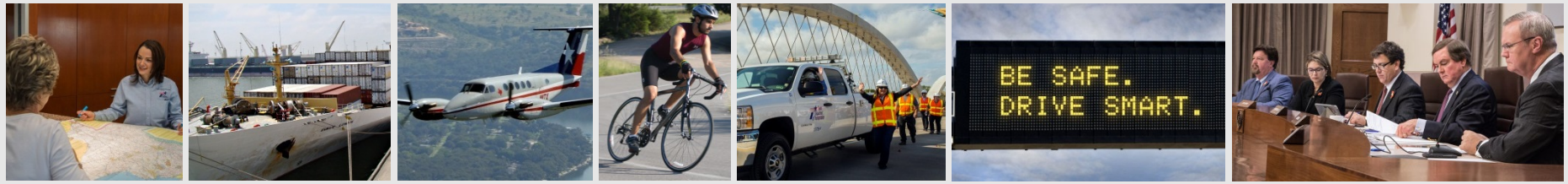
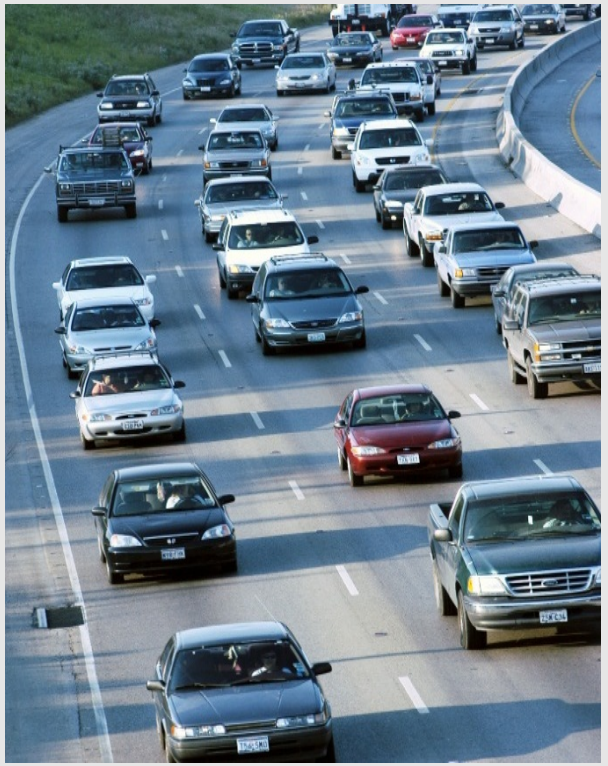



