Specialty Applications of FRP Composites om Heavy Civil/Infrastructure Projects

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Learning Objectives

1. Learn why and how FRPs are being used in heavy/civil infrastructure projects.

2. Learn, through case studies, what made FRPs an attractive alternative.

3. Learn, through case studies, some of the challenges that had to be overcome to enable the use of FRPs.

Outline

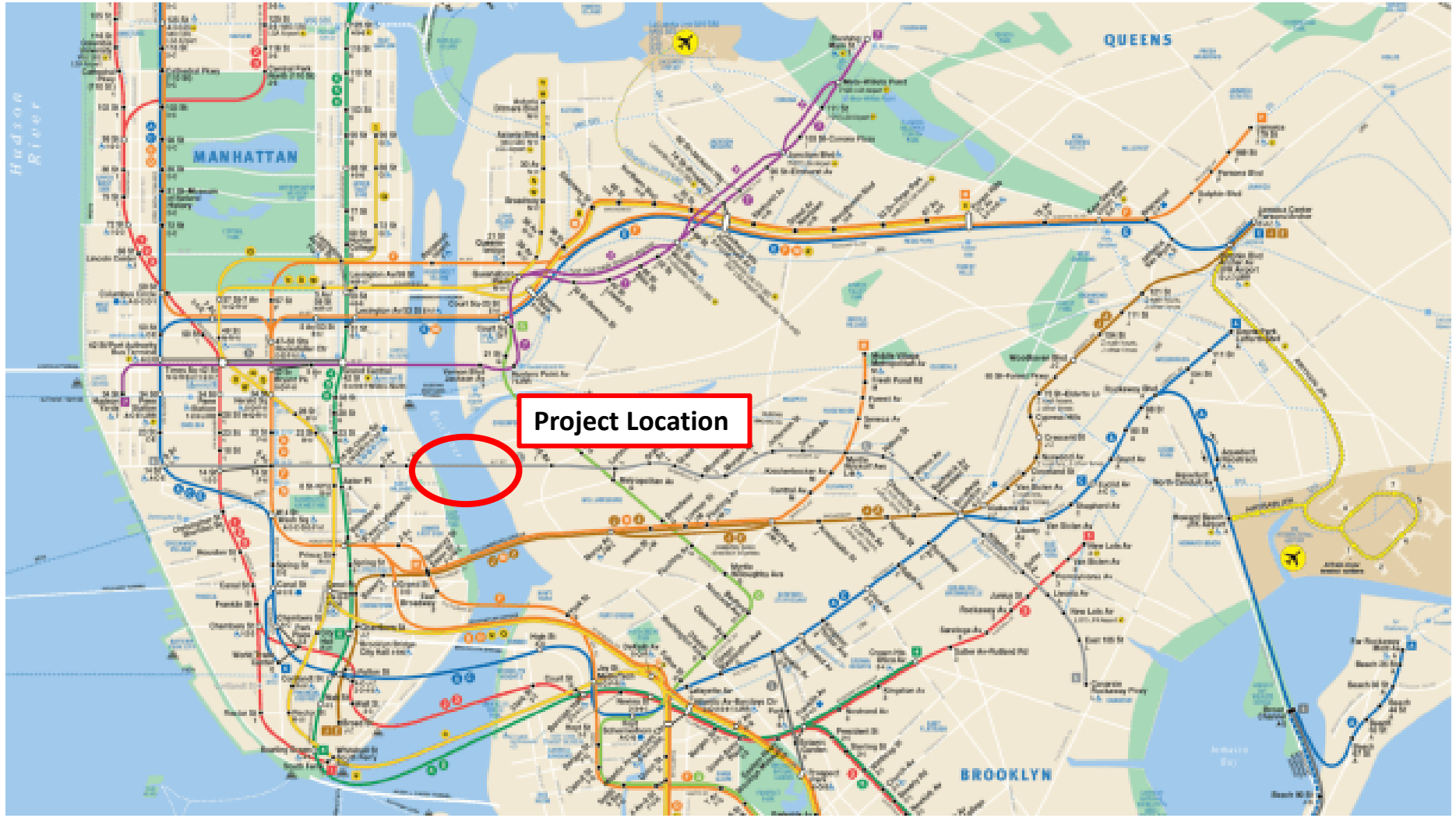
- Canarsie Subway Tunnel Rehabilitation
- East Lechmere Viaduct Rehabilitation
- Final Thoughts

