Cantilever Sidewalks: Share the Road with FRP

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Composite Advantage

FRP Infrastructure Products

Manufactured in Dayton, Ohio

Outline

- FRP Benefits
- Case Study 1. Tower Lift Bridge, Sacramento
- Material Details
- Design Details
- Case Study 2. Wilson-Burt Bridge, Niagara, NY
  - Weight and Cost Evaluation
- Case Study 3. Water Street, Albany, NY
- Resources
- Questions?

Fiber Reinforced Polymer (FRP) Composite Benefits

- Lightweight
  - Panels are 20% of reinforced concrete panels
  - Decking weights are 4 to 12 psf
  - Simpler installation
- Design Flexibility
- Prefabricated Structures
  - Accelerated construction
  - Incorporate features in shop fabrication
  - Lower cost; higher quality
- Corrosion Resistance to chemicals and water
  - Long lasting
  - No maintenance

Local Objectives Across the Nation: More Pedestrian and Bicycle Paths

- Nationwide initiatives to increase bicycle lanes and pedestrian paths
- Bridges are constrictions
- Squeezing lanes or sidewalks on existing vehicle bridges is difficult and unsafe
- Erecting new bridges is costly

Share the Road: Cantilever Sidewalk

- Elegant solution is to cantilever a lightweight pedestrian bridge off the vehicle bridge
- Fiber Reinforced Polymer (FRP) composites are an enabling material

The First: Tower Lift Bridge, Sacramento (2007)

- Original 3’ concrete sidewalk too narrow to support current and future bicycle and pedestrian traffic
- Long-term growth of both riverfronts depend on safe and easy access
- Weight limitations for center lift span would not allow for desired 10’ concrete sidewalk width
- Solution is FRP decking on steel framing

FRP Panels, Steel Frame

Installation

Lift Span in Motion


GATE-KEEP
AWAY WHEN
BELL RINGS

Typical FRP Construction

Fiberglass Fabric

Core Material

Resin

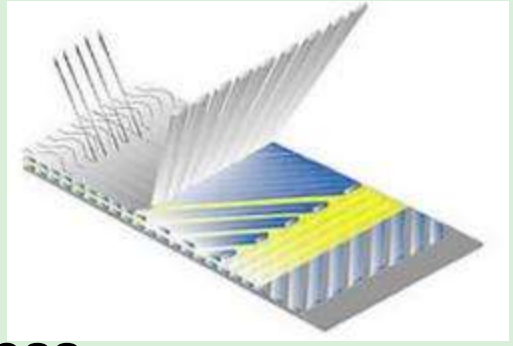
Strong, stiff fibers

surrounded by

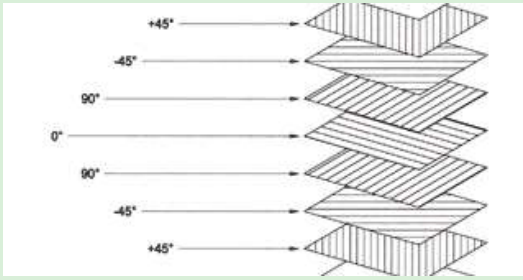
tough, environmentally resistant, polymers

FRP Composites Design 101

- FRP Composites are orthotropic materials (properties are different along each axis). This is because FRP Composites are comprised of directional fibers that can be placed in any orientation to achieve the design goal.



- Allows us to tailor the properties (strength, stiffness, CTE) in the direction that needs them. This is basically a rule of mixtures; what you add in one direction takes away from the other.



