



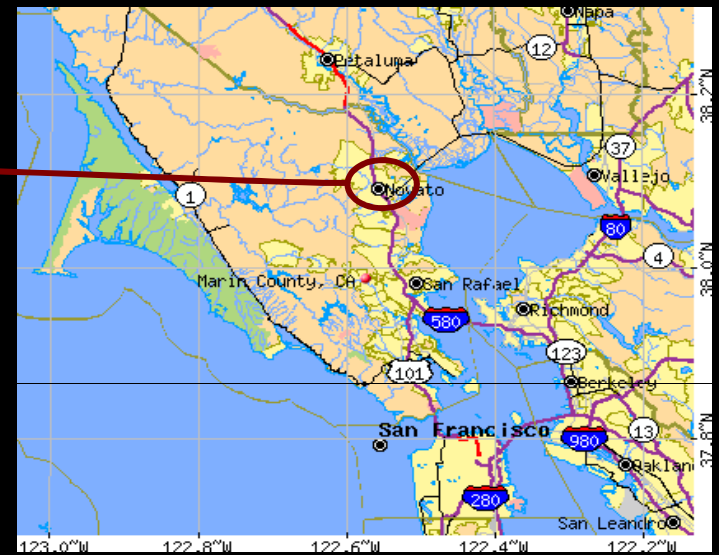
Mitigation of Girder Deck Construction Joint Slippage in T-beam and Box Girder Bridges

