When Things Go Wrong: Post-tension Repairs

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Topics

1 History & Background

2 Repair Planning

3 Case Study - Slab Repairs

4 Case Study – Beam Repair

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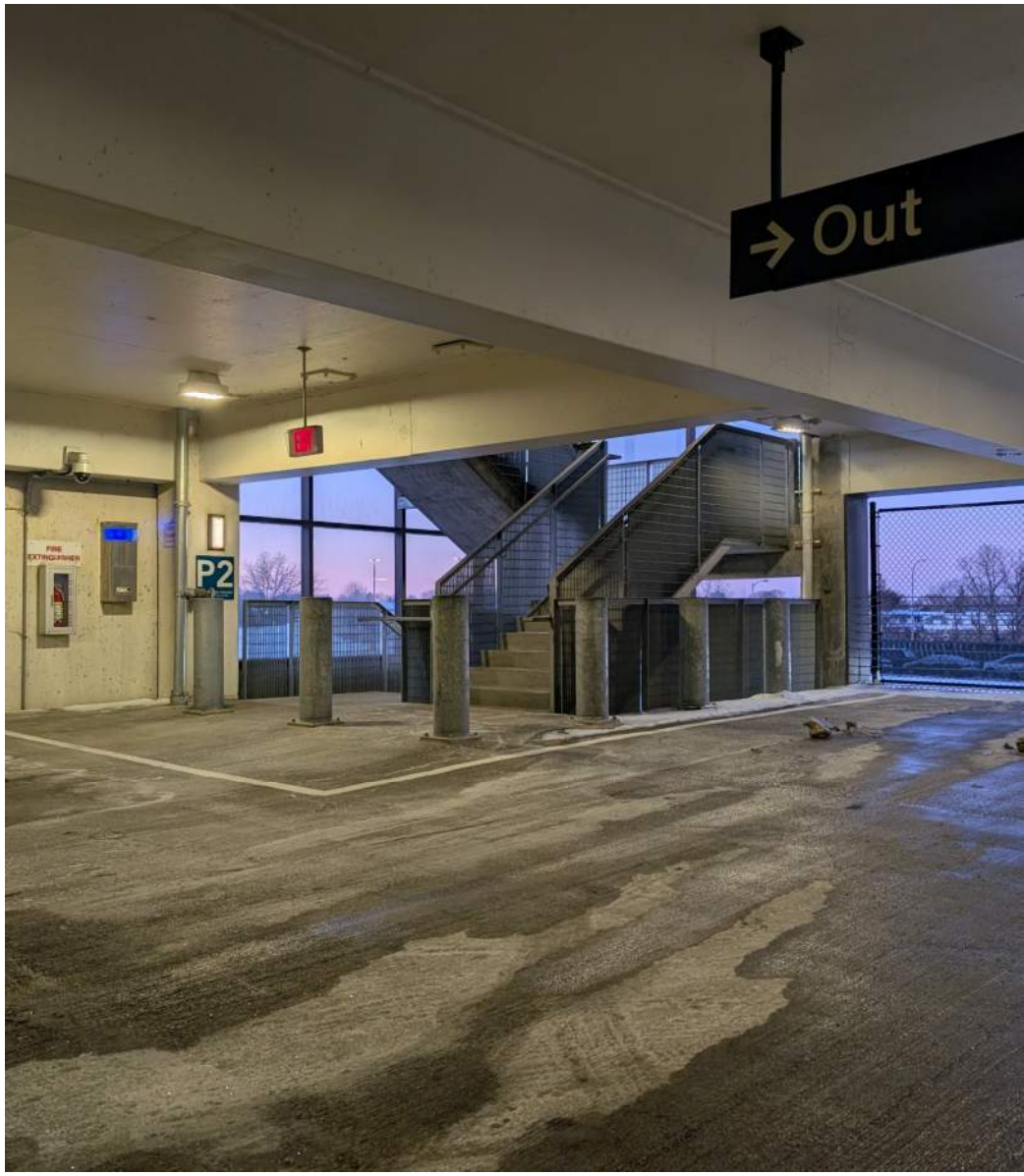
4 Case Study – Beam Repair



