

Optimization of Bridge Systems using ChromX[®]

September 24, 2019

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Agenda

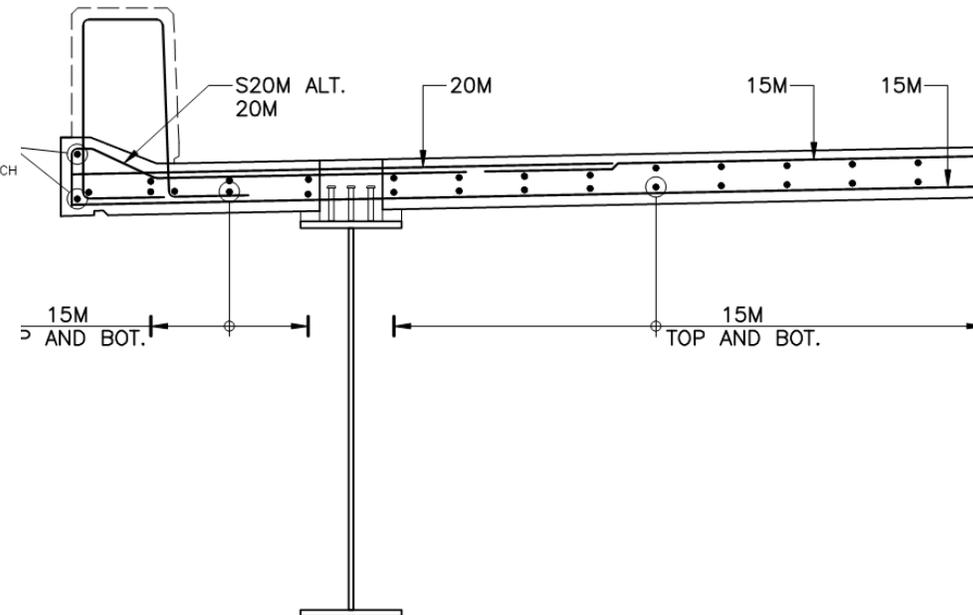
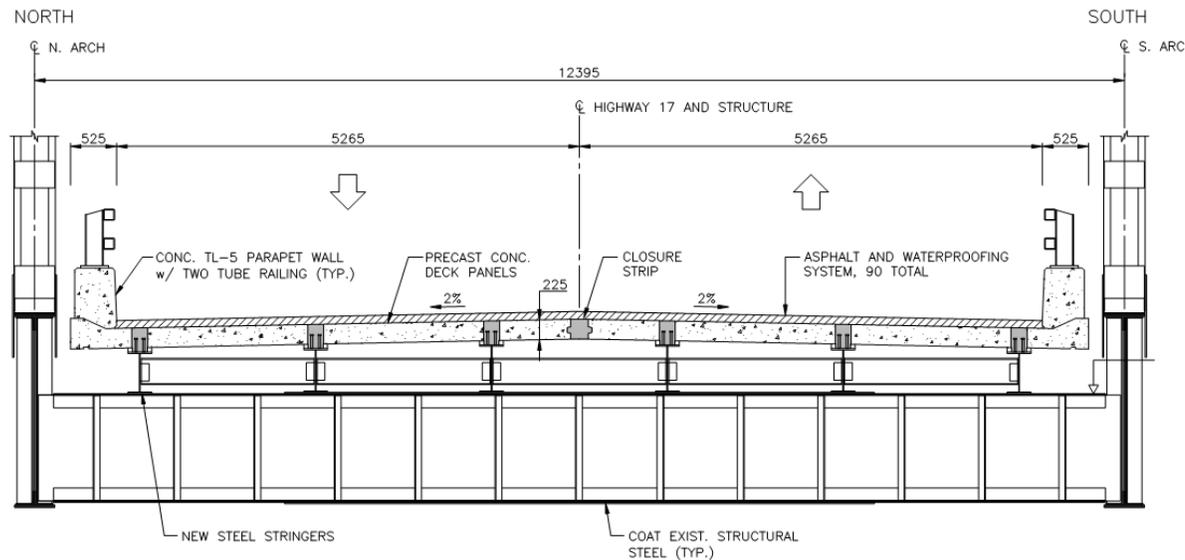
- ▶ Converting a Bridge Deck to Waffle Panels
- ▶ UHPC Decked I-Beam using ChromX[®] Reinforcement
- ▶ NEXT Beam
- ▶ Abu Dhabi International Airport
- ▶ Curved Tub Girder Bridge
- ▶ Pedestrian Walkway in Alabama (proposal stages)
- ▶ Buchanan County Single Tee ChromX[®] Reinforced Bridge
- ▶ NDOT: Development 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

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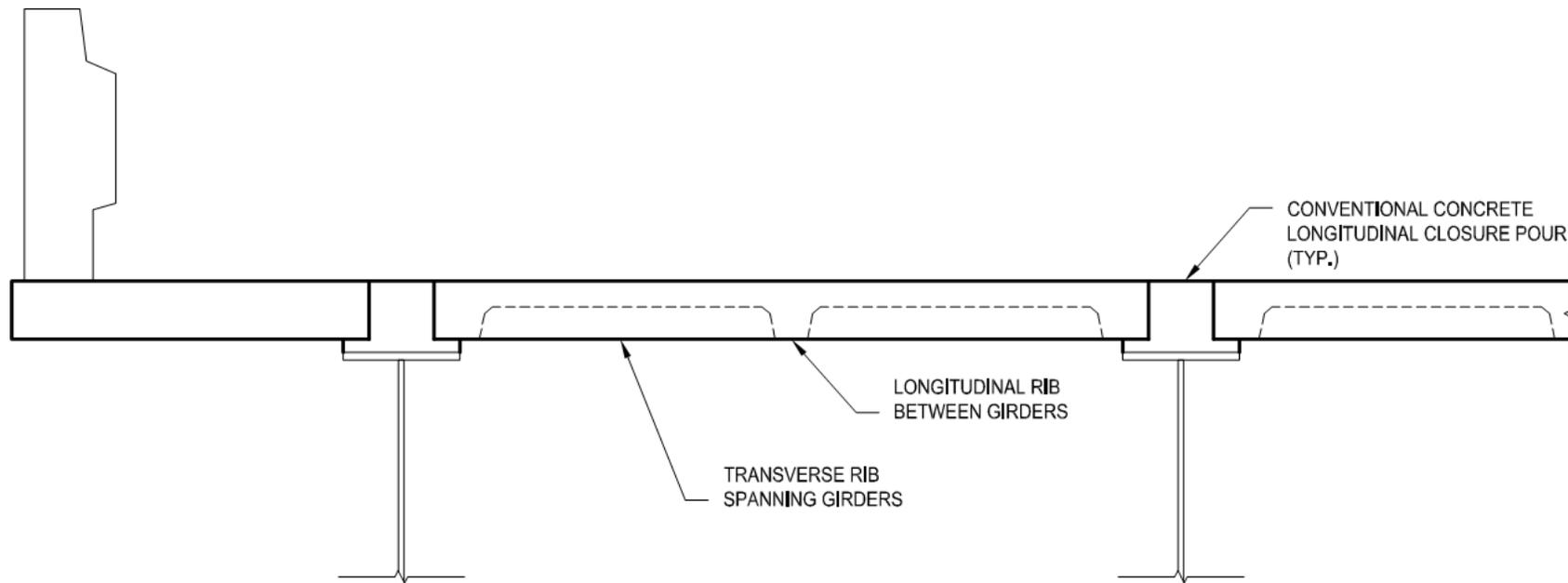
Converting an Existing System to Waffle Panels

