Mitigation of Girder Deck Construction
Joint Slippage in T-beam and Box Girder Bridges

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WBPP meeting
Sacramento, CA
December, 2010
What is this Presentation

• Since 2006 we have found 21 state bridges with slippage at the girder deck construction joint
  – 20 bridges located at Route 40 in the So Cal desert
  – one bridge located at highway 101 in SF Bay Area

• This presentation discusses
  – probable causes
  – methods of repair
  – changes in design specifications and construction procedures
Background - Rte 40 T-Beam Bridges

- In 2006, 12 Cast in Place T-beam girder bridges on Rte 40 experienced deck-girder interface joint failure

- 5 Girder - 3 interior girders had extensive interface cracking and movement the exterior girders were OK

- Interface cracks initiated at mid span, moved along the length and culminated in shear failure and fracture of shear and other reinforcement.

- All 12 bridges built under the same contract in 1973

- All 12 bridges replaced under emergency contract
Slippage at construction joint

Fracture of rebar
T-Beam multi span continuous - 38 to 55 foot spans

No. of Girders: 5

Width: 42 ft

Girder depth: 3 ft, Width: 13 inches

Girder spacing: 8 ft 6 in (6 ft 10)

Deck thickness: 6 ½ in (6 1/8 in)

Stem width: 13 inches
Fracture of shear Reinforcing
Investigation of T-beam Bridges

- Hired Wiss, Janney, Elstner Associates, Inc. (WJE) to investigate
  - Performed inspections took concrete rebar samples just prior to demolition
  - Performed material tests
  - Performed literature search
  - Performed detailed modeling of const joint
  - Reviewed design of bridge
WJE report – conclusions

• Primary Factors
  – *Inadequate construction joint roughness*
  – Design Specs - construction joint shear capacity dependant on joint roughness – joint fatigue
  – Inadequate quantity of joint/shear reinforcement
  – Truck load intensity and frequency (high stress-high cycle)
  – Deck stiffness - Concrete Modulus 30% lower severe deck cracking
Joint Horizontal Shear Capacity
AASHTO LFD

(b) When minimum ties are provided in accordance with paragraph 8.16.6.5.5, and contact surface is clean and free of laitance, but not intentionally roughened, shear strength \( V_{nh} \) shall not be taken greater than \( 80b_v d \), in pounds.

(c) When minimum ties are provided in accordance with paragraph 8.16.6.5.5, and contact surface is clean, free of laitance, and intentionally roughened to a full amplitude of approximately \( \frac{1}{4} \) inch, shear strength \( V_{nh} \) shall not be taken greater than \( 350b_v d \), in pounds.
Deck Cracking Route 40 T-Beam Bridges
WJE Report – Conclusions

• Secondary factors
  – Alkali silica reactivity (ASR) – minor and insignificant
  – Transverse moments at the joints (not a design parameter)
Background - Box Girder Bridges

- Concerns for I-40 Box Girder Bridges
  - “Lost-deck” forms stripped out of 10 RC box girder bridges built under the same contract
  - Girder-Deck interface cracks found in 8 of these box girder bridges
  - Failure had not reached the same “critical stage” as T beam bridges (not a diagonal shear crack yet)
Two of the Eight Box Girder Bridges with Deck/Girder Const Joint Cracks

- Single span and multi-span continuous
- Conventionally reinforced
- 5 girder
- 70 foot typical span length

Clipper Wash L/R

Rojo Wash, 54 0894L/R
Box Girder Problems

• Girder cracking similar to T beam bridges
  – Begins at 1/3 to 1/2 span and progresses towards supports
  – Longitudinal Slippage up to 1/32” along joint
  – Cracking only in middle 3 girders
  – Crack lengths vary from 5 feet to 25 feet
  – Moderate to severe deck cracking

• Slippage did not cause fracture of rebar
  – Live load deflections seemed normal
Box Girder Repair

- Hydro Demo Deck above girder construction joint and re-pour Concrete
- Must stage concrete removal so as to not shore bridge
- Relative costs (for 8 bridges total)
  - Replace bridges $23,000,000
  - Re-deck Bridges $11.5 million
  - Repair slipping joint $2.0 million
Staggered removal/replacement of deck concrete over girders so shoring of the bridge is not required
Hydro Demo leaves very rough surface for good construction joint bond
Novato Creek

- Multi girder T-beam left and right bridge
- Highway 101 Marin County
- 5 span continuous 38 foot spans
- Some slippage on interior girders
  - Right Bridge - 4 of 10 girder defective
  - Left Bridge - 3 of 8 girders defective
- Under truck lanes
Novato Creek Repair
November 2009

- Drill and Bond new #8 shear reinforcing headed bars 11 inches on center
- Epoxy inject one (worst) girder
- Install displacement devices to monitor effectiveness of repair over time
- This may not be a permanent repair
- This method of repair works well under traffic
DOELE SPACING AT TYPICAL GIRDER - PLAN

EXISTING GIRDER LAYOUT

SECTION A-A

GIRDER REPAIR DETAILS

NOTES:

1. Solid dots on arrow denote connection of existing girders.

2. Verify existing girders properly prior to drilling dowel holes. In existing girders, adjust spacing of new dowels to avoid interference with adjacent girders. Remove plugs and bond dowels in drilled holes. Fill through with high-strength concrete.

3. Apply crack injection along entire length of girders at girders 5 to 15 on right bridge only.

4. Provide 16 displacement sensors purchased and installed by Lomeco Technologies. Place sensors on midline of Span 2 on right bridge and midline of Span 4 on left bridge, 2 sensors on each location.

1 thru 10 - Indicates girder designation.
Construction joint cracking turning down into shear crack
Epoxy Injection Girder 6 right bridge
DECK CRACKING NOVATO CREEK
Instrumentation measure displacements in 3 directions
So far repairs have been effective. Dowels have significantly reduced and maintained relative displacement between girder and deck.

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<th>Girder 7</th>
<th>Girder 8 (Control)</th>
<th>Duration (Days)</th>
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Design Construction Changes

- Intentionally Roughen Construction Joint
- Shear steel maximum spacing 18 inches
Lessons Learned

• Bridge Preservation begins at Design and Construction
• Design practices should be consistent with construction practices
• Problems do not always occur where we expect them to occur