Development, Field Testing, and Implementation of Improved Bridge Parapet Designs

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Sponsored by:

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Research Objectives

- Observe and monitor construction of test and control parapets
- Observe construction practices to assess effect on parapet cracking
- Determine which modifications (if any) work best to address parapet cracking
- Recommendations for future research
Research Approach

- ODOT design modifications for bridge parapets
- Literature review
- Review of costs to replace parapets
- Experimental design
- Field monitoring
Cost estimates from several ODOT districts as well as other state DOTs
Replacement costs range from $60 to $435 per linear foot of parapet, many in $300 range, average ODOT $238
Complete details in Lauren Hedges thesis
Design Modifications

- Control – per original plans
- Addition of polypropylene microsynthetic fibers at 1 lb./CY or 2 lb./CY
- Substitute glass fiber reinforced polymer (GFRP) reinforcement, with 3 ½ inch deep saw cut
- Field cut gaps in rebar at joints, with 3 ½ inch deep saw cut
Bridge Parapet Test Sites

- Deck and parapet replacements
- 10 bridges on I-90 in Lake County, 2 parapets each, total 20 parapets
- Marginal Road over I-90
- Control parapets – 3 bridges built in 2012 in Lake County, also 3 parapets in 2014 construction season
- 2013 – 4 Lake County bridges, Marginal Road
- 2014 – 3 Lake County bridges
Test Variables

- Polypropylene fibers (two dosages, 1 or 2 lb/CY)
- 3 ½ inch deep saw cut, combined with either:
  - Glass fiber reinforced polymer (GFRP) reinforcing bars
  - Field cut steel reinforcing bars
- Cut spacing 5 to 6 feet in the tension zones, over bridge piers, and 10 to 15 feet at other locations
Tension Zone
Tension Zone

PROFILE SHOWN ALONG PROFILE GRADE OF EASTBOUND I.R. 50 OVER BIG CREEK
Field Cut Bars

Face of Backwall

Field Cut 9” of Steel

Bars in 12” space

Locate control joint in center of 9” gap in reinforcing

Part Plan at Abutment

See appropriate expansion joint standard bridge drawing

Section A-A
Field Testing Plan

- Pre-construction observation – steel reinforcement location, cuts, etc.
- Installation of maturity sensors for temperature monitoring
- Placement observations – weather conditions, sample concrete
- Sawcut observations – timing, depth, whether concrete has already cracked
Field Testing Plan

- Maturity data collection – temperature history, thermal shock
- Investigate whether joints have cracked
  - James R-meter for reinforcement depth, location, continuity
  - James V-meter for continuity – wave speed and signal across joint or crack
- Post construction crack survey – also for control bridges
Wave transition speed relates to elastic modulus (strength)
High UPV = uncracked joint
Low UPV or no signal = cracked joint
Some intermediate results – may be transmitted by reinforcing steel
Maturity Measurements

- May be used to predict strength based on concrete temperatures
- Used to record temperature history of parapets
Temperature Measurements

![Graph showing temperature measurements from Jul 3 to Jul 15. The graph indicates a general decrease in temperature with fluctuations.]
Results

- Case study overviews
- Deck and parapet replacement projects
- All used concrete with improved gradation and reduced joint spacing
- Construction observations
- Crack monitoring
- Joint UPV measurements
Eastbound Big Creek Bridge

- 3 spans, maximum 140 feet, 2 lanes, originally built in 1960
- Construction in 2012, both parapets control

[Diagram showing the bridge structure]
Eastbound Big Creek Bridge
Eastbound Big Creek Bridge

- Crack surveys September 30, 2013, and February 27, 2014
- Both parapets had mid panel cracking
Eastbound Paine Creek Bridge

- 3 spans, maximum 188 feet, 2 lanes, originally built in 1960
- Construction in 2012, both parapets control
Eastbound Paine Creek Bridge

- Crack surveys February 27, 2014
- Both parapets had mid panel cracking
Eastbound Paine Road Bridge

- 3 spans, maximum 58 feet, 2 lanes, originally built in 1960
- Construction in 2012, both parapets control
Eastbound Paine Road Bridge

- Crack surveys February 27, 2014
- Both parapets had mid panel cracking, south parapet also had cracks at joints
Eastbound Hermitage Road Bridge