Canarsie Subway Tunnel Rehabilitation

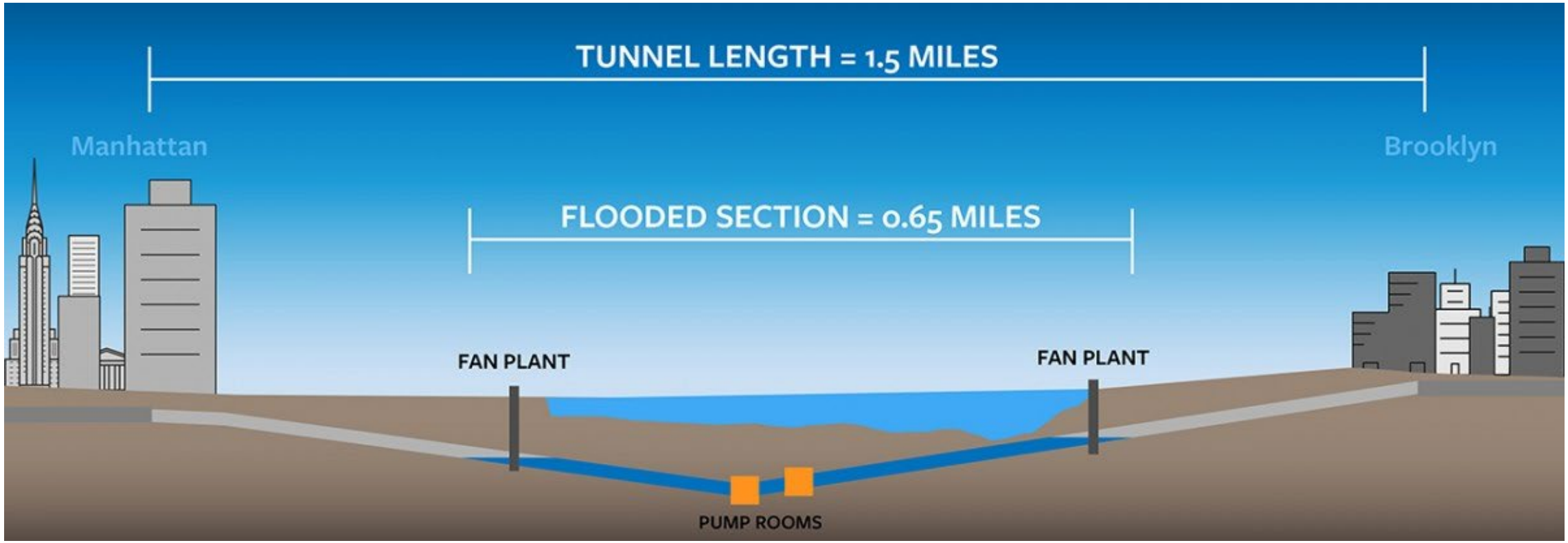
Background

- Carries L-Train under East River (connects Brooklyn and Manhattan)
- Consists of two tunnels (inbound and outbound)
- Constructed in 1920's
- One of 8 tunnels flooded during Hurricane Sandy (2012)
- Canarsie Tunnel took on 7 million gallons of seawater and was closed for 11 days.
- Seawater accelerated corrosion and deterioration of concrete structures.
- Utilized by over 250,000 commuters per day

