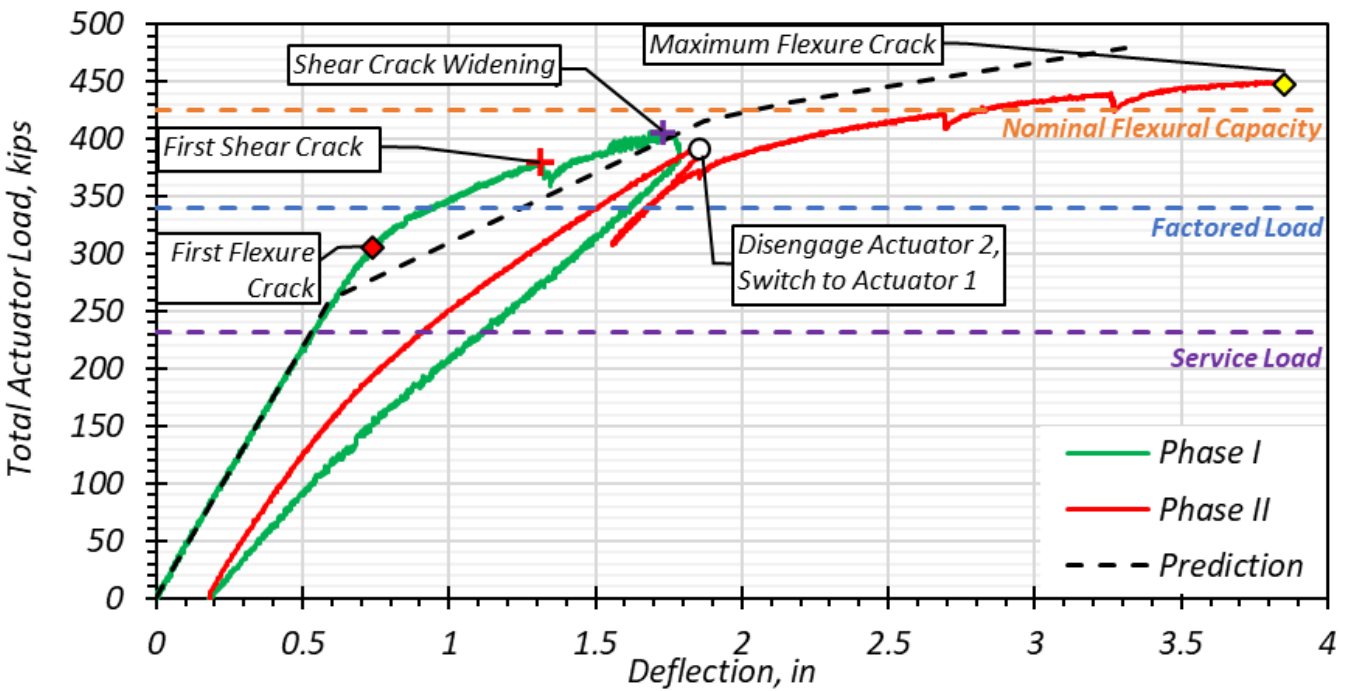
Bars R = #4, Bars UC = #5, at 24 in. spacing at midspan and 12 in. spacing at ends (closer spacing of 3 in. for bursting resistance)



Tx34-1 Flexure Test Results



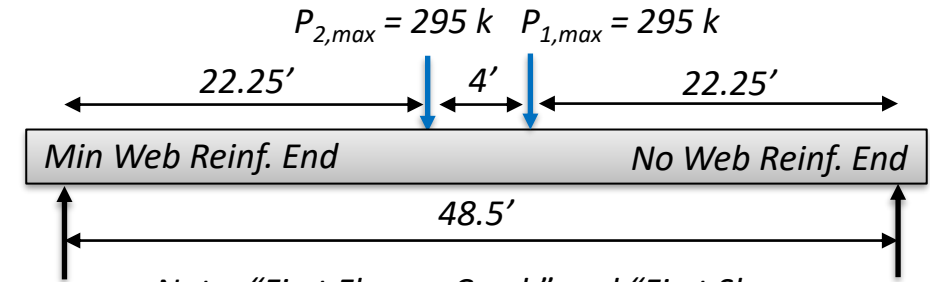
*Shear Cracks at end without transverse reinforcement
(end of Phase 1 testing)*



