American Segmental Bridge Institute

2022 Construction Practices for Segmental Concrete Bridges

Inspection and Maintenance of Segmental Bridges

Purpose

The Seminar on Construction Practices for Concrete Segmental and Cable-Supported Bridges is intended to provide a basic understanding of segmental construction technology with the goal of facilitating the construction process, avoiding some problems previously encountered, and reducing delays and costs caused by concern over non-critical construction issues, or lack of understanding of critical issues.

At the end of the Seminar, participants will understand:

- **The Advantages of Segmental Construction**
- **Segmental Structure Types:**
  - Precast Segmental Span-by-Span
  - Precast Segmental Balanced Cantilever Bridges
  - Precast Segmental Progressive Placement
  - Cast-in-Place Segmental Balanced Cantilever Bridges
  - Cast-in-Place Segmental Incremental Launching
  - Precast and Cast-in-Place Segmental Cable-Stayed Bridges
- **General, Post-Tensioning and Grouting Terminology**
- **Special Requirements for Construction of Concrete Segmental Cable-Supported Bridges**
- **Segmental Substructures**
- **Production of Precast Segments**
- **Handling Transporting and Erecting Precast Segments**
- **Geometry Control**
- **Bearings and Expansion Joints**
- **Lessons Learned**
- **QA QC Inspection Guidelines for Segmental Concrete Bridges**

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Best Practices for NBIS Inspection of Segmental Bridges

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NBI Condition Ratings

Federal Highway Administration, Bridge Inspector's Reference Manual (BIRM)

Condition codes are properly used when they provide an overall characterization of the general condition of the entire component being rated. Conversely, they are improperly used if they attempt to describe localized or nominally occurring instances of deterioration or disrepair. Correct assignment of a condition code must, therefore, consider both the severity of the deterioration or disrepair and the extent to which it is widespread throughout the component being rated. - FHWA Coding Guide

Although the *FHWA Coding Guide* states that it is improper to use the condition codes to describe localized instances of deterioration or disrepair, it also states that the inspector must consider both the severity and extent of the deterioration. With this in mind, there are occasions when a severe, localized condition affects the structural capacity of a component member.

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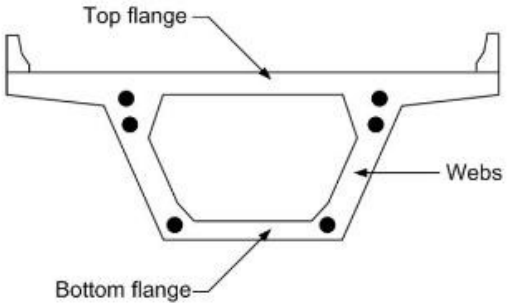
NBI Condition Ratings

Federal Highway Administration, Bridge Inspector's Reference Manual (BIRM)

Evaluating Components - The following major components of bridges receive an overall Structure Inventory and Appraisal (SI&A) component condition rating:

- Item No. 58 – Deck
- Item No. 59 – Superstructure
- Item No. 60 – Substructure



- Code Description
- N NOT APPLICABLE
- 9 EXCELLENT CONDITION
- 8 VERY GOOD CONDITION - no problems noted.
- 7 GOOD CONDITION - some minor problems.
- 6 SATISFACTORY CONDITION - structural elements show some minor deterioration.
- 5 FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
- 4 POOR CONDITION - advanced section loss, deterioration, spalling, or scour.
- 3 SERIOUS CONDITION - loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
- 2 CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
- 1 "IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components, or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put bridge back in light service.
- 0 FAILED CONDITION - out of service; beyond corrective action.

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NBI Elemental Condition States

AASHTO Guide Manual for Bridge Element Inspections

- **National Bridge Elements (NBEs)** – Primary structural components (load carrying members). Cannot be modified, generic to afford consistency across agencies.

- **Bridge Management Elements (MBEs)** – Elements that are added to suit an agency's needs. Must be a part of a primary load carrying member and have a distinct functional role. Examples include, expansion joints, wearing surfaces, protective coatings, etc.