Project Location



Project Details



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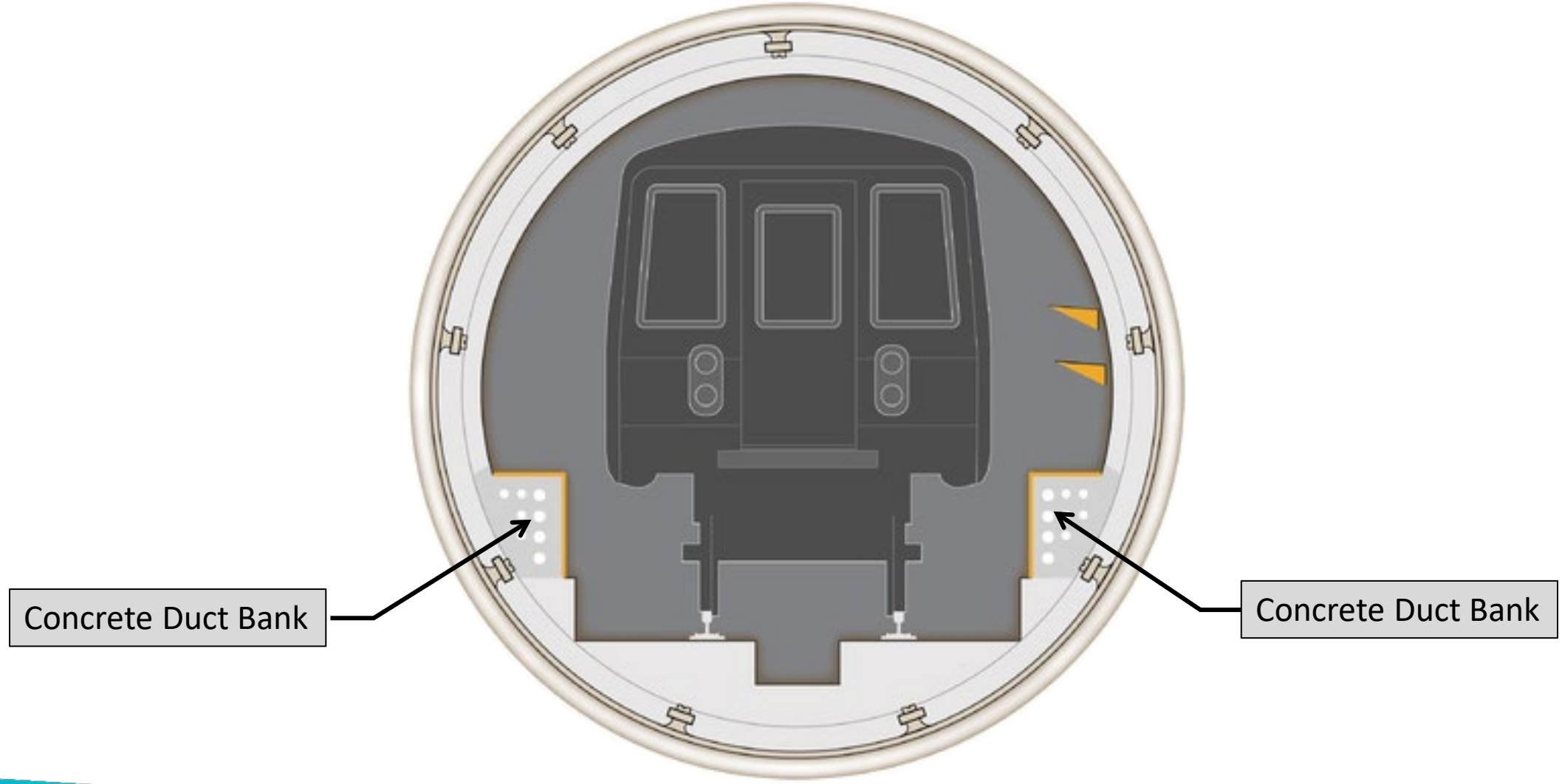


Project Details

- Flooding accelerated deterioration of the concrete duct banks
- Pieces of spalled concrete were falling onto tracks resulting in a safety concern
- Design to address problem commenced in 2014
- Repair contract awarded to Judlau-TC Electric JV in 2018

Original Design Concept

- Remove/replace cables
- Demolish concrete duct bank
- 18-month shutdown of both L-train tunnels
- $477M construction cost
- Disruption to 250,000 daily commuters using L-train