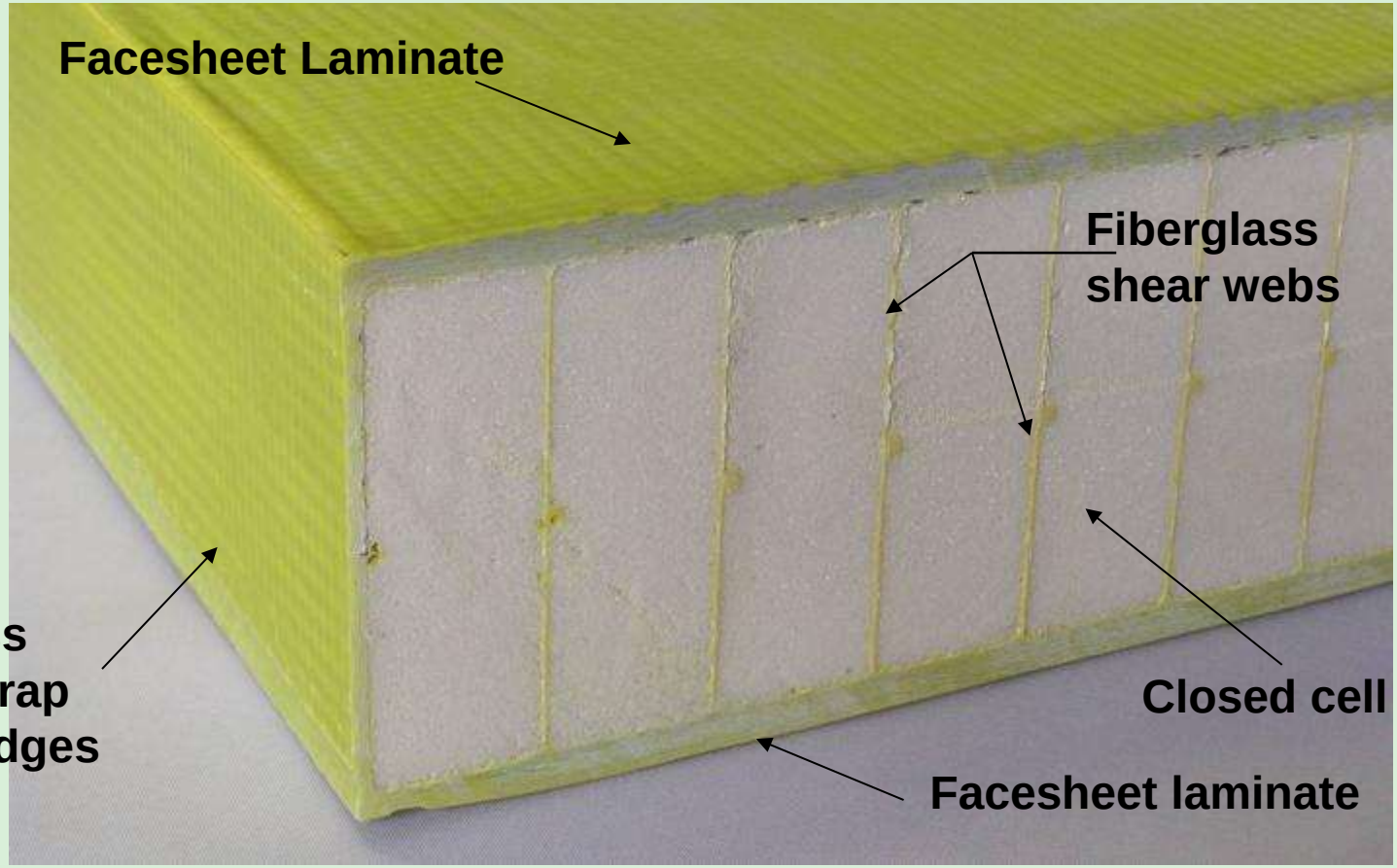
- Fiber orientation is important. Almost all structures that we build have fibers going in 0°,45°,90°,-45° directions.

Materials Comparison

		Material		
Property	**Unit**	**FRP**	**Concrete**	**Steel**
Tension Strength	psi	40,000 to 50,000	500	50,000
Tension Modulus	msi	3 to 5.5	2 to 6	29
Coeff of Thermal Expansion	x 10^-6 in/in/^{o}F	6.5 to 10.5	5.5	6.5
Density	lb/cu.in.	0.072 for laminate; 0.014 for panel	0.088	0.29

FRP Sandwich Construction

- Consists of fiberglass facing skins on fiberglass webs in foam core
- Design flexibility (stiffness, strength, size)
- Embedded steel for concentrated loads and attachments