- **Condition States (CS)** – Describe the severity of the defect with a 1-4 scale. CS-1 is good, CS-4 is severe. The AASHTO Guide Manual for Bridge Element Inspections provides guidance on typical condition states based on common defects.

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NBI Elemental Condition States

AASHTO Guide Manual for Bridge Element Inspections

NBE No.	Description
• **Decks/Slabs**	
• 15	Prestressed/Reinforced Concrete Top Flange*
	• * Note that this element designation is used regardless of the type of riding surface
• **Superstructure**	
• 104	Prestressed Concrete Closed Web/Box Girder

BME No.	Description
• **Wearing Surfaces and Protection Systems**	
• 520	Deck/Slab Protection Systems
• 521	Concrete Protective Coating

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NBI Elemental Condition States

- Combination of NBI Condition Ratings and Elemental Condition States provides owners with a detailed evaluation of the structures condition and how to best maintain the structure by being proactive in addressing minor defects.
- For Example: A mile long segmental box girder superstructure has had a Condition Rating of 7 for the past few cycles mostly due to minor shrinkage cracking. During the current inspection, the inspector finds a 4 square feet spall with exposed rebar. Because this spall is an isolated defect and not systemic across the more than 5,000 feet of superstructure, the inspector maintains the Condition Rating of 7.

  Without the Elemental Condition States, this defect would only be recorded in the Bridge Inspection Report comments and potentially overlooked by structure management. The elemental process allows owners to identify these minor defects and repair them before they grow to the point of affecting Condition Rating because they have now become detrimental to the load capacity.

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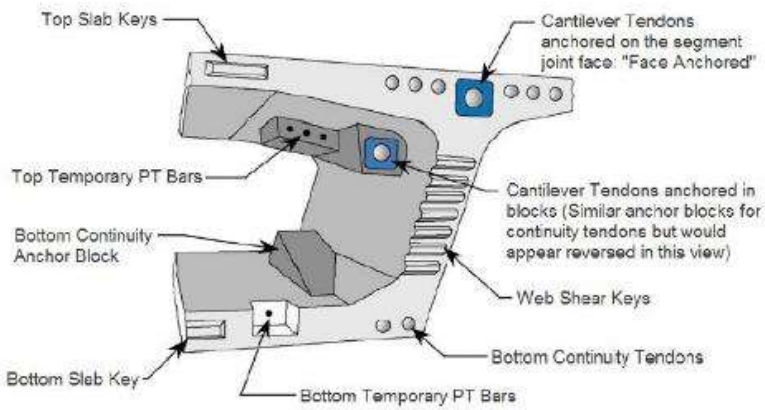
Best Practices



- Prestressed concrete box girders are designed to limit tensile stresses in the concrete. Therefore, cracks need to be identified and thoroughly investigated to determine cause and severity.
- Visual and physical inspection with sounding rods, hammers, and chain drags should be used to find delaminations. Crack gauges with color coding keel can be used to measure and track crack propagation.

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Best Practices

Precast concrete box culvert top slab cracking (Visual Inspection)

Solely based on visual inspection the top slab may have been rated a 6.

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Best Practices

Precast concrete box culvert top slab cracking (Physical Inspection)

After physical inspection, structure was rated a 3 and required load posting.

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Best Practices

Common deficiencies that occur on concrete box girder bridges include:

- Cracking (structural, flexure, shear, crack size, nonstructural, crack orientation)
- Scaling
- Delamination
- Spalling
- Chloride contamination
- Freeze-thaw
- Efflorescence
- Alkali silica reactivity (ASR)
- Ettringite formation
- Honeycombs
- Pop-outs
- Wear
- Collision damage
- Abrasion
- Overload damage
- Internal steel corrosion (Rust Leaching)
- Loss of prestress
- Carbonation

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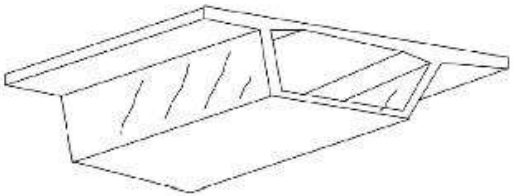
Best Practices
Types of Cracking

Shear Zones

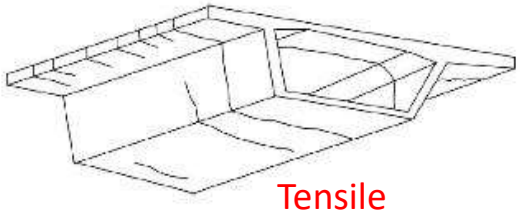
Check girder ends and sections close to piers for diagonal shear cracks in webs. These web cracks will project diagonally upward at approximately a 45 degree angle from the support toward midspan (see Figure 9.11.29).