Flexure Cracks

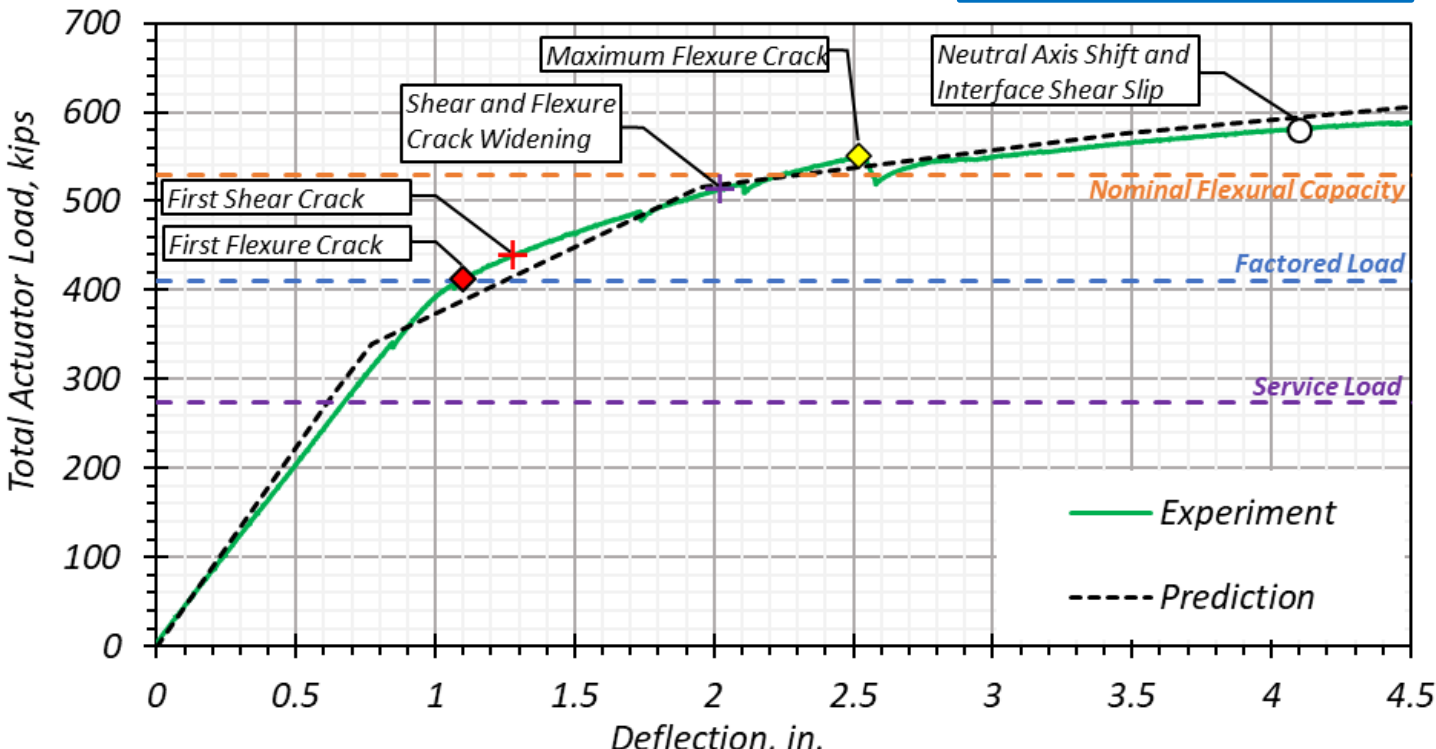
Tx34-2 Flexure Test Results

- Flexure crack occurred at 413 kips (total actuator load)
- Shear crack developed at the ends at 440 kips
- Flexure and shear crack formation increased at 513 kips
- Potentially some interface shear slip between deck and girder at 550 kips and 580 kips after which steel engages.