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History & Background

Various methods have been utilized in the Midwest

Button Head - up through 1970ish

Paper wrapped – through mid to late 1970s

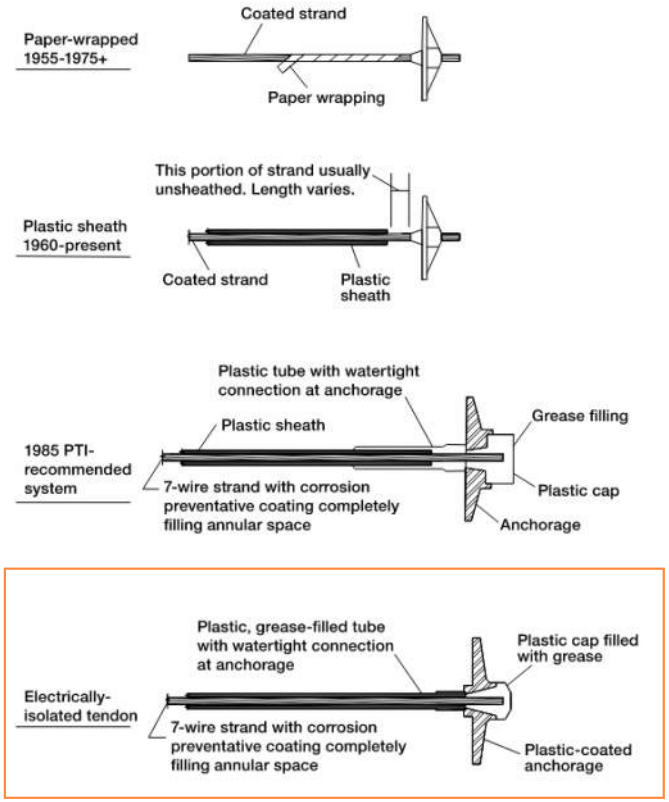
Heat-seamed – to mid 1980s

Extruded – mid 1980s

Completely Encapsulated

Required by ACI 318-14

Durability



PTI DC80.3-24 Fig.3.6

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History & Background

So why did this happen?

In the 1950's drivers began to expect clean and dry roads in all weather conditions, resulting in widespread use of salt (sodium chloride) as a roadway deicer.

Through the 1950s and 1960s distribution of salt on roadways became commonplace; dramatically increasing in application volume across the nation approximately ten-fold between 1950 and 1970.

"Highway Deicing – Comparing Salt and Calcium Magnesium Acetate," Transportation Research Board, Report 235, 199a1.

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History & Background

Which lead us to this…

Structures built in the 1960s-1980s are particularly vulnerable

Coatings & Sealers can buy time … sometimes

Many of the button-head and paper-wrapped systems are no longer around

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Dry, but OK!

Broken Wires

Gone!

Severely Corroded

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Repair Planning

- PT Garages built with modern protections are typically well-protected and will be very long-lasting
- So, while most PT structures appear to be in good condition …