FRP Deck Manufacturing

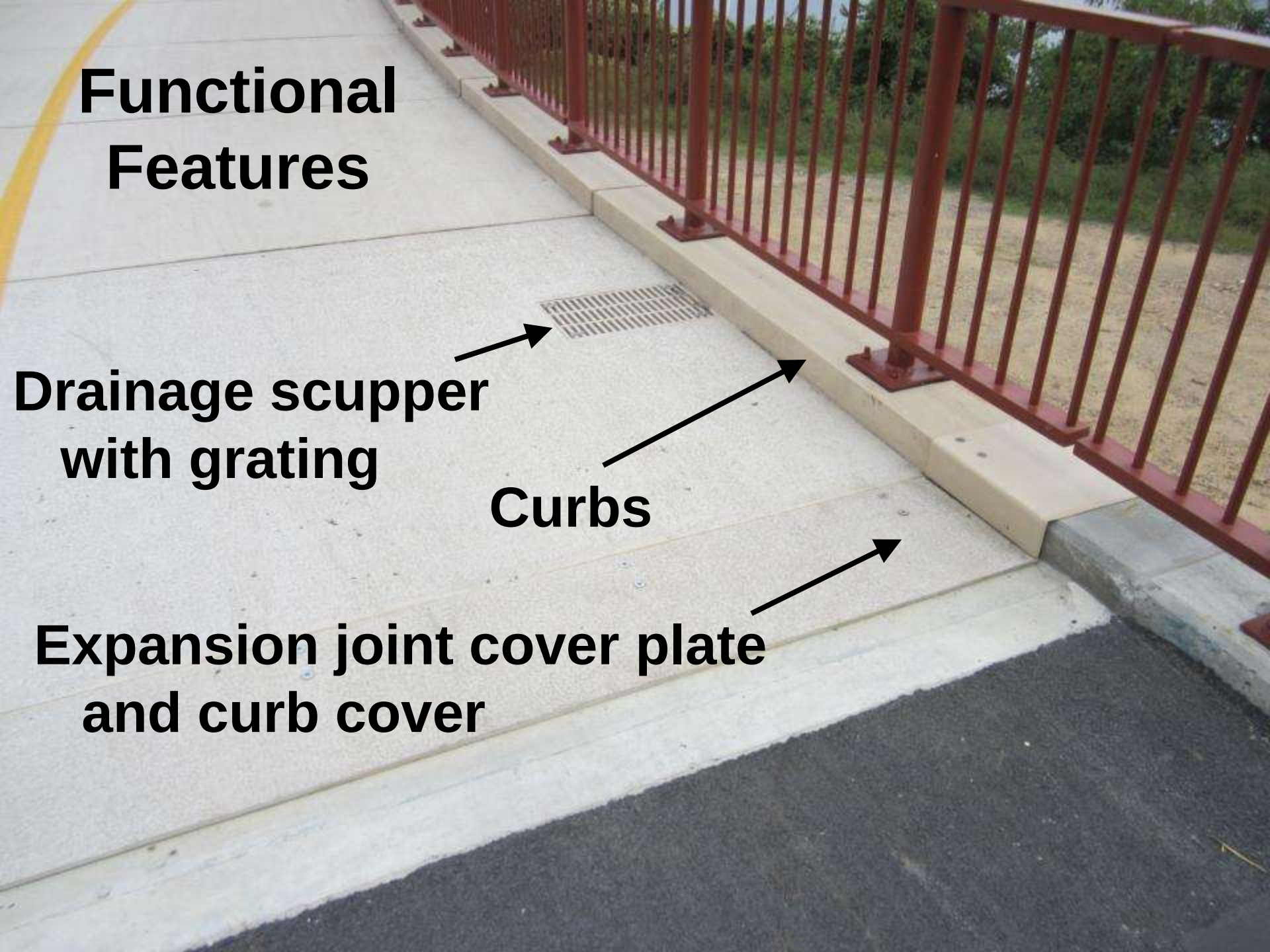
Fiberglass layers in molding tool

Internal core with fibers for shear

Sealed and ready for resin infusion

Solid part removed from mold

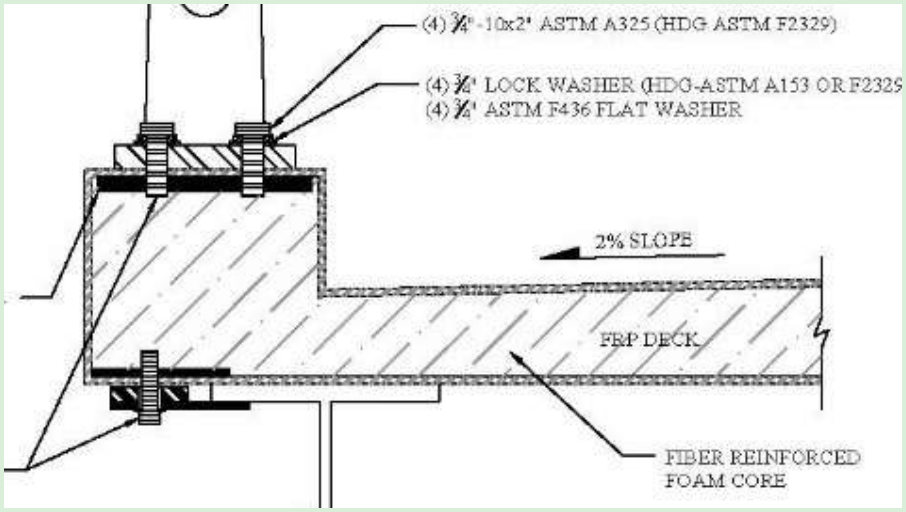
Design Features


Functional Features
Drainage scupper with grating
Curbs
Expansion joint cover plate and curb cover

Crown or Cross Slope

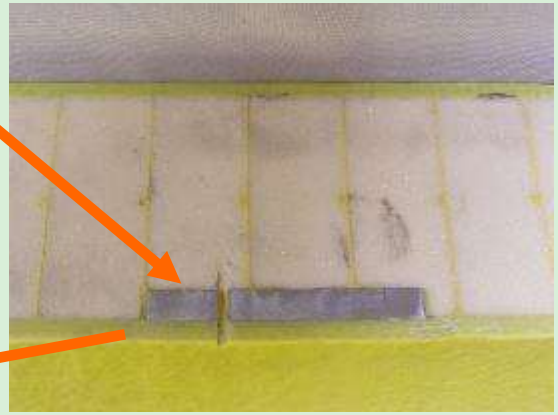
Sidewalk Features

- Crown or cross slope
- Embedded steel for connections (rail post, clip)