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



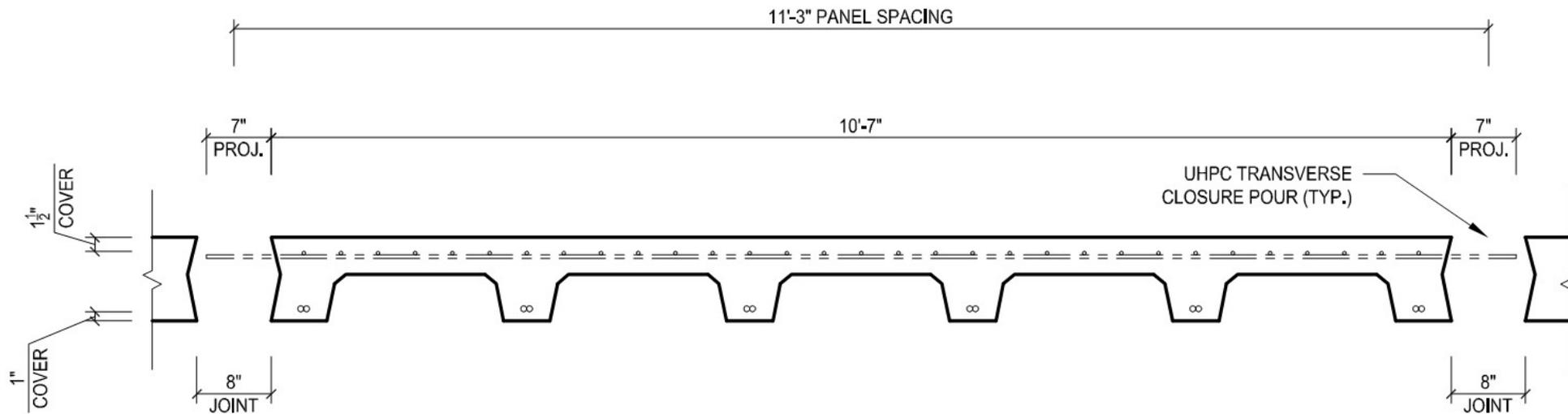
Optimized Waffle Panel – Bridge Deck Geometry

- ▶ 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



Optimized Waffle Panel Reinforcement

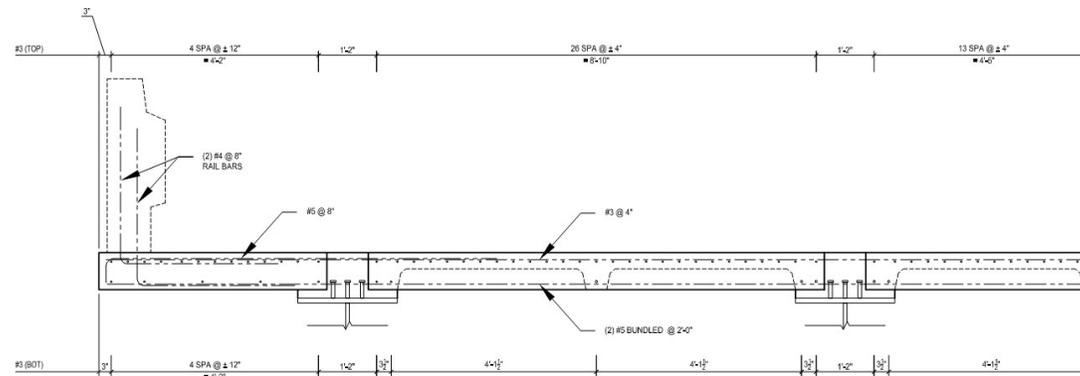
- ▶ Transverse positive flexural reinforcement (2 - #5's) bundled in ribs.
- ▶ Small diameter bar mat (#3 @ 4" each way) in the 4" top of deck.
- ▶ #5 @ 8" additional overhang reinforcement.
- ▶ Barrier reinforcement cast into panel for later CIP barrier pour.



Optimized Waffle Panel Comparison

Material	Units	Example Project	ChromX® 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%

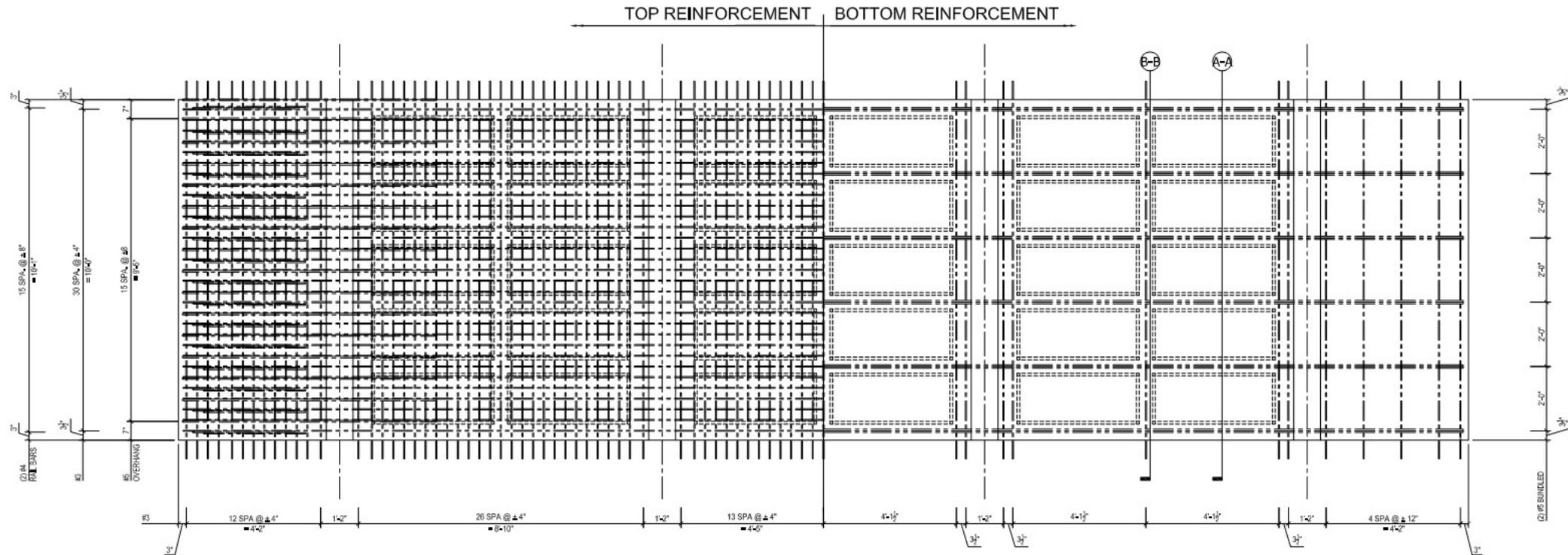
The ChromX® Design uses full panel width longitudinal haunch/shear pocket closure pours filled with conventional concrete, whereas the example project uses discrete shear pockets spaced along the beam length that are filled with UHPC.



