Optimization of Bridge Systems using ChrōmX

September 24, 2019

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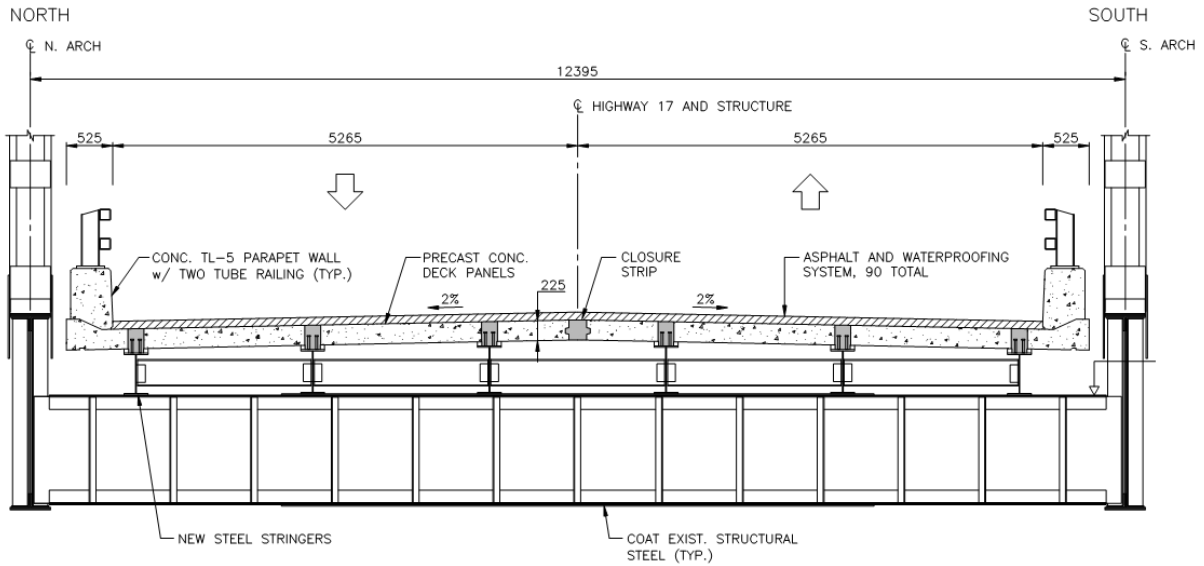
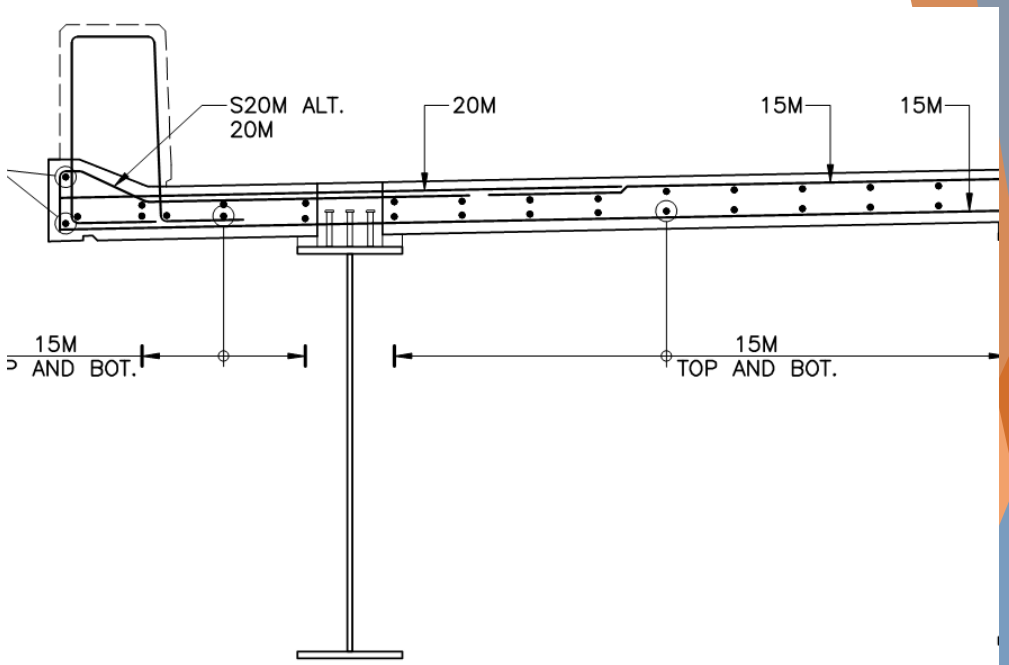
Agenda

- Converting a Bridge Deck to Waffle Panels
- UHPC Decked I-Beam using ChromX Reinforcement
- NEXT Beam
- Abu Dhabi International Airport
- Curved Tub Girder Bridge
- Pedestrian Walkway in Alabama (proposal stages)
- Buchanan County Single Tee ChromX Reinforced Bridge
- NDOT: Development of ChromX Reinforced Short Span Bridge members
- VDOT: Wolf Creek Bridge Replacement
- PennDOT: Bridge Deck Reinforcement Optimizations
- Colorado DOT: Bridge Deck Reinforcement Optimizations
- TxDOT: Optimization of a CIP Bridge Deck Over Spread Box Beams

Converting an Existing System to Waffle Panels

- Existing system at White Lake:
  - #5 at top and bottom in both directions
  - 9 inch. precast deck (excluding overlay)





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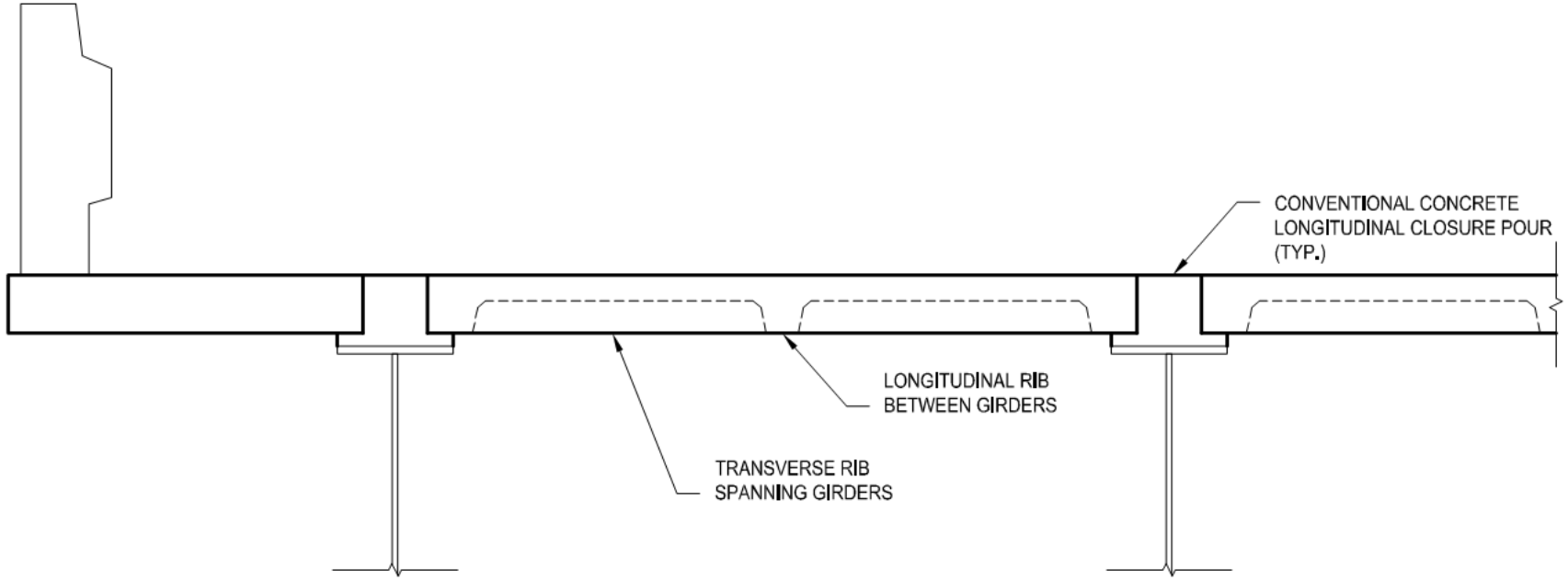
Optimized Waffle Panel – Bridge Deck Geometry

- Transverse ribs provide flexural capacity between girders.
- Longitudinal rib between girders for additional load distribution to transverse ribs.
- No ribs used in overhang (drive by flexural design and panel production).
- UHPC longitudinal haunch/shear pocket closure pours