- 3 spans, maximum 60 feet, 2 lanes, originally built in 1961
- Construction in 2013
- North parapet GFRP rebar with 3 ½ in. cut, south parapet poly fibers
Concrete placed on July 2, 2013 for north parapet and October 15, 2013 for south
No mid panel or joint cracks
Eastbound Auburn Road Bridge

- 3 spans, maximum 63 feet, 3 lanes, originally built in 1960
- Construction in 2013
- North parapet GFRP rebar with 3 ½ in. cut, south parapet GFRP rebar with 3 ½ in. cut plus poly fibers
Eastbound Auburn Road Bridge

- Concrete placed on July 1, 2013 for north parapet and June 24, 2014 for south parapet
- Final site visit on July 16, 2014
- Some mid panel and joint cracks on both parapets
Westbound Paine Road Bridge

- 3 spans, maximum 46 feet, 2 lanes, originally built in 1960
- Construction in 2013
- North parapet field cut rebar with 3 1/2 in. cut, south parapet poly fibers
Westbound Paine Road Bridge

- Concrete placed on September 23, 2013 for north parapet and June 17, 2013 for south parapet
- Final site visit on February 21, 2014
- No cracks on either parapet
Westbound Paine Creek Bridge

- 3 spans, maximum 188 feet, 2 lanes, originally built in 1960
- Construction in 2013
- Both parapets poly fibers
Westbound Paine Creek Bridge

- Concrete placed on September 30, 2013 for north parapet and June 19 and 24, 2013, for south parapet
- Final site visit February 21, 2014
- North parapet had mid panel and joint cracks, south parapet none
Westbound Paine Creek Bridge
South Marginal Road

- 4 spans, maximum 68 feet, 2 lanes, originally built in 1959
- Construction in 2013
- North parapet control, south parapet GFRP rebar with 3 ½ in. cut
South Marginal Road

- Unlike Lake County bridges, both parapets have vandal protection fences.
- Concrete placed on August 13, 2013 for north parapet and August 15, 2013 for south parapet.
- Due to pressure to open bridge for Cleveland Browns game, only 2 days of curing for parapets.
South Marginal Road

- Control parapet had about 12 large cracks
- South parapet had fewer cracks
- VPF base plate anchor bolts drilled into green concrete
South Marginal Road
South Marginal Road – North Parapet
South Marginal Road – South Parapet
Westbound Big Creek Bridge

- 3 spans, maximum 140 feet, 2 lanes, originally built in 1960
- Construction in 2014
- North parapet GFRP rebar with 3 ½ in. cut, south parapet GFRP rebar with 3 ½ in. cut plus poly fibers
Westbound Big Creek Bridge

- Concrete placed on September 4, 2014 for north parapet and June 17, 2013 for south parapet
- Inspection on October 30, 2014, some cracks on north parapet, none on south parapet
Westbound Auburn Road Bridge

- 3 spans, maximum 63 feet, 2 lanes, originally built in 1960
- Construction in 2014
- North parapet control, south parapet field cut rebar with 3 ½ in. cut plus poly fibers
Westbound Auburn Road Bridge

- Concrete placed on October 10, 2014 for north parapet and June 23, 2014
- Site visit on October 30, 2014
- No cracks found
Westbound Hermitage Road Bridge

- 3 spans, maximum 60 feet, 2 lanes, originally built in 1961
- Construction in 2014
- North parapet control, south parapet field cut rebar with 3 ½ in. cut plus poly fibers
Westbound Hermitage Road Bridge

- Concrete placed on September 19, 2014, for north parapet and June 27, 2014 for south parapet
- Site visit on October 28, 2014
- No cracks found
Summary of Results – South Marginal Road

- Only two days curing – very severe condition for cracking
- Experimental parapet had fewer and thinner cracks than control
- VPF base plate bolt may be cast in place or drilled – early drilling can cause damage
Summary of Results

- Poly fibers at 2 lb./CY exceeded manufacturer’s recommendation, led to problems with air
- Maturity sensors did not show any thermal shock problems
- Cost of fibers $1.34 to $2.48 per linear foot
- Cost of GFRP or field cut steel $8.48 to $15.01 per linear foot
# Joint Cracking vs. Sawcut Depth