Deck Connection: Clips

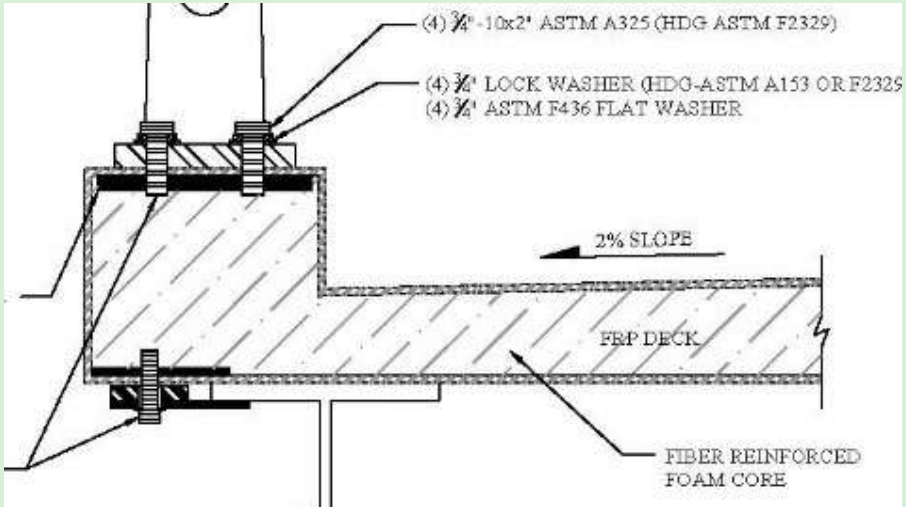
- Mechanical connection
- Clips to capture any type of beam
- Provides vertical constraint; allows for longitudinal thermal expansion
- Bolted into embedded steel that is drilled and tapped
- Provides vertical constraint; allows for longitudinal thermal expansion



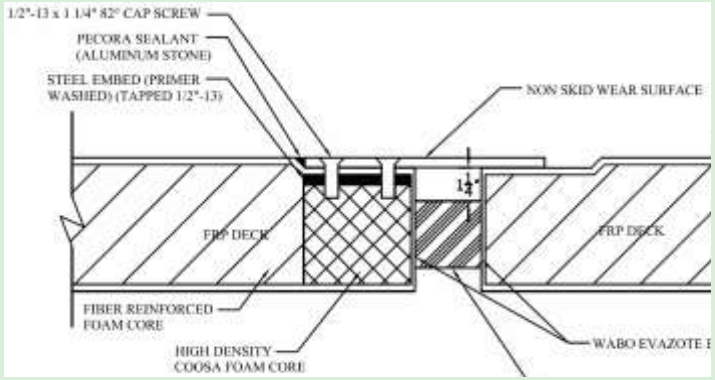
Embedded Steel in Bottom of Deck Panel

Rail Post Attachments

- Embedded steel for connections



Sidewalk Features



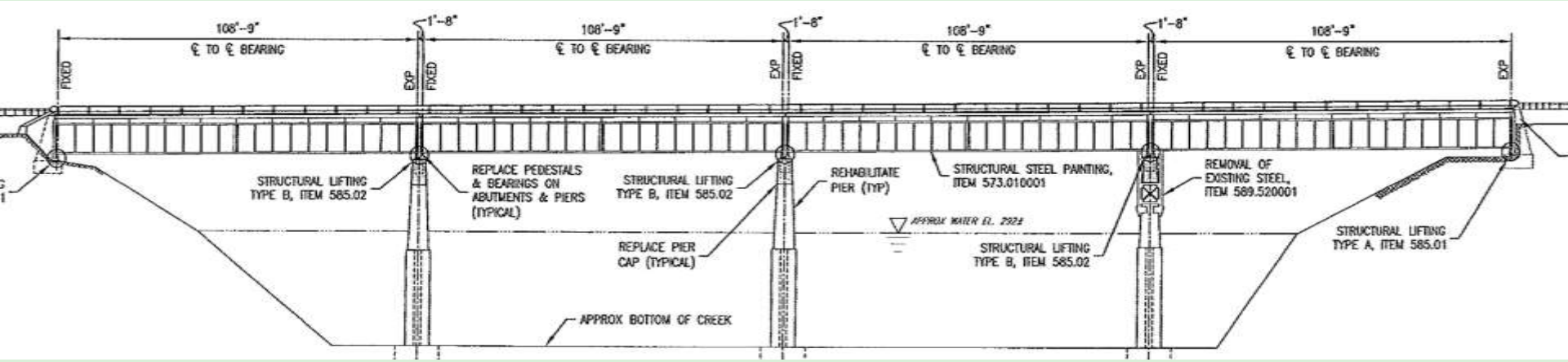
- Expansion joint at span ends
- Drainage scuppers
- Seal for panel-to-panel joints