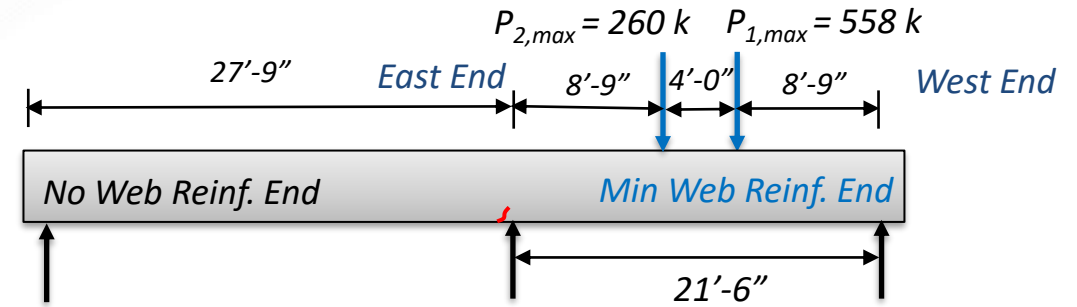
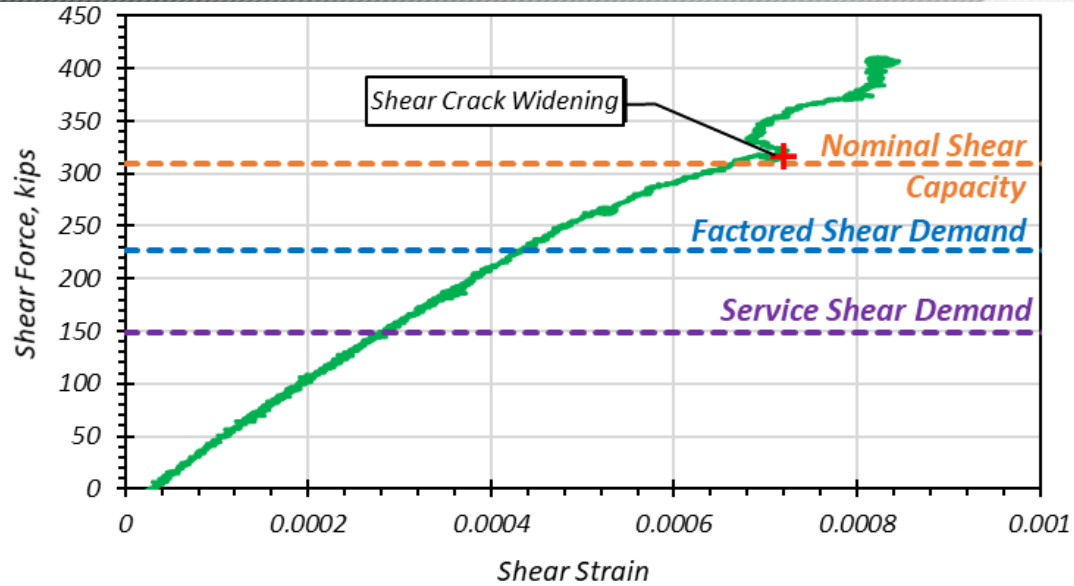
Note: "First Flexure Crack" and "First Shear Crack" are based on change in strain