Reinforcement diagram at barrier

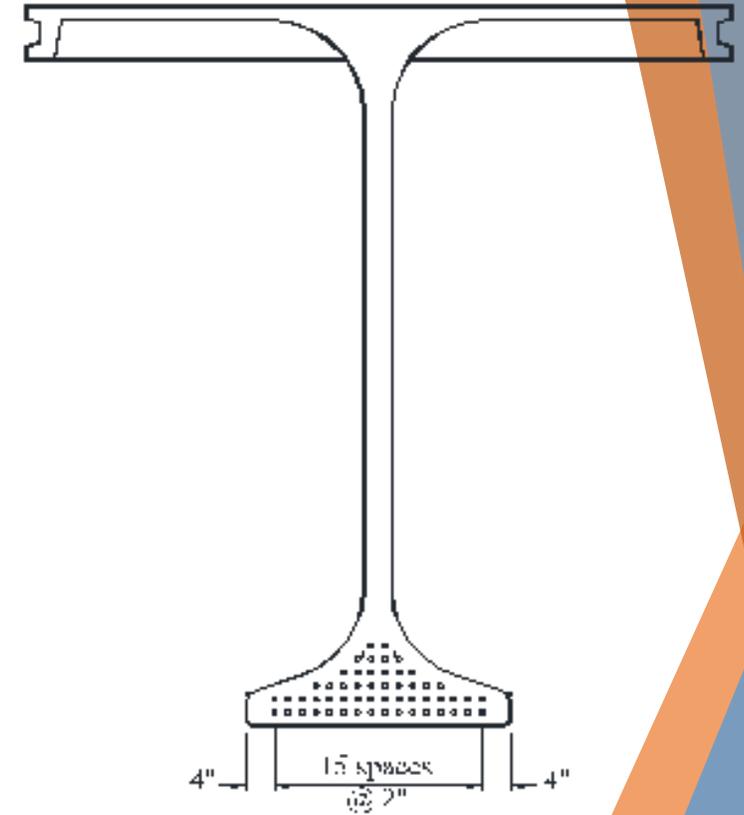
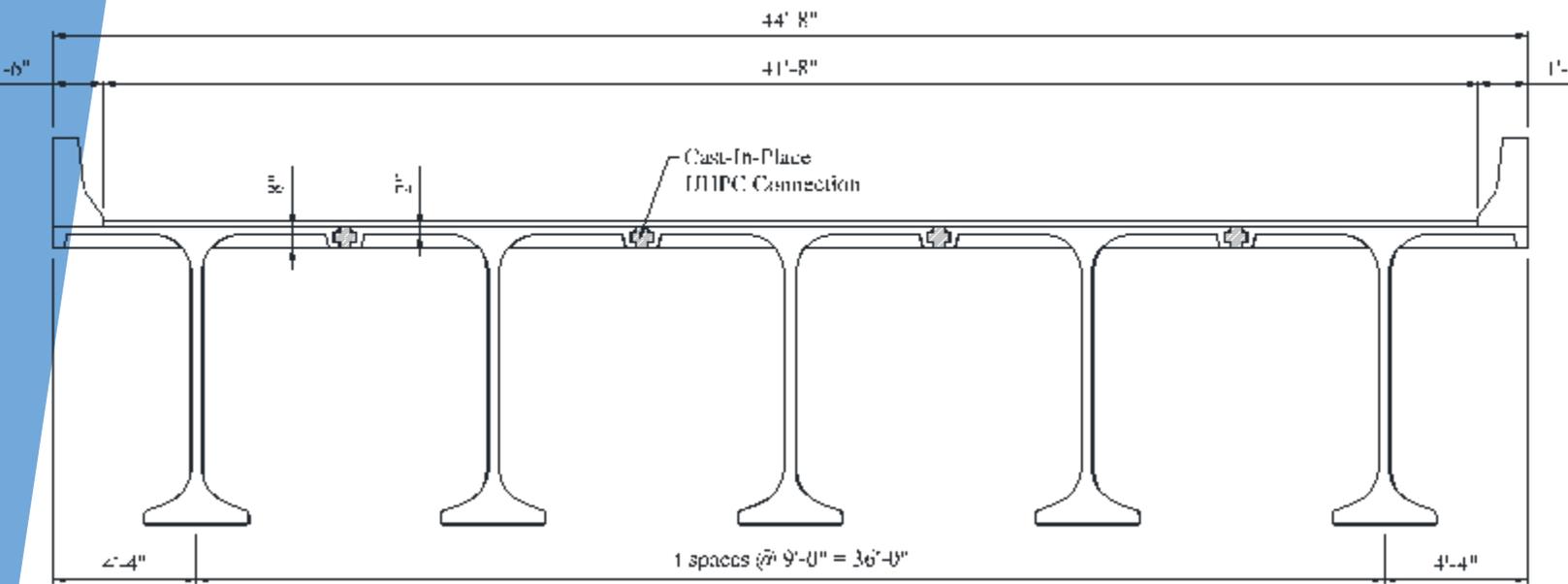
Optimized Waffle Panel System

- ▶ All reinforcement is ChromX® 9100



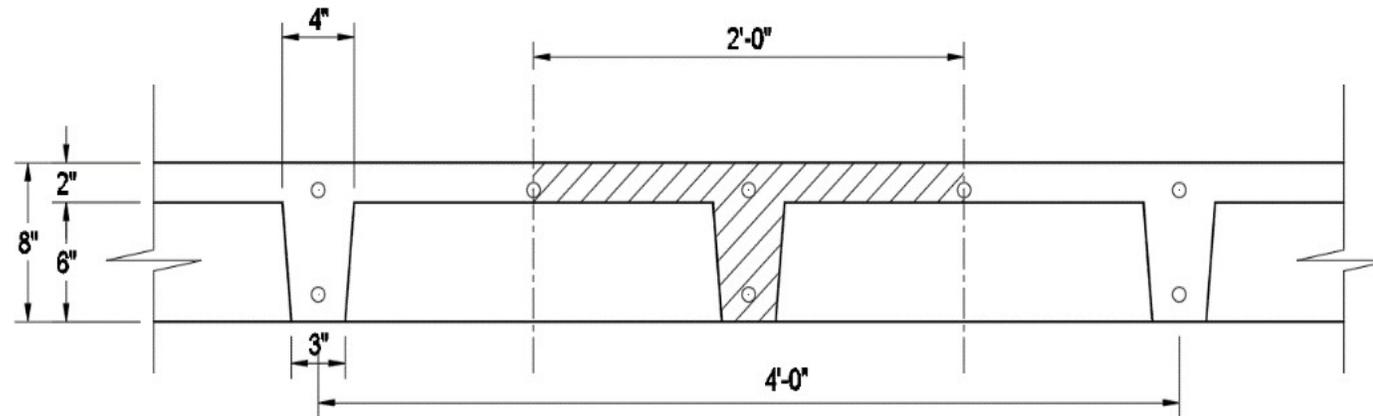
UHPC Decked I-Beam (submitted example)

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



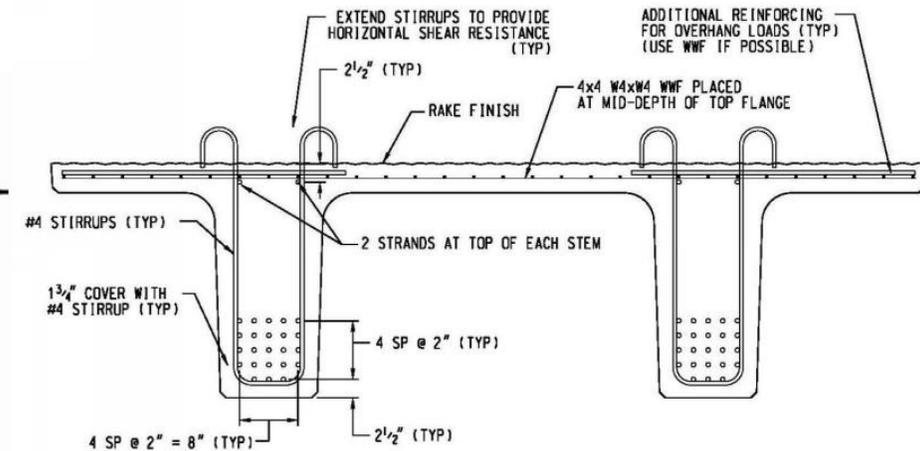
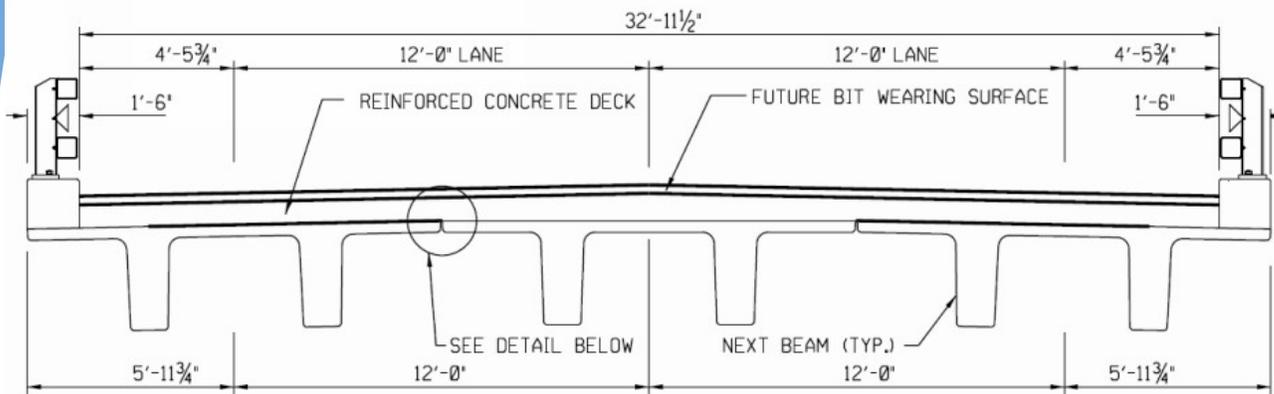
Compression and Bursting Reinforcement in the Decked I-Beam