# CARBON FIBER REINFORCED POLYMER USE IN TEXAS



Steven Austin

Texas Department of Transportation

April 17, 2019

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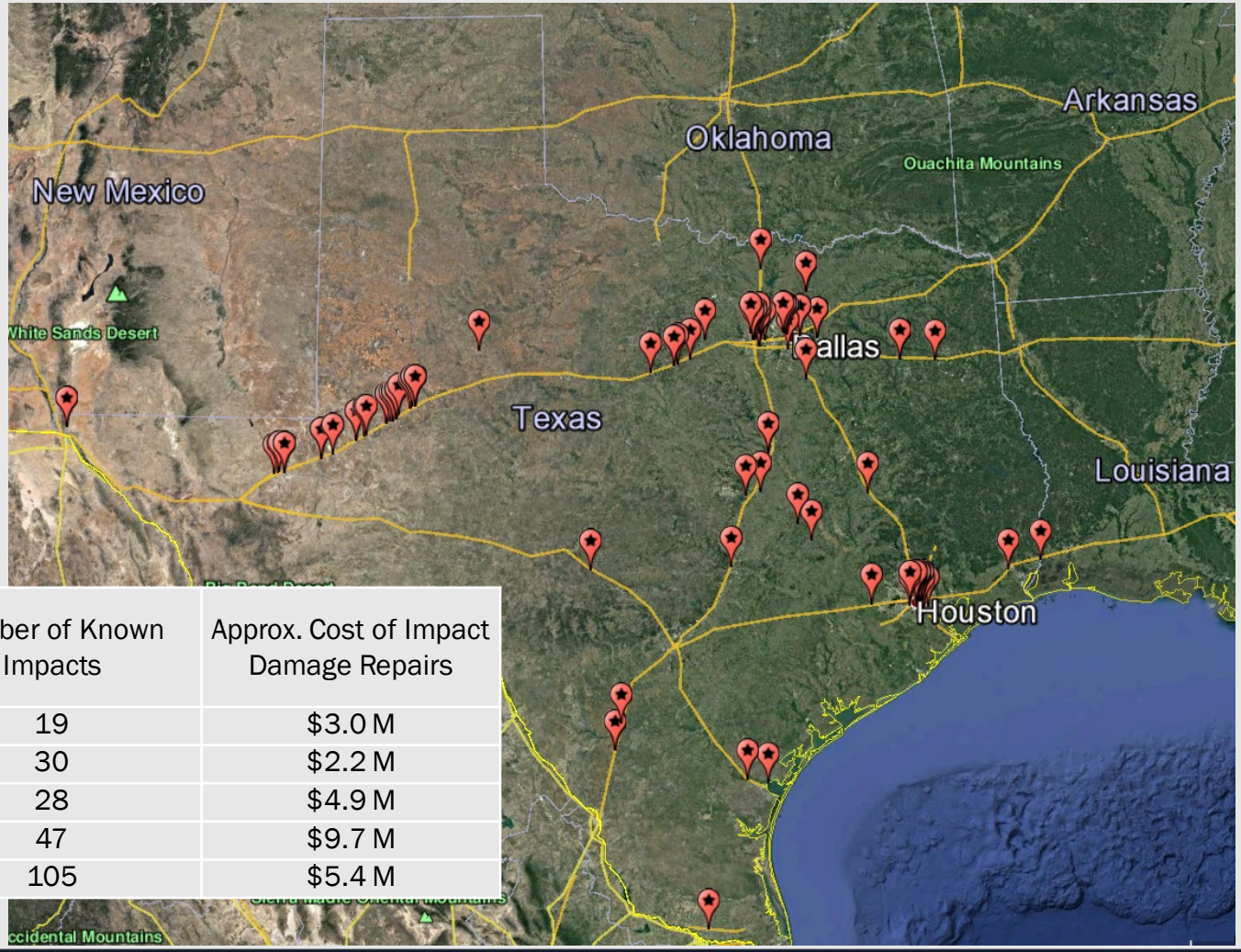
# Overheight Bridge Impacts