Anthony Gugino
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



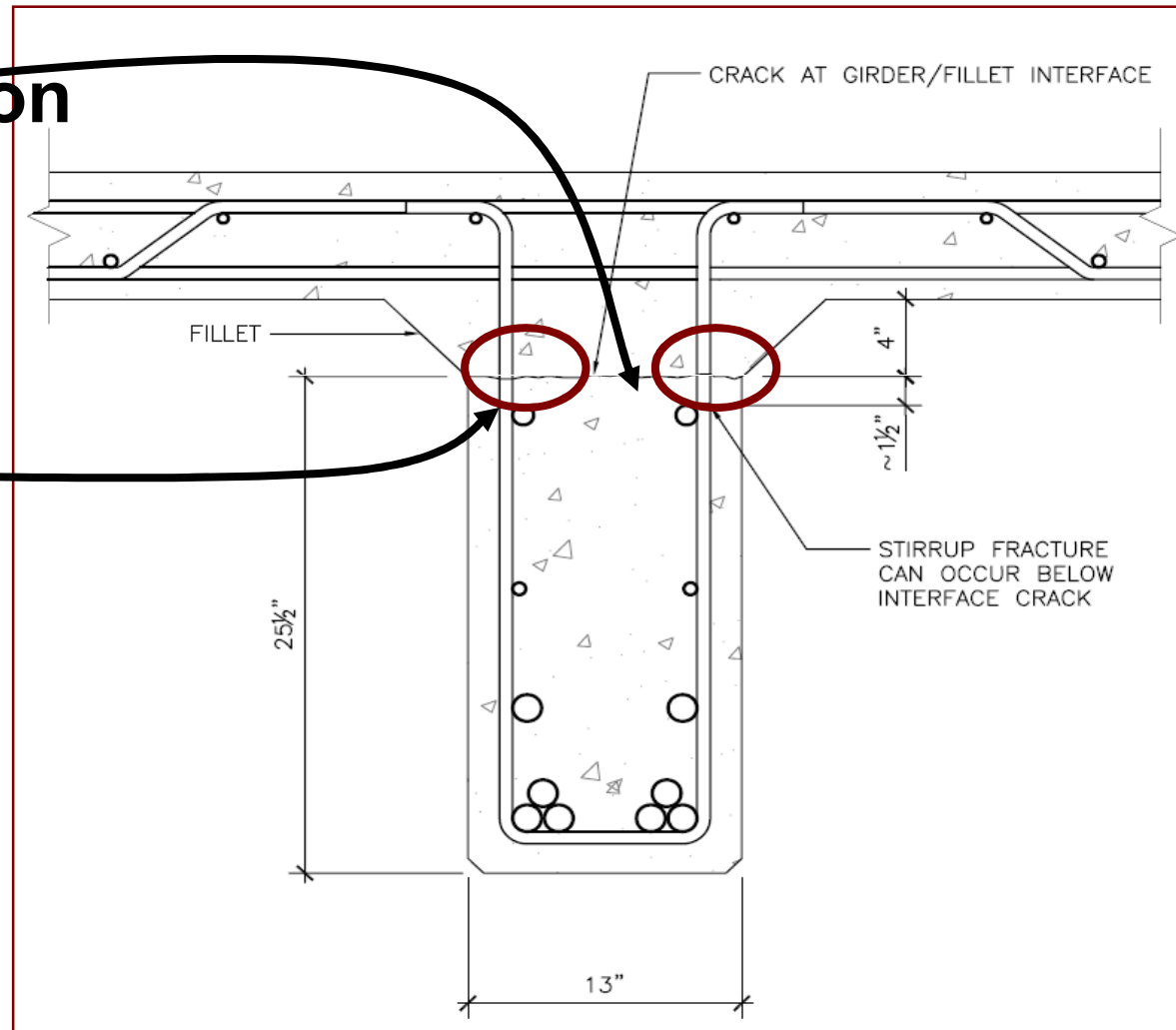


Background- Rte 40 T-Beam Bridges

- 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

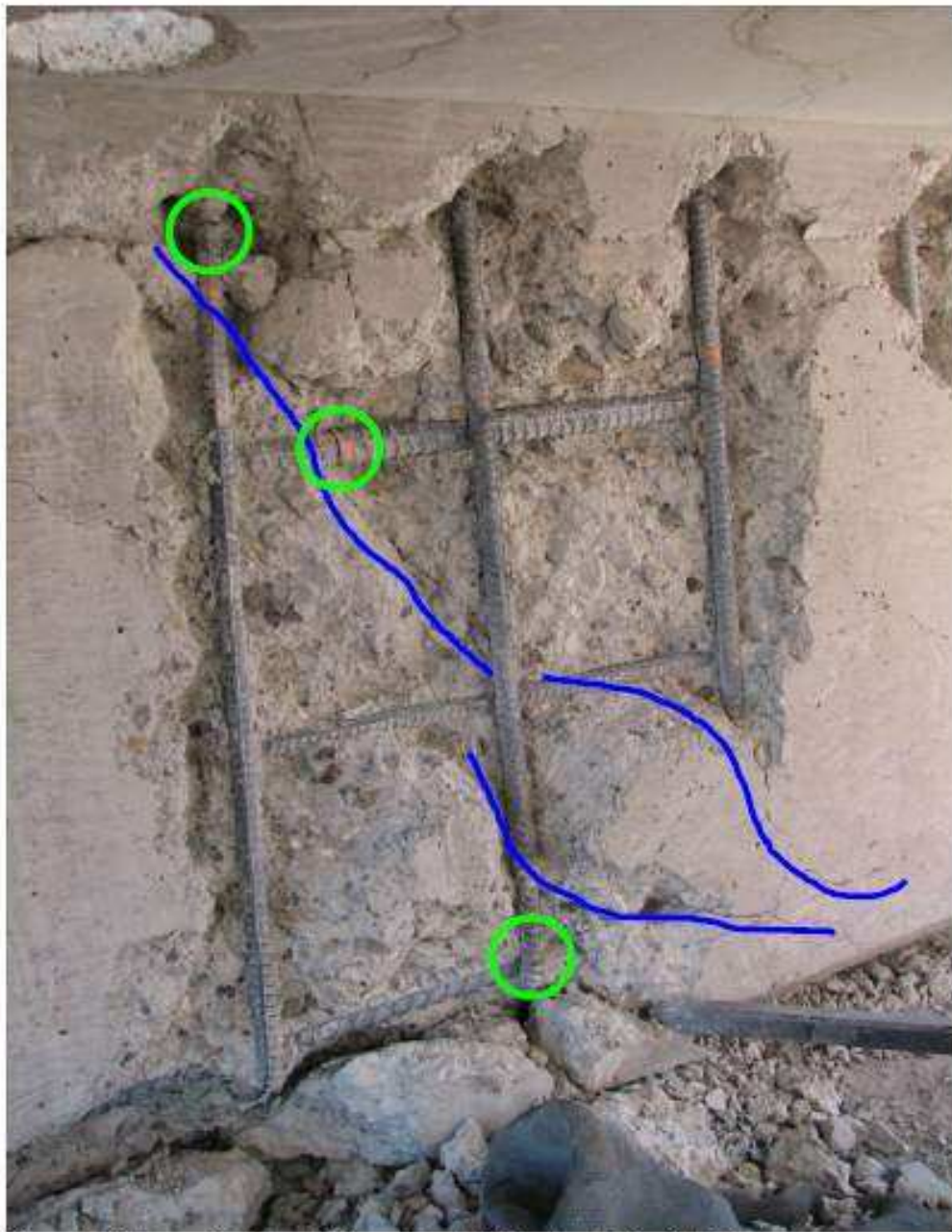
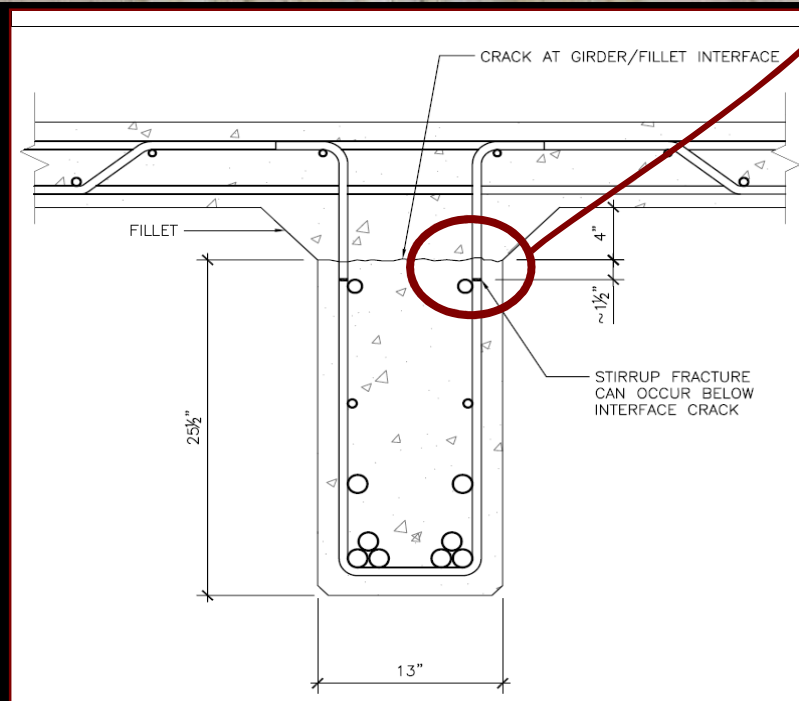


