Effectiveness of Longitudinal Joints in Adjacent Box-Beam Bridges

Anil Patnaik, Ph.D., and Mohamed Habouh Ph.D.
The University of Akron

Waseem Khalifa, Ph.D., P.E., ODOT District 11
Jim Welter, P.E., ODOT Central Office and
Perry Ricciardi, MSCE, P.E., ODOT District 3

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Outline

• Introduction
• Factors affecting joint performance
• Membrane performance
• Joint performance
• Practical Issues
• Implementation
• Conclusions
Introduction

Longitudinal Joints

Typical Cross-Section
Problems with Box-Beam Bridges

Typical Cross-Section

- Water Leakage
- Deck Surface Cracking
- Prestressing Strand Corrosion
The primary objective of this study is to develop insight into the performance of longitudinal joints with a particular reference to cracking and differential deflection, and to develop preventive measures through careful evaluation of alternatives.
The primary factors that affect joint performance are addressed in this study:

- Membrane Performance
- Joint Performance
- Practical Issues
Membrane Performance
Membrane Tests

- Tensile tests at different temperatures
- Adhesion tests
- Differential deflection tests
- Punching tests
- Tests to detect initiation of leakage
## List of Membranes Tested

<table>
<thead>
<tr>
<th>#</th>
<th>Brand Name</th>
<th>Type</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Polyguard 1100</td>
<td>Type III</td>
<td>Polyguard Products, Inc</td>
</tr>
<tr>
<td>2</td>
<td>665 Membrane</td>
<td>SA, Not in ODOT QPL (Type II)</td>
<td>Polyguard Products, Inc</td>
</tr>
<tr>
<td>3</td>
<td>Coldflex 2000 SA</td>
<td>SA, Not in ODOT QPL (Type II)</td>
<td>Polyguard Products, Inc</td>
</tr>
<tr>
<td>4</td>
<td>PavePrep</td>
<td>Type III</td>
<td>Crafco, Inc.</td>
</tr>
<tr>
<td>5</td>
<td>PavePrep SA</td>
<td>Type II</td>
<td>Crafco, Inc.</td>
</tr>
</tbody>
</table>

SA refer to Self-Adhesive (Type II)
QPL refers to ODOT Qualified Product List
Tensile Tests

- Five systems were tested at different temperatures 70°, 40°, 23°, 14° and –4° F
- Each sample was conditioned in an environmental chamber at the desired temperature for at least one hour.
- More than 75 specimens were tested
Adhesion Tests

- Improvement in adhesive strength due to the use of direct heat is limited.
- Sealant and primer together perform better than the use of primer alone as bonding agent.
- The peel-out strength is very small

Specimen Details

Test Setup
Differential Deflection Tests

This test was designed to determine the maximum differential deflection that a membrane can accommodate.
Differential Deflection Tests

Most samples from Polyguard, ColdFlex, 665 membranes failed in this manner; some failed by full rupture

Paveprep, Paveprep SA, almost all samples failed by full rupture

Differential deflection was recorded to be well over 1.0 inch in most of the tests

![Graph showing load vs. elongation for different materials: 665, ColdFlex, Polyguard, Paveprep, Paveprep SA. The graph indicates that the load increases with elongation and then decreases, with each material having a distinct load-elongation curve.](image_url)
Punching Tests

• Punching tests are commonly done to find out the punching resistance of waterproofing membranes.
• Punching can occur if there is any grit/gravel under or above the membrane. Any use of equipment or traffic over the membrane may cause punching.
• The results show that waterproofing membranes can be punched through at about 100 to 150 lb force.
Tests to Detect Initiation of Leakage

Plastic Tube of 7” outer diameter 6½” inner diameter

Metal loading plate of 4” diameter

Test Setup

This test revealed that there is no leakage through the membranes up to at least 1.0” of deformation
Joint Performance
Joint Performance Tests

• Key Way Joint Tests
• Beam Assemblies Subjected to Symmetric Loading
• Joints Subjected to Shear and Out-of-Plane Moment (i.e., Loaded with Eccentric Loads)
Key Way Joint Tests

- Even a small tie force increases shear transfer strength
- Deeper and wider key ways perform better
- Sandblasting is very effective
- High strength concrete as a grout is excellent
# Beam Assembly Tests