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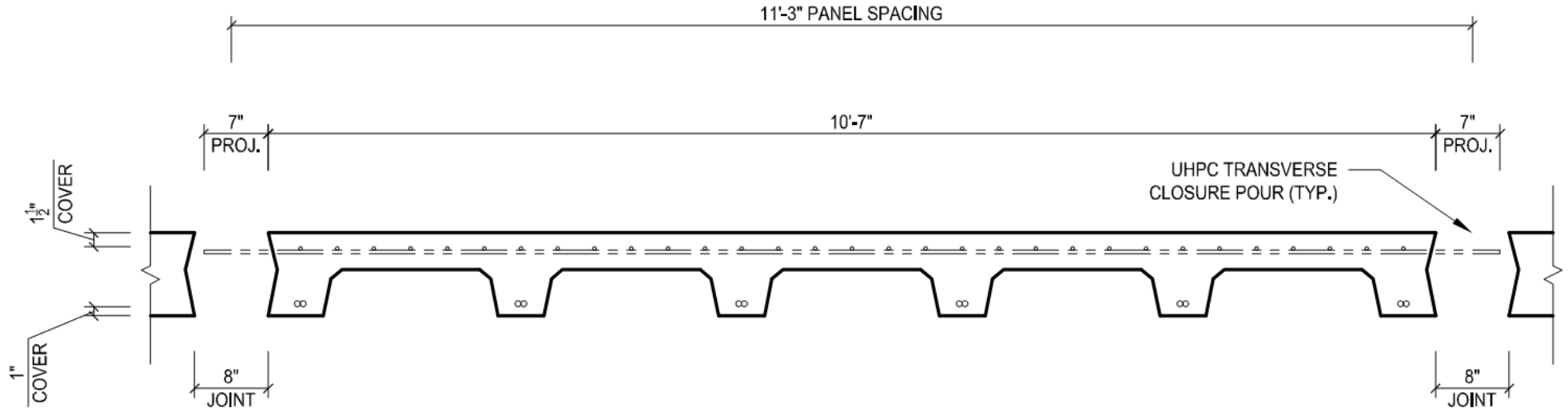
Optimized Waffle Panel Reinforcement

- Transverse positive flexural reinforcement (2 - #5's) bundled in ribs.
- Small diameter bar mat (#3 @ 4" each way) in the 4" top of deck.
- #5 @ 8" additional overhang reinforcement.
- Barrier reinforcement cast into panel for later CIP barrier pour.



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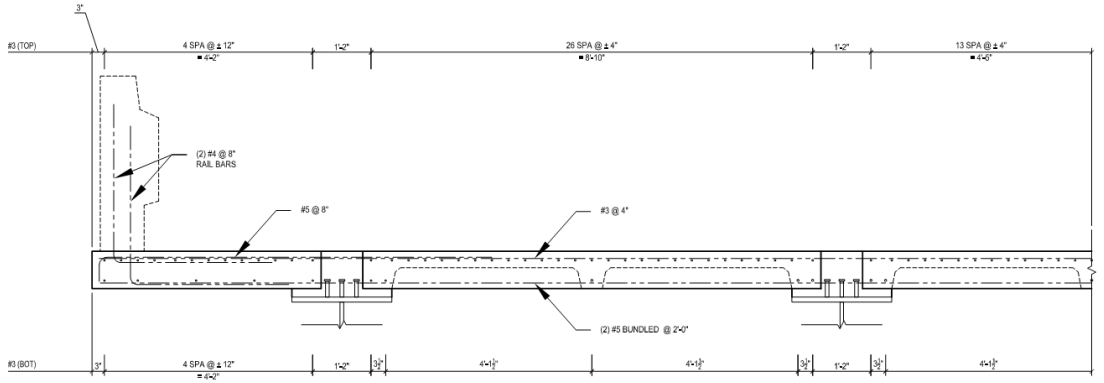
Optimized Waffle Panel Comparison

Material	Units	Example Project	ChrōmX Design	Savings
Precast Concrete	ft^3 / ft^2	0.657	0.471	28%
CIP Conventional	ft^3 / ft^2	0	0.090	-100%
UHPC	ft^3 / ft^2	0.096	0.046	52%
Reinforcement	lb / ft^2	6.62	4.33	35%

The ChrōmX Design uses full panel width longitudinal haunch/shear pocket closure pours filled with conventional concrete, whereas the example project uses discrete shear pockets spaced along the beam length that are filled with UHPC.



Reinforcement diagram at barrier

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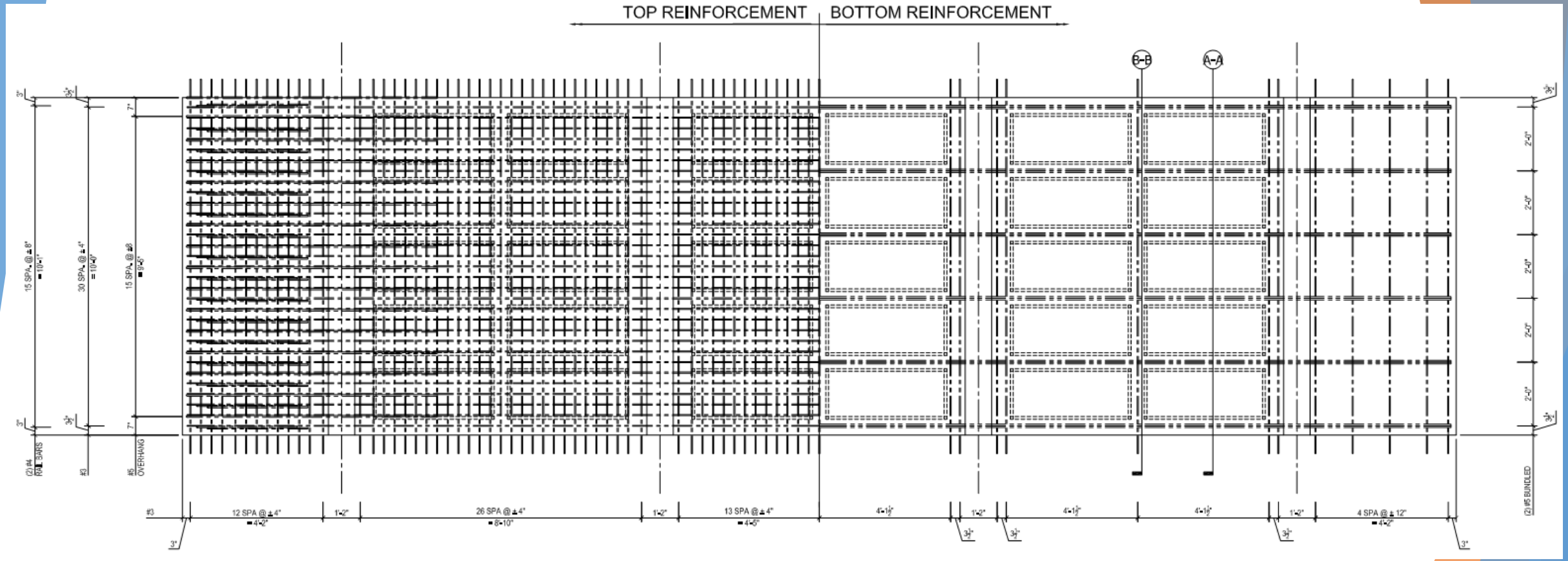
Optimized Waffle Panel System