Shear

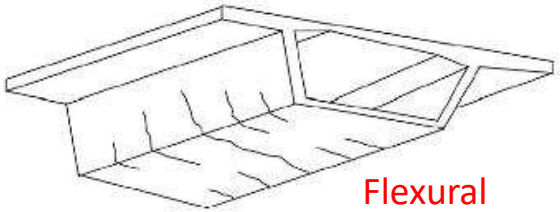
Tension Zones

Direct Tension - Tension cracks can appear as a series of parallel cracks running transverse to the longitudinal axis of the bridge. The duct cracks are normally located on both sides of the longitudinal or neutral axis. The cracks can possibly be through the entire depth of the box girder section. Cracks will probably be spaced at approximately 1 to 2 times the minimum thickness of the girder component (see Figure 9.11.30).

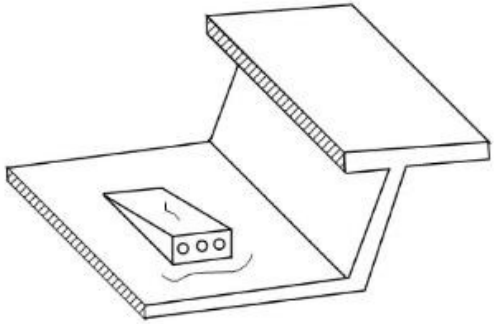


Tensile

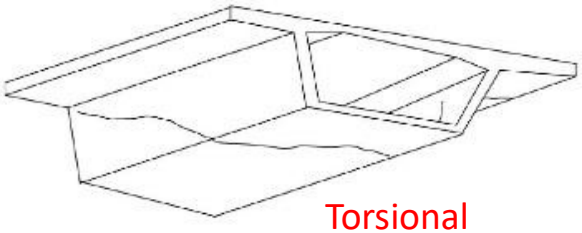
Flexure - These cracks can appear in the top flange at pier locations and on the bottom flange at mid-span regions. The extent of cracking will depend on the intensity of the bending being induced. Flexure cracks will normally propagate to the neutral axis or to an area around the half-depth of the section. Examine flexural cracks found in post-tensioned members very carefully. This could indicate that the member is overstressed. Accurately identify the location of the crack, the length and width of the crack, and the spacing to adjacent cracks (see Figures 9.11.31 and 9.11.32).



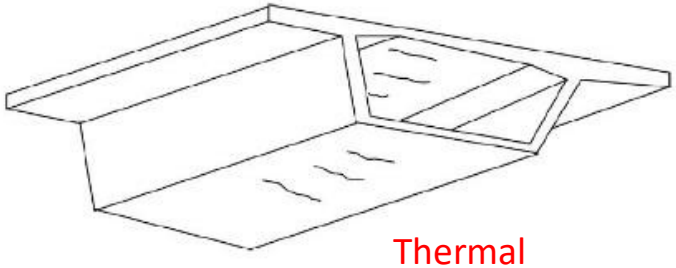
Flexural



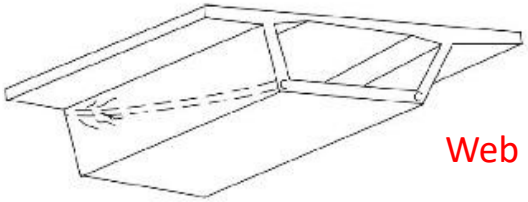
Anchorage



Torsional



Thermal



Web Splitting

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Best Practices
Wearing Surfaces

Latex Modified Concrete Overlay

- Latex Modified
- Polyester Overlay
- Epoxy Overlays
- High Performance Concrete