- Prestressed Beam
  - Protection
  - Repair



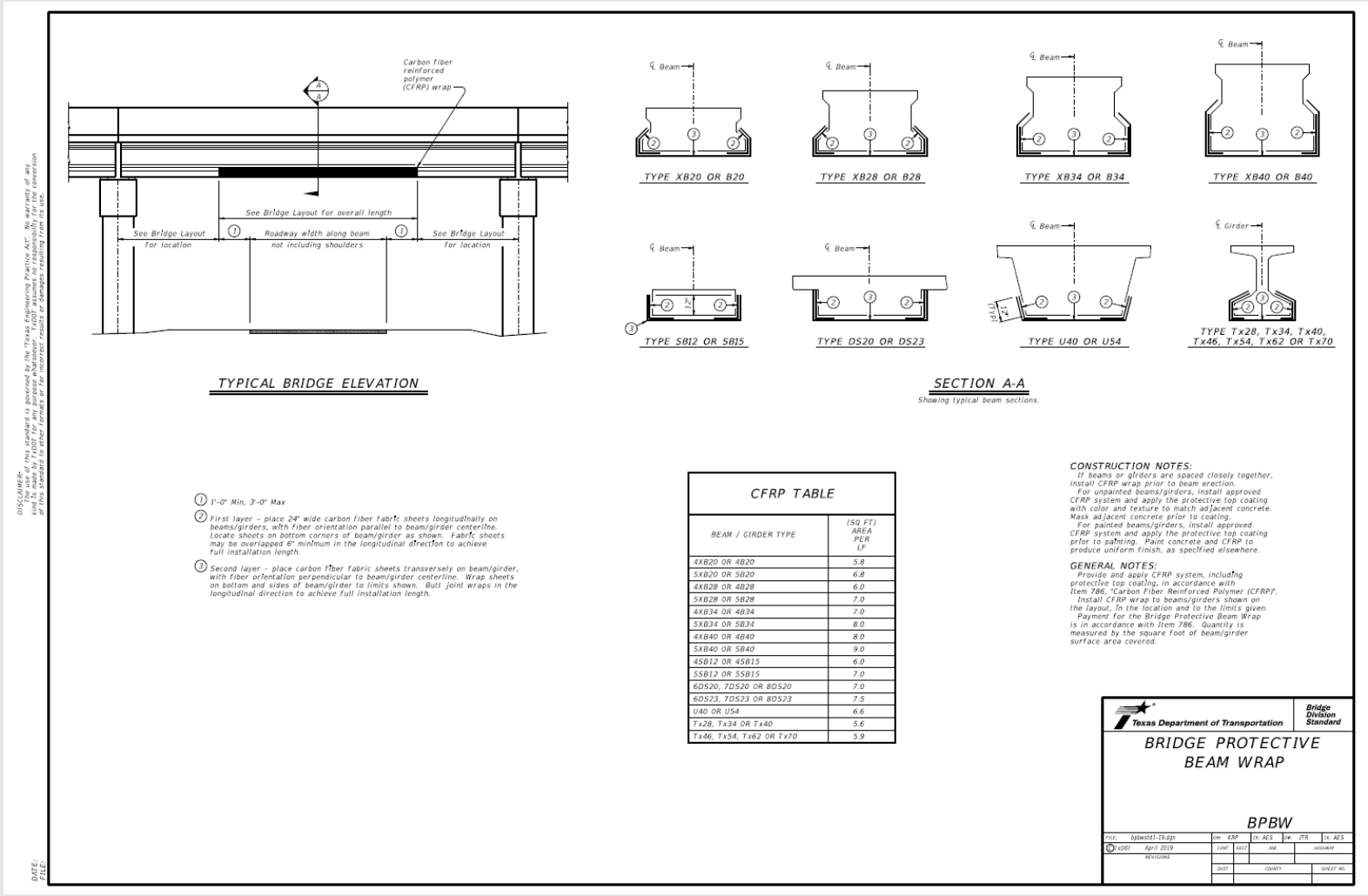

| Calendar Year | Number of Known Impacts | Approx. Cost of Impact Damage Repairs |
|---|---|---|
| 2014 | 19 | $3.0 M |
| 2015 | 30 | $2.2 M |
| 2016 | 28 | $4.9 M |
| 2017 | 47 | $9.7 M |
| 2018 | 105 | $5.4 M |

# CFRP As Bridge Protection

- Bridge Protective Assembly was replaced in 2013

# CFRP As Bridge Protection

- Bridge Protective Beam Wrap



# CFRP As Bridge Protection

- CFRP is more effective at containing minor impact damage

# CFRP As Bridge Protection

- Moderate Impact Damage without CFRP

# CFRP As Bridge Protection

- Moderate Impact Damage with CFRP
  - Provides resistance like a bullet proof vest - CFRP layers likewise dissipate the impact energy and spread to a larger surface area

# CFRP for Beam Impact Repair

- Contains/confines repair material
- Strengthen beams
- Serves as sacrificial protection to preserve beams against future impacts.
- Some bridges have been repaired with CFRP many times.

# CFRP for Beam Impact Repair

- Concerns with CFRP used for Impact Damage Girders
  - Installation procedures must be followed to ensure surface preparation and application of adequate bonding resins.
  - Some pre-mature failures have been noted due to poor bonding of CFRP to substrate.
  - Potential for UV damage.  Application of UV topcoat has been utilized and no UV damage has been noted to date.
  - Potentially conceals issues.
  - History of strand or stirrup loss and record of repairs

# CFRP for Beam Impact Repair

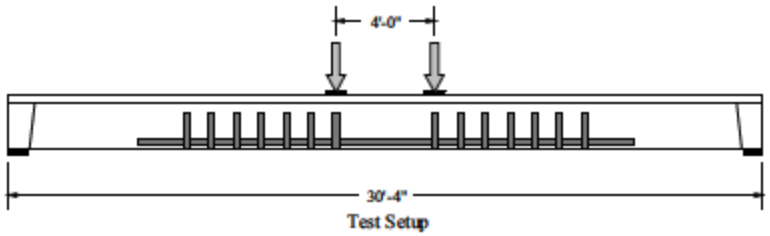
- History of strand or stirrup loss and record of repairs

# Other Impacts

- Bridge Impact Repair
  - Beams
  - Bent caps
  - Columns

# CFRP - Flexure

- 0-1776 - Using Carbon Fiber Composites to Increase the Flexural Capacity of Reinforced Concrete Bridges
- Strength of most of the specimens with CFRP exceeded the capacity of the original reinforced concrete beams
- Displacement capacity was approximately half the displacement capacity of the unstrengthened beams.