- All reinforcement is ChromX 9100



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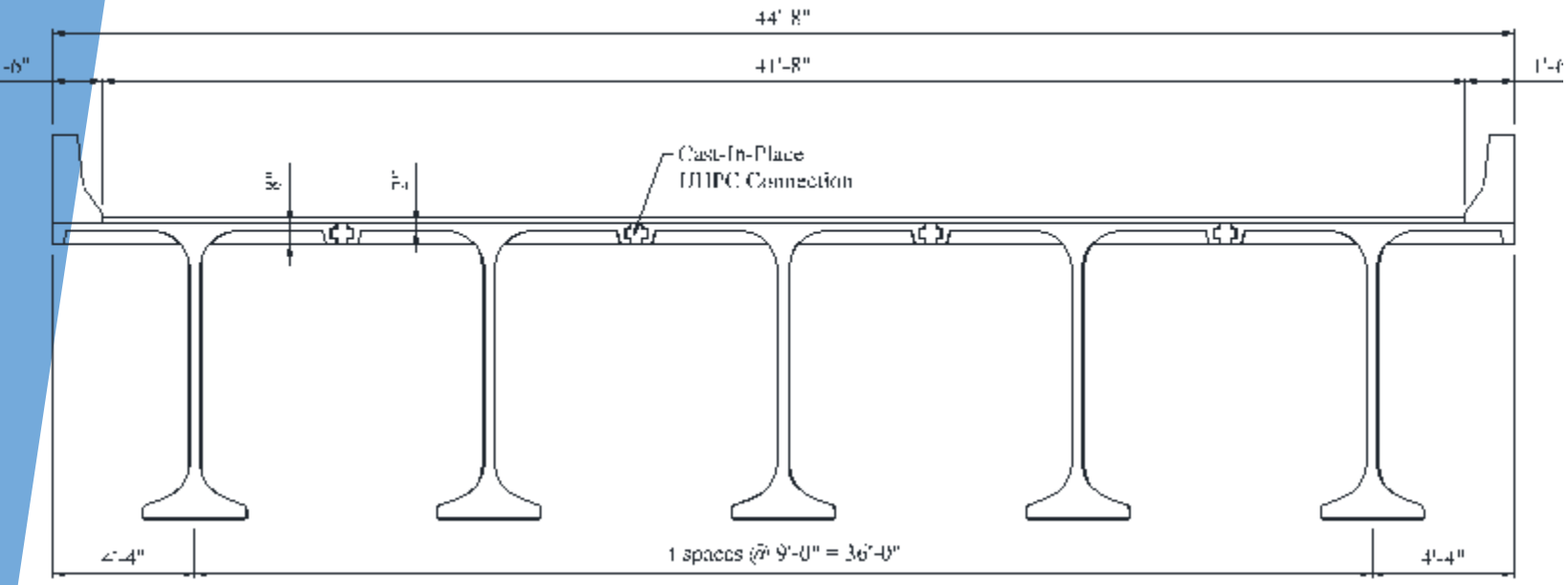
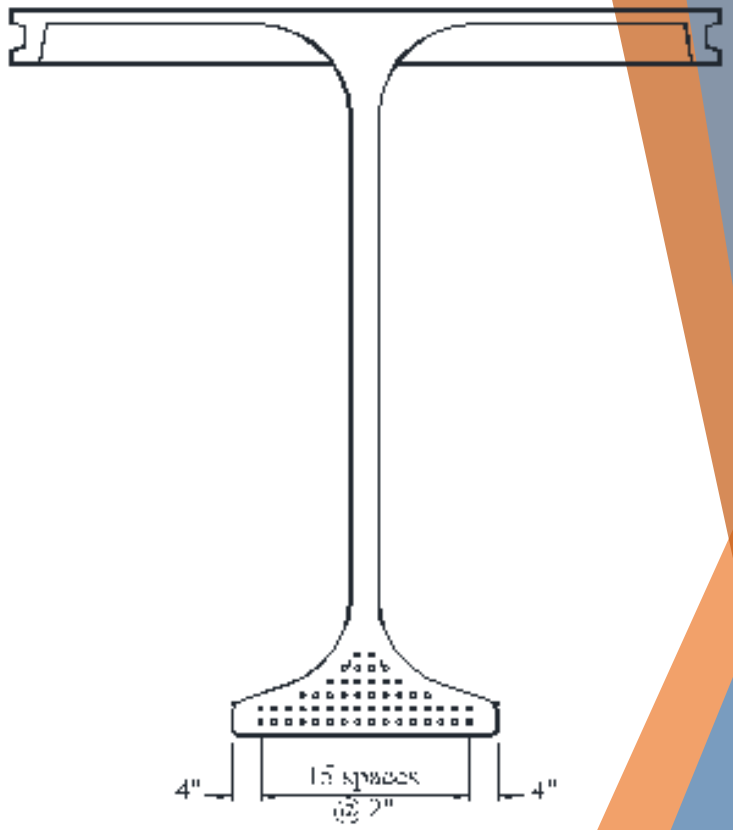
UHPC Decked I-Beam (submitted example)

- This example was created to be used for the PCI funded project for UHPC.





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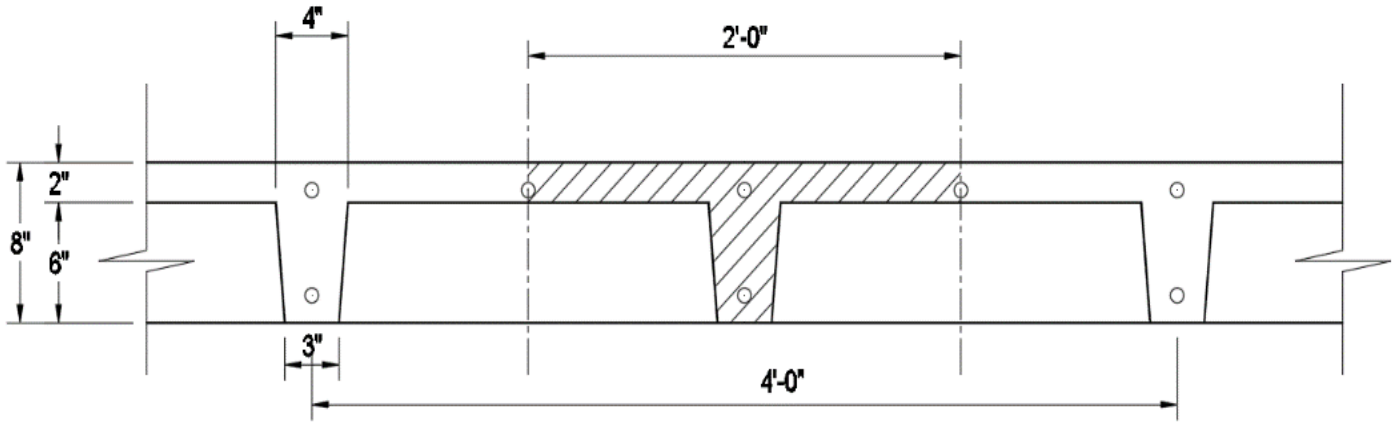
Compression and Bursting Reinforcement in the Decked I-Beam

- The deck of the I-beam consists of ChromX rebar.
  - Due to the wide spacing of ribs, either large bars are needed at the ribs, or a smaller high strength bar, such as MMFX.
  - This allows for a wide rib design using minimal reinforcement.
- The less bursting reinforcement, the better UHPC can be utilized.
  - ChromX allows for less overall reinforcement in the anchorage zone



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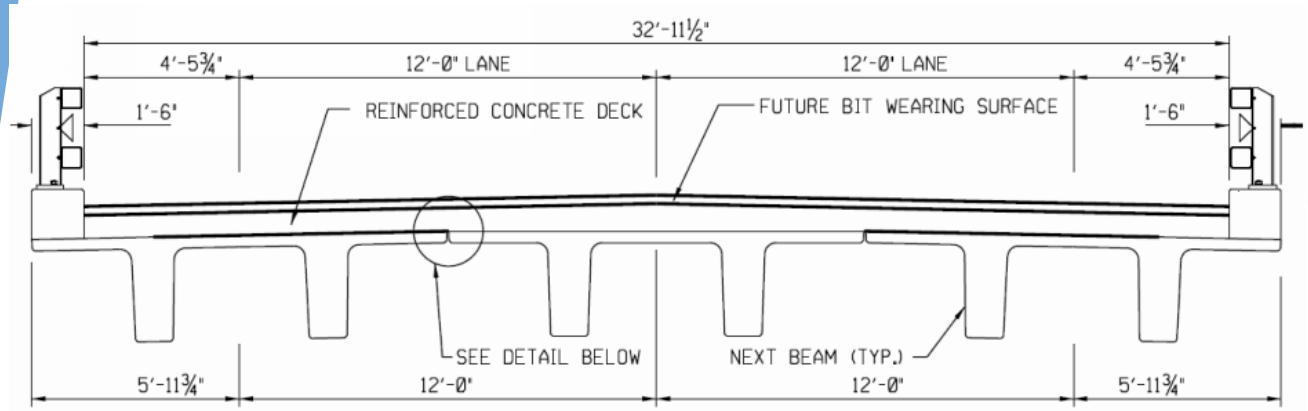
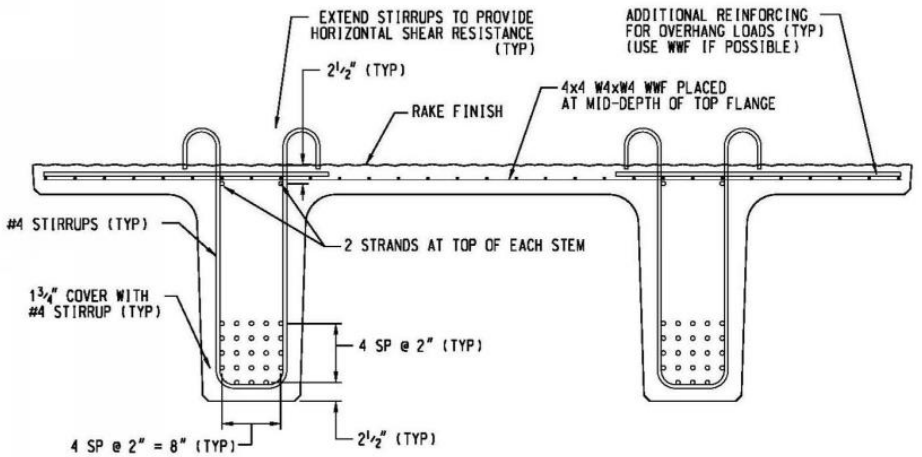
Original NEXT Beam Features and Advantages