Non-Slip Wear Surface

- Quartz aggregate in polymer
- High elongation (toughness); great adhesion to FRP
- Thickness of 1/8 inch
- High traffic
- Many standard colors; UV stable

Wilson Burt Bridge, Niagara, NY (2015)

- Bridge length of 441 feet
- Extend sidewalk width to 6’ -4”



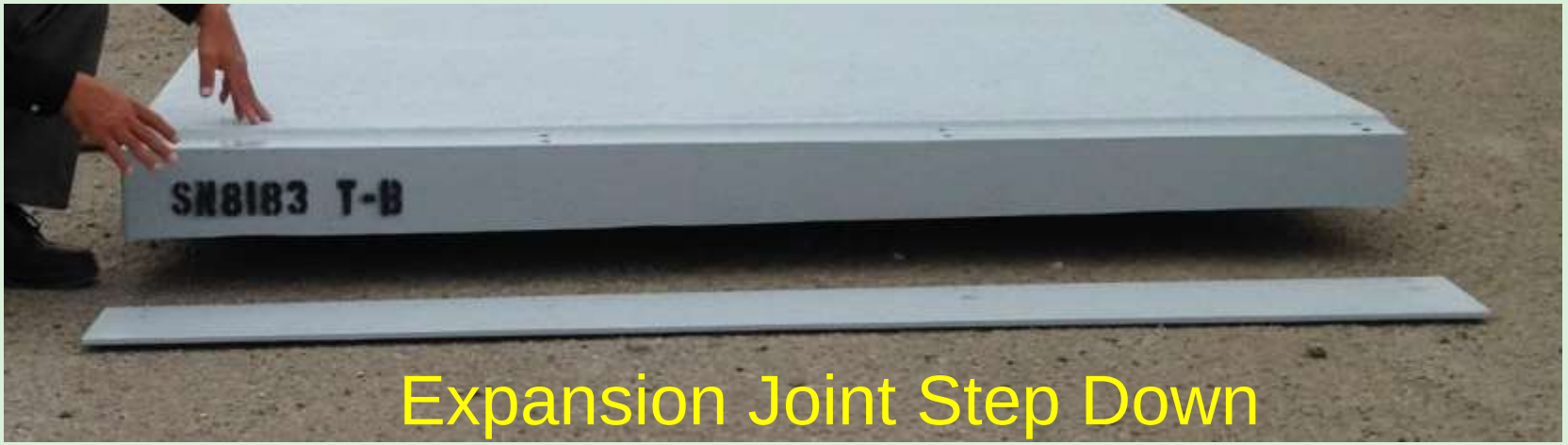
Design Requirements

- Loads
  - Live load of 85 psf
  - Deflection limits of L/500 between supports
  - Uplift load of 30 psf
  - Temperature differential of 100ºF
- Geometry
  - Floor beam spacing of 10’ – 10”
  - Cross slope of 1.76%
  - Rail posts
  - Expansion plates at bridge ends

Design Summary

- Deck sizing is driven by deflection criteria
  - Relatively low material modulus
  - Can adjust depth; facesheet thickness; and facesheet modulus
  - Slopes from 6 3/8” to 5”
- High strength safety factors
  - Bending SF>20
  - Shear SF=14
- Uplift load determines number of clips
- High natural frequency (22 Hz)

Deck Details



Start of Sidewalk Installation

Fast Installation

Clip Connection to Floor Beam

Cantilever Bridge Weight

- Sidewalk Width 6.375 ft
- FRP Deck Weight 7.9 psf
- FRP Deck Weight 50.4 lb/ft
- Railing Weight 54.0 lb/ft
- Steel Weight 54.0 lb/ft
- Total Dead Load 158 lb/ft

- For 440 ft length,
  - Dead Load is 69,680 lb
  - Live + Dead Load is 275,380 lb

- Concrete deck on steel pan and supports would have added 180,000 lb more dead load

Cantilever Sidewalk Costs

- Deck $ 274 /ft
- Railing $ 189 /ft
- Beams and Install $ 270 /ft
  (Steel, hardware, installation)
- Total Installed Cost $ 733 /ft
  or $ 114 /sf

- Total for Wilson-Burt Sidewalk is $322,575.