- ▶ 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

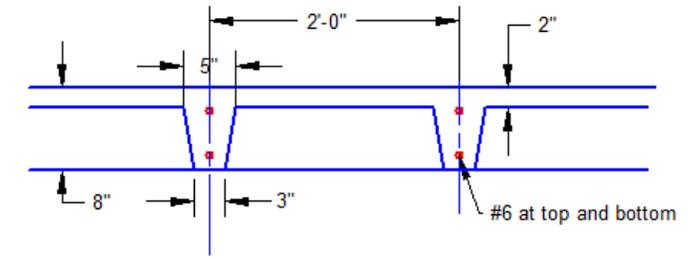
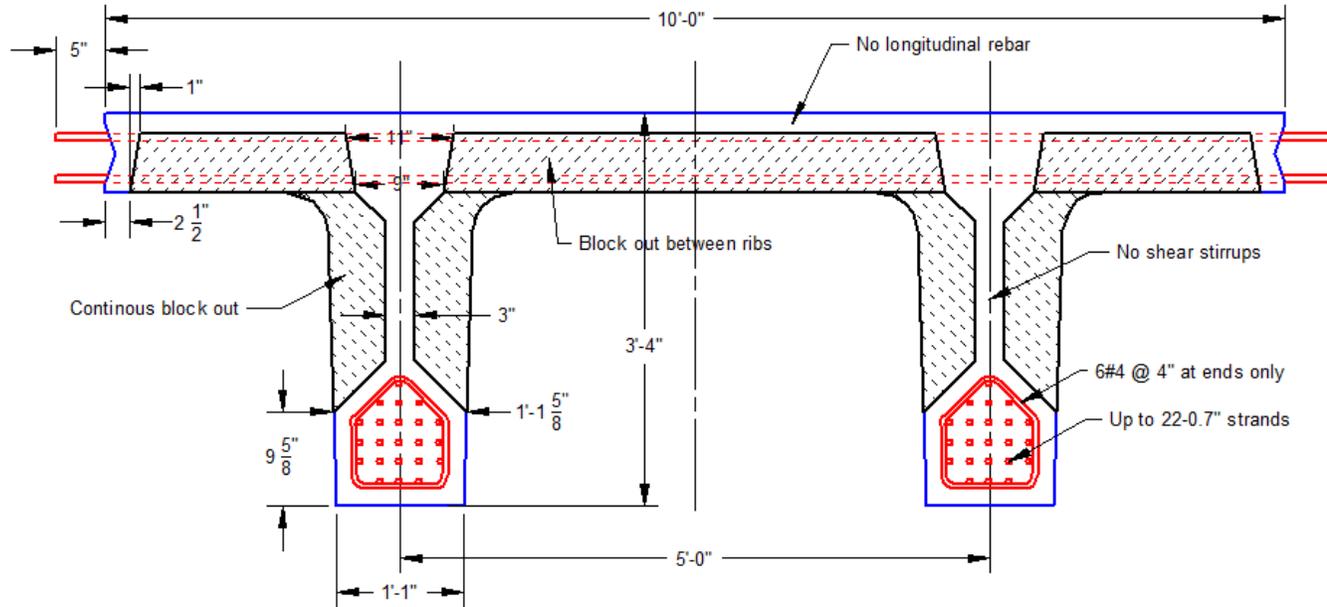


Original NEXT Beam Features and Advantages

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



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

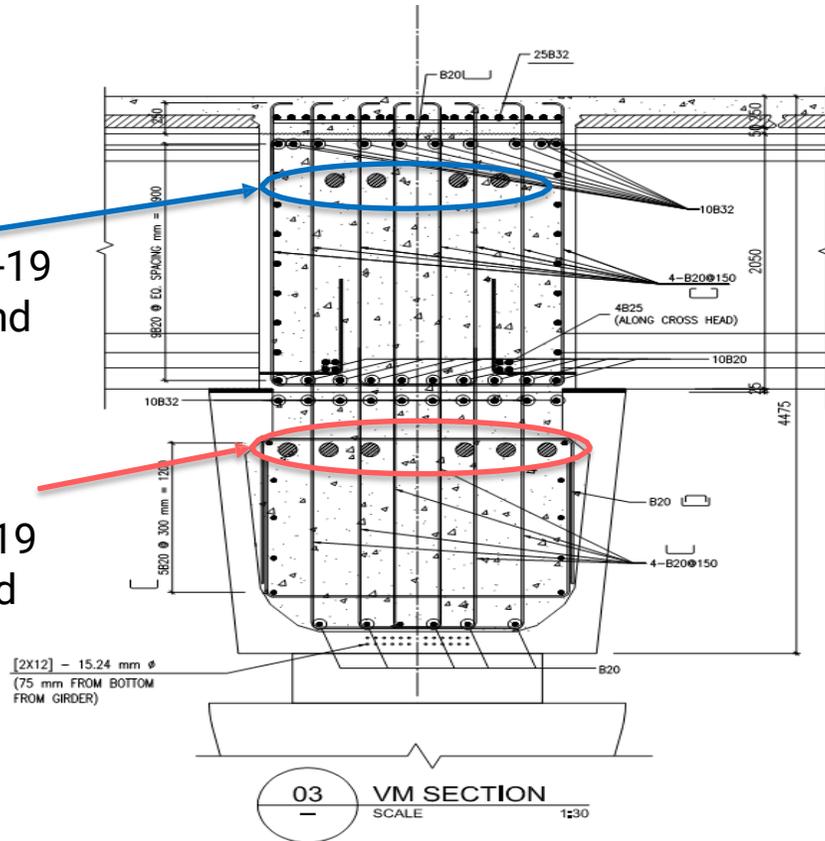
- ▶ Keeping the same advantages while reducing the weight tremendously, making shipping and handling more cost effective.
- ▶ Increase in max span length.