Gov. Cuomo Intervention

- Word of 18-month shutdown appeared in press leading to Gov. Cuomo to become personally involved in project.
- Gov. Cuomo tasked Columbia and Cornell Universities with finding an alternative, less disruptive rehabilitation approach.
- University task group suggested the following concept:
  - Relocate cables to a racking system suspended from the side of the tunnel
  - Cover the deteriorated concrete duct banks with an FRP strengthening system
- Gov. Cuomo announced on Jan. 3, 2019, the tunnel would not be shut down to make repairs

Gov. Cuomo Intervention

Initial FRP Strengthening Concept

- University task group suggested using an FRP strengthening system to encapsulate the duct bank.
- WSP USA was retained to convert the University “FRP strengthening concept” into a practical design that could be constructed.

Initial FRP Strengthening Concept

- When WSP reached out to an FRP strengthening expert to discuss the project it was apparent traditional wet lay-up strengthening systems were not practical for this application:
  - Epoxy based FRP strengthening systems would likely not meet non-combustible requirements of NFPA 130.
  - Extensive concrete repairs/crack injection would likely be required before installing FRP fabrics.
  - Surface prep would create extensive silica dust
  - Limiting work to a few hours each night would take forever to complete project

The Solution

- The FRP expert suggested to WSP an alternate FRP concept:
  - Pre-fabricate a constant cross-section FRP shell that could bolted to the tunnel walls
  - Eliminates need for surface prep
  - Eliminates need for mixing epoxies, wetting out fabrics, laminating to the concrete duct banks, and cleaning up.
  - Many FRP shells could be fabricated prior mobilizing the tunnel to insure no disruption in schedule.
- WSP and FRP manufacturer proposed the pre-fab option to MTA and worked to secure approval.

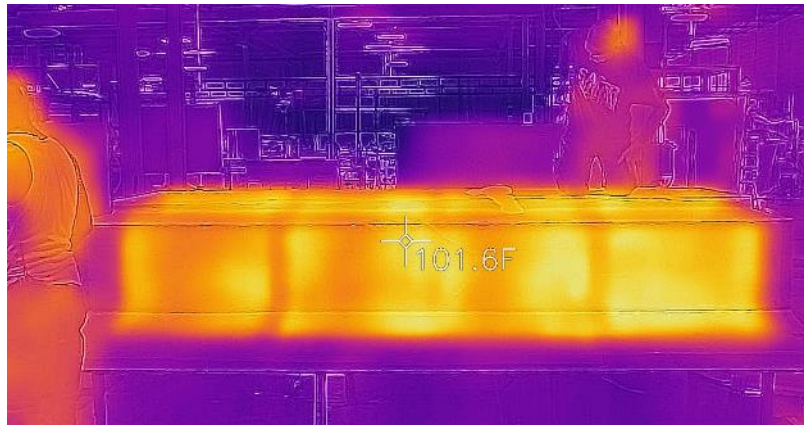
FRP Shroud Details

- Mock-up panels supplied to familiarize MTA and contractor with the FRP shrouds and installation techniques.
- Most shrouds were 5’, 10’ or 11.5’ long
- Avg shroud weight = 32lbs/ft
  (160 lbs for a 5’ long shroud)

FRP Shroud Details

- Designed for 150 psf live loading

- FRP shells/shrouds were required to meet the noncombustible requirements of NFPA 130
  - Manufacturer adapted their vacuum infusion process to use a phenolic resin achieve the noncombustible requirements.
  - Developed heated tooling to cure the resin
  - Post-cured in ovens for final cure



Comparison of Repair Plans

Original Rehab Plan	Revised Rehab Plan
18-month duration	15-month duration
Complete shutdown of both tunnels	Work to be done during night and weekend closures
250,000 commuters/day affected	Limited impact to commuters
$477M	< $477M

Note: FRP shroud manufacturer was fabricating 20 shrouds per day to meet demanding delivery requirements.

Installation

Installation

Conclusions

- Why was FRP the right choice?
  - Speed of construction.
  - Virtually no disruption to the public.
  - Reduced labor costs = reduced project costs
- Innovative manufacturing techniques and use of phenolic resin enabled a successful project
- Canarsie is a good example of where FRPs offer tremendous advantages over traditional techniques.
- MTA recently specified FRP shrouds on the Rutgers Tunnel rehab project.