Water Street, Albany, NY (2017)

Project Overview

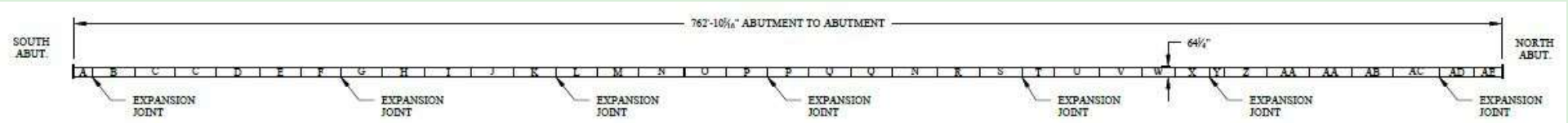
- State of New York Office of General Services
- Closed a 17 year old walkway due to deterioration
  - Concrete cracking
  - Steel pans rusted in 6 years
- Connected state offices with Water Street parking garage
- Total replacement to avoid multiple shutdowns
- Selected FRP after considering lightweight concrete and precast planks
- Contractor was Arold Construction Co.
- Schedule
  - Request for information in May 2017
  - FRP Sidewalk delivered in September 2017

Design Requirements

- Loads
  - Live load of 75 psf
  - Deflection limits of L/400 between supports
  - Uplift load of 30 psf
  - Temperature differential of 100ºF
- Geometry
  - Longitudinal beams
    - Widest spacing of 56 inches
  - Cross slope of 2%
  - Six expansion joints

Sidewalk Panels

- Sidewalk length of 763 feet
- Sidewalk width of 5’ -4”
- 36 panels with 31 different types
  - Lengths; support steel layout; expansion joints
- Longest panel is 24’-8”



Sidewalk Panels

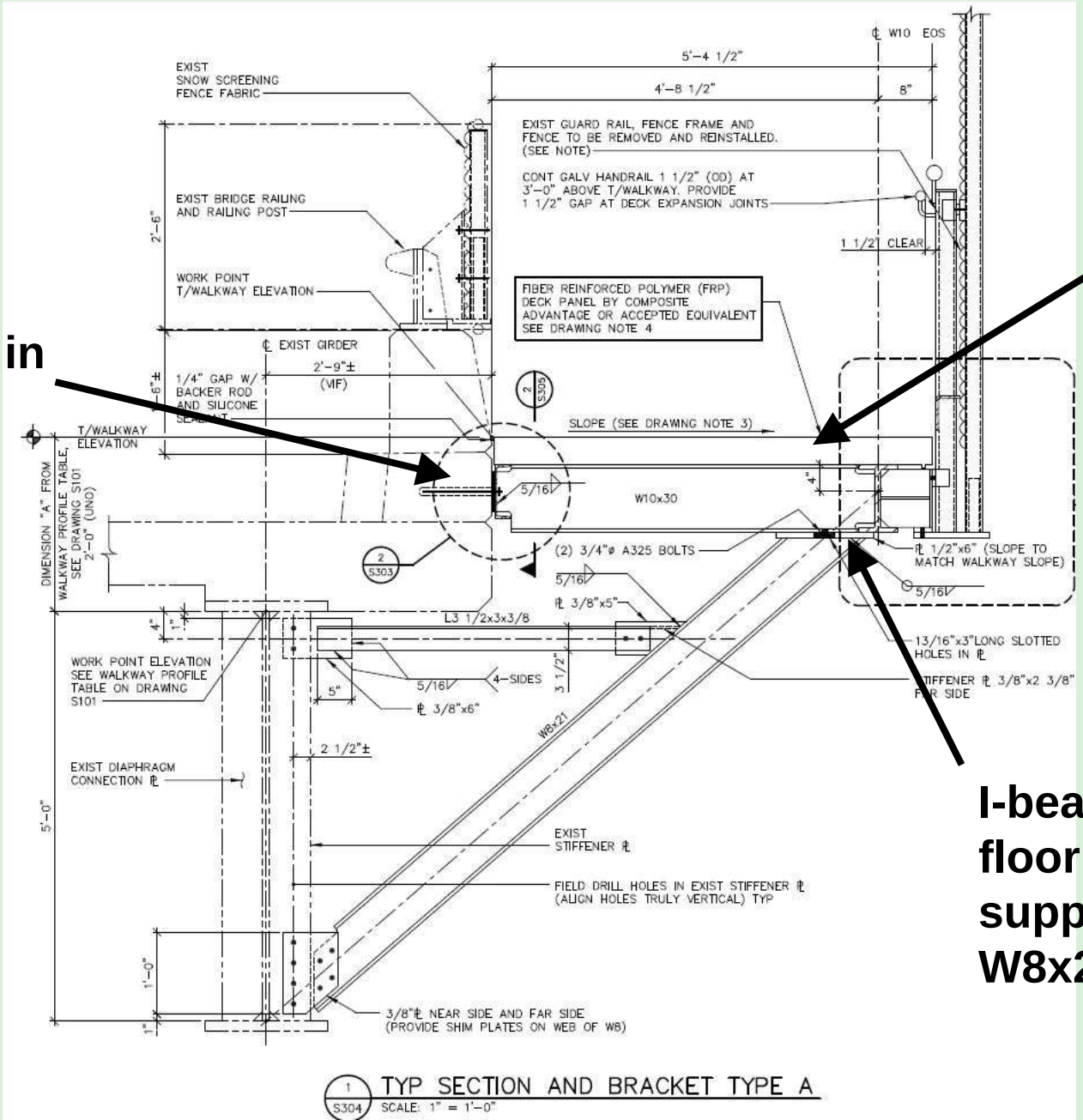
- Panel depth of 4 inches
  - Includes 1/8” of non-slip overlay
  - Matches original concrete
- Weight is 6.8 psf
- Largest panel is 900 lb
- Cross-slope of 2%
  - Panel bottoms have step on up-slope edge
- Drip strip added on bottom exterior edge