$$\frac{M_{n,exp}}{M_{n,pred}} = 1.08$$



Flexure Cracks Tx34-2

Tx34-1 Min. Web Reinforcement End Shear Test Results

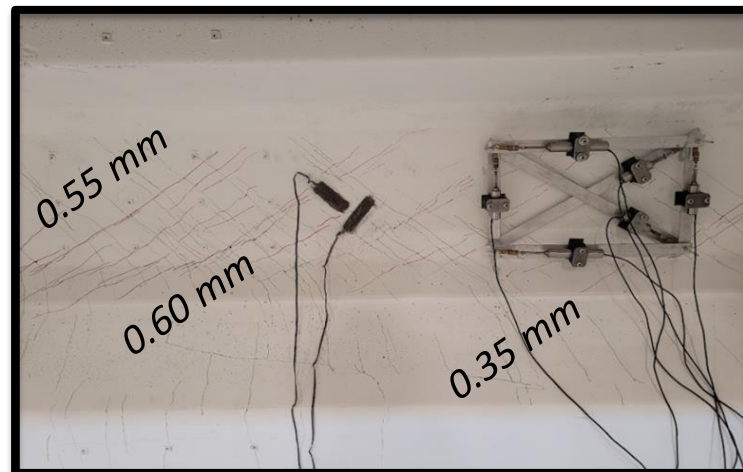


$$\frac{V_{n,exp}}{V_{n,pred}} = 1.02$$

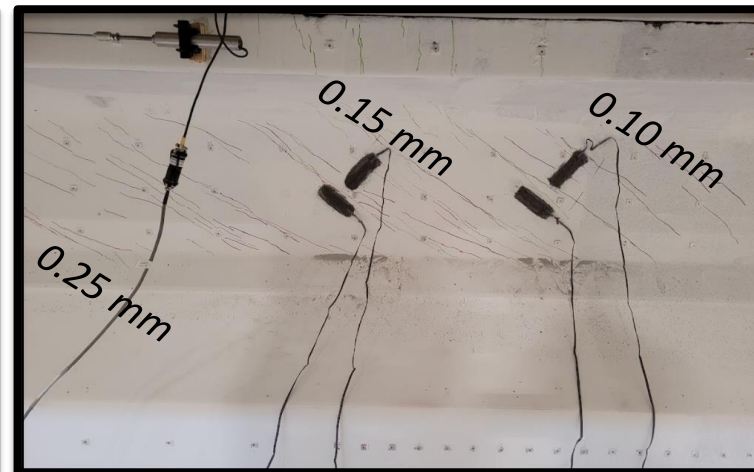
$$\text{Shear span/depth ratio} = 2.36$$

Note: Uniaxial Tensile Strength = 0.55 ksi

Shear Force vs Shear Strain at Shear Cracks (5'-0" from West End)

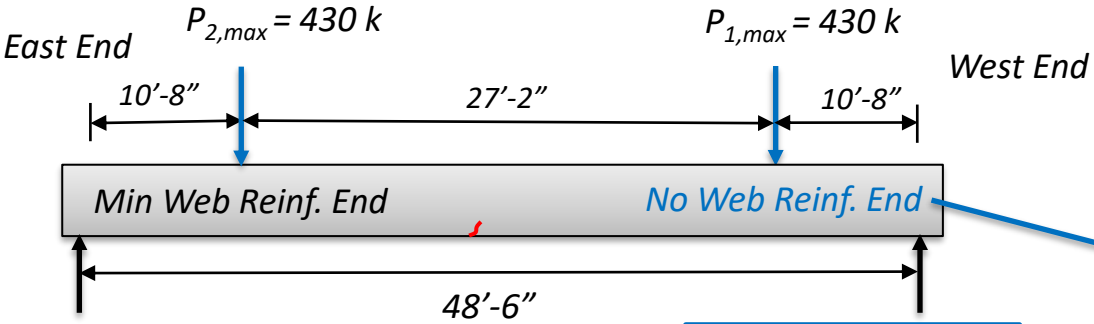


East End (min. web reinf. end)



West End (min. web reinf. end)