<table>
<thead>
<tr>
<th>Set # 1, 2, and 3</th>
<th>Set # 4, 5 and 7</th>
<th>Set # 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beam length/Span</strong></td>
<td>14'/13'</td>
<td>16'/15'</td>
</tr>
<tr>
<td><strong>Grout material</strong></td>
<td>ODOT Approved Grout</td>
<td>ODOT Approved Grout</td>
</tr>
<tr>
<td></td>
<td>ODOT Approved Grout</td>
<td>High strength concrete</td>
</tr>
<tr>
<td></td>
<td>Polymer Grout</td>
<td>HSC - Sandblasted</td>
</tr>
</tbody>
</table>

Test specimen for:
- Set # 1 ODOT approved grout - as cast concrete surface
- Set # 2 ODOT grout - as cast concrete surface
- Set # 3 Polymer grout - as cast concrete surface

Test specimen for:
- Set # 4 ODOT approved grout - as cast concrete surface
- Set # 5 HSC grout - as cast concrete surface
- Set # 7 HSC grout - sand blasted surface

Test specimen for:
- Set # 6 Polymer grout

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Beam Assembly Tests
• Polymer grout is implementable
• Deeper wider key ways perform better than shallow key ways
• Sandblasting is very effective
• High strength concrete as a grout is excellent
Typical Failure Modes

- HSC – sandblasted Surface
- Minor cracks occurred at 275 kip test load;
- The beam units could not be separated without a jack hammer;
- Joint separation occurred through concrete and not at the interface

Beam assembly tests with ODOT Key Way Details;
The three beam units separated effortlessly
Test Setup for Eccentric Load Tests

Joint under study load case I

Load

Rigidly Supported

Loading Bracket

Loaded Unit

Kuhlman 1107
MasterFlow4316 (Polymer)
HSC Kuhlman 1107 UHPG

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Test Setup for Eccentric Load Tests

Failure Mode of HSC Grout with Sandblasted Surface
Effect of Tie Rods
A small amount of tie force normal to the key way joint noticeably enhances the shear transfer strength of joints.

Key Way Geometry
Full-depth key way joints that are much deeper than the ODOT-specified key way joints, along with suitable surface preparation and high strength concrete grout, increase the shear transfer strength by a large margin (up to a factor 5.0).

Grout Type
Cement-based high strength concrete grout with compressive strength of at least 10,000 psi increases joint strength significantly.
Joint Surface Preparation
Sand blasting increased joint shear strength significantly and allowed the high grout compressive strength to be utilized

Current ODOT Key Way Geometry and Grouts
Key way joints with a combination of the currently specified ODOT geometry and ODOT-approved grouts are incapable of carrying shear loads in conjunction with out-of-plane moments.

Suitable Modifications
Suitable modifications to key way geometry and the grout materials that were developed in this project were found to provide adequate joint shear strengths and performance under the simultaneous action of out-of-plane moment and shear.
Practical Issues
Observations During Demolition

Surface Cracks

Snipping Of Corroded Strands Corrosion

Joint Crack
Construction Process – Shreve, OH

1- Box-Beam Assembly

2- Dimensional Tolerance of Key Way

3- Oakum

4- Filling Key Ways

4- Sandblasted Surface

5- Placing Grout
Vertical differential deflections and horizontal differential movements due to a 67,400 lb truck were measured.
Dial gages were installed at 11 locations.
The joint locations were marked on the top of the bridge to drive the truck above the girder where the gages were attached.
Differential Deflection Measurements

Dimensions are in inches

Maximum differential deflections measured:
Vertical = 0.0045 inch
Horizontal = 0.015 inch

Maximum differential deflection between 7th and 8th box beam girders for loaded moving truck

ASD HW 42 MILE 12.49
Implementation
• Implementation was limited to simple changes to the key way geometry and the use of high strength grout materials in place of the currently used ODOT-approved grout.
• ODOT specifications relevant to the grouting and waterproofing membrane were marginally modified.
Implemented in April 2018

RIC-CR184-2.17 Over Kuhn Road, Shelby OH
Result of Implementation

• No cracks were found after five months
• Change order costed additional $4,450
Conclusions

• Membrane failure is not the primary cause of water leakage through the longitudinal joints of box-beam bridges.

• The currently used ODOT key ways are ineffective and the placement and consolidation of ODOT approved grouts impractical.

• Joint performance can be improved by
  (i) revising the key way geometry
  (ii) using high strength concrete grout
  (iii) better joint surface preparation, and
  (iv) strict enforcement of specifications.

• The recommended modifications are practical, achievable and easily implementable.
Acknowledgment

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Thank you

Questions?