Figure 5: Mustang Section #4 Shear Crack & Fractured Bars [197.jpg]



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

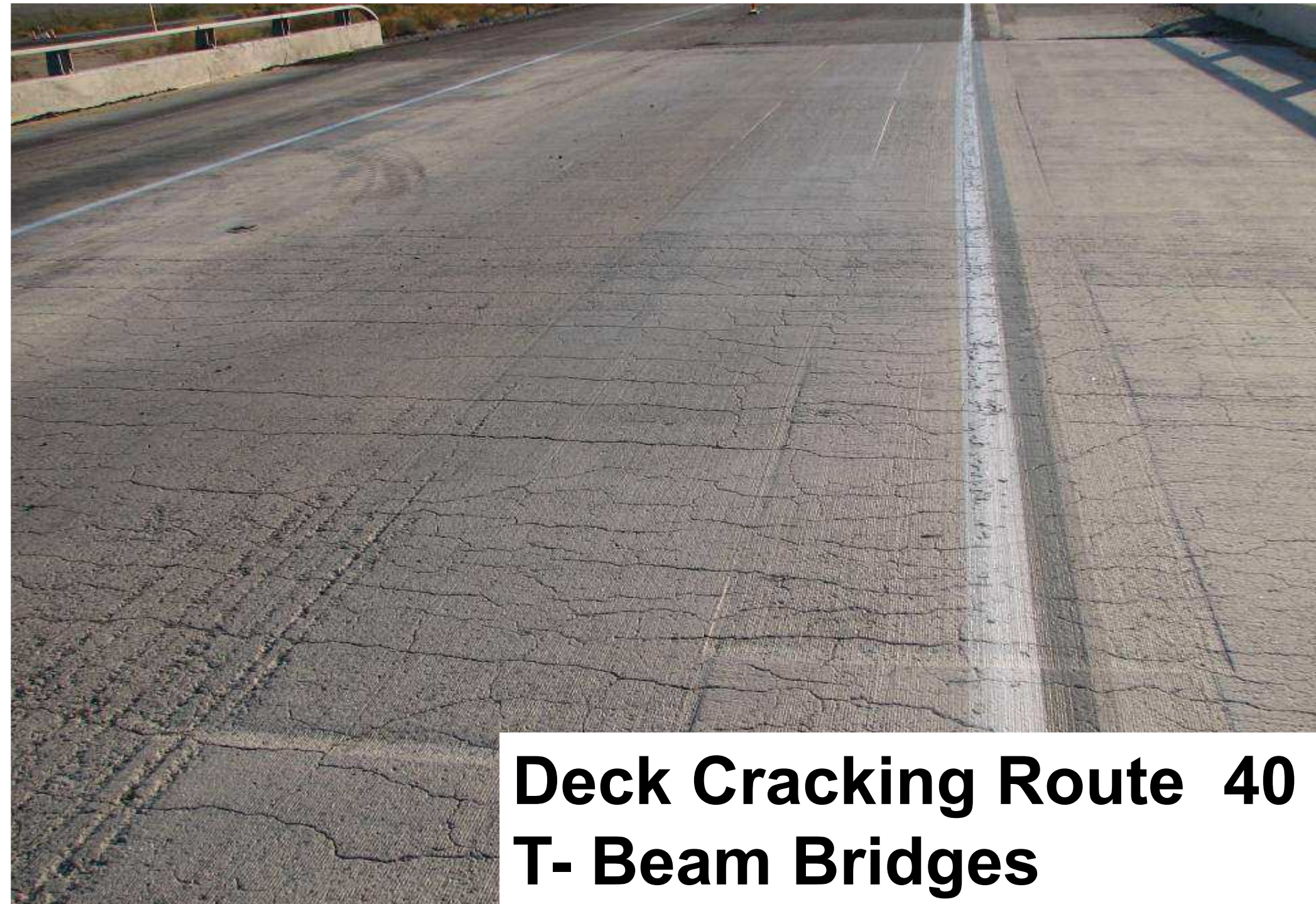
- **Primary Factors**
 - *Inadequate construction joint roughness*
 - **Design Specs - construction joint shear capacity dependant on joint roughness – joint fatigue**
 - **Inadequate quantity of joint/ shear reinforcement**
 - **Truck load intensity and frequency (high stress-high cycle)**
 - **Deck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