Thin Epoxy Overlay

- Rideability
- Drainage
- Waterproofing
- Top Flange Protection (Transverse PT)

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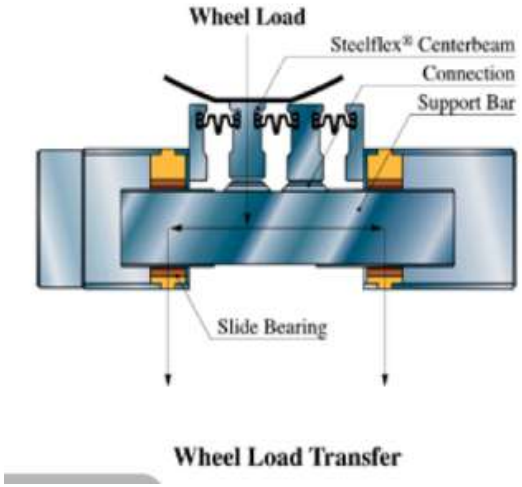
Best Practices
Expansion Joints

Modular Expansion Joint

Joint Device Symbol	Model Number	Total Movement	Cells	"A" Blockout Depth	"B" Blockout Width	"C" Min.	"C" Max.	"W" Mid Temp	"X"
	D-160	6.30 (160)	2	14 (356)	15 (391)	3.35 (85)	5.71 (145)	8.17 (208)	12.2 (310)
	D-240	9.45 (240)	3	14 (356)	18 (457)	4.92 (125)	9.65 (245)	12.24 (311)	12.2 (310)
	D-320	12.60 (320)	4	14 (356)	22 (559)	6.50 (165)	13.78 (350)	16.32 (415)	12.2 (310)
	D-400	15.75 (400)	5	14 (356)	25 (635)	8.07 (205)	17.91 (455)	20.39 (519)	12.2 (310)
	D-480	18.90 (480)	6	14 (356)	28 (711)	9.65 (245)	21.85 (555)	24.47 (622)	12.2 (310)
	D-560	22.05 (560)	7	14 (356)	31 (787)	11.22 (285)	25.98 (660)	28.54 (725)	12.2 (310)
	D-640	25.20 (640)	8	15.25 (387)	34 (864)	12.80 (325)	30.12 (765)	32.62 (829)	13.3 (338)
	D-720	28.35 (720)	9	15.5 (394)	37 (940)	14.37 (365)	34.06 (865)	36.69 (932)	13.6 (345)



Load Transfer

- Number of seals based on necessary expansion and contraction
- Provides wheel load transfer when in excess of typical 4” joint
- Provides watertight seal to protect superstructure elements
- Listen for clicking or slapping sounds under traffic
- Barrier and fascia opening should match joint opening (distress of barrier plates)
- Susceptible to snowplow damage (early spring inspection)

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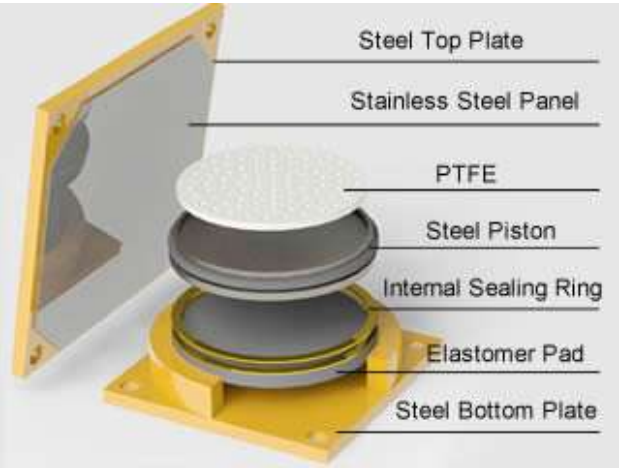
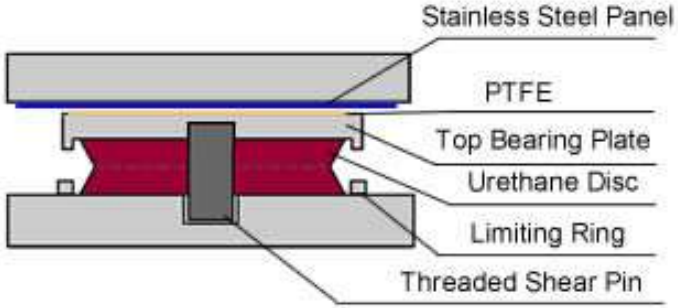
Best Practices
Bearings