- Open Double Tee, Single Pour Production
- Varying depths and widths
- Accommodates utilities
- Spans 30 to 90 ft





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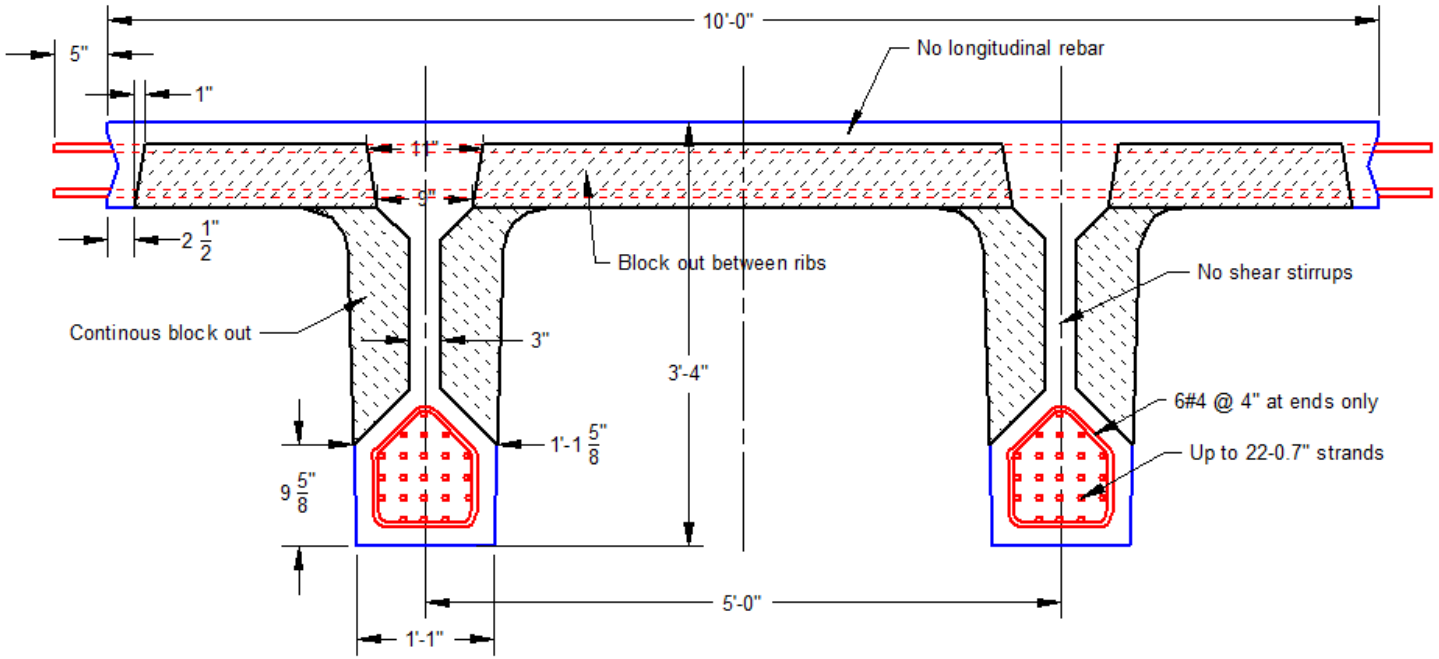
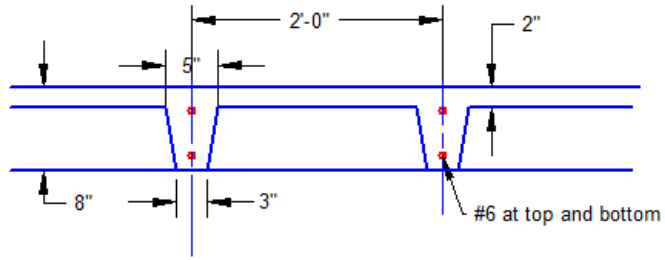
Optimized UHPC NEXT Beam to be Tested in Phase II of PCI Project





Note: ASTM A1035 rebar is needed in the top flange ribs for transverse flexure. Also, rebar is used at the ends for confinement and bursting crack control

- Keeping the same advantages while reducing the weight tremendously, making shipping and handling more cost effective.
- Increase in max span length.

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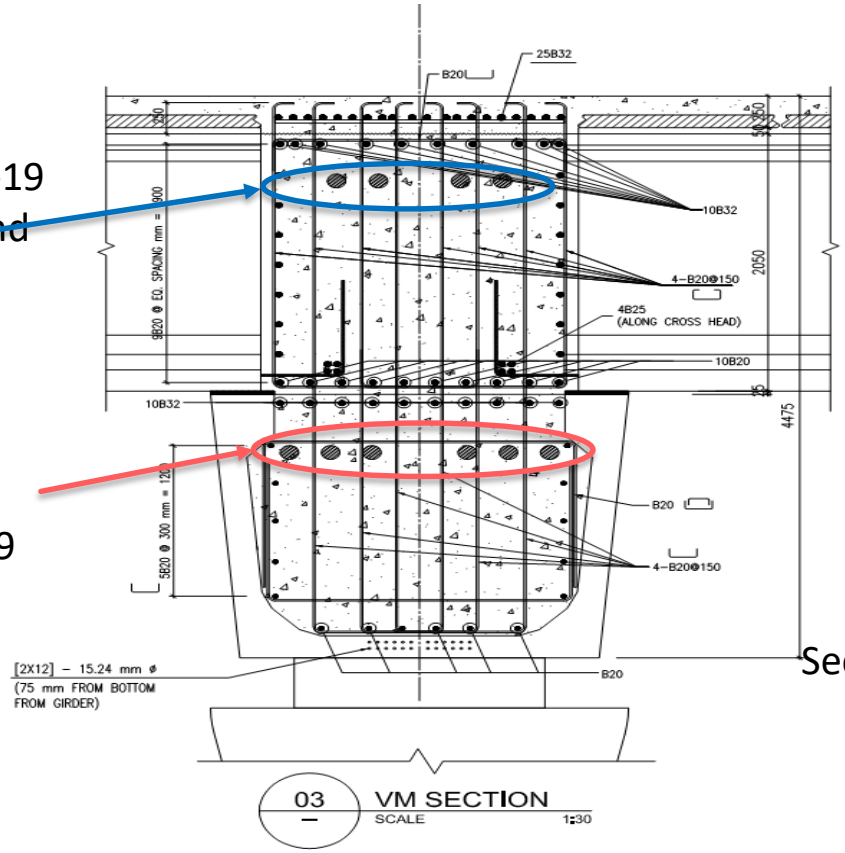
Abu Dhabi Midfield Terminal