Construction Joint Roughness



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 $80b_vd$, 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 $1/4$ inch, shear strength V_{nh} shall not be taken greater than $350b_vd$, 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



Clipper Wash L/R



Rojo Wash, 54 0894L/R

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

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

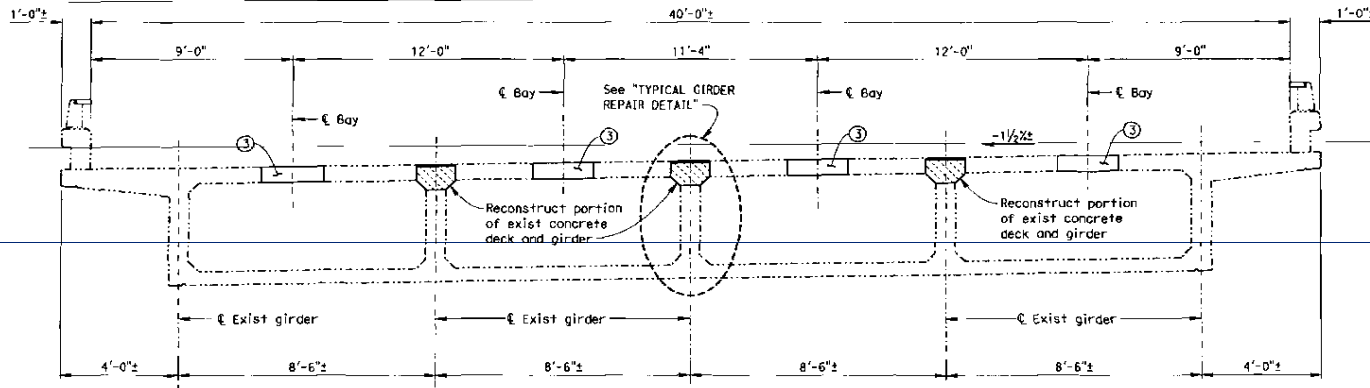


Box Girder Repair

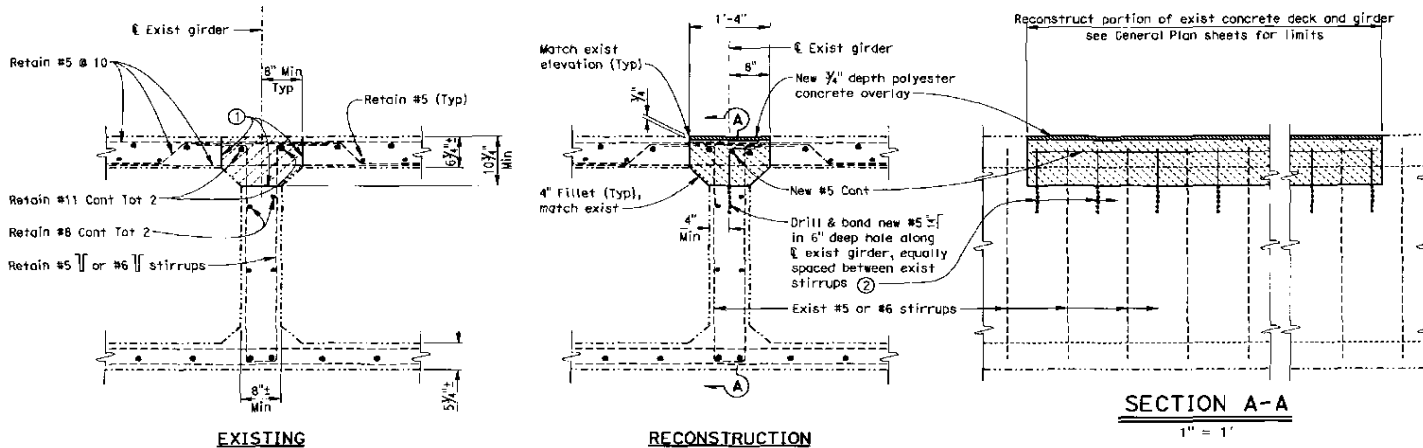
- **Hydro Demo Deck above girder construction joint and re-pour Concrete**
- **Must stage concrete removal so as to not shore bridge**
- **Relative costs (for 8 bridges total)**
 - **Replace bridges** **\$23,000,000**
 - **Re-deck Bridges** **\$11.5 million**
 - **Repair slipping joint** **\$2.0 million**



Box Girder Bridge Repair



TYPICAL SECTION
LEFT BRIDGE SHOWN, RIGHT BRIDGE SIMILAR
1/2" = 1'



TYPICAL GIRDER REPAIR DETAIL
1" = 1'

08	SBd	10	
REGISTERED CIVIL ENGINEER DATE		X	
PLANS APPROVAL DATE		CIVIL	

THE STATE OF CALIFORNIA or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of these plans.

- NOTES: (APPLY TO THIS SHEET ONLY)**
- ▨ Indicates limits of sawcut 1/2" and remove existing concrete and retain existing reinforcing steel. The intention is to remove concrete to horizontal crack in girder stem.
 - ▨ Indicates limits of place new concrete.
 - ① Roughen existing concrete surface to 1/2" amplitude.
 - ② See GIRDER REPAIR DETAILS NO. 2 sheet for existing girder stirrup spacing.
 - ③ New temporary deck access opening, for details see TEMPORARY DECK ACCESS OPENING DETAILS sheet.