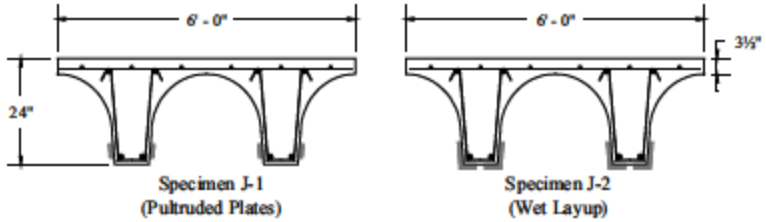
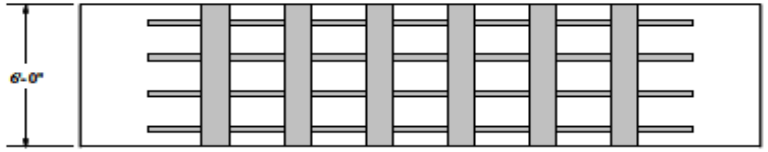




Figure 1 Full-Scale Pan-Girder Test Specimens



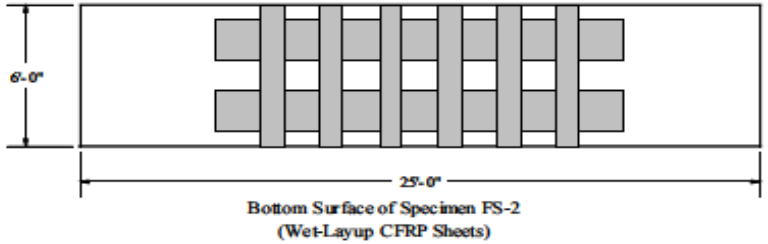




Figure 2 Full-Scale Flat-Slab Test Specimens

# CFRP - Flexure

- The presence of flexural cracks influenced the response of the strengthened specimens.
- Debonding of the longitudinal CFRP materials tended to start at the location of flexural cracks.
- The long-term wetting and drying cycles had essentially no influence on the response of the strengthened beams.
- Sustained gravity loads also had essentially no influence on the response of the strengthened beams.
- Performed well with cyclic loading (1,000,000 cycles!)

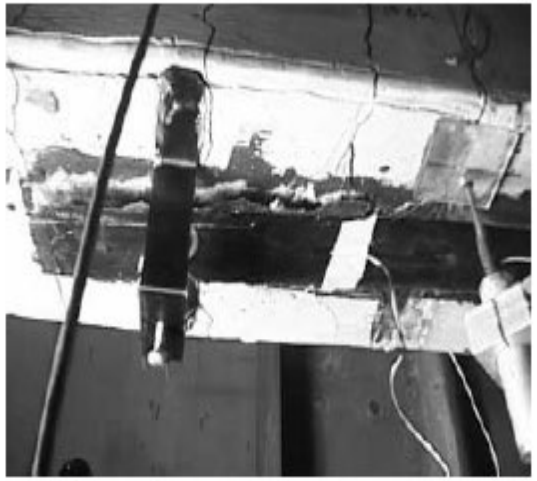
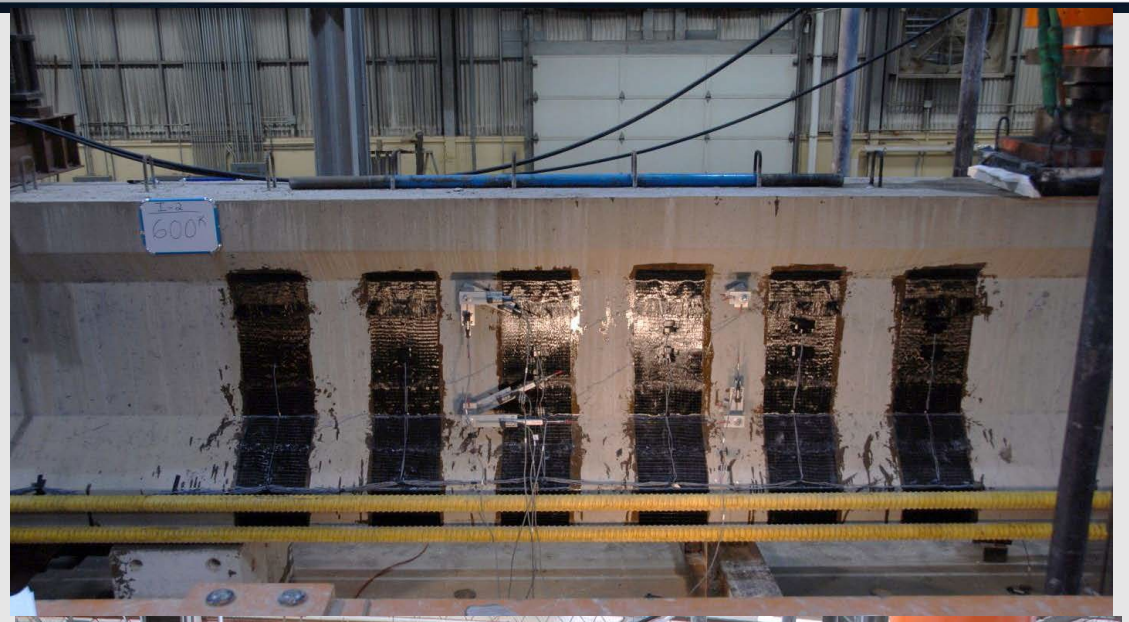
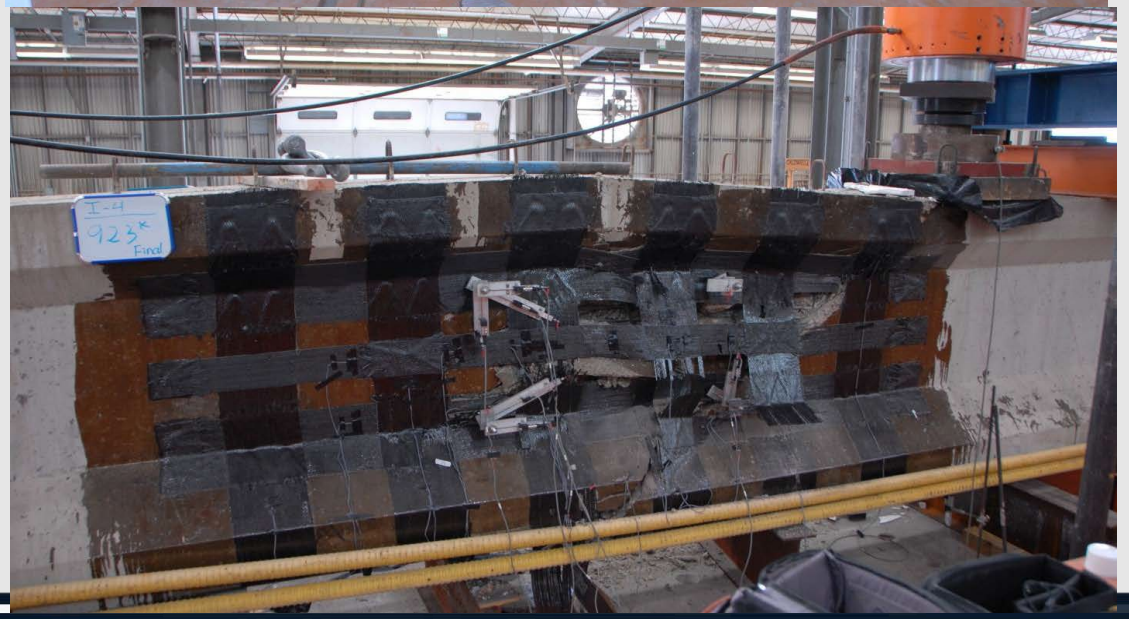