Pot Bearing

- Multi-directional
- Rotational
- Sealed bottom pot
- Difficult to Inspect
- Leaking sealing ring
- Wear to top plate
- Excessive rotation (Measuring plates)



Disc Bearing

- Multi-directional
- Rotational
- Urethane Disc
- All components visible
- Grout integrity, cracking
- Deformation of urethane disc
- Wear to top plate

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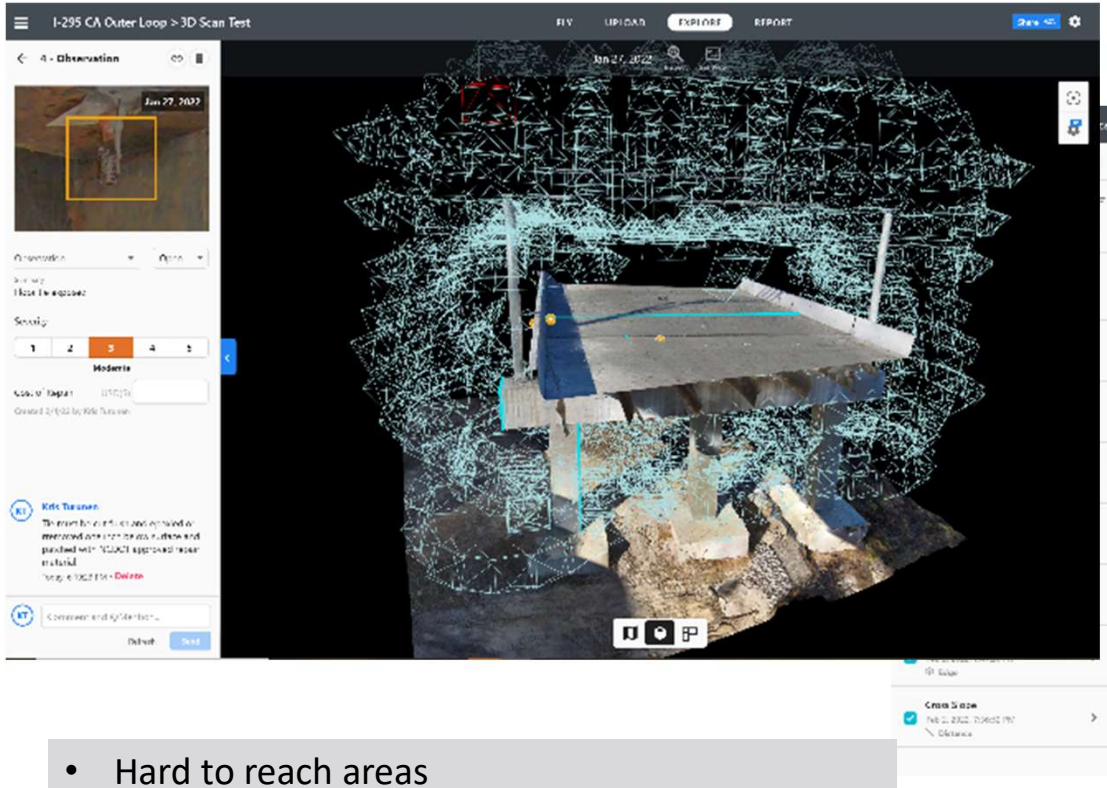
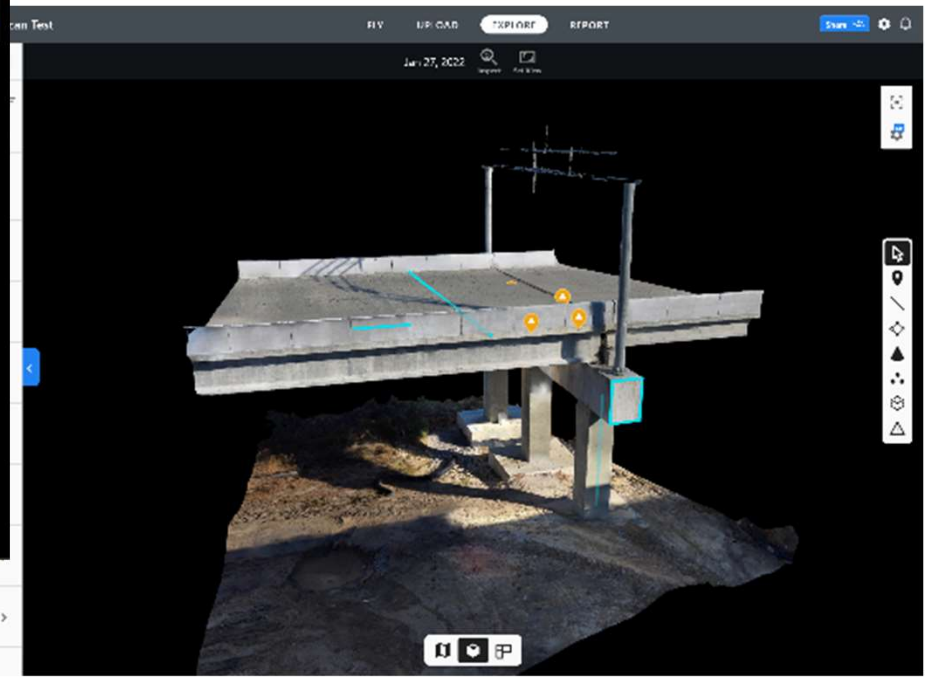
Best Practices