Subsituting Post-Tensioning with MMFX ChromX Gr. 100

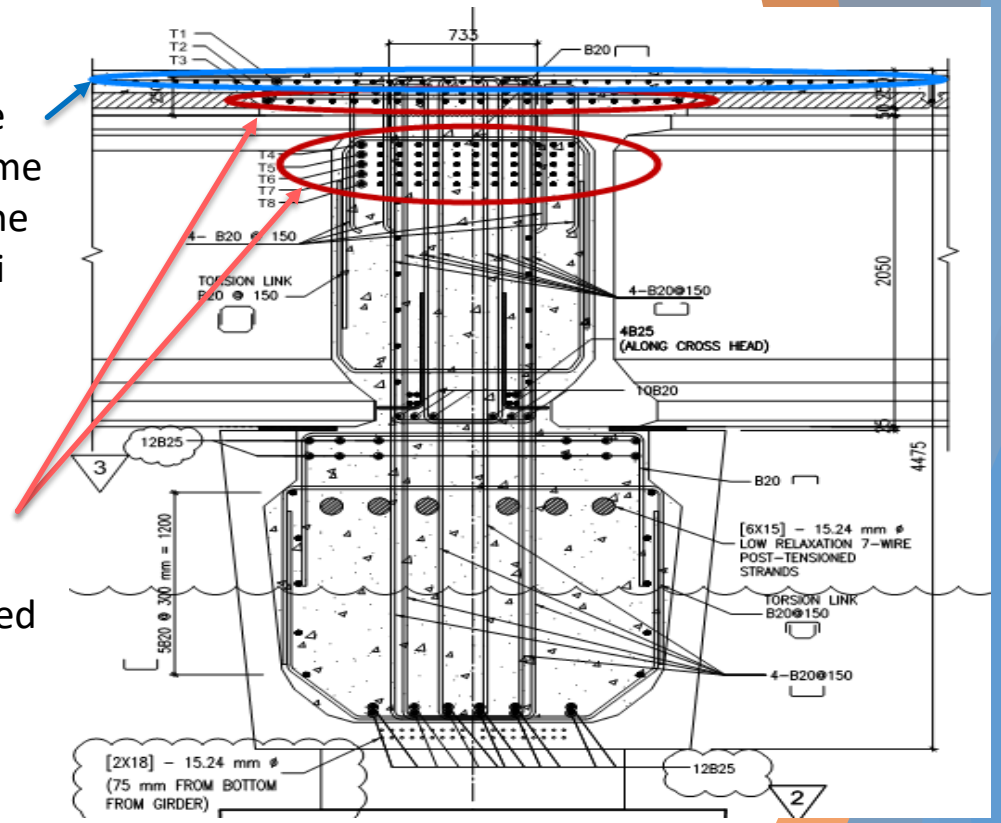
2nd Stage 4-19 0.6 in. Strand Tendons

1nd Stage 6-19 0.6 in. Strand Tendons



Design Using the Strain in the Extreme Tension Steel in the CIP Deck – 72 ksi

Second Stage PT Replaced with ChromX



Accelerated construction and increased ease of construction

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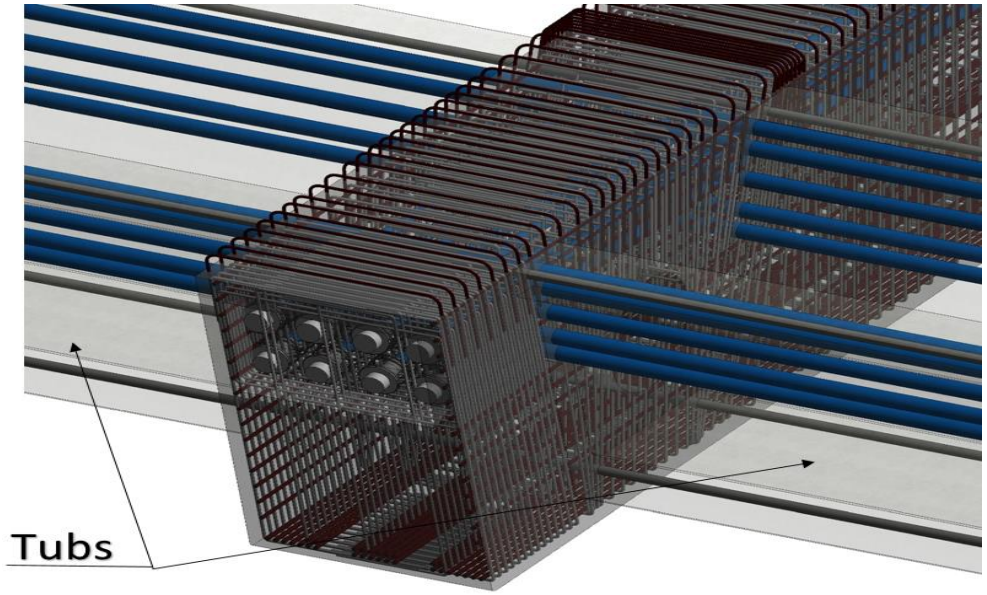
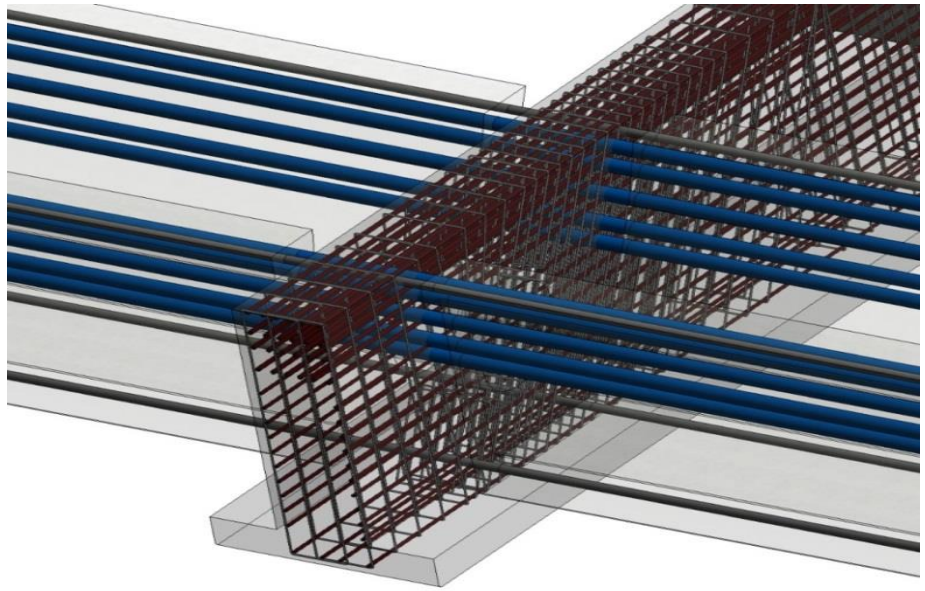
Curved Tub Girder Bridge

- Three span bridge, 120-230-120 ft long, 48.5 ft. wide
- 8.5 feet deep pier cap is 8.5 ft deep supporting two 7.5 ft. U-beams



Original



Redesigned

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Redesigned Pier Cap

- Reduce section width at the top to 2 ft.
- Use 1.5 ft wide by 1 ft deep ledges to support the 7.5 ft deep U-beams
- Pier cap weight is less than 50% of original
- No need to flare the cap ends 5 ft – 6 in. width to accommodate PT
- Shoring is eliminated; reduced contractor time and risk

Item	Unit	Original Design	MMFX Design	Savings
Concrete	$yard^3$	60.900	28.600	53%
Flexure Reinforcement	tons	2.763	2.580	7%
Vertical Shear Reinforcement	tons	2.242	1.486	34%
Horizontal Shear Reinforcement	tons	1.637	0.833	49%

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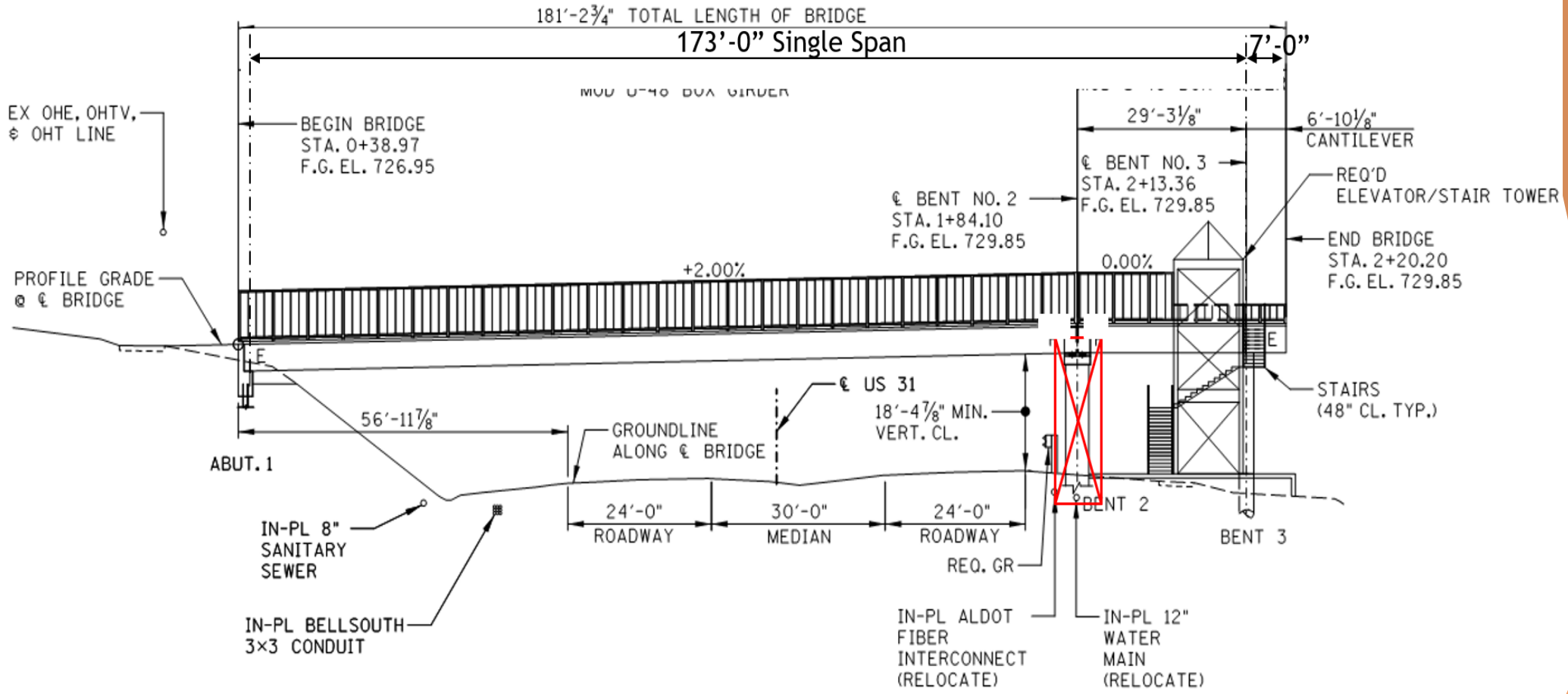
Pedestrian Walkway in Alabama (proposal stages)