GENERAL NOTES
LOAD FACTOR DESIGN

DESIGN: BRIDGE DESIGN SPECIFICATIONS (1996 AASHTO with Interims and Revisions by CALTRANS)

DEAD LOAD: Includes 35 psf for future wearing surface.

LIVE LOADING: HS20-44 and alternative.

REINFORCED CONCRETE: f_y = 60,000 psi
f'_c = 3,600 psi
n = 9

INCOMPLETE PLAN FOR DESIGN STUDY PRINTED
DATE: 23-APR-2008
TIME: 09:01
STRUCTURE MAINTENANCE AND INVESTIGATIONS
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DESIGN	BY Khanh Truong	CHECKED Tim Powell	BRIDGE NO.	VARIOUS	ROUTE 40 BRIDGES (GIRDER REPAIR)
DETAILS	BY G.F. Bidwell	CHECKED Tim Powell	POST MILE	VARIES	
QUANTITIES	BY Khanh Truong	CHECKED Hossein Mozami	VARIES	VARIES	

STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

DIVISION OF MAINTENANCE STRUCTURE MAINTENANCE DESIGN

CU 08 EA 0L6401

DATE: 08-01-04

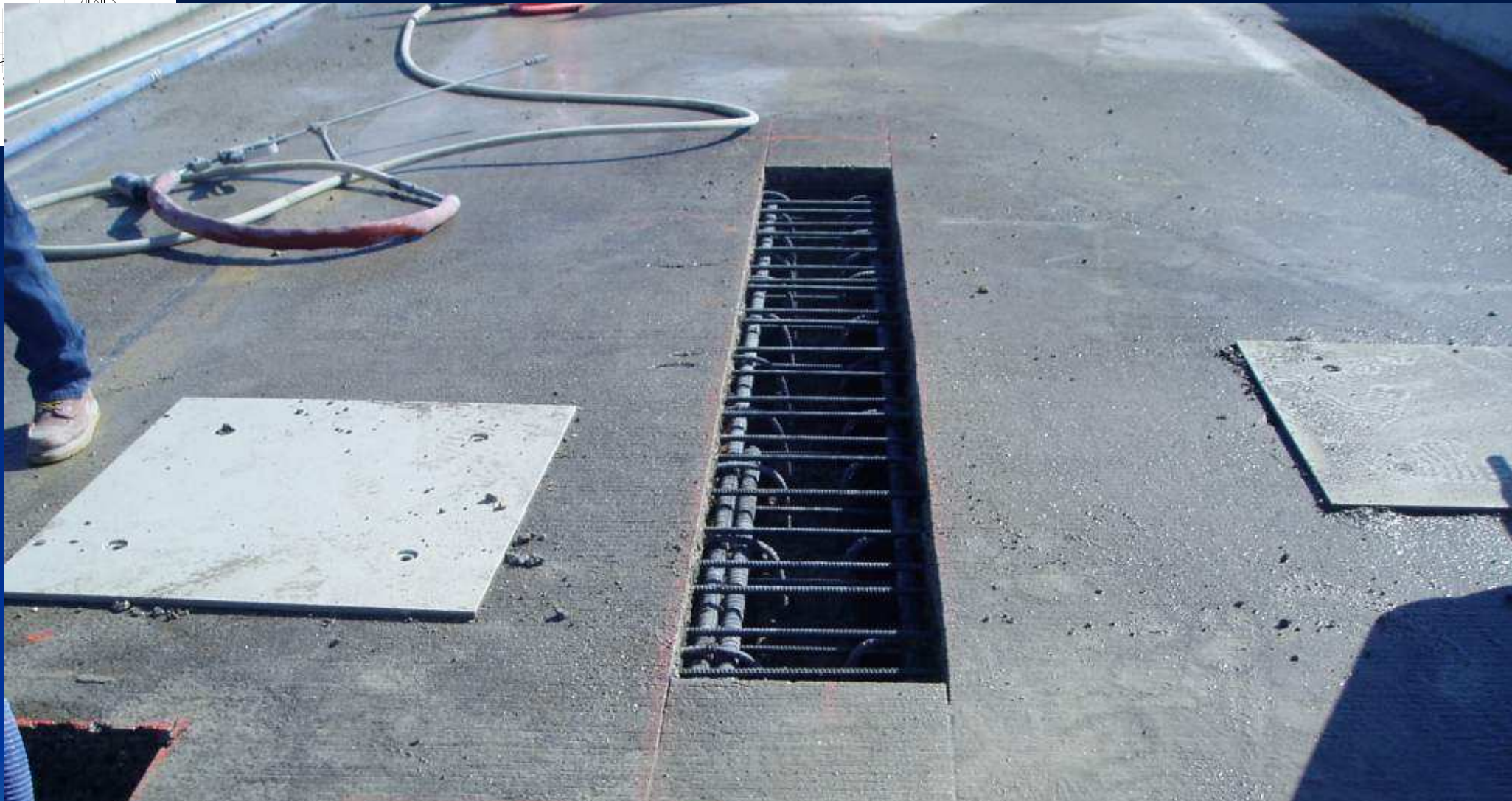
REVISIONS: 1, 2, 3

SCALE: ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

DATE PLOTTED: 09/01

DATE PLOT: 03/23/08

USER: 08-01-04-01-05skd1st.dgn



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

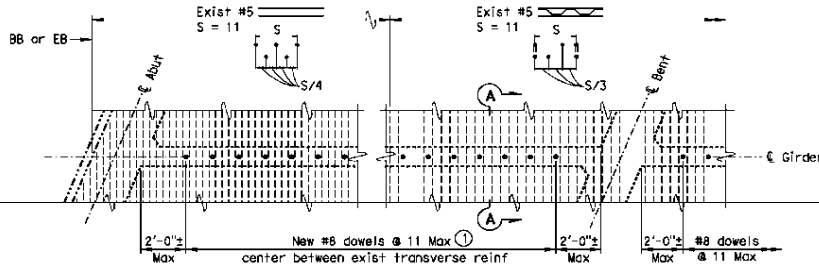
- **Multi girder T-beam left and right bridge**
- **Highway 101 Marin County**
- **5 span continuous 38 foot spans**
- **Some slippage on interior girders**
 - **Right Bridge - 4 of 10 girder defective**
 - **Left Bridge - 3 of 8 girders defective**
- **Under truck lanes**