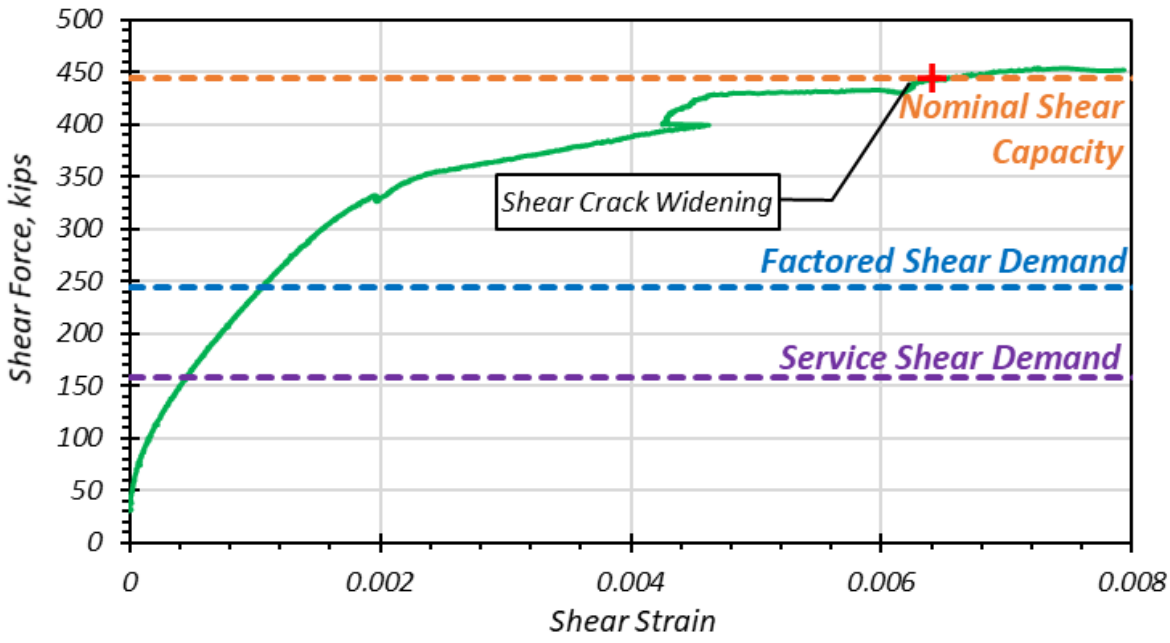
Tx34-2: No Web Reinf. End Shear Test Results



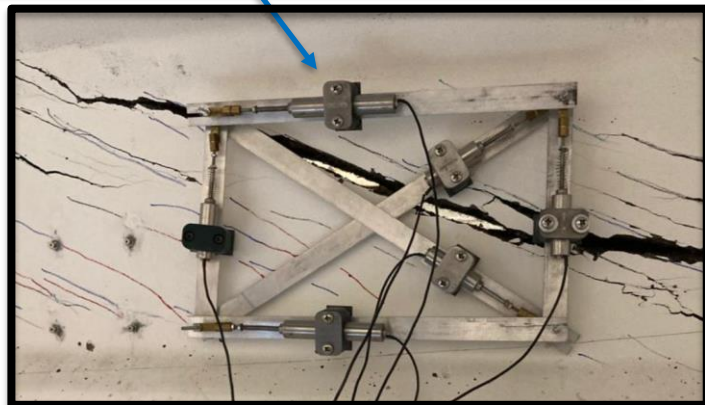
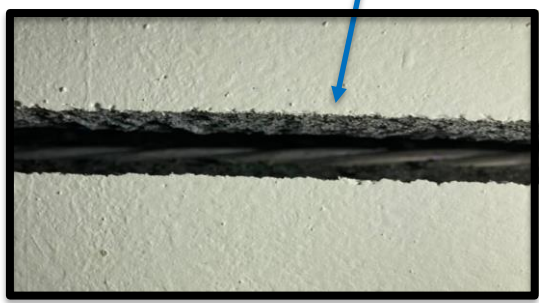
Shear span/depth ratio = 2.88

$$\frac{V_{n,exp}}{V_{n,pred}} = 1.02$$

Note: Uniaxial Tensile Strength = 0.63 ksi



Shear Force vs Shear Strain at Shear Cracks (at 5'-0" from West End)