East Lechmere Viaduct Rehabilitation

East Lechmere Viaduct

Background

- Lechmere Viaduct carries MBTA's Green Line over Charles River
- Part of Green Line Extension (GLX) project which will add 6 new stations to the northern end of the Green Line.
- Separate contract awarded to SPS New England to rehabilitate viaduct
- Viaduct to be closed during rehabilitation work
- Aggressive schedule required viaduct to be "functionally complete" to allow GLX testing

Background

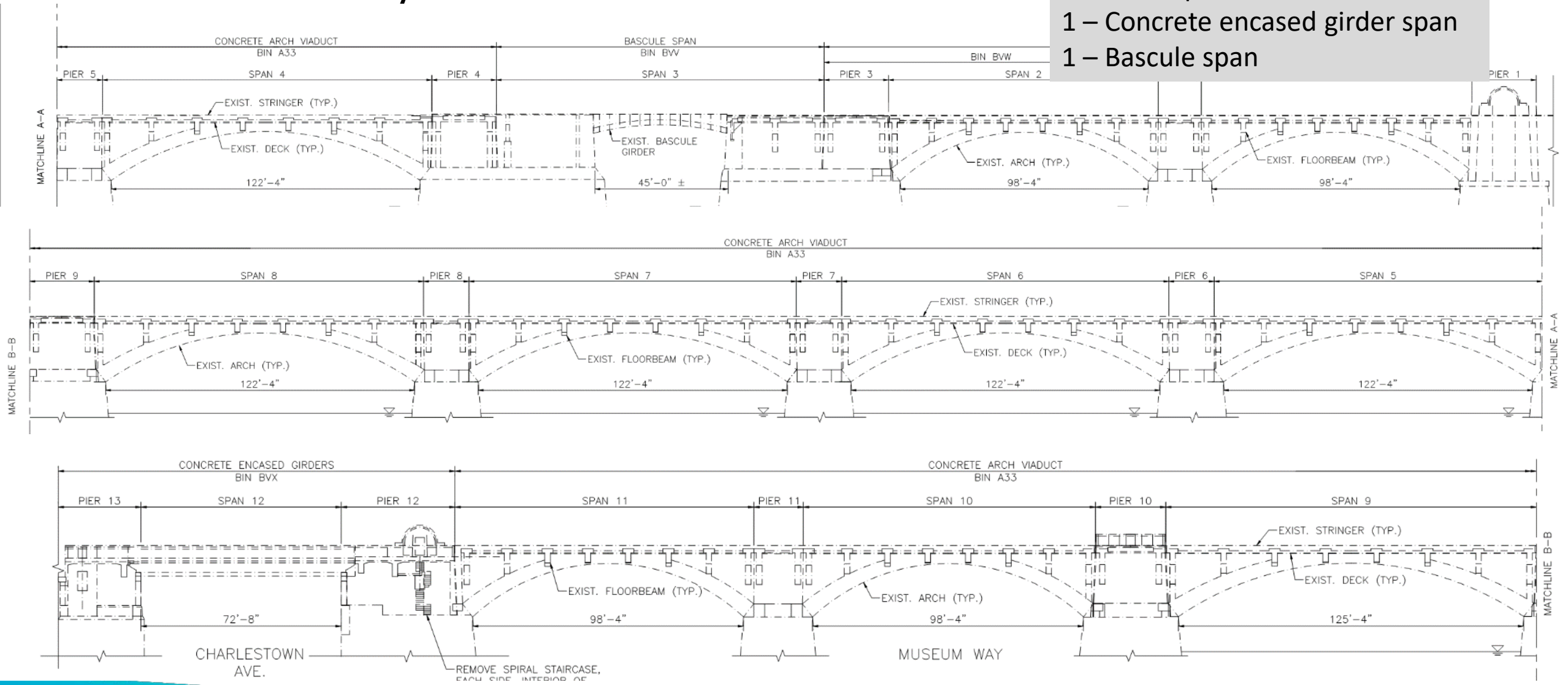
- Lechmere Viaduct is 110-year old historic concrete arch bridge over Charles River