Abu Dhabi Midfield Terminal

Substituting Post-Tensioning with ChromX® Gr. 100

2nd Stage 4-19
0.6 in. Strand
Tendons

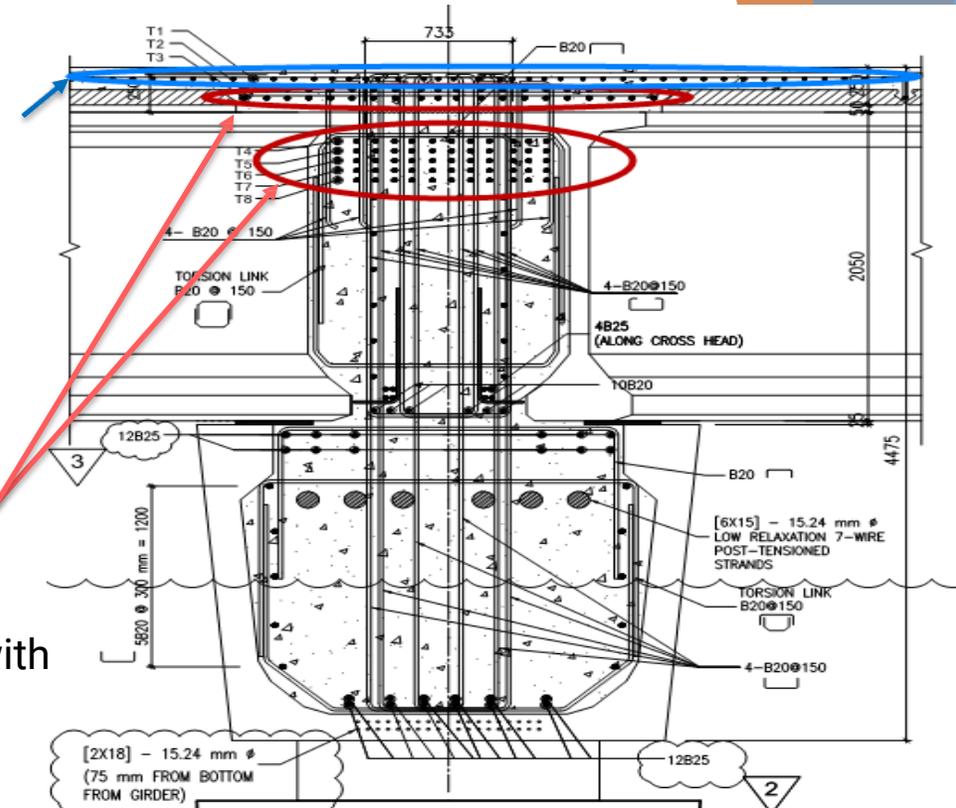
1st Stage 6-19
0.6 in. Strand
Tendons



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



Second Stage PT
Replaced with
ChromX®



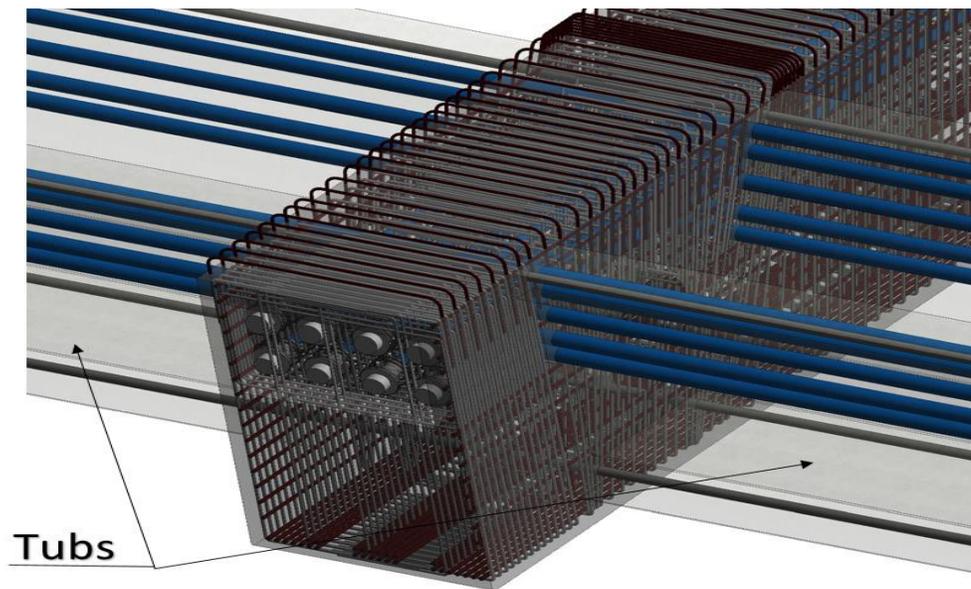
Accelerated construction and
increased ease of construction

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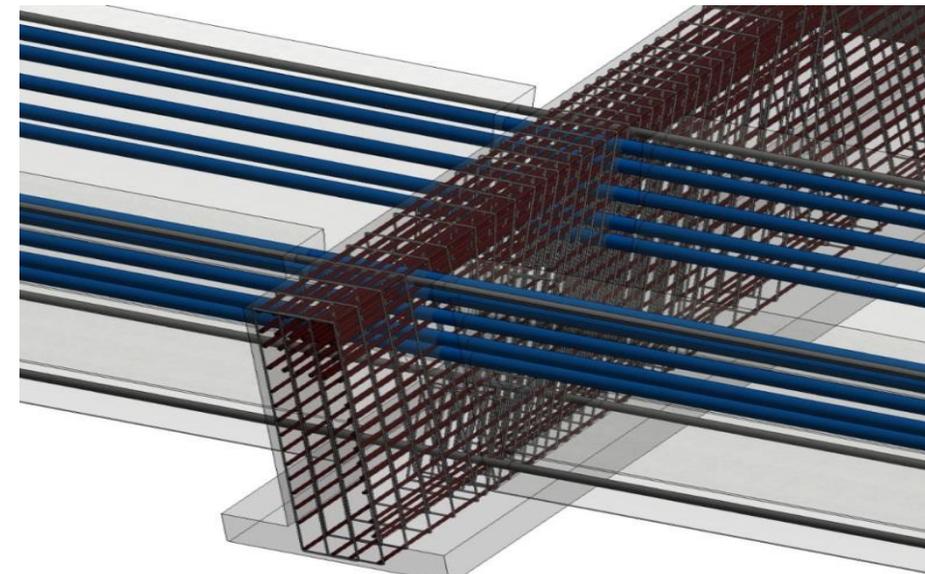
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Curved Tub Girder Bridge