<table>
<thead>
<tr>
<th>Depth of Cut</th>
<th>Parapets Included</th>
<th>Average % of All Cracked Joints</th>
<th>Average % of Not Cracked Joints</th>
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<tr>
<td></td>
<td>Bridge</td>
<td>Name</td>
<td>Parapet</td>
</tr>
<tr>
<td></td>
<td>South Marginal</td>
<td>North</td>
<td>Steel</td>
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<tr>
<td>1 1/2 inches (38 mm)</td>
<td>EB</td>
<td>Hermitage</td>
<td>South</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>Paine Creek</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>Paine Creek</td>
<td>South</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>Paine Road</td>
<td>South</td>
</tr>
<tr>
<td>3 1/2 inches (89 mm)</td>
<td>WB</td>
<td>Paine Road</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>EB</td>
<td>Auburn</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>EB</td>
<td>Hermitage</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>South Marginal</td>
<td>South</td>
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## Joint Cracking vs. Fibers

<table>
<thead>
<tr>
<th>Amount of Polypropylene Fibers</th>
<th>Parapets Included</th>
<th>Average % of All Cracked Joints</th>
<th>Average % of Not Cracked Joints</th>
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<tr>
<td>No Fibers</td>
<td>Bridge Name</td>
<td>Parapet</td>
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</tr>
<tr>
<td>-</td>
<td>South Marginal</td>
<td>North</td>
<td></td>
</tr>
<tr>
<td>EB</td>
<td>Paine Road</td>
<td>North</td>
<td>81.2</td>
</tr>
<tr>
<td>WB</td>
<td>Paine Road</td>
<td>North</td>
<td></td>
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<tr>
<td>EB</td>
<td>Auburn Road</td>
<td>North</td>
<td></td>
</tr>
<tr>
<td>EB</td>
<td>Hermitage Road</td>
<td>North</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>South Marginal</td>
<td>South</td>
<td></td>
</tr>
<tr>
<td>1 lb/yd³ (0.59 kg/m³)</td>
<td>EB</td>
<td>Hermitage Road</td>
<td>71.3</td>
</tr>
<tr>
<td>WB</td>
<td>Paine Creek</td>
<td>North</td>
<td></td>
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<tr>
<td>WB</td>
<td>Paine Road</td>
<td>South</td>
<td></td>
</tr>
<tr>
<td>2 lb/yd³ (1.19 kg/m³)</td>
<td>WB</td>
<td>Paine Creek</td>
<td>53.0</td>
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</tbody>
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Conclusions and Recommendations

- GFRP or field cut steel reinforcement with 3 ½ inch sawcut increased probability of joint cracking
- Some benefit to poly fibers, but less significant
- Do not exceed manufacturer’s recommendations for poly fibers
Conclusions and Recommendations

- Parapets used reduced joint spacing in negative moment areas, effective at reducing cracking
- Early saw cutting more likely to beat cracking
- Cure parapets for 7 days minimum
- Average cost of ODOT parapet replacements $188,000 per parapet or $238 per linear foot
Issues Not Resolved

- Slipforming – ODOT has not allowed slipforming of parapets for some time
- Vibration – long versus short bridges, no different found
- Installation of VPF bases
  - Cast in place anchors
  - Drilled anchors (green concrete)
Recommendations for Future Research

- Return to test parapets after five years to monitor long term performance
- Monitor effects of slipforming implementation
- Compare long to short span bridges for cracking
Implementation Recommendations

1. Use a smaller spacing between parapet control joints over piers, in negative moment regions.
2. Use discontinuous lengths of steel reinforcement, with gaps at the control joints, to allow for 3 ½ inch (89 mm) saw cuts.
3. Use GFRP reinforcement, to allow for 3 ½ inch (89 mm) saw cuts.
Implementation

- This was essentially field monitoring of the implementation of the previous project
- Implementation through ODOT BR-1-13 January 17, 2014
Acknowledgements

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Student Study

- Jeff Bazzo (thesis published)
- Amy Kalabon (thesis published)
- Lauren Hedges (thesis published)
- Larissa Susinskas
- Jennifer Woods
Question/Answer Period

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Graduate and Undergraduate Research Assistants – Jeff Bazzo, Amy Kalabon, Lauren Hedges, Larissa Susinskas, Jennifer Woods