- Rehabilitation work on viaduct includes:
  - Reconstruction of track, signals and traction power
  - Remove and deteriorated concrete walkways with lighter FRP decking
  - Strengthen concrete components to handle heavier loads

- Engineer is VHB

Viaduct Layout

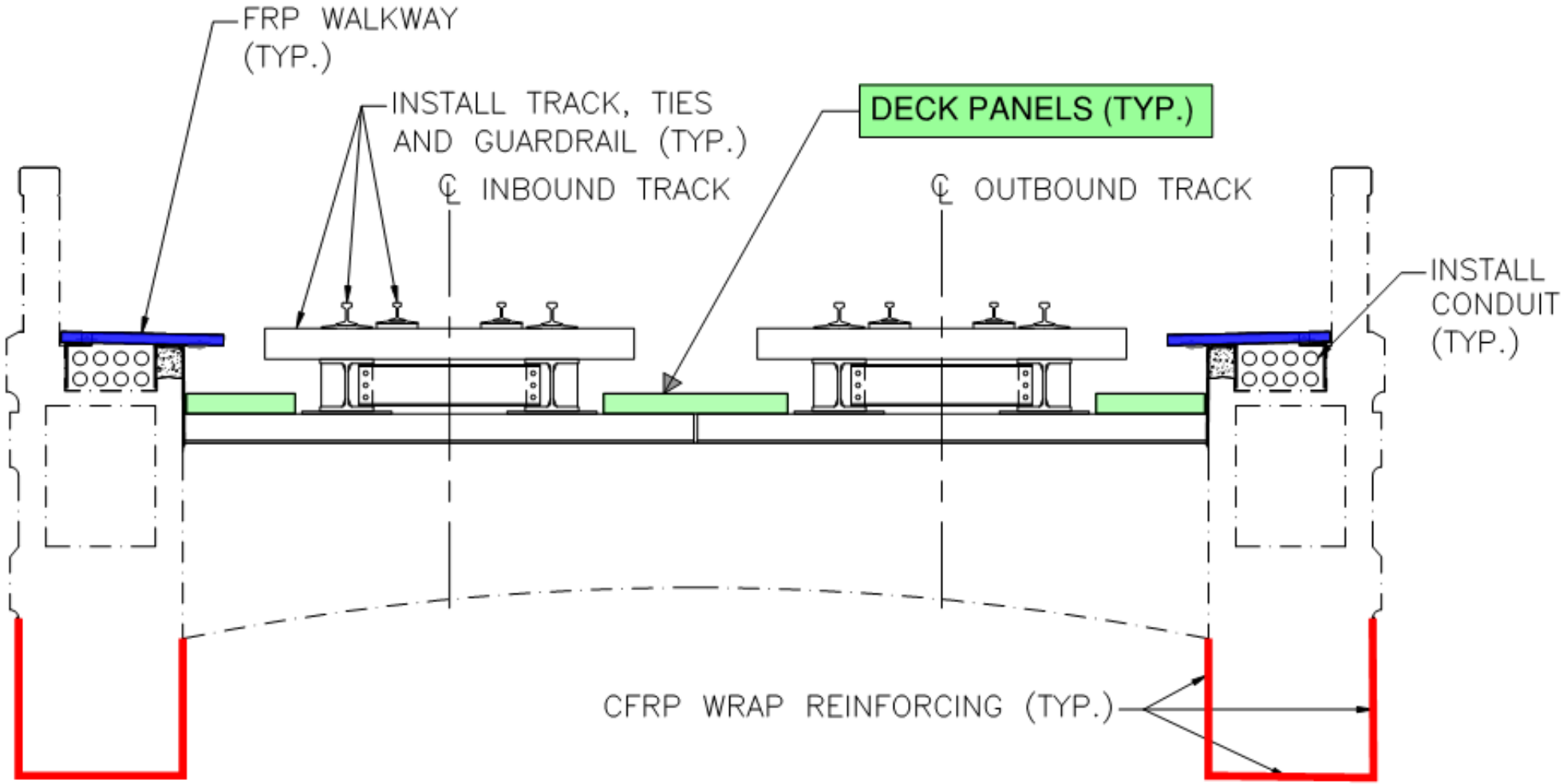
10 – Arch spans
13 – Pier span
1 – Concrete encased girder span
1 – Bascule span