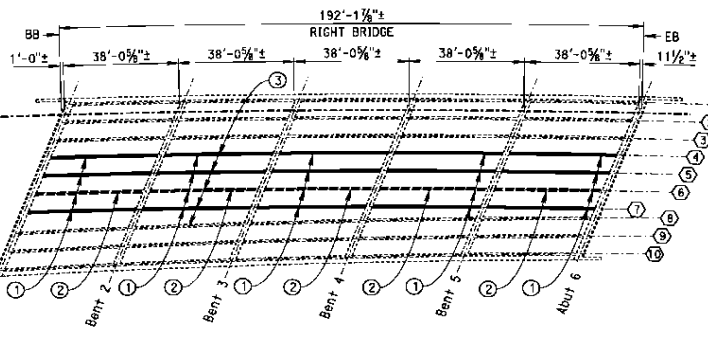
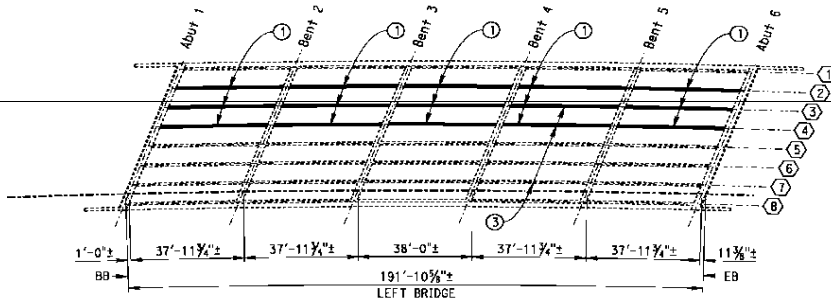
Novato Creek Repair November 2009

- **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**



DOWEL SPACING AT TYPICAL GIRDER - PLAN

NO SCALE



EXISTING GIRDER LAYOUT

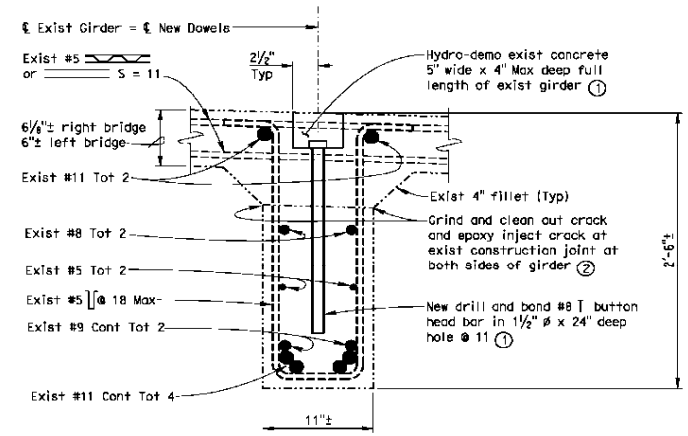
1" = 20'

DIST	COUNTY	ROUTE	POST MILES	SHEET	TOTAL
04	Mvn	101	TOTAL PROJECT	NO.	SHEETS
 REGISTERED CIVIL ENGINEER			DATE	9-14-09 Exp. 3-31-10	
PLANS APPROVAL DATE					
<small>THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF ELECTRONIC COPIES OF THIS PLAN SHEET.</small>					

NOTES: (APPLY TO THIS SHEET ONLY)

- ① Drill holes for dowels along centerline of existing girder. Verify existing girder spacing prior to drilling dowel holes. Ferrascan deck to locate existing reinforcement prior to drilling for new dowels. Adjust spacing of new dowels to avoid existing reinforcement. Plug drilled holes and hydro-demo trough in existing concrete deck along girder centerline full length of girder. Remove plugs and bond dowels in drilled holes. Fill trough with rapid-strength concrete.
- ② Epoxy inject cracks along entire length of girder at Girder 6 on Right Bridge only.
- ③ Provide 16 displacement sensors purchased from and installed by Lifespan Technologies. Place sensors on indicated girders at middle of Span 2 on Right Bridge and middle of Span 4 on Left Bridge, 2 sensors at each location.