  … some are in good condition …

  … but some are severely deteriorated with few signs that are easy to miss

Repair Planning

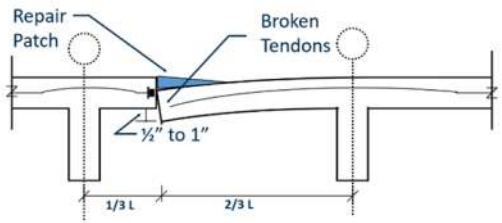
Repair Planning

Slab deflection / offset

Tendon protruding, grease cap missing

Tendon protruding at expansion joint gap

Anchor displacement



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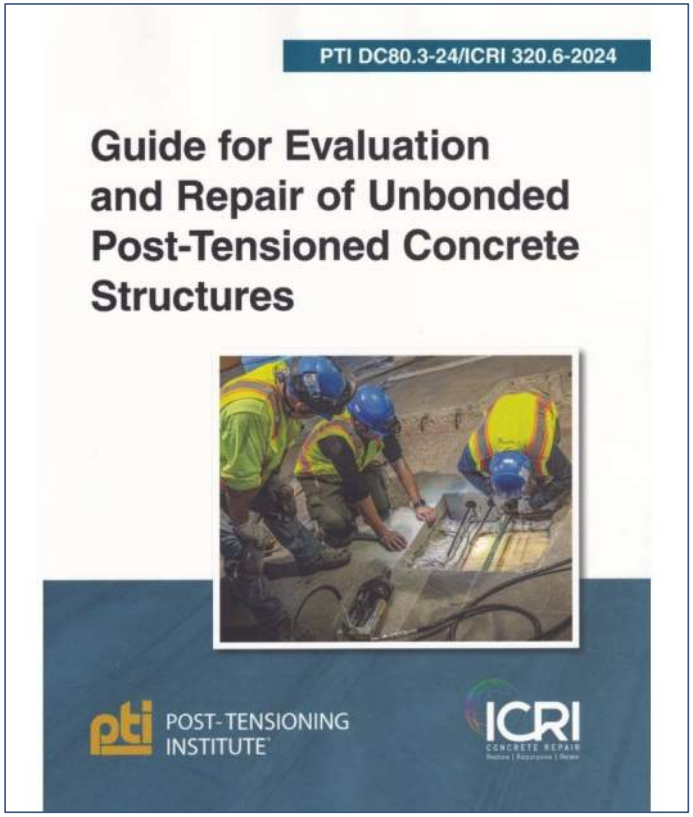
Repair Planning

So, where to start?

1. Gather History of the Structure
2. Visual Examination (NDT)
3. Limited PT Examination (DT)
4. Determine Repair methods
5. Develop Construction Documents
6. Construction Administration



PTI DC80.3-24

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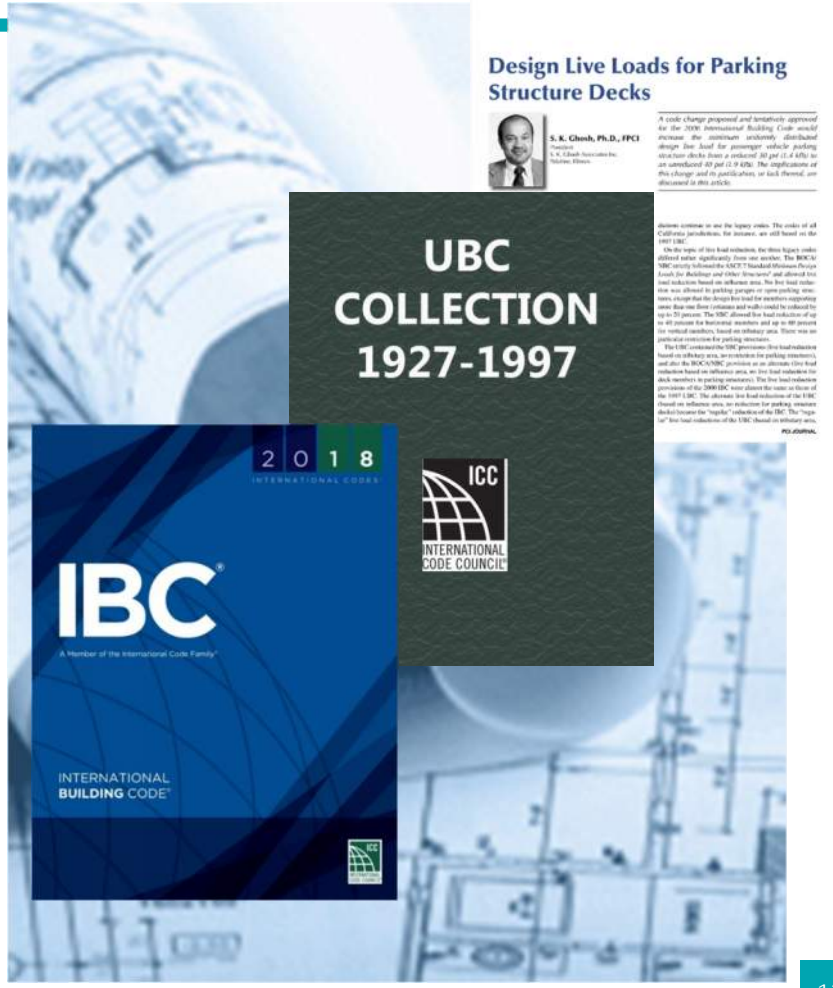
Repair Planning