- ▶ 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



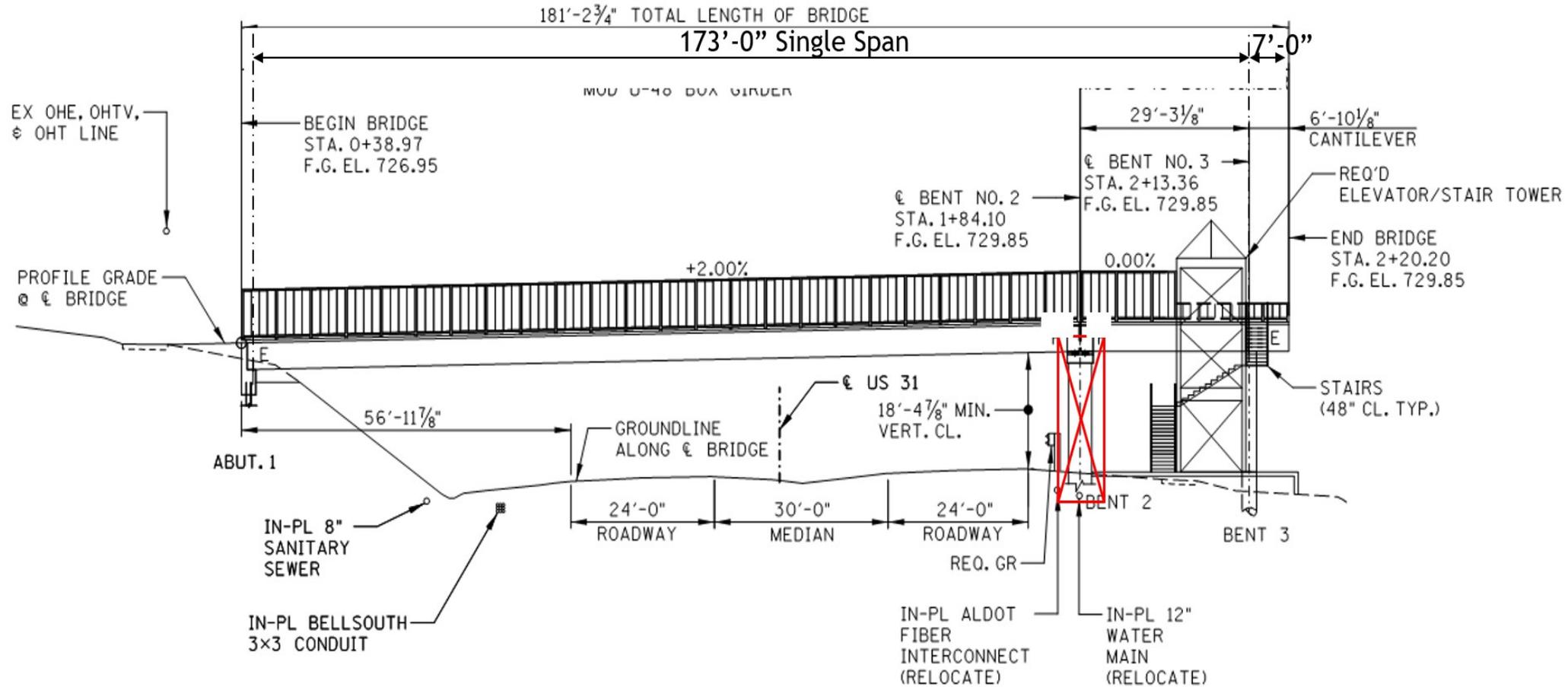
Redesigned

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

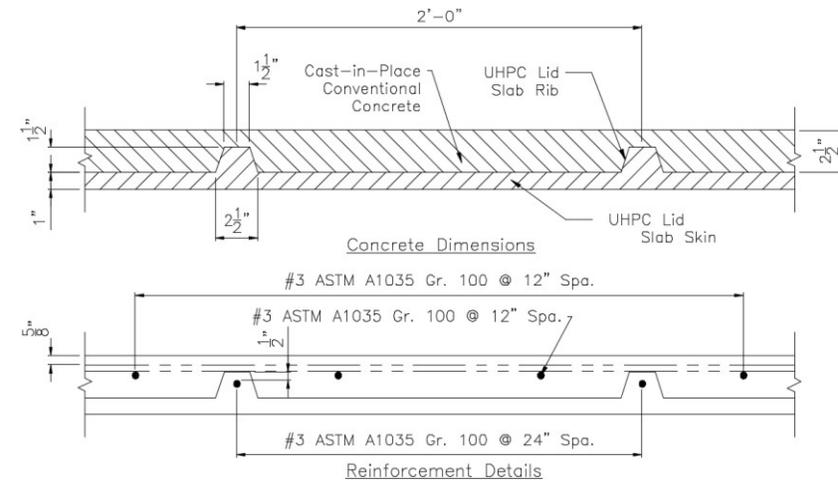
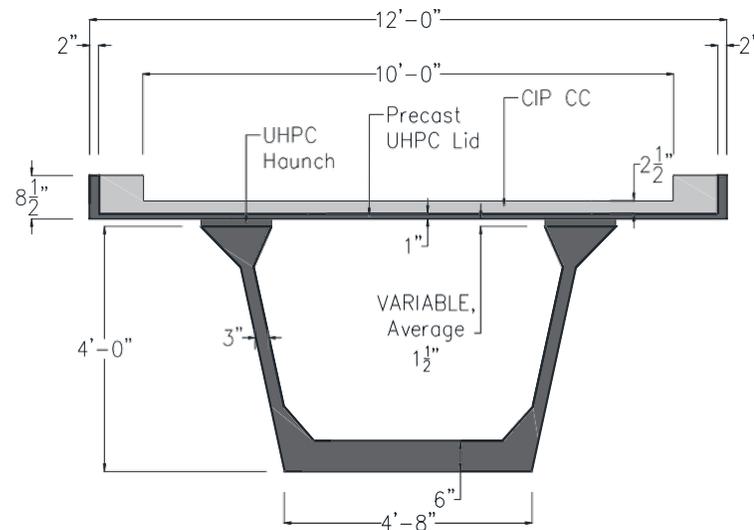
Item	Unit	Original Design	ChromX [®] Design	Savings
Concrete	yard ³	60.900	28.600	53%
Flexure Reinforcement	tons	2.763	2.580	7%
Vertical Shear Reinforcement	tons	2.242	1.486	34%
Horizontal Shear Reinforcement	tons	1.637	0.833	49%

Pedestrian Walkway in Alabama (proposal stages)



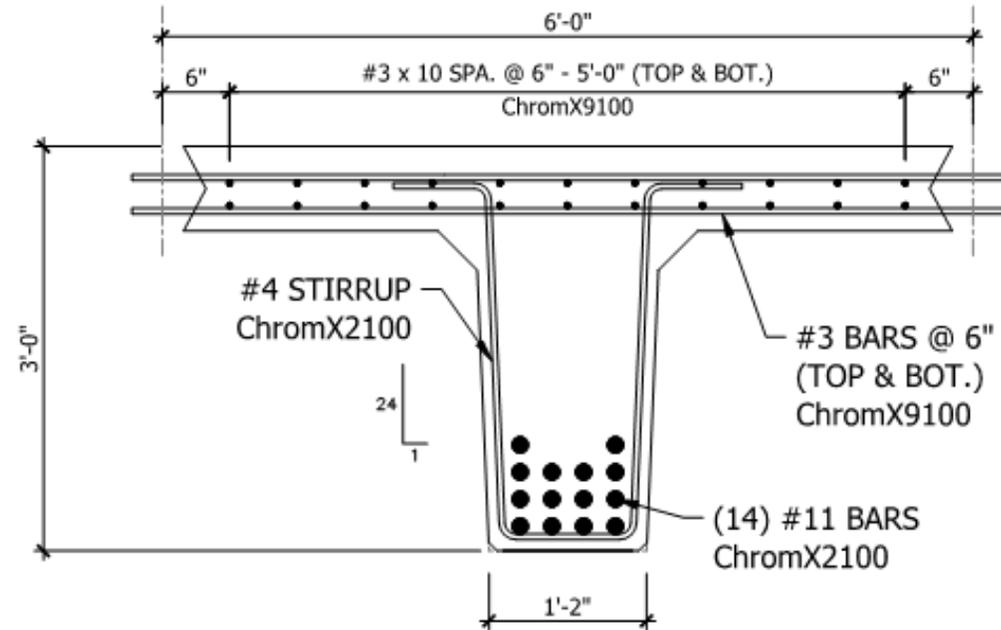
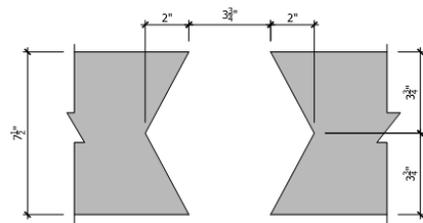
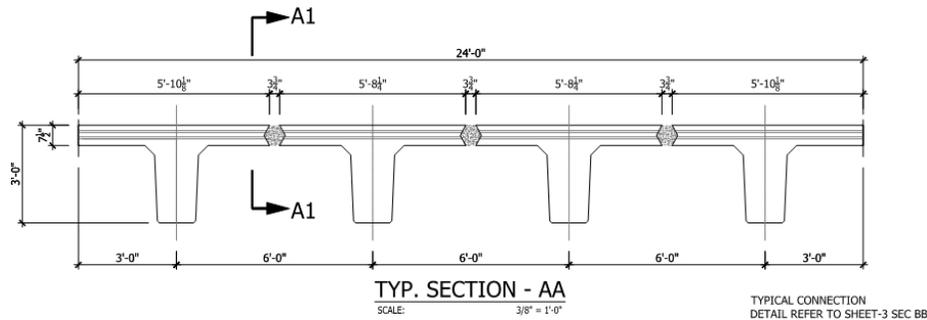
Pedestrian Walkway Cross Section

- ▶ 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



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



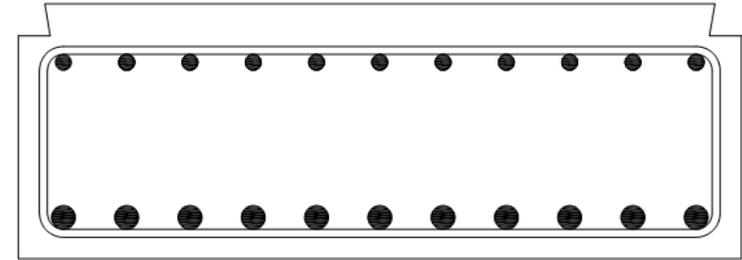
NDOT Research: ChromX[®] Reinforced Planks for Short Span Bridges