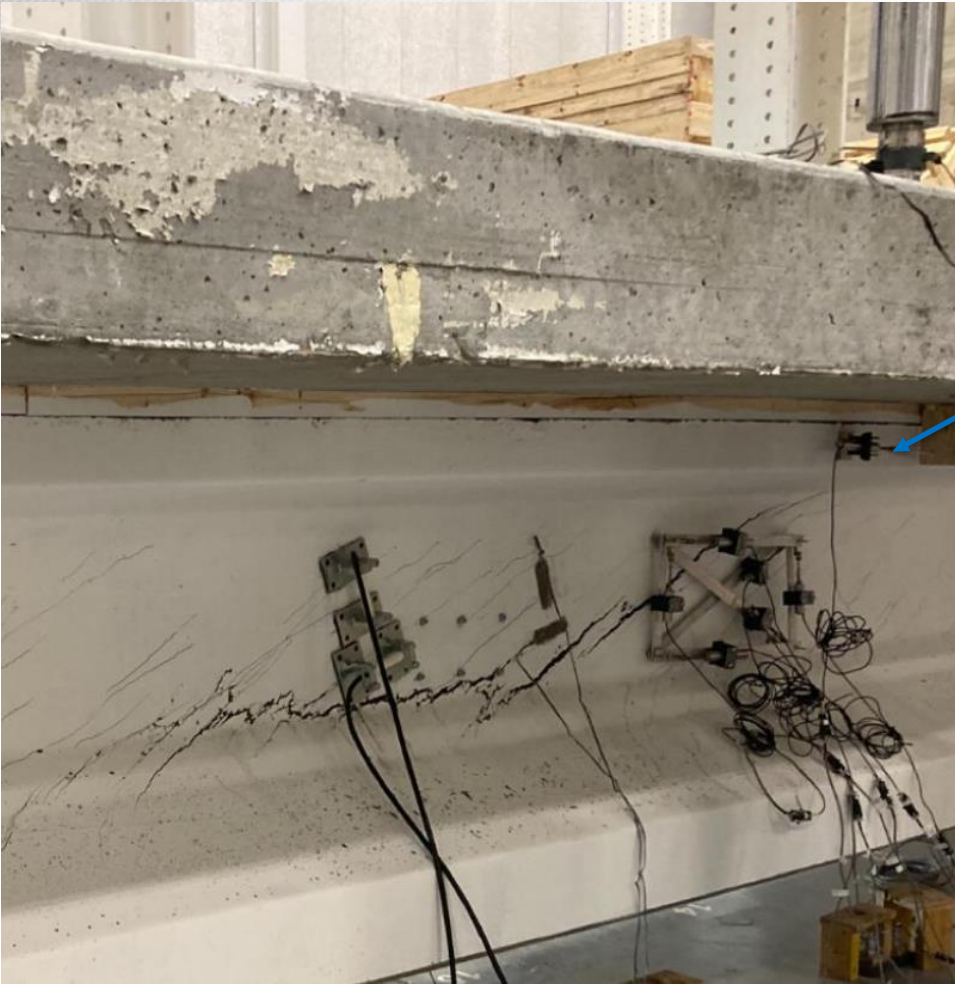
Shear crack and exposed prestressing strand