Gather History of the Structure

1. Obtain original design drawings (if possible)
2. Review prior repairs and maintenance
   - Cleaning & upkeep history
   - Snow removal & deicing methods
   - Chloride environmental exposure
3. Determine original design intent
   - ✓ Post-tension forces in slabs and beams
   - ✓ Strand layouts – tendon drape & cover
   - ✓ Construction joints and expansion joints
   - ✓ Material properties
   - ✓ Original design loads / model code



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Repair Planning

Visual Examination

1. Non-destructive testing
   - ✓ Delaminations (chain drag & sounding)
2. Visual observation &
   - ✓ Cracking
   - ✓ Displacement/deflections
   - ✓ Protruding / erupted tendons
   - ✓ Exposed reinforcing bar
   - ✓ Anchorage zones
   - ✓ Leaking / rust staining
   - ✓ PT grease marks
   - ✓ Waterproofing systems

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Repair Planning

Limited PT Examination

1. Destructive testing (DT)
   - ✓ Locate reinforcing w/GPR
   - ✓ Conduct Testing Openings
   - ✓ Quantify deterioration

Often ±6 lines of 15 openings will tell you quite a bit

- Pry bar Test
- Screwdriver test

(Mostly top-side to start. And, yes, there's a lot of other testing locations and methods possible, too)

Courtesy of GSSI

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Repair Planning

Limited PT Examination

1. Destructive testing (ctd.)
   - Pry bar Test
   - Screwdriver test

2. Visual Examination of Condition

✓ Sheathing intact?

✓ Quality of grease?

✓ Corrosion?

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Repair Planning

Limited PT Examination

This representative examination can yield insight as to expectations for how many may need repair

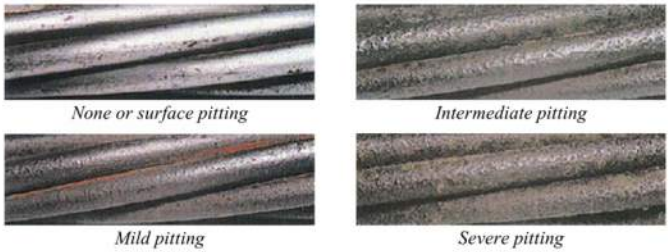
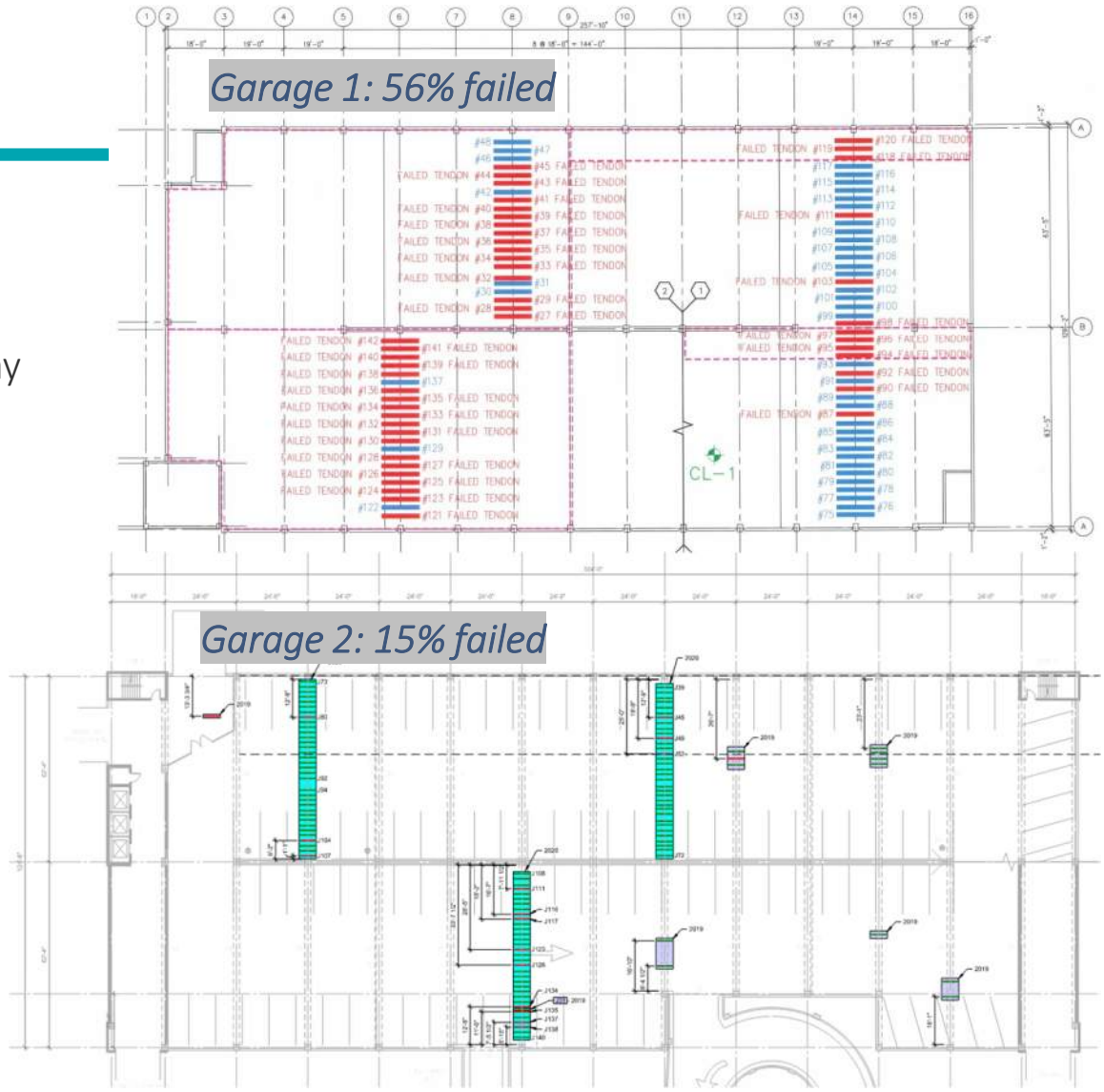