*Figure 6.2 View of the Bottom Face of Specimen A1 after Debonding of the CFRP Composite*

# CFRP - Shear

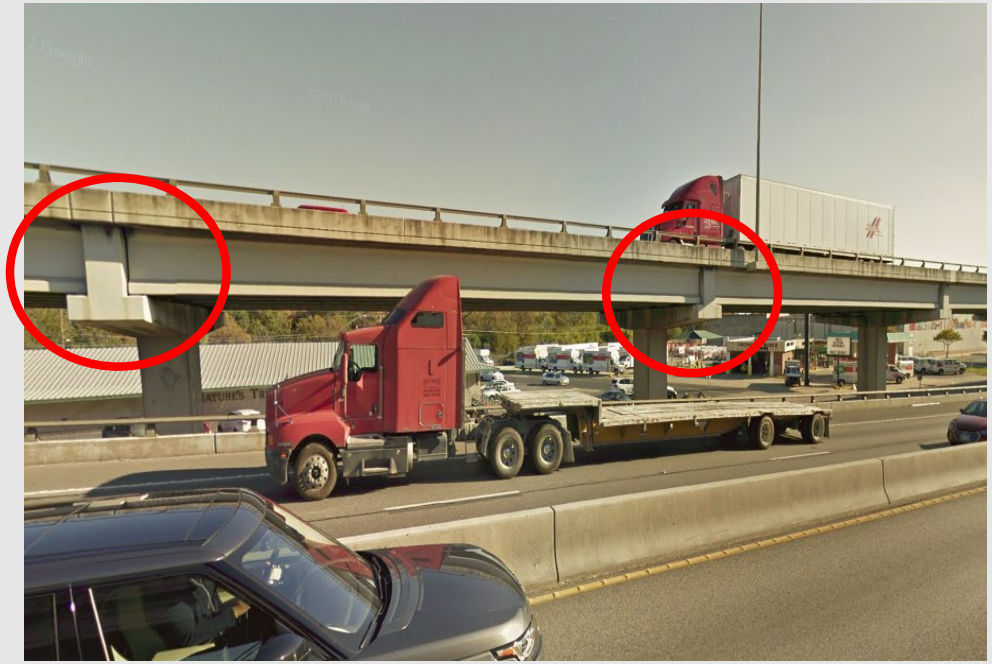
- CFRP strengthening does not appear to be effective for beams with an a/d ratio less than 2.
- An increase in the amount of CFRP strengthening does not produce a proportional increase in shear strength.
- The fatigue performance was acceptable.
- Anchors for CFRP  performed well under sustained loading.
- Bi-directional better control of crack width and higher stiffness
- Anchors permit higher design values and makes better use of the strength of carbon fiber.