Tx34-2 Min Web Reinf. End Shear Test Results

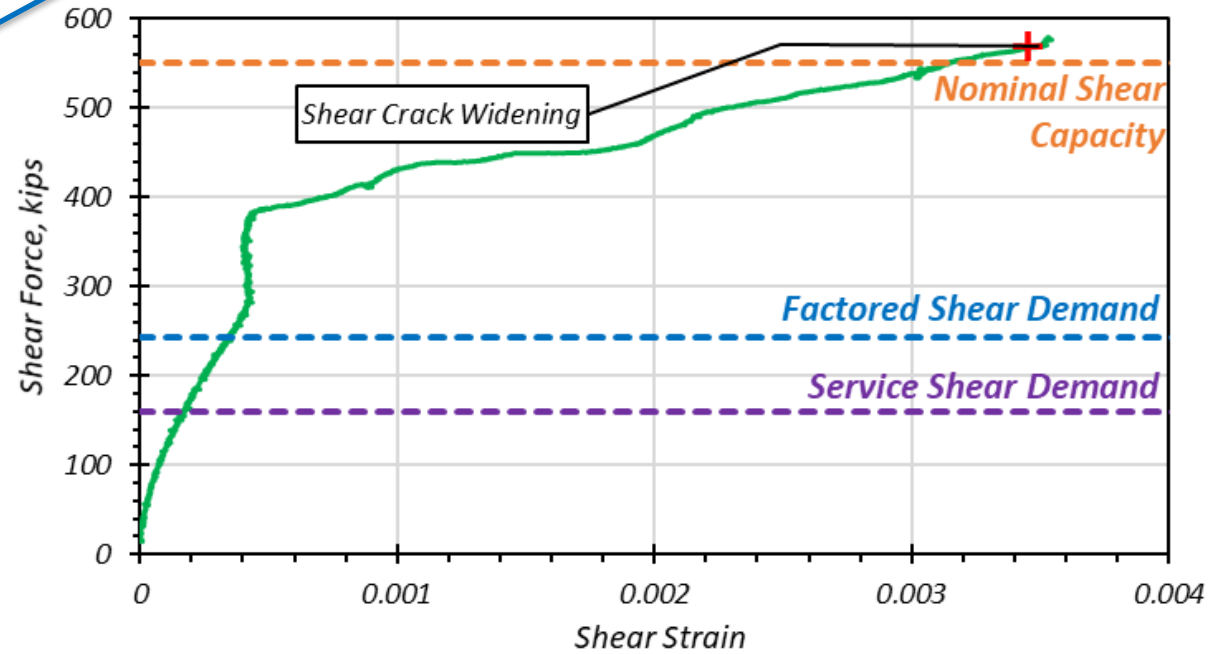
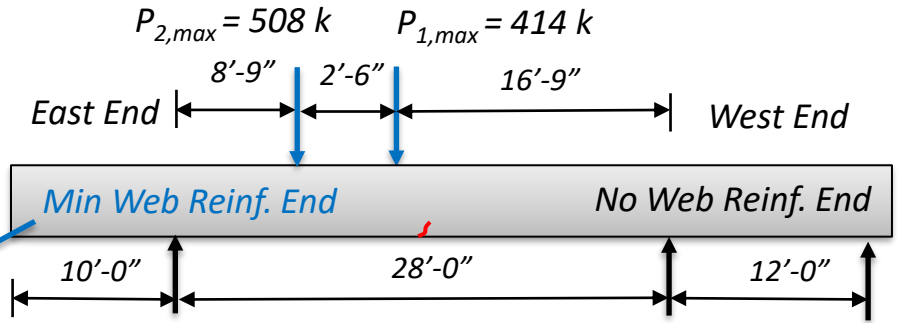
Shear span/depth ratio = 2.36

Note: Uniaxial Tensile Strength = 0.63 ksi

$$\frac{V_{n,exp}}{V_{n,pred}} = 1.04$$



Shear Crack Tx34-2 at Minimum Web Reinf. End



Shear Force vs Shear Strain at Shear Cracks (4'-6" from East Support)