Drones





- Hard to reach areas
- Pier columns and caps
- Preliminary analysis to identify hands-on needs

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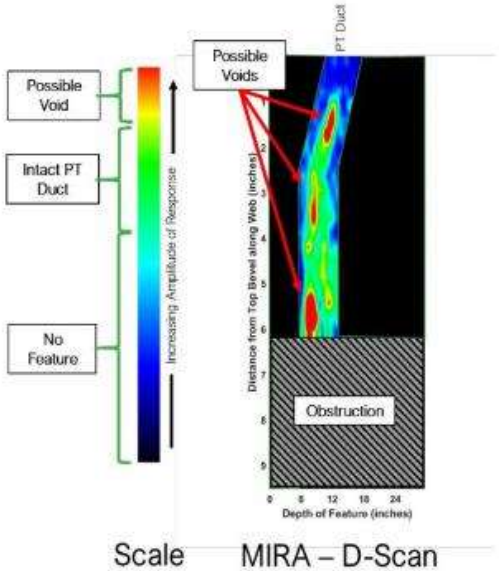
Best Practices

Advanced Inspection Techniques

- Acoustic wave sonic
- Electrical methods
- Delamination detection machinery
- Ground-penetrating radar
- Electromagnetic methods
- Pulse velocity
- Flat jack testing
- Impact-echo testing
- Infrared thermography
- Laser ultrasonic testing
- Magnetic field disturbance
- Neutron probe for detection of chlorides
- Nuclear methods
- Pachometer
- Rebound and penetration methods
- Ultrasonic testing
- Radiography

NDE

Tendon Bore Scope



Ultrasonic Tomography (MIRA)

BDI
RAW DATA. REFINED RESULTS.

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Best Practices for Maintenance of Segmental Bridges

Segmental Bridge Maintenance

Best Practices

- Much the same as typical reinforced concrete maintenance
- Cleanliness is key
  - Bird fencing
  - Debris and litter pick-up
  - Drain cleaning
  - Sweeping
  - Vegetation control
  - Joint clean-out
  - Graffiti Control
  - Accident Response
- Access for aerial equipment
- Epoxy crack injection
- Concrete patching
- Carbon fiber wrapping
- External post-tensioning strengthening
- Scour and erosion control
- De-icing practices
- Structural health monitoring

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Best Practices
Crack Injection