Fig. 3.38—Relative corrosion pitting classification.

PTI DC80.3-24 Fig.3.38

Note: Pitting determination can only be performed in the lab. Practically, intermediate (+10% loss) to severe (+25%) shouldn't be relied upon.



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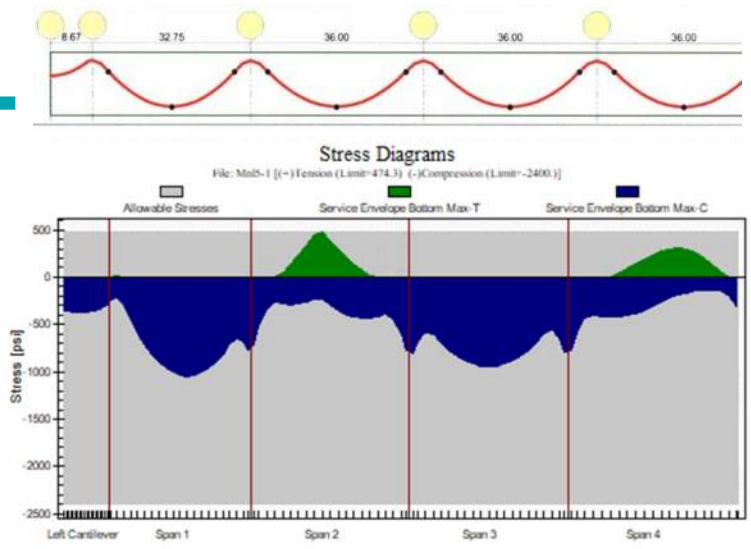
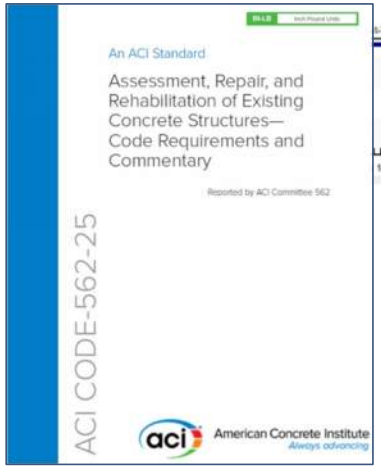
Repair Planning

