Elimination of Deck Joints Using a Corrosion Resistant FRP Approach

Louisiana Transportation Conference
February 2009

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Acknowledgment

• LTRC – LA DOTD
  – State Project Number: 736-99-1391
  – Research Project Number: 06-2ST
• Dr. Guoqiang Li
• Mr. Walid Alaywan, P.E. (LTRC)
• Mr. Randy Young (LTRC)
• Mr. Darryl Moczygemba
  – Fibergrate, Stephenville Texas
• Ashok Aleti (PhD Candidate), Prashant Arasanagi (MS Candidate)
• Jim Ellingburg, Chris Fournerat, Lance Speer
Outline

• Background and Motivation
• Lab-scale Study
• Proof of concept study & characterization
• Full-scale beam study
  – Modeling (ANSYS) Theory
  – ANSYS Results
  – Experimental Work and Results
• Summary and Recommendations
Background and Motivation

• Bridge deck joint – critical structural component
• Steel reinforced linkslab – heavyweight and corrosion
• FRP rebar reinforced linkslab – sliding or slipping between FRP rebar and concrete
• FRP grid reinforced concrete linkslab – mechanical interlocking and positive composite action
Properties of FRP and Concrete

• Lab-made FRP grid
  – Fiber volume fraction 27%
  – $E_1=22.8$ GPa
  – $E_2=4.3$ GPa
  – $\nu_{12} = 0.32$

• Commercial FRP grid
  – Fiber volume fraction 27%
  – $E_1=18.4$ GPa
  – $E_2=6.1$ GPa
  – $\nu_{12} = 0.28$

• Concrete
  – Slump 15.2 cm
  – Air content 8.1%
  – 28-day compressive strength 50.0 MPa
  – Weight loss 0.0036 g/cm$^2$
Theoretical Studies using ANSYS Bridge Dimensions

Three Span Bridge Model

A Typical AASHTO Type III Girder

Four Girder model used for Modeling
Modeling Theory

Reinforced Concrete Element
- SOLID 65 “Commonly used for 3-D modeling of solids with or without reinforcing bars…. capable of cracking in tension and crushing in compression”

Fiber Reinforced Polymer (FRP)
- SOLID 46 “a layered structural element… designed to model thick layered shells or solids”
- Volumes for the girders, slabs, diaphragms and FRP were modeled
Modeling Theory

- Meshed Model
Modeling Theory

Loading System

- Truck load applied in analysis
  - AASHTO LRFD Specifications
  - HS20-44 (GVW- 72 kip )

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>Dead Load (DL)</th>
<th>Vehicular Live Load (LL)</th>
<th>Live Load Surcharge (LS)</th>
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<tbody>
<tr>
<td>Strength I Max</td>
<td>1.25</td>
<td>1.75</td>
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- HS-20 Truck
ANSYS Results

Girder Notations
Comparison between Flexural Stresses (Sz) for Bottom Elements of Third Girder in First Span (S1G3)
ANSYS Results (Girder Stresses)

Span2

Comparison between Flexural Stresses (Sz) for Bottom Elements of Third Girder in Second Span (S2G3)
ANSYS Results (Girder Stresses)

Comparison between Flexural Stresses (Sz) for Bottom Elements of Third Girder in Third Span (S3G3)
# ANSYS Results (Comparison of Girder Stresses)

<table>
<thead>
<tr>
<th>Girder no.</th>
<th>Open Joint Bridge</th>
<th>Link Slab Bridge</th>
<th>% Decrease in Girder Stresses due to link Slab</th>
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<tbody>
<tr>
<td></td>
<td>Maximum Flexural Stress (psi)</td>
<td>Location (in.) x, y, z</td>
<td>Maximum Flexural Stress (psi)</td>
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<tr>
<td>S1G1</td>
<td>308.9</td>
<td>0,0,384</td>
<td>253.7</td>
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<tr>
<td>S1G2</td>
<td>370.5</td>
<td>104,0,384</td>
<td>300.6</td>
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<td>S1G3</td>
<td>366.8</td>
<td>208,0,384</td>
<td>307.0</td>
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<tr>
<td>S1G4</td>
<td>312.8</td>
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<td>245.6</td>
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<tr>
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<td>0,0,1086</td>
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<td>S2G2</td>
<td>114.1</td>
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<td>0,0,1812</td>
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Comparison between Maximum Flexural Stresses (Sz) for Bottom Elements for bridge Girders
Experimental Work

• FIBERGRATE FRP Grid

FRP Grid
Experimental Work

Beam dimensions & Test set-up

- Rectangular beam was designed as per ACI 318-05
- Two beams were cast
- No shear reinforcement as depth < 10 inch
Experimental Work

- Instrumentation Plan

![Diagram of instrumentation plan with labels: FRP Grid, Layer 1, Layer 2, strain gage markers at specific intervals (e.g., 26", 30", 34", 39", 48", 57", 66", 70").]
Experimental Work

- Strain Gage Installation
- Fixing Strain Gages
Experimental Work
Experimental Work
Experimental Work

• Pouring the Concrete in Cylinders

• Cylinder Testing
Experimental Work

• Beam Testing

• Beam at Collapse
Experimental Results

- Concrete Age Curve

![Concrete Average Compressive Strength Graph]

- 8-inch concrete cylinders were cast and tested as per ASTM C39
Beam1 Results

Load Deflection Response for Beam1

- Max. deflection - 0.067 at an applied load of 26 kips
Beam1 Results

- **Max. tensile strain**: 4.8 milli strains at the ultimate load: 28.2 kips

- **Tensile stress**: 12 ksi (40% of max. tensile stress)
Beam1 Results

Layer1

Distribution of Longitudinal Strain along FRP Grid for Layer1 in Beam1
Beam1 Results

Layer1

Typical Load/Strain along FRP Grid for Layer1 in Beam1
Conclusions

• Durable link slabs for jointless bridge decks based on using FRP Grid for reinforcement. Specifically the ductility of the FRP material can be utilized to accommodate bridge deck deformations.

• The results indicated that the technique would allow simultaneous achievement of structural need (lower flexural stiffness of the link slab approaching the behavior of a hinge) and durability need of the link slab.

• A cost-effective solution to a number of deterioration problems associated with bridge deck joints.
Recommendations

- Durable jointless concrete bridge decks may be designed and constructed with FRP grid link slabs.
- It is recommended that the link slab technique is used during new construction of bridge decks.
- It is recommended that the advantages of using the FRP Grid link slab technique in repair and retrofit of bridge decks are considered along with the amount of intrusive field work required to develop the required mechanical properties at the bridge deck joints.
Future Application

- Field-level installation
- Bridge selection, off-system small-span bridge with expansion joints and RC deck on concrete girders
- Linkslab design function of geometry of deck, superstructure and substructure Information.
- FRP grid
  - Purchasing from manufacturer
  - If unavailable, lab-fabrication can be considered as an alternative
- Monitoring
  - Installation of strain gages
Audience

Comments / Questions