Oregon DOT Experience with FRP

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Oregon DOT has conducted research on the use of FRP composites for shear strengthening and on durability of FRP composite materials. We have used FRP composite materials for bridge components, FRP wraps and strips used to strengthen or reinforce concrete.

Oregon DOT’s primary interest in the use of FRP in bridges has been for strengthening and rehabilitation of existing bridges. However, ODOT has used GFRP reinforcement in one new bridge application.

The presentation will cover:
1. Research on FRP composites
2. Bridge applications using FRP composites
3. Inspection and assessment or performance of FRP applications
4. Conclusions and recommendations
Completed Research

1. Capabilities of Diagonally-Cracked Girders Repaired with CFRP
   • June 2006, Chris Higgins, Oregon State University

2. Environmental Durability of Reinforced Concrete Deck Girders Strengthened for Shear with Surface-Bonded CFRP
   • May 2009, Chris Higgins, Oregon State University
   • Freeze-thaw applications reduce shear panel stiffness and capacity due to increased de-bonding
   • Long term moisture exposure reduced the contribution of CFRP to the overall member strength
   • ACI 440 environmental reduction factors do not fully account for losses in stiffness and strength

3. Shear Repair Methods for Conventionally Reinforced Concrete Girders and Bent Caps
   • December 2009, Chris Higgins, Oregon State University
Summary of Environmental Results

- Moisture at CFRP-concrete bond interface reduced strength

- Freeze-thaw cycling without moisture did not reduce strengths
  - Some T-specimens subjected to freeze-thaw exposure exhibited significant strength reduction
  - IT specimens did not exhibit freeze-thaw degradation because moisture was not able to infiltrate the free ends

- Fatigue combined with Freeze-Thaw increased debonding but did not reduce strength

- Epoxy injection kept moisture from freely moving through section
Summary of Environmental Results

- ACI-318 and ACI-440 provided conservative shear strength predictions

- The ACI 440 specified environmental factors were not sufficient to provide uniform levels of safety. Environmental exposure factor should always be applied to limit the effective CFRP stress/strain

- Locations with very large numbers of wet freeze-thaw cycles and extended exposure to continuous moisture may warrant even smaller environmental exposure factors
## Oregon DOT FRP Applications

- **Girder shear strengthening with CFRP Strips** 32 Bridges
- **Pier cap shear strengthening with CFRP Strips** 12 Bridges
- **Girder flexure strengthening with CFRP Strips** 8 Bridges
- **Modular FRP bridge decks** 4 Bridges
- **Deck strengthening with NSM CFRP rods** 4 Bridges
- **Deck strengthening for rail LL with NSM CFRP Rods** 4 Bridges
- **GFRP Reinforcement** 2 Bridges
- **Pier cap flexure strengthening with CFRP Strips** 1 Bridge
- **Arch rib strengthening with CFRP Strips** 1 Bridge
Methods of Assessing Durability Issues of FRP

1. Visual – bulging, separations, fretting, discoloration
2. Sounding – tapping, rotary percussion tool,
3. NDT - IR Thermography
4. Check sources of moisture getting behind FRP

Age of ODOT Installations

1. FRP Shear and Flexure Strengthening 1998
2. FRP Decks 2006
3. NSM FRP 2008
4. GFRP Reinforcement 2010
Inspection and Assessment of FRP Durability

- Overall, FRP laid up construction is performing well in a variety of environment and loading cases.
- We have found a few isolated cases of small delaminations, corners peeling away, gaps on the edges of laid up construction, voids or trapped air bubbles.
- ODOT has had significant problems with early FRP deck modules, such as seam separation, attachment failure, wearing course adhesion, cracking.
- NSM FRP is universally performing well.
Topics for Further Research

1. CRFP Surface-bonded specimens with lower transverse steel shear contributions should be investigated to enable shear failure with increased CFRP shear contribution.
2. CRFP Surface-bonded specimens should be tested with minimum transverse steel requirements.
3. Specimens should be precracked prior to application of CFRP, as this is representative of field applications.
4. Specimens should be reloaded after strengthening, to produce recracking prior to environmental exposure.
5. Specimens should be strengthened and be subjected to freeze-thaw exposure in the orientation that reflects field conditions.
6. Additional data are needed for combined environmental exposure and fatigue loading.
Topics in Need of Further Research

1. Constructability details for FRP tied arch hangers and suspenders for suspension bridges
2. Constructability details for FRP cable-stayed bridges
3. Constructability details for FRP external post-tensioning repairs
4. Development lengths for FRP strand in prestressed girders
5. Prestress losses for FRP strand in prestressed girders
6. Ways to eliminate the crack in the wearing surface over butt joints in the top sheet of FRP decks
7. Better attachment details for FRP decks