Applications of FRP on Lechmere Viaduct

- CFRP Strengthening:
  - Carbon fiber used to increase the shear and flexural capacity of the concrete floor beam and arch rib elements
  - Primarily to handle larger loads, but also to address code changes
- Molded FRP Walkway Panels
  - Replaced deteriorated concrete walkways
  - Reduction in weight (4” concrete replaced with 3” FRP)
- Pultruded FRP Deck Panels

Case Study: East Lechmere Viaduct Rehabilitation



Original Deck Panel Design

- Original design called for 6” precast concrete planks (75 psf)
- Original schedule:
  - Strengthen bridge
  - Erect new steel framing to support track
  - Install FRP walkways and precast concrete deck panels
  - Lay down new track
- Aggressive milestone to meet GLX testing led to SPS New England wanting to install the walkways and deck panels after the track was laid.

Proposed Value Engineer Option

- Erecting heavy precast concrete panels and maneuvering between newly laid track was risky and time consuming.
- Lightweight FRP deck panels could be erected from above or even lifted from below the bridge through the openings between tracks.
- Lightweight FRP decking panels gave SPS New England flexibility to install the deck panels after the viaduct was “functionally complete”.
- Proposed deck panels pultruded FRP components.

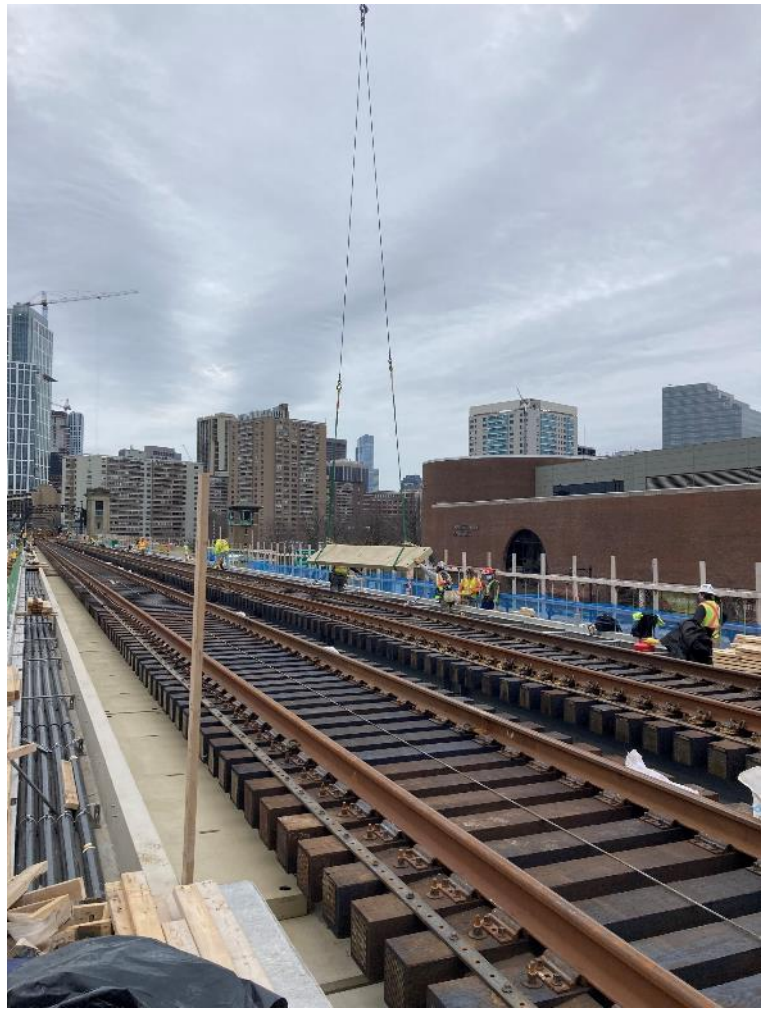
FRP Deck Panel Requirements

- Worked with SPS New England to secure approval from VHB and MBTA.
- Deck panels were classified as covers and not required to be designed for full pedestrian live loads.
- Some panels were required to support heavy power units.
- Needed to meet ASTM E84 Class A requirements
- Color/texture was selected by historical commission based on multiple mock-ups.
- FRP panels included drain openings and were secured to the pier caps using bolted connections.