1 thru 10 - Indicates girder designation.



SECTION A-A

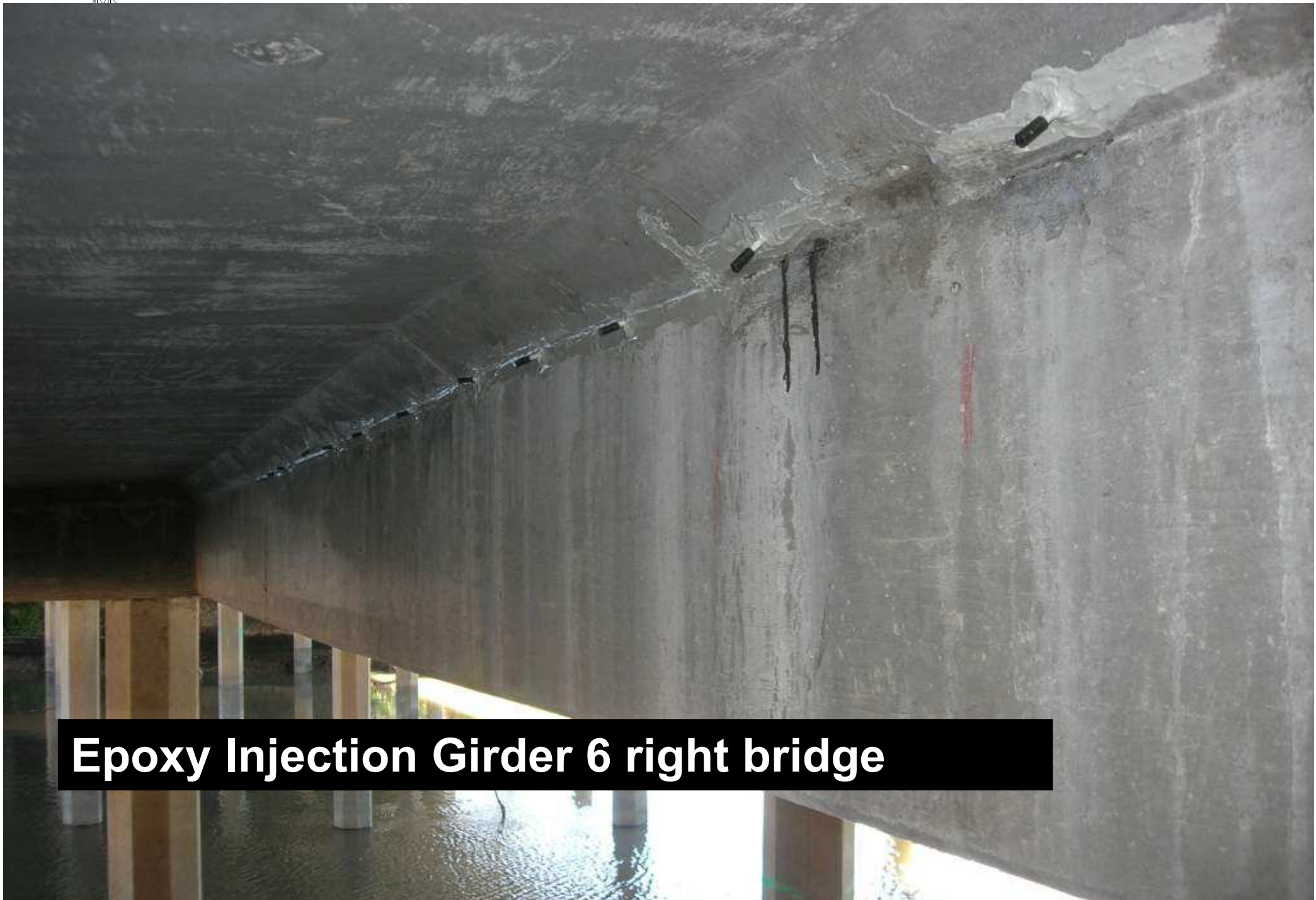
2" = 1"

DESIGN BY D. Vanderahaf CHECKED M.J. Lee DETAILS BY G.F. Bidwell CHECKED M.J. Lee QUANTITIES BY D. Vanderahaf CHECKED M.J. Lee	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF MAINTENANCE STRUCTURE MAINTENANCE DESIGN	BRIDGE NO. 27-0069R/L POST MILE 20.6	NOVATO CREEK (REPAIR GIRDERS) GIRDER REPAIR DETAILS	
				ORIGINAL SCALE IN INCHES FOR REDUCED PLANS	REVISION DATES