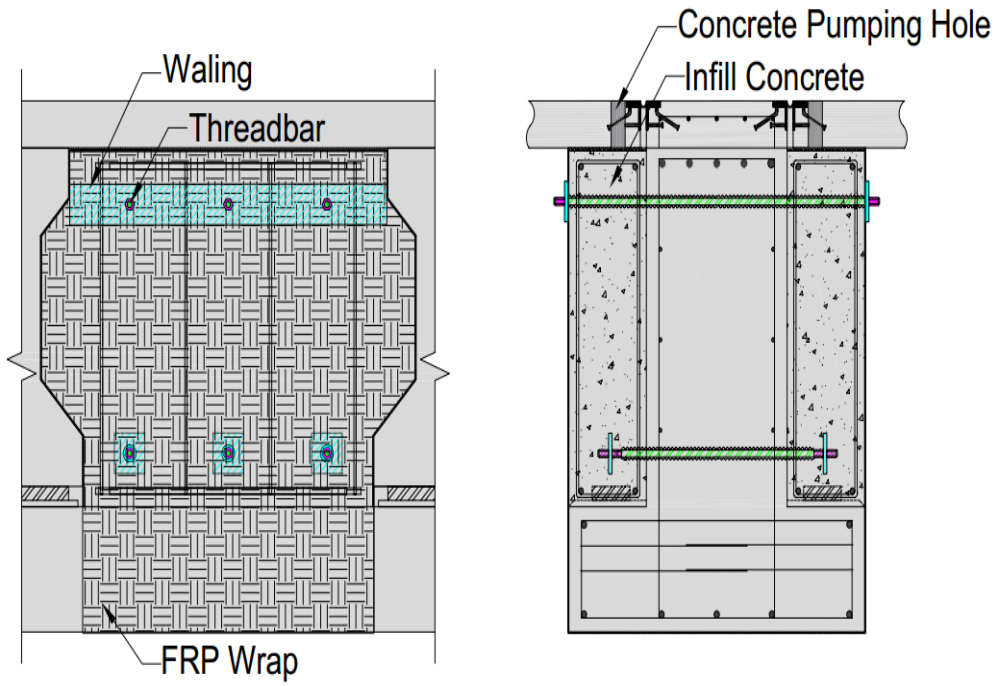



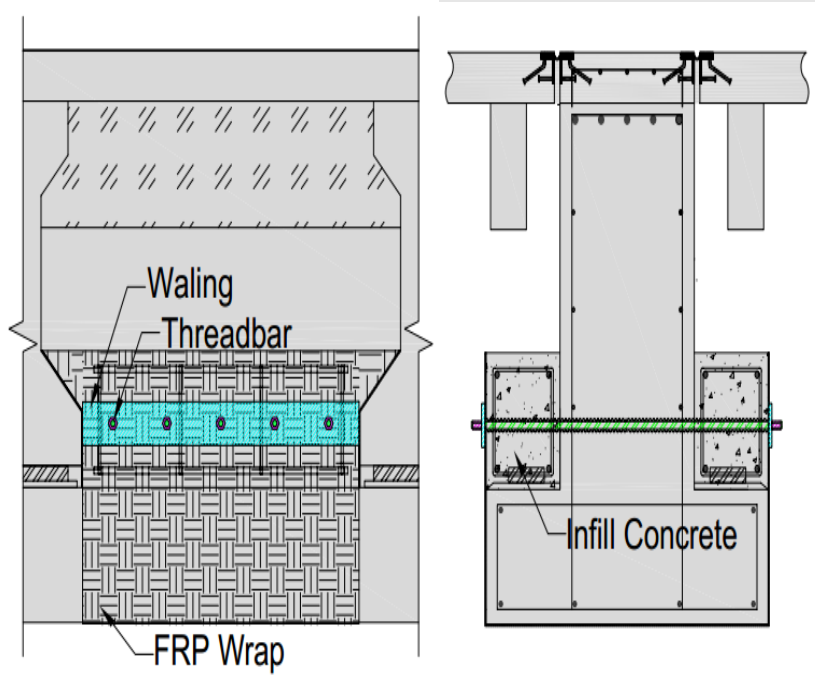
# CFRP for Inverted-T

- TxDOT Research Project 6893 – Strengthen in-service inverted-T bent caps
  - Increase capacity to address change in lane configuration
  - Vertical clearance