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

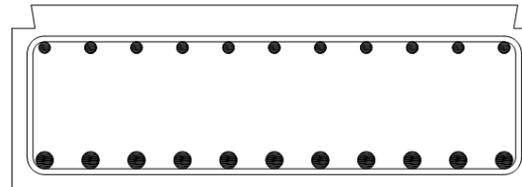
- ▶ Use of high-strength steel reinforcement
- ▶ Use of high performance concrete or low shrinkage grouts at transverse joints; less joints means a comparable cost



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	

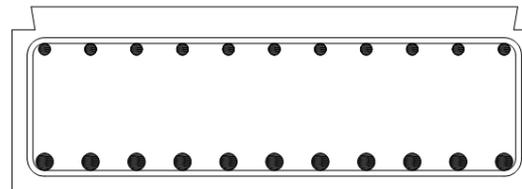
REINFORCED GR. 60



11-#6 Grade 60 Top

11-#9 Grade 60 Bottom

REINFORCED ChromX®



11-#6 ChromX® 9100 Top

11-#9 ChromX® 9100 Bottom

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.

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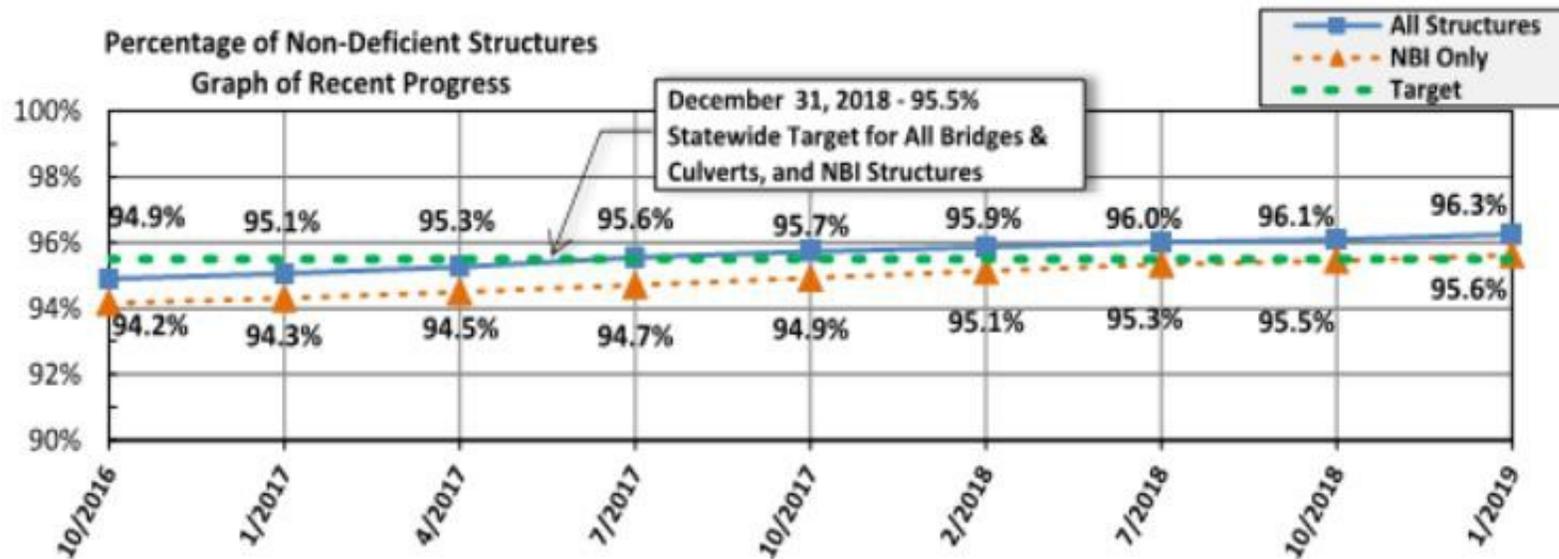
VDOT: Wolf Creek Bridge Replacement

- ▶ 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



VDOT Maintenance Cost Reduction Focus

- ▶ ChromX[®] 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

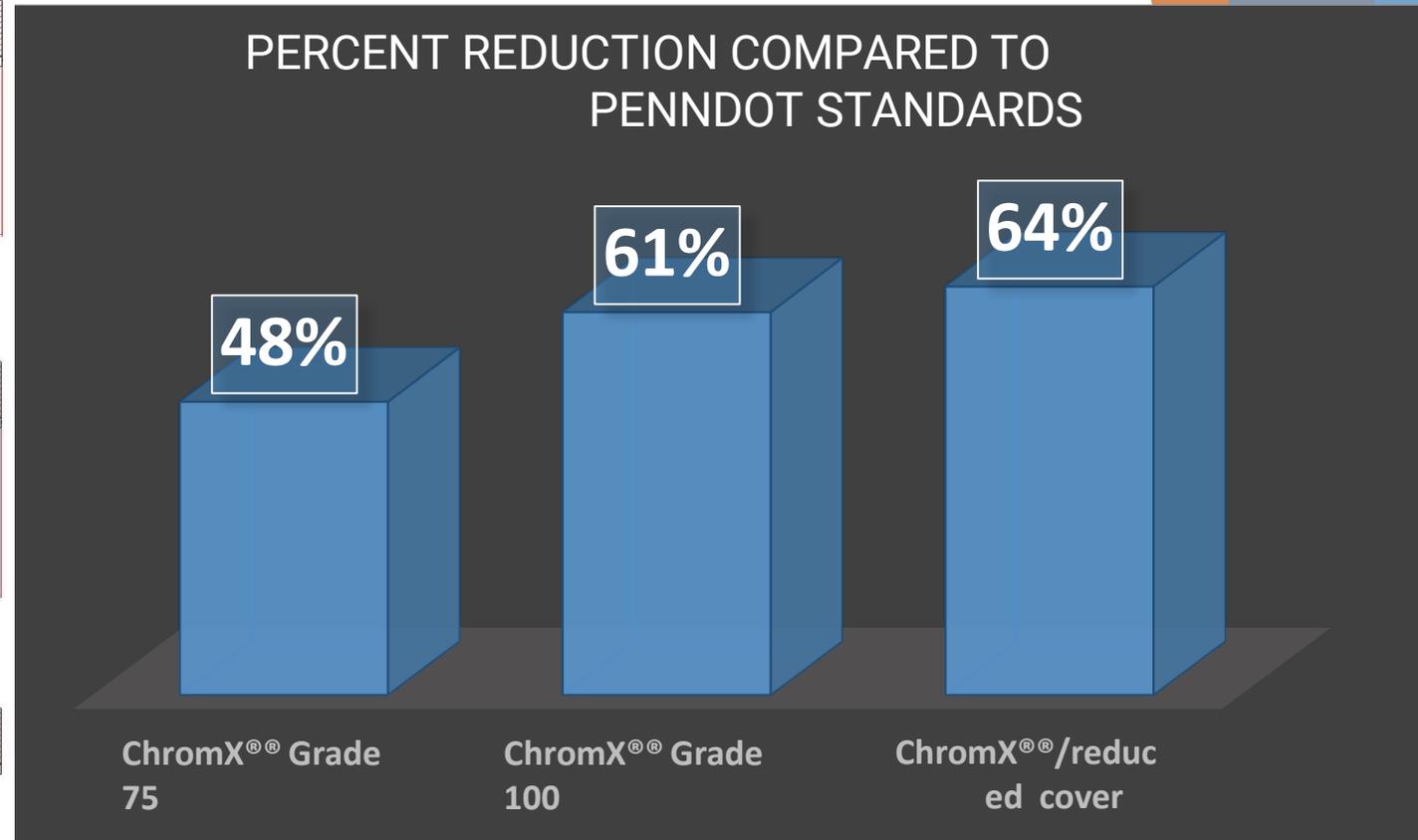
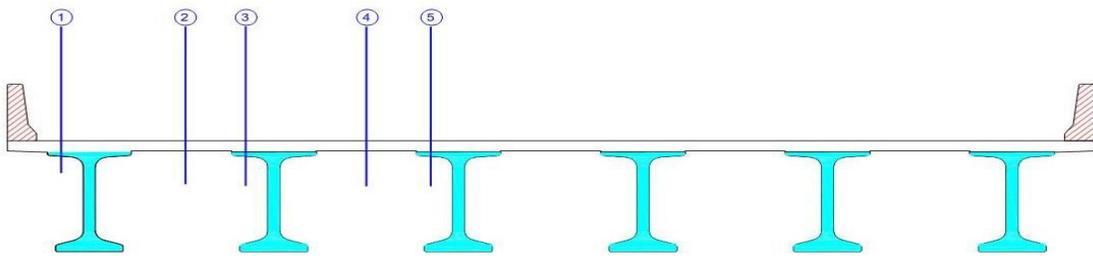
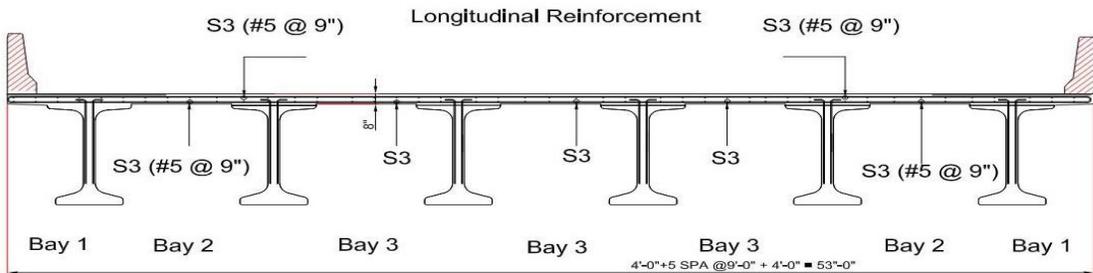
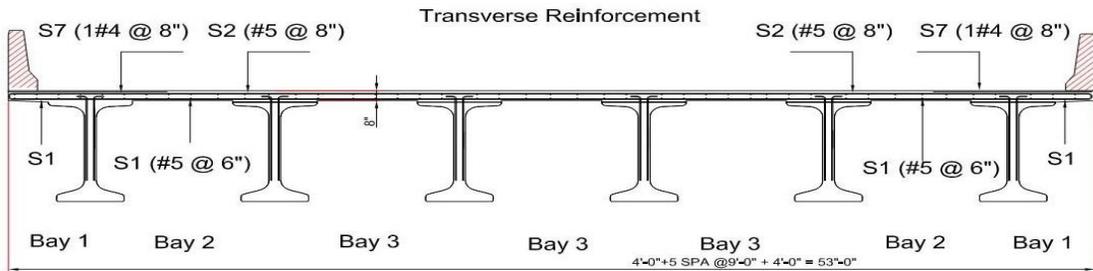