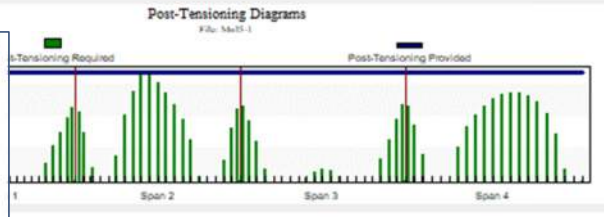
Develop Construction Documents

- Use ADAPT to model main PT beams or typical PT slabs.
- Analysis & Design typically tries to honor original design first.
- In cases of severe damage or inadequacy, use ACI 562 to establish a new *design basis code* for the project…usually current Code

Even if not adopted, ACI 562 is best available guidance







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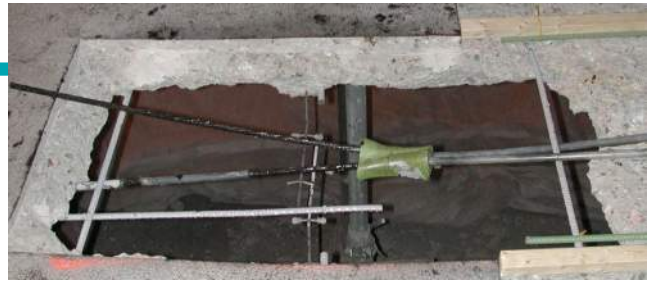
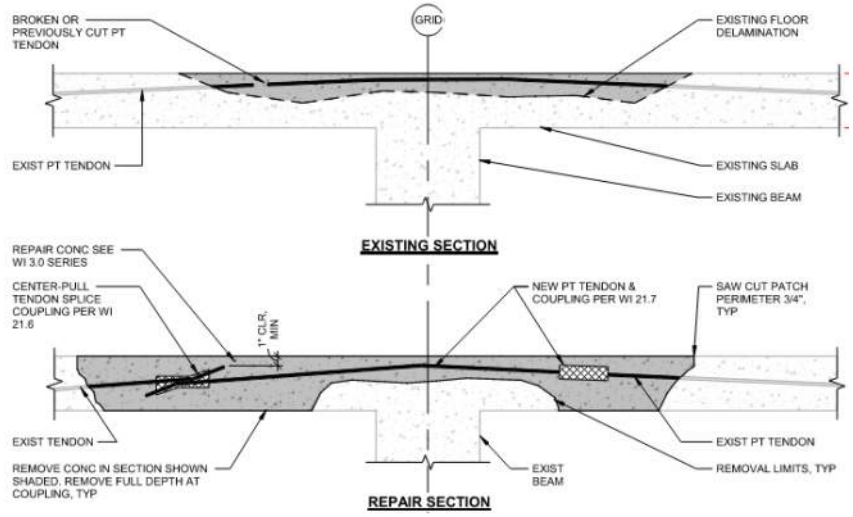
Repair Planning

Construction Documents

Industry often specifies spot-patching:

- Often dangerous and unpredictable
- Lots of openings
- Lots of rework





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Repair Planning

Construction Documents

… as a result, we are often leaning toward “full-length” repairs

- Often similar cost
- Fewer openings
- More Predictable
- Can remove intermediate CJ anchors
  (be mindful of how much elongation may occur)

CDs Must include:

- Specifications for product requirements, execution and quality control
- Drawings detailing repairs, supplemental reinforcing
- CLEAR shoring/bracing requirements
- Can consider unit-pricing type contract

562 does not require the EOR to design shoring, but it must be by a PE

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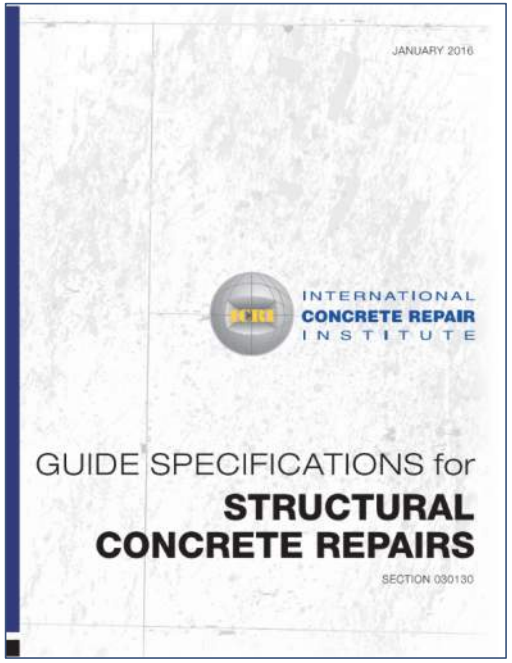
Repair Planning