**Construction joint
cracking turning down into
shear crack**



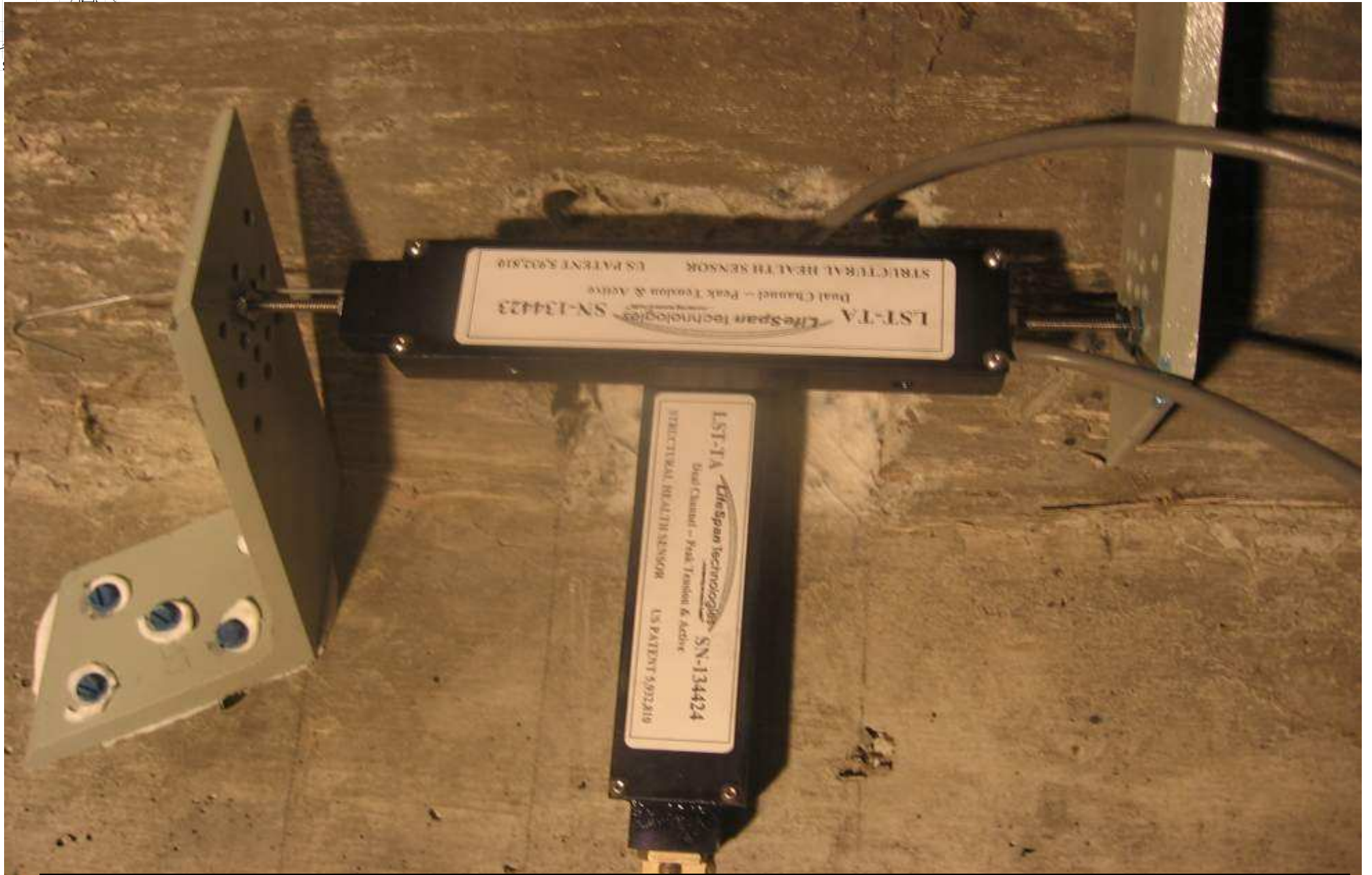


Epoxy Injection Girder 6 right bridge

A wide-angle photograph of a concrete deck, likely on a bridge or overpass. The deck is covered in a dense network of fine, irregular cracks, some of which are quite deep. A single white line is painted across the deck in the upper third of the image. In the background, a dark metal guardrail runs along the edge of the deck, with some greenery visible behind it. The overall scene is brightly lit, suggesting a sunny day.

DECK CRACKING NOVATO CREEK





Instrumentation measure displacements in 3 directions

Right Bridge over Novato Creek on Route 101 (27-0089R)

Peak Relative Horizontal Displacements (Microns)						Peak Relative Vertical Displacements (Microns)					
Girder 4	Girder 5	Girder 6	Girder 7	Girder 8 (Control)	Duration (Days)	Girder 4	Girder 5	Girder 6	Girder 7	Girder 8 (Control)	Duration (Days)
238	286	479	626	180	19	150	111	30	100	23	19
3	51	2	3	0	1	11	17	5	32	0	1
3	51	2	3	8	27	19	31	11	45	5	27
3	56	2	33	26	90	27	33	19	48	5	90
5	59	2	33	26	140	27	33	19	48	5	140
5	59	2	33	26	257	27	33	19	48	5	257

So far repairs have been effective. Dowels have significantly reduced and maintained relative displacement between girder and deck.

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**