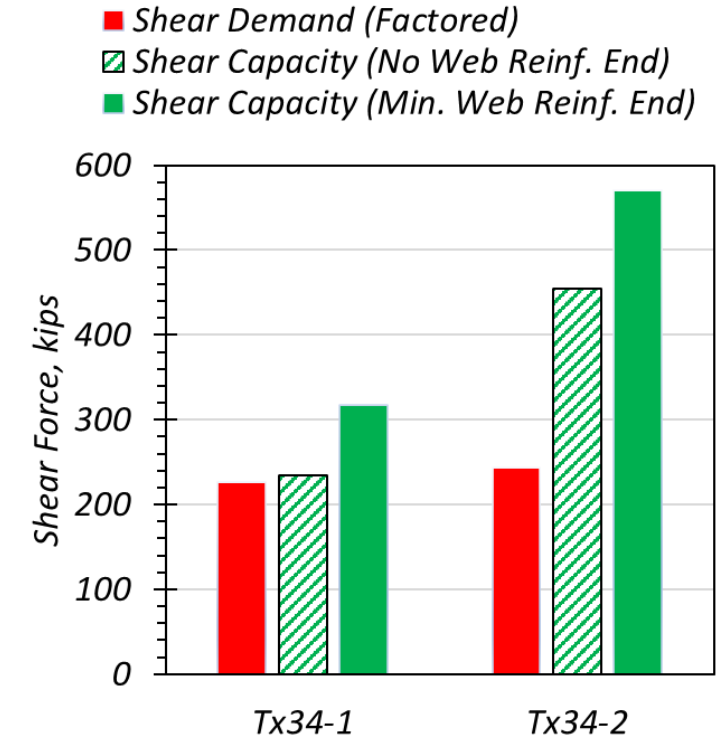
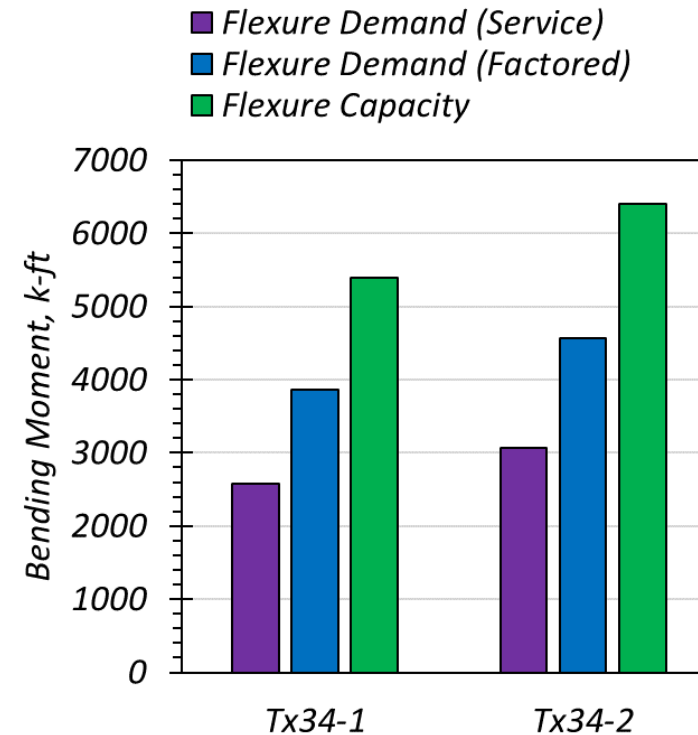
Tx34 Girder Specimens – Demand and Capacity

Demands	Tx34-1	Tx34-2
Flexure (Service)	2580 k-ft	3065 k-ft
Flexure (Factored)	3870 k-ft	4560 k-ft
Shear (Factored)	227 kips	244 kips

Capacity	Tx34-1	Tx34-2
Flexure	5400 k-ft	6400 k-ft*
Shear (No Web Reinf. End)	235 kips	454 kips
Shear (Min. Web Reinf. End)	317 kips	570 kips

*Slip at haunch and girder interface at 6000 k-ft

Tx34-1 end without shear reinforcement was critical zone for shear failure during flexure test.



Crack widths (mm)	Tx34-1	Tx34-2
Flexure	Generally 0.1 to 0.2 mm cracks; 4.5 mm crack at soffit	Generally 0.1 to 0.25 mm; 3 mm crack at soffit
Shear (No Web Reinf. End)	0.25 to 0.6 mm cracks	0.3 to 17.5 mm
Shear (Min. Web Reinf. End)	Hairline to ≤ 0.6 mm	0.1 to 8 mm

- **Design and Prediction**
 - Girder designs were adequately developed using existing code provisions and recommendations for UHPC
 - Standard constitutive relationships, sectional analysis, and stress-strain curves were implemented with modifications for UHPC and gave good agreement with experimental values
 - Shear strength is highly depended on tensile strength of UHPC
- **Flexural Performance of Decked UHPC Girder Specimens**
 - Tensile strength of UHPC girder was engaged → crack bridging property of fibers resulted in more ductile flexural performance with limited cracking.
 - At service load: cracks were not visible
 - At factored load: hairline cracks were observed
 - At failure, max crack width: 4 mm
 - Near the max load, Tx34-2 exhibited initial slip at interface of CIP concrete deck slab and UHPC girder
- **Shear Performance of Decked UHPC Girders Specimens**
 - Crack bridging property of the fibers delayed the onset of shear failure
 - At service load: cracks were not visible
 - At factored load: hairline cracks were observed
 - At failure load, maximum crack widths: 0.6 mm (Tx34-1) and 8 mm (Tx34-2)
 - Tx34-2: harped tendon profile and increased UHPC tensile strength improved shear capacity.
 - Minimum mild steel reinforcement provided additional ductility when approaching shear failure



Thank you!

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Questions and Discussion