ICRI has many useful guides

- 120.1-2009 Safety in the Concrete Repair Industry
- 130-1R-2009 Measurement and Contract Types for Concrete Repair Work
- 210.1R-2016 Verifying Field Performant of Epoxy Injection in Concrete Cracks
- 210-3R-2013 Using In-Situ Tensile Pulloff Tests to Evaluate Bond of Concrete Surface Materials
- 210-4-2009 Nondestructive Evaluation Methods of Condition Assessment, Repair, and Performance Monitoring of Concrete Structures
- 310-1R-2008 Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion
- 310-2R-2013 Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair
- 310-3R-2014 Preparation of Concrete Surfaces for Repair using Hydrodemolition Methods
- 320.3R-2012 Inorganic Repair Material Data Sheet Protocol
- 320.5R-14 Pictorial Atlas of Concrete Repair Equipment
- 320-1R-1996 Selecting Application Methods for the Repair of Concrete Surfaces
- 320-2R-2009 Selecting and Specifying Materials for Repair of Concrete Surfaces
- 320-6-2012 Evaluation and Repair of Unbonded Post-Tensioned Concrete Structures
- 330-1-2006 Selection of Strengthening Systems for Concrete Structures
- 330-2-2016 Guide Specifications for Externally Bonded FRP Fabric Systems for Strengthening Concrete Structures
- 340-1-2006 Selection of Grouts to Control Leakage in Concrete Structures
- 410-1-2008 Evaluation of Masonry Façade Structures
- 510-1-2013 Electrochemical Techniques to Mitigate the Corrosion of Steel for Reinforced Concrete Structures
- 710-2-2014 Horizontal Waterproofing of Traffic Surfaces



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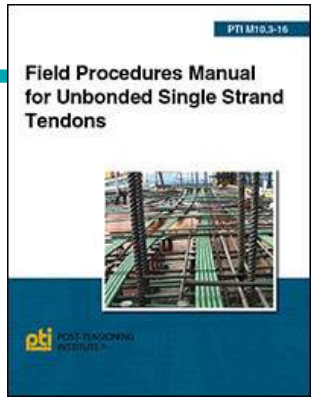
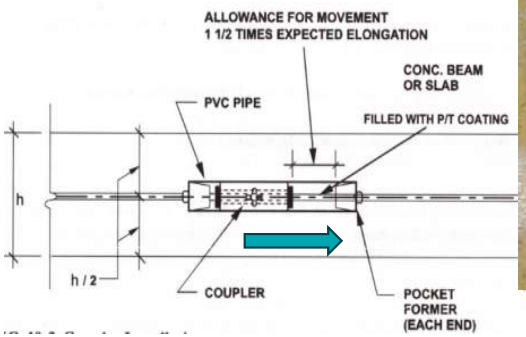
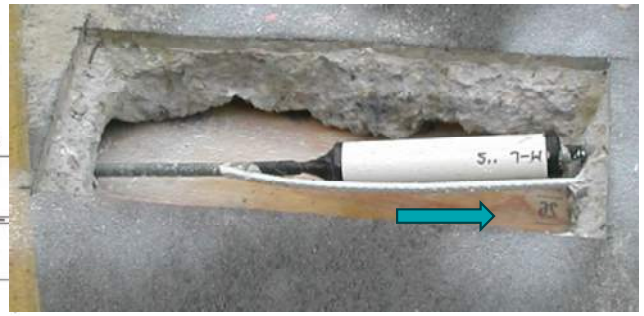
Repair Planning

Construction Administration

- Repairs need to be monitored by Engineer
- Stressing can be frustrating
  - They may need to attempt multiple times
  - Typically, we stress tendons to provide a final tensile force after seating loss of ~0.64 Pu. To obtain 64% of specified tensile strength in tendon after the anchors are seated, the jacking force should not exceed 74% of the specified tensile strength of the strand.
- Sheathing Repair is Critical
  - See PTI Field Procedures Manual
  - Heat-shrink can work too!