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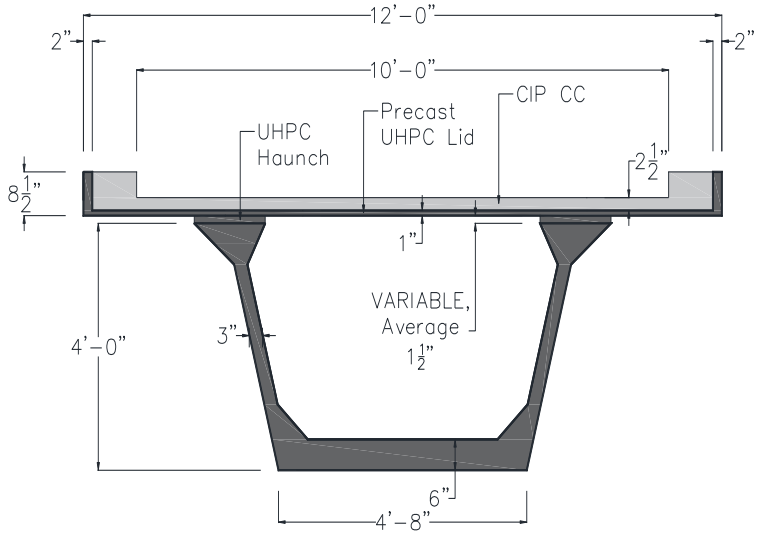
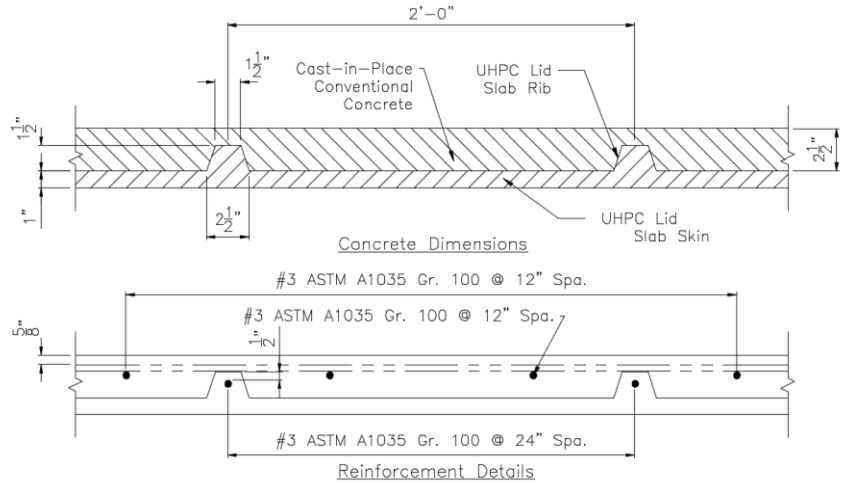
Pedestrian Walkway Cross Section

- UHPC allows for a long single span bridge with thinner members
- ChromX allows for less compression reinforcement with a reduced cover
  - This results in a lower weight for both production and construction
- ChromX is to be used for bursting reinforcement to reduce amount of steel needed





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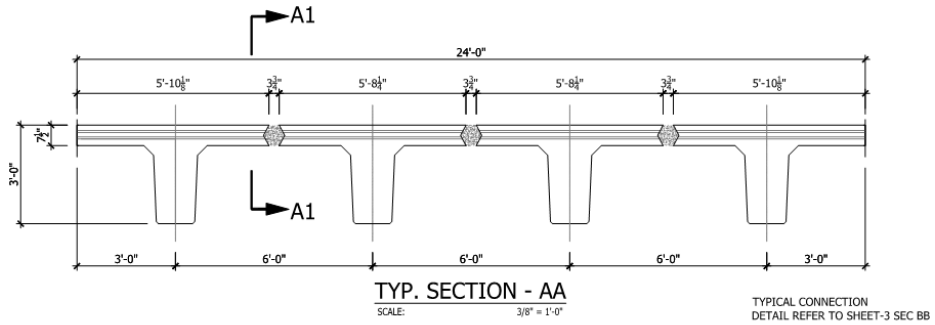
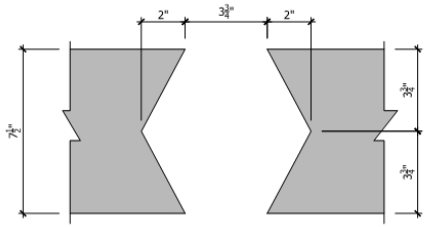
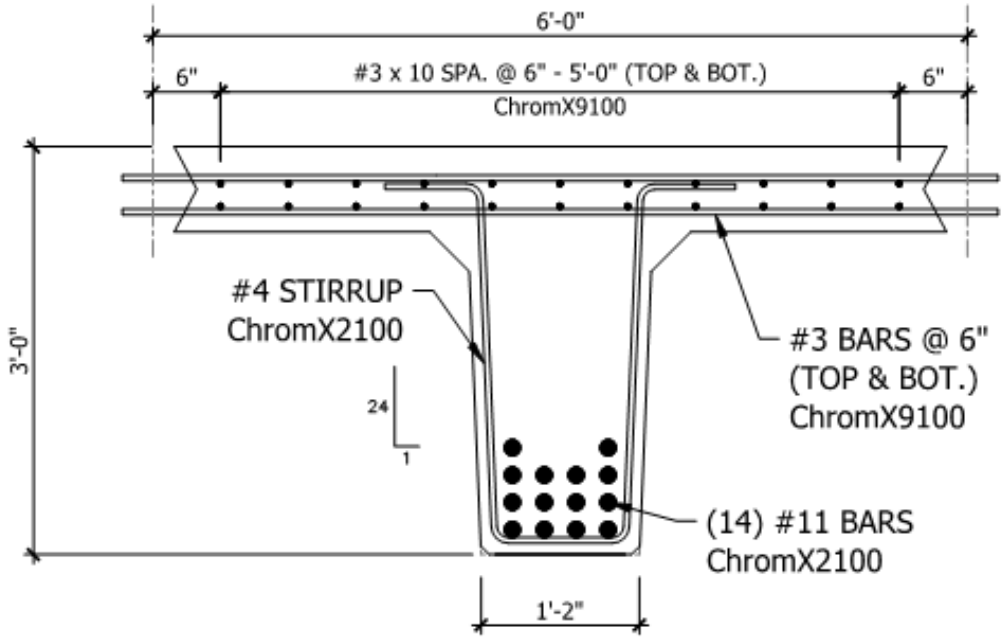
Buchanan County Single Tee ChromX Reinforced Bridge

- UHPC with ChromX allows for a 62 ft span using only a 3 ft deep beam
  - Removes need for prestressing; easier for counties to implement and construct this







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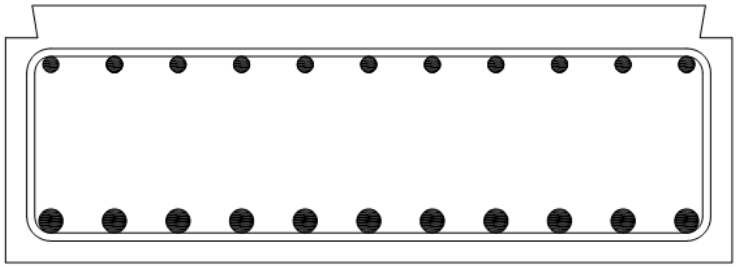
NDOT Research: ChromX Reinforced Planks for Short Span Bridges

Overview of the System Requirements

- Less Joints using Wider Planks (less joints, less leakage)
- Light Weight (less than 50 tons)
- Simple Construction (no prestressing or transverse PT)
- Flexibility for various lengths



Solution

- Use of high-strength steel reinforcement
- Use of high performance concrete or low shrinkage grouts at transverse joints; less joints means a comparable cost

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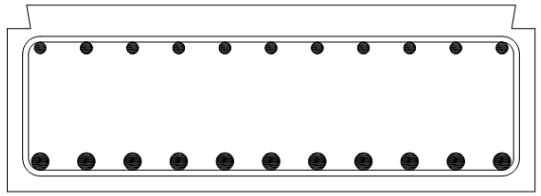
Reinforcement Details

Beam Type	Reinforcement Type	Beam Size (in.)	Equivalent Solid Slab Thickness (in.)	Beam Weight (k/ft)	Max. Span (ft)	Corresponding Concrete Strength (Initial, Final) (ksi)	Corresponding Reinforcement (Bottom, Top)
Plank	Reinforced Gr. 60	34x12	12	0.42	27	-, 8.5	11-#9 B, 11-#6 T
	Reinforced ChromX 9100				36	-, 12	

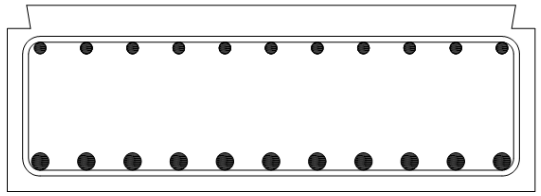
REINFORCED GR. 60



11-#6 Grade 60 Top

11-#9 Grade 60 Bottom

REINFORCED CHROMX



11-#6 ChromX 9100 Top

11-#9 ChromX 9100 Bottom

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Advantages

- Longer span length than with conventional rebar, using the same amount of bars in ChromX.
- High strength (8 ksi) concrete is recommended to take advantage of the high strength steel.
- We recommend wider planks to get fewer joints.
- If we reduce the cover by ½" we gain more span capacity.