- Seals cracks to prevent moisture intrusion and corrosion
- Epoxy sealant brittle enough to monitor re-cracking
- Full depth/width injection
- Non-aesthetic, can be ground smooth and coated with CSC

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Best Practices

Carbon Fiber Wrapping

Fumed Silica

Wet Layup Application

- Improves shear and flexural strength
- Confinement for concrete patches
- Surface prep dependent
- Susceptible to impact and UV damage (can be coated)

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Best Practices

Concrete Surface Preparation

CSP Chips

- http://www.icri.org/
- $129 non member
- $90 members

Thin Overlay Surface Prep

- International Concrete Repair Institute Guideline No. 03732 defines the profiles:
  - CSP 1 – Acid Etched
  - CSP 2 – Grinding
  - CSP 3 – Light Shotblast (Healer Sealer)
  - CSP 4 – Light Scarification
  - CSP 5 – Medium Shotblast
  - CSP 6 – Medium Scarification
  - CSP 7 – Heavy Abrasive Blast (Thin Epoxy Ovly)
  - CSP 8 – Scabbed
  - CSP 9 – Heavy Scarification

- Maintenance activities dependent on surface prep
  - Deck Overlays (Thin epoxy, healer sealer)
  - Carbon fiber wrapping
  - Concrete surface coating

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Best Practices

Wearing Surface Maintenance

- Thin Epoxy Overlays to seal cracks and improve ride
- Penetrating Healer Sealers to seal cracks
- Crack Chasing when cracking is minor
- Deck Patching
- Surface Prep
- Skid Resistance (Bauxite)
- Dead Load Considerations, multi layer systems can add significant weight

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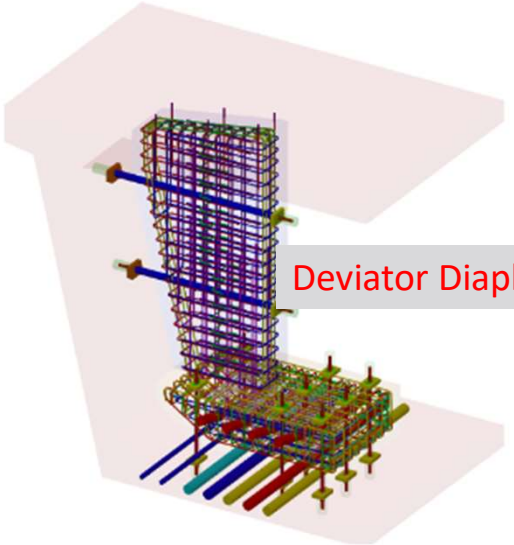
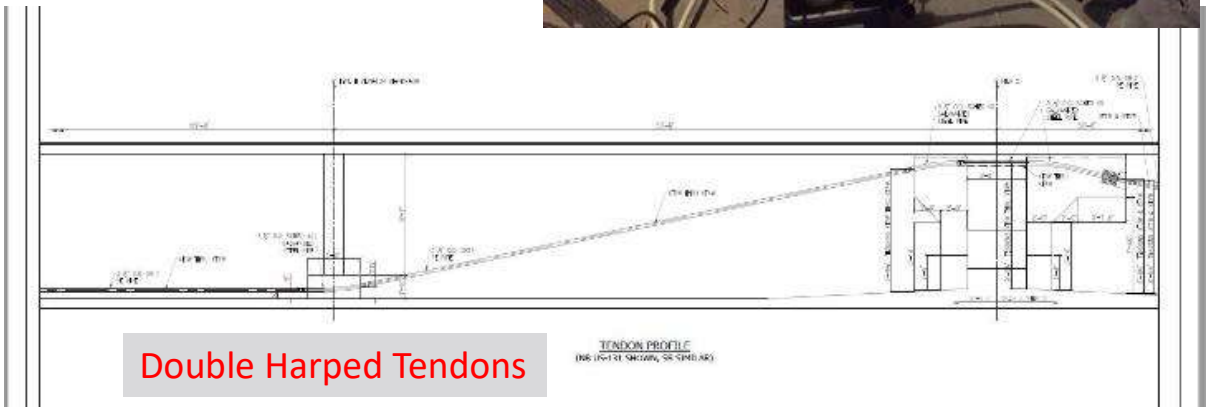
Best Practices