# CFRP for Inverted-T

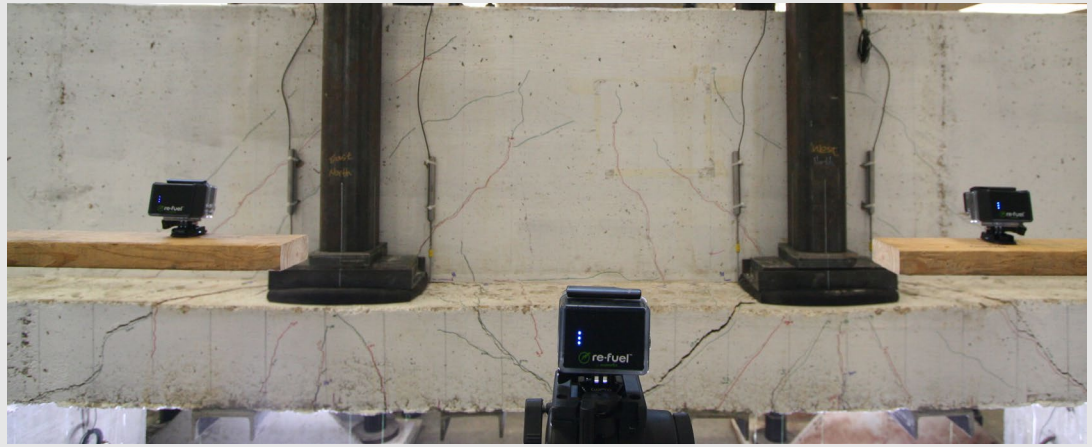


# CFRP for Inverted-T

- 120% - 180% increase in capacity for ledge flexure and punching

# CFRP for Inverted-T

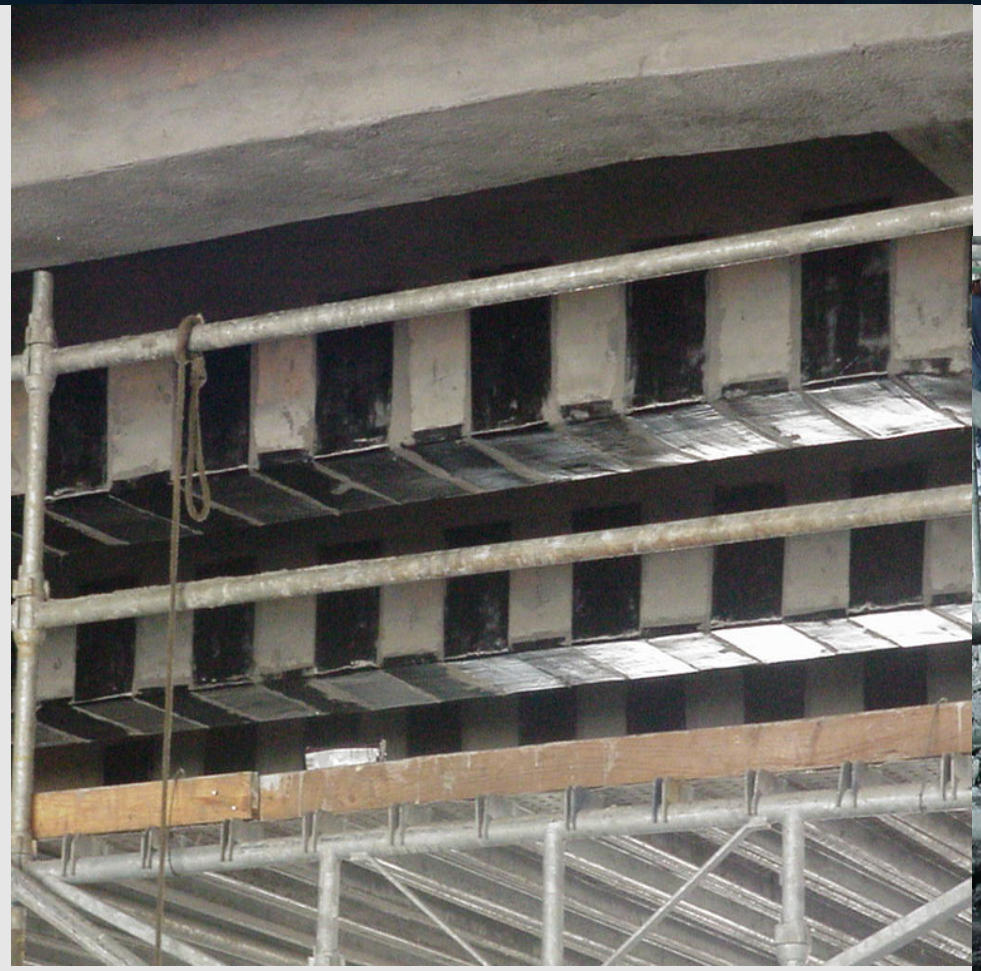

- 120% capacity for int
- 155% capacity for ext

# Fire Damaged Concrete Bridge

- 2005 Fire

# Fire Damaged Concrete Bridge

# Fire Damaged Concrete Bridge



# Fire Damaged Concrete Bridge

- 2005 – 2017
  - Bridge replaced to increase functional capacity of roadway.

# ASR Damage

- CFRP to provide structural confinement to restrain the concrete expansion caused by alkali-silica reaction (ASR) in bridge columns
- ASR, a heterogeneous chemical reaction in concrete between alkaline-hydroxyl ions in pore solution and reactive silica in aggregates. The product is an alkali-silica gel that occupies more space causing internal destructive expansion to concrete members. The concrete starts cracking when the expanding pressure builds up and exceeds the concrete tensile strength.

# ASR Damage

- 2004 Work –
  - 1st application of CFRP to address ASR damage
  - After surface prepared, CFRP strips were applied to the lower portion of all columns as structural confinement to restrain the swelling potential of ASR.
  - The CFRP confinement consisted of strips of 12” wide carbon fiber fabric installed vertically and horizontally with un-wrapped “window” areas for monitoring future ASR development.