VDOT: Wolf Creek Bridge Replacement

- Decrease in bar size, from No. 5 to No. 4
  - Reduces congestion of bars
  - Better consolidation of concrete
- No significant defects within 2 months of construction
- Compared with the standard design:
  - 23% reduction in weight of reinforcement
  - 23% (or $7,513) reduction in price of bridge deck

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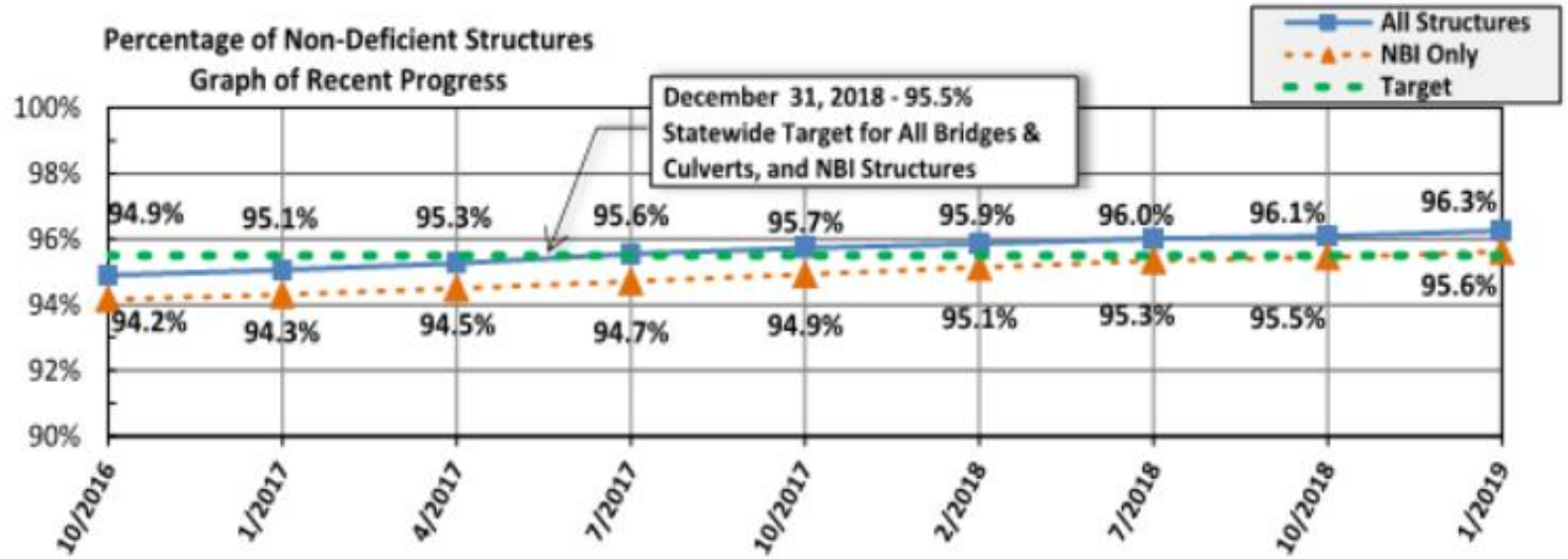
VDOT Maintenance Cost Reduction Focus

- ChrōmX helps to reduce long term maintenance costs
  - Less joints
  - Corrosion resistant
  - Higher strength; less bars/reduction in bar size
- Elimination of joints and utilization of corrosion resistant reinforcement has helped to decrease the long term maintenance costs of bridges



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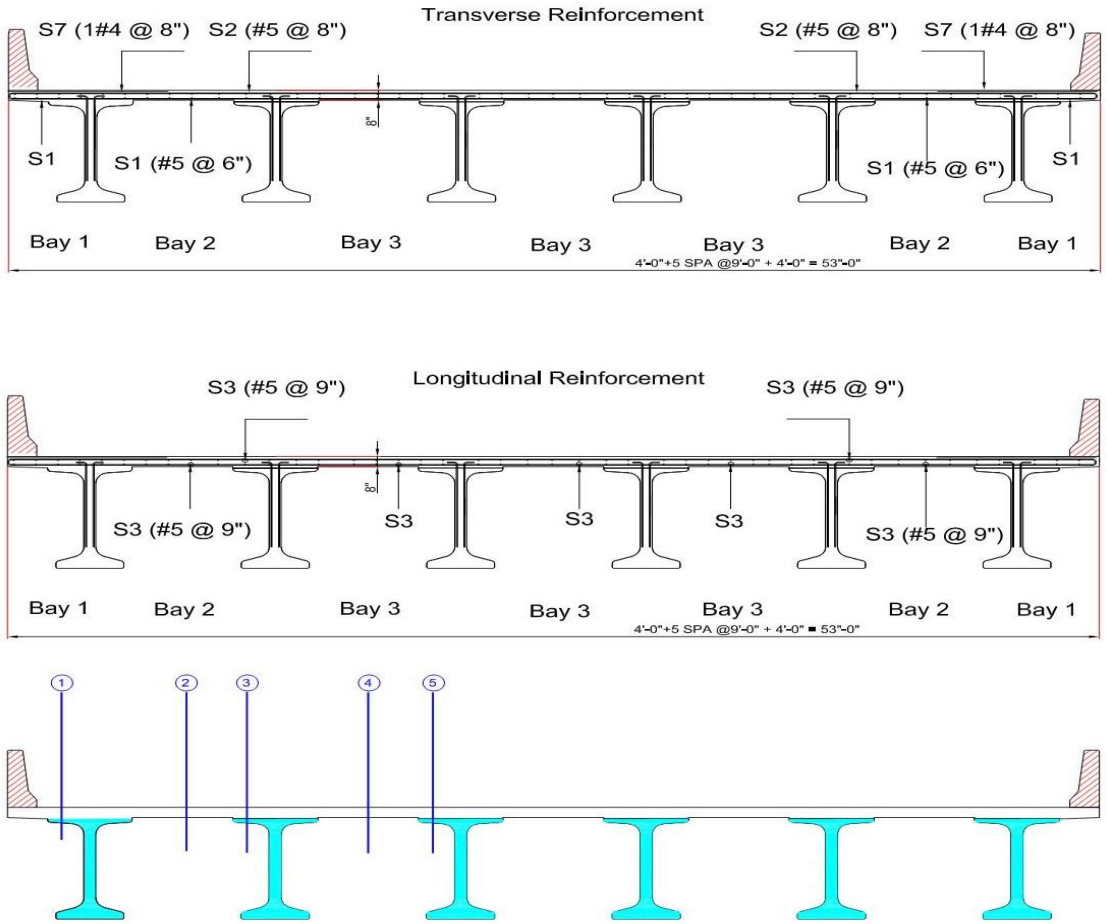
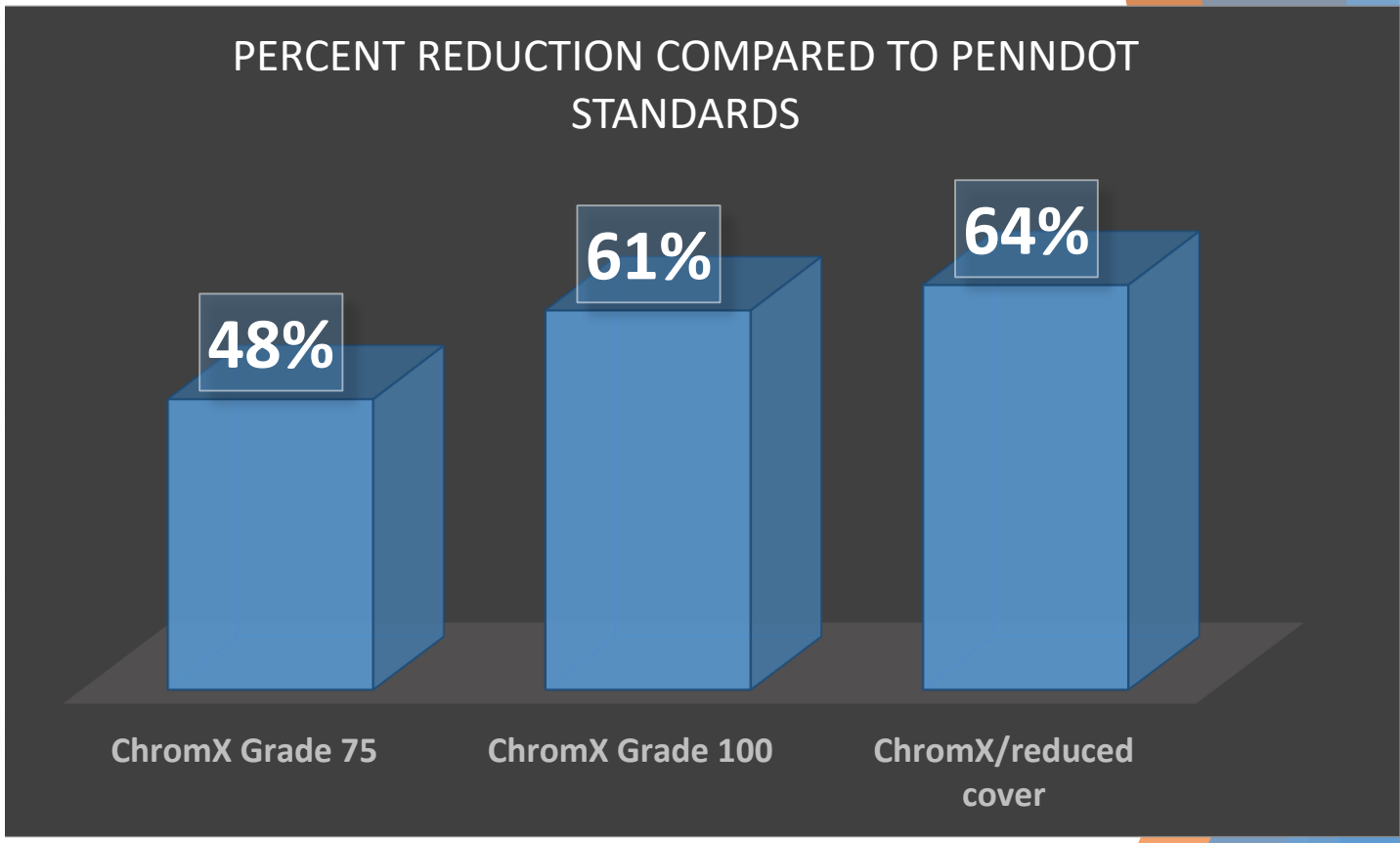
PennDOT: Optimization of a Bridge Deck Reinforcement