External Post-Tensioning Strengthening



Deviator Diaphragms

Tendon Stressing



Double Harped Tendons

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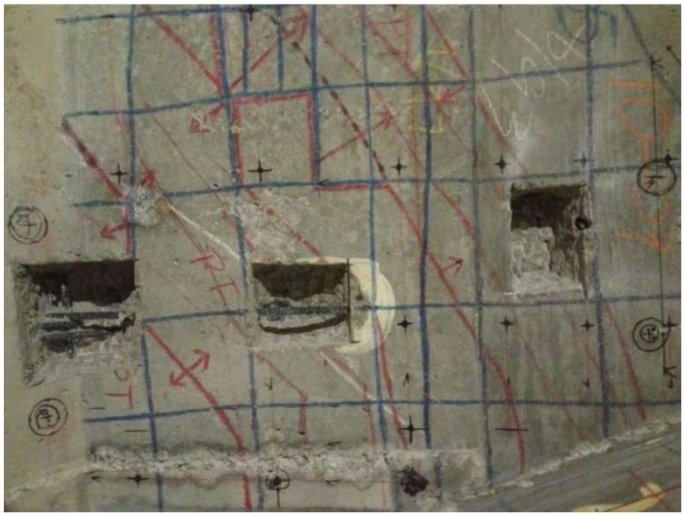
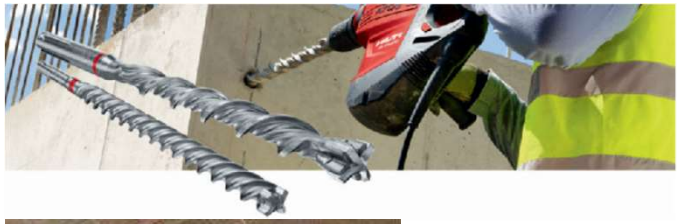
Best Practices

External Post-Tensioning Strengthening





- Ground Penetrating Radar
- Use of As-Builts
- Proper Specs and Equipment
- Coring Plan (Modify as-needed)
- Experienced Operators
- Hand Chipping

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Best Practices

Scour and Erosion Control

- Turf establishment, monitoring and varmint control
- Integrity of rock rip rap
- Use of gabion baskets in non-corrosive environments, steep slopes
- Articulating concrete block when excavation is restricted
- Flood monitoring

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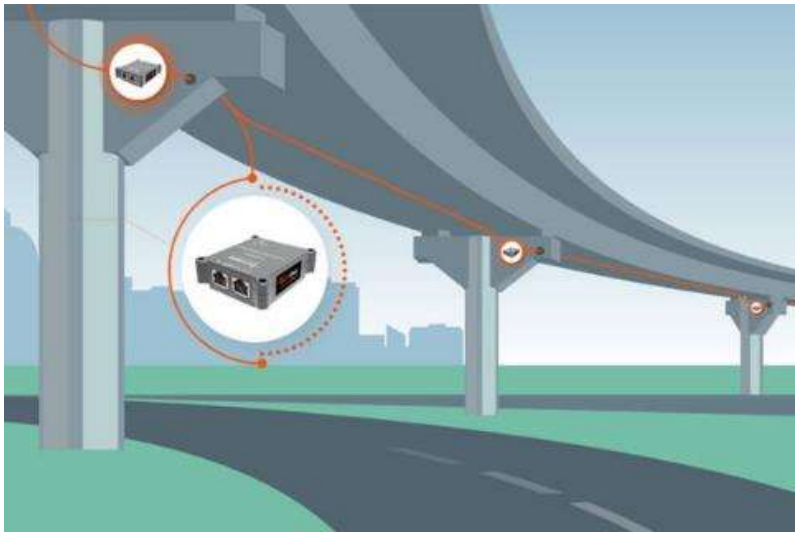
Best Practices

Structural Health Monitoring



Strain gauge monitoring at Z-Bridge

- Active monitoring of deflections and vibrations
- Strain gauge monitoring of cracks
- Real-time data collection for heavy load analysis
- Expedited response time
- Requires power, PCU, and router

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Questions?