Primary Support Steel

Channel anchored in concrete

FRP Deck

I-beam and floor beam supported by W8x21 gusset

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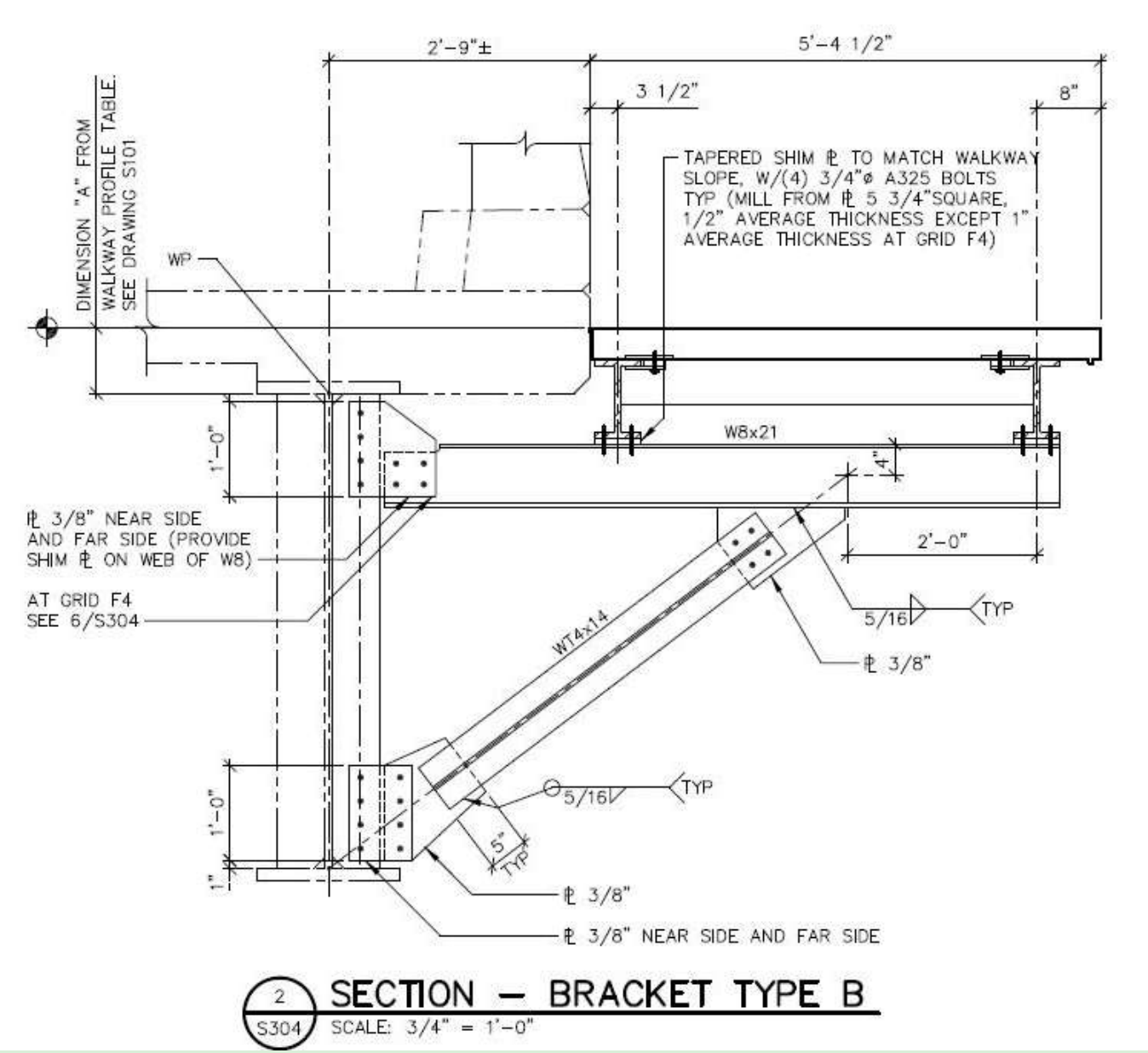
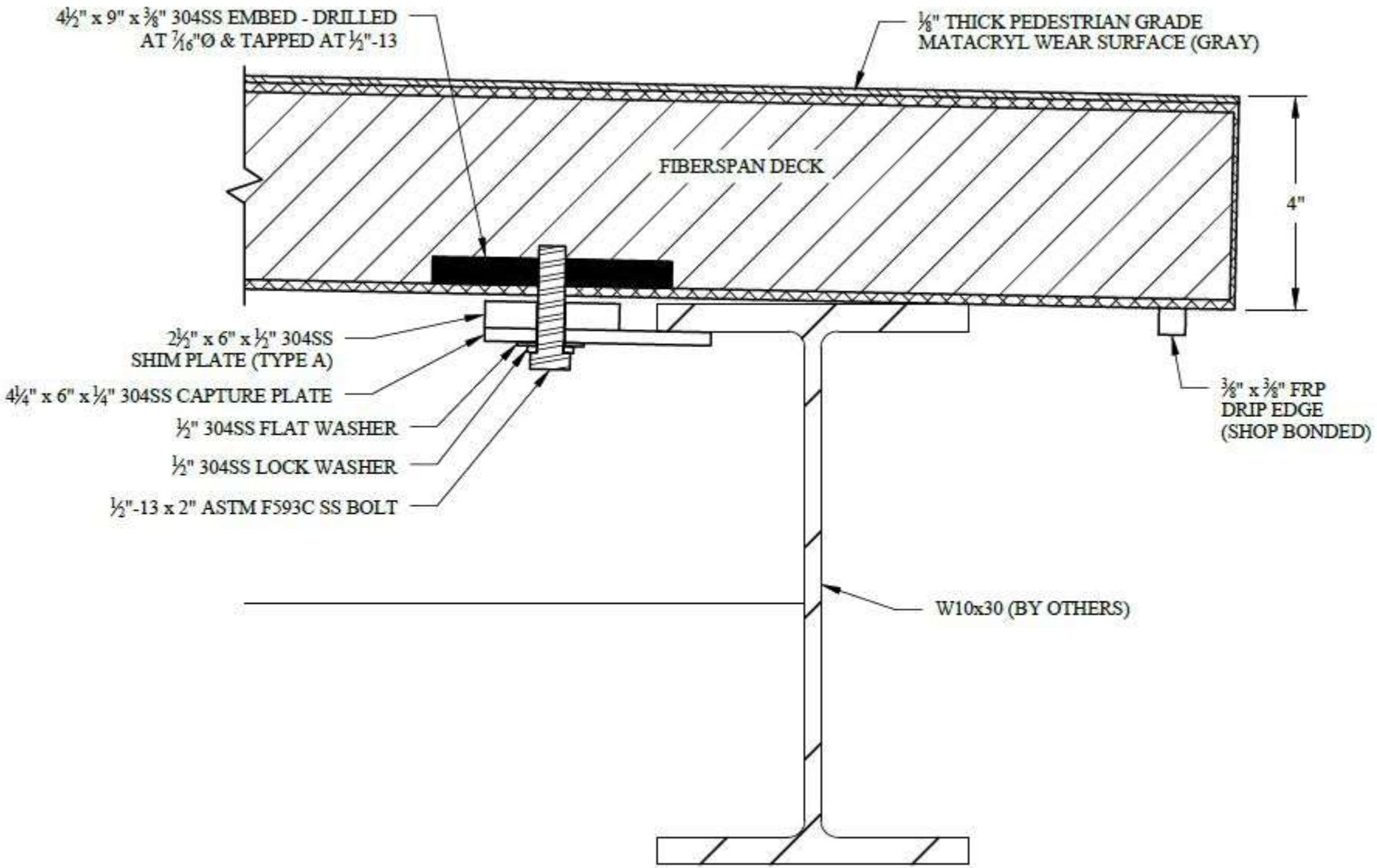
TERDAM VODKA

One of Four Other Bracket Types



Panel Joints Offset from Floor Beams



DRIP EDGE PANEL CLIP DETAIL

SCALE: 3" = 1'-0"

Cutouts for Light Posts

Easy Installation

- 36 panels installed in 4 days
- Not sequential due to RR schedule

Design Considerations

- FRP dead load reduction can enable a wider sidewalk (with higher live load) that is still less total load than a concrete sidewalk
- New additions and much wider sidewalks require analysis of existing bridge capacity
  - Can strengthen girders
  - Connect exterior girders to interior with bracing

Resource Information

- Product information and Installation photos
  - www.compositeadvantage.com
    - Resource Center with Cantilever Sidewalk section
  - Request a Quote page
    - Will send Design & Cost estimate
- Videos
  - www.youtube.com/CompositeAdvantage

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Questions ?

- Contact:
  - Scott Reeve, Composite Advantage
  - sreeve@compositeadvantage.com
  - Phone 937-723-9031

- All attendees will receive a link to the presentation and a PDH certificate if they request it

Thank You !

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