- With ChrōmX, a reduced cover can be used, lowering the amount of steel needed





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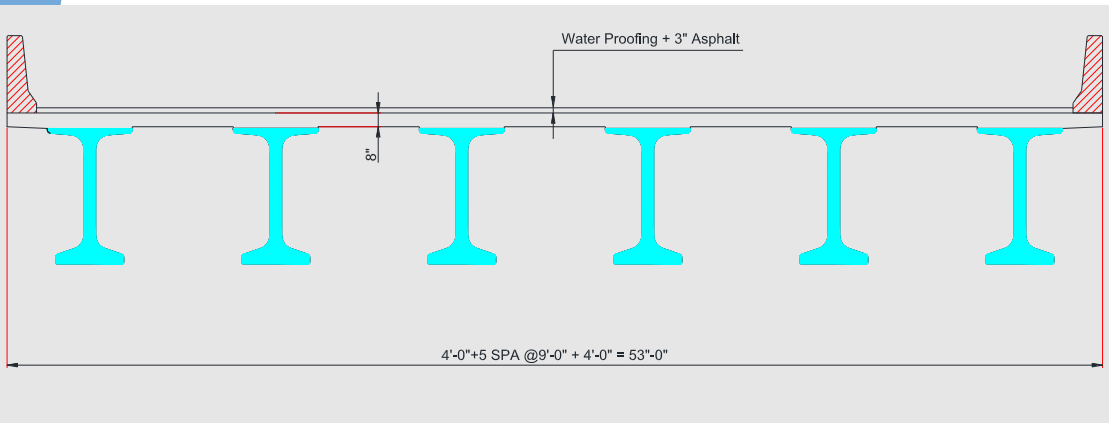
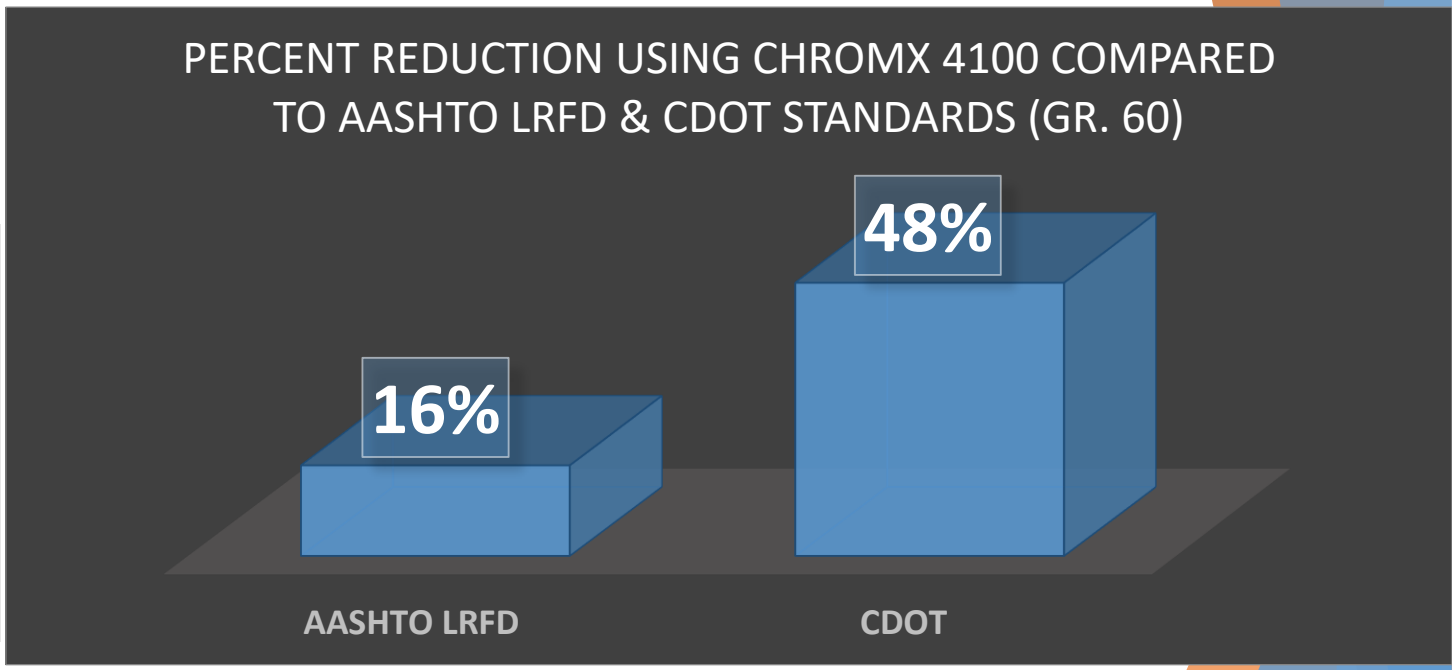
Colorado DOT: Optimization of Bridge Deck Reinforcement

- Using ChromX gives a 16% reduction in overall reinforcement compared to using the AASHTO LRFD design.
- ChromX also gives a 48% reduction in reinforcement compared to the CDOT standards.





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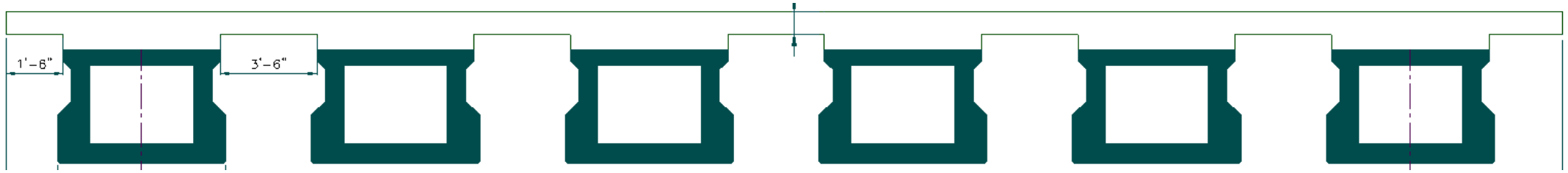
TxDOT: Optimization of a CIP Bridge Deck Over Spread Box Beams

- ChromX 2100 gives a 50% reduction in materials!

The weight of grade 60 steel per Texas DOT requirements is	5.69	psf
ChromX 2100 ASTM A1035 steel designed at Fy = 100 ksi using the Strip Method	2.81	psf

- This does not account for the increased savings from:
  - Increased life span due to corrosion resistance
  - Reduction of top clear cover by 0.5”



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