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PennDOT: Optimization of a Bridge Deck Reinforcement

- ▶ With ChromX[®], a reduced cover can be used, lowering the amount of steel needed

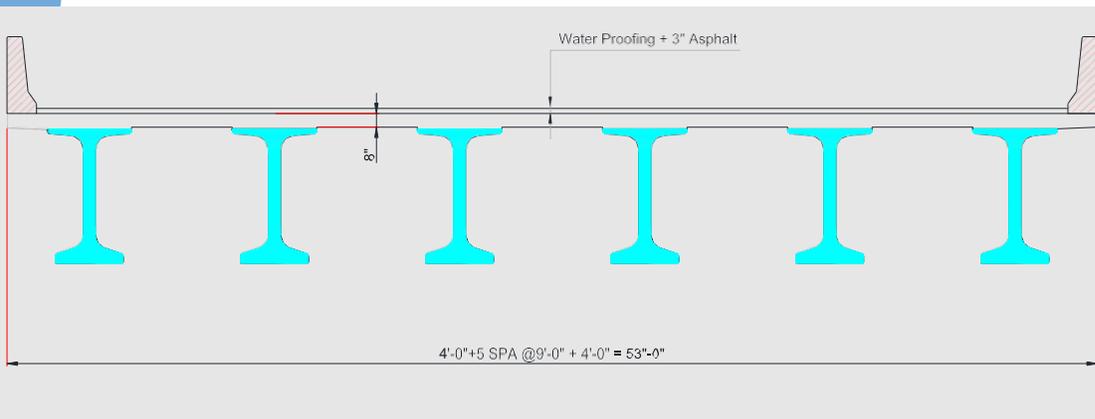


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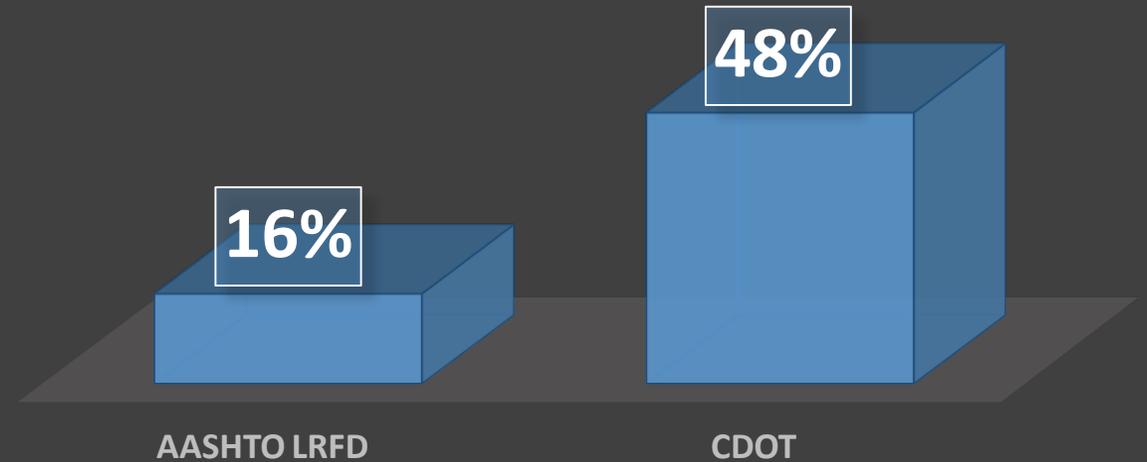
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Colorado DOT: Optimization of Bridge Deck Reinforcement

- ▶ 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.



PERCENT REDUCTION USING CHROMX 4100 COMPARED TO AASHTO LRFD & CDOT STANDARDS (GR. 60)



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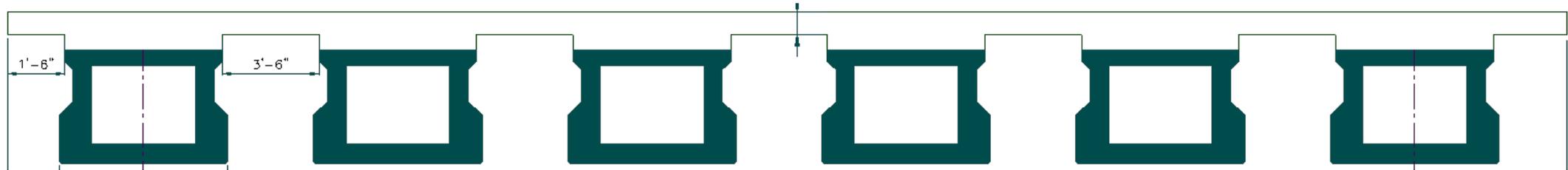
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TxDOT: Optimization of a CIP Bridge Deck Over Spread Box Beams

- ▶ 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 $F_y = 100$ 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"



Thank you

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