# ASR Damage

- 2012 Work –
  - Installed 100% coverage to columns after monitoring the 2004 strips for several years.

# ASR Damage

- 2012 – 2019
- CFRP wrapped concrete appears to be performing well.  UV protection is holding up well
- Cracking apparent at other unwrapped locations

# Chloride Induced Corrosion Repairs

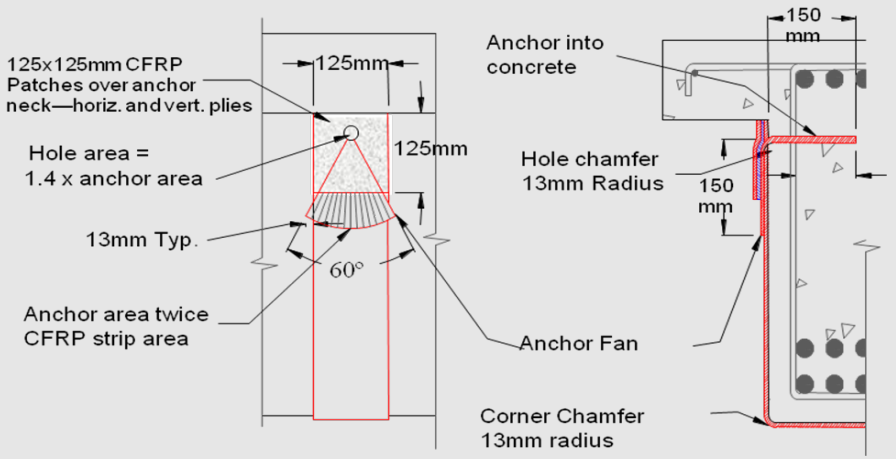
- 1999 CFRP Wrap on 12 bridges in the Lubbock District
- 1970s & 1980s construction


# Chloride Induced Corrosion Repairs

- 2019 condition rating is 8 for columns and caps on some of these bridges.
- Half-cell potential indicates very low probability of active corrosion
- CFRP wrapped concrete appears to be performing well.
- UV protection is holding up well

# Closing Remarks

- CFRP is very effective for preservation
- TxDOT's experience with durability of protective coating has been good.
- Proper application is important
  - Very minor issues with debonding
  - No instances of deterioration through "bathtub" retention of water.
- Recent research has shown
  - Bi-directional layering improves performance.
  - Use of anchors improves performance.
  - Significant strength increase on Inverted-Tees can be achieved through CFRP

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