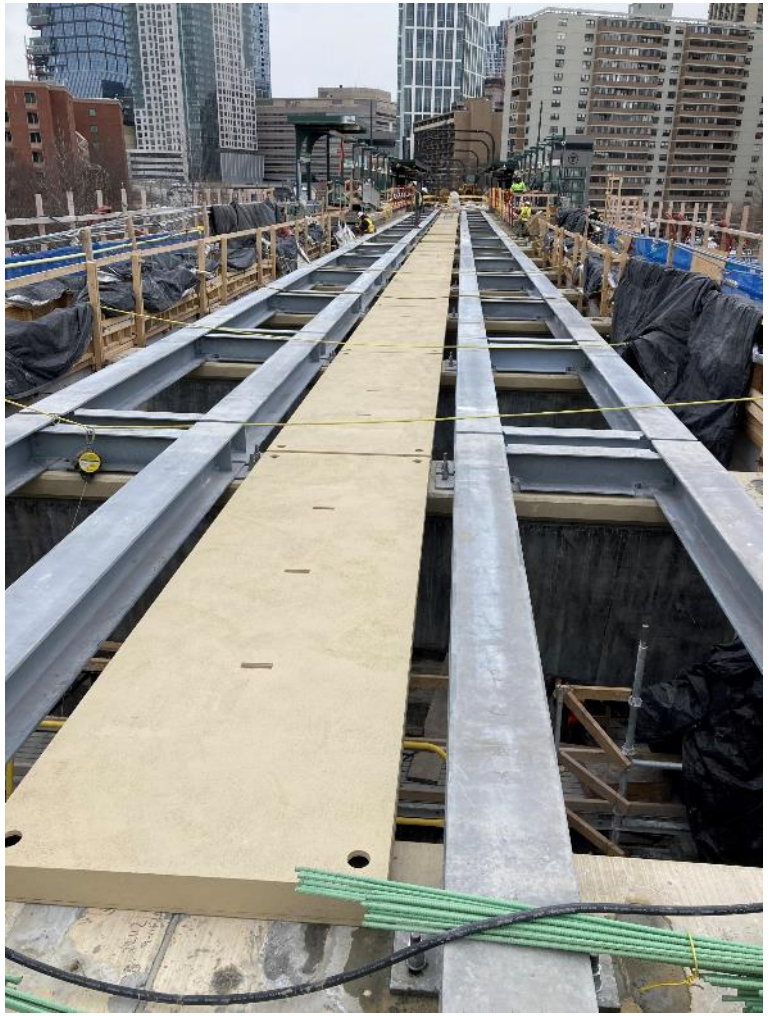
FRP Deck Panel Option-Selected

- Panels were either 2’-8” or 4’-6” wide
- Panel length varied (approximately 13’ to 20’)
- Panel thickness approximately 6”
- Approximately 236 panels (13,000 SF)
- Estimated weight savings = 1,000,000 lb

FRP Deck Panel Erection



FRP Deck Panel Erection



Conclusions

- Why was FRP the right choice?
  - Schedule flexibility
  - Not meeting GLX Testing Milestone carried large liquidated damages
  - FRPs enabled SPS New England to relocate a critical path item.

- Closely working with the MBTA on numerous other FRP platform projects expedited the approval process

- Still, aesthetics were a much more important aspect to this project than initially thought

FINAL THOUGHTS

- FRP do have a place in heavy civil/infrastructure applications.
- FRPs lighter weight is usually one of the most important benefits to the contractor
- Lighter weight structures often lead to cost savings in the form of less labor, equipment, or accelerated schedule, that will offset the more expensive price of the materials.
- FRPs are no longer a curiosity…they have arrived!

Thank You!

For additional information:

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