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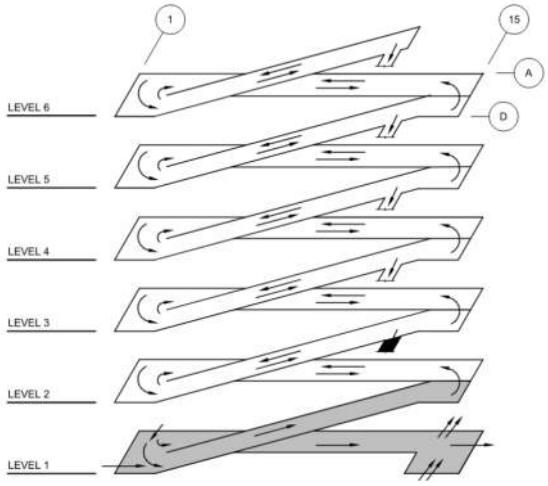
Case Study – Slab Repairs

Background:

- 680 space, 6 Level one-way PT Garage
- 324’ x 124’ – 6 PT in. slab x 24 ft. spans
- 200 psi slab PT (!)
- Three “structures” separated by (2) expansion joint gaps
- Single threaded garage up – separate helix down
- 1976 construction – split seam sheathing
- Coating installed 1987 + Major repairs



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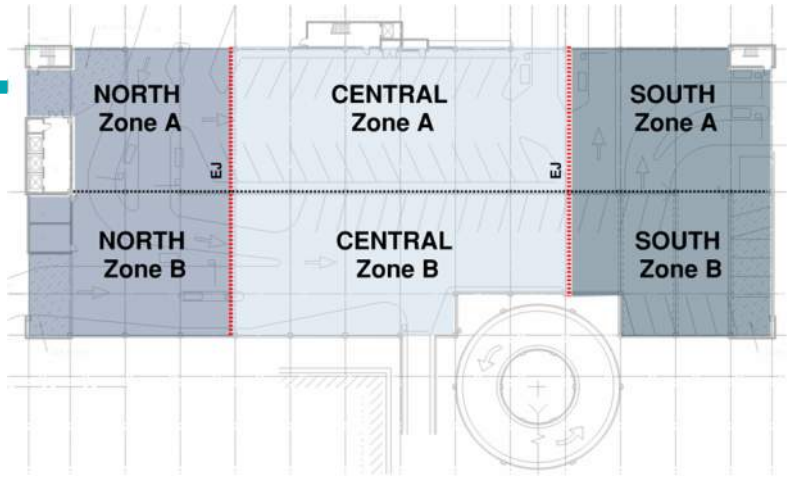
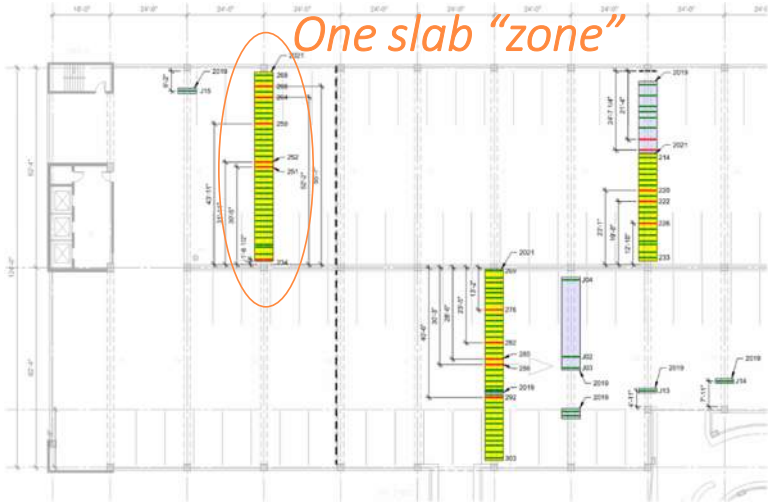
Case Study – Slab Repairs

Background:

- 2018 Condition Assessment identified limited concerns… but tendons popping through slab undersides on Level 3-6
- Developed an investigative plan to gauge potential deterioration
- Facility has 986 tendon segments in 29 slab “zones”
- Traffic Needed to be kept operational to 80% of spaces – no more than ±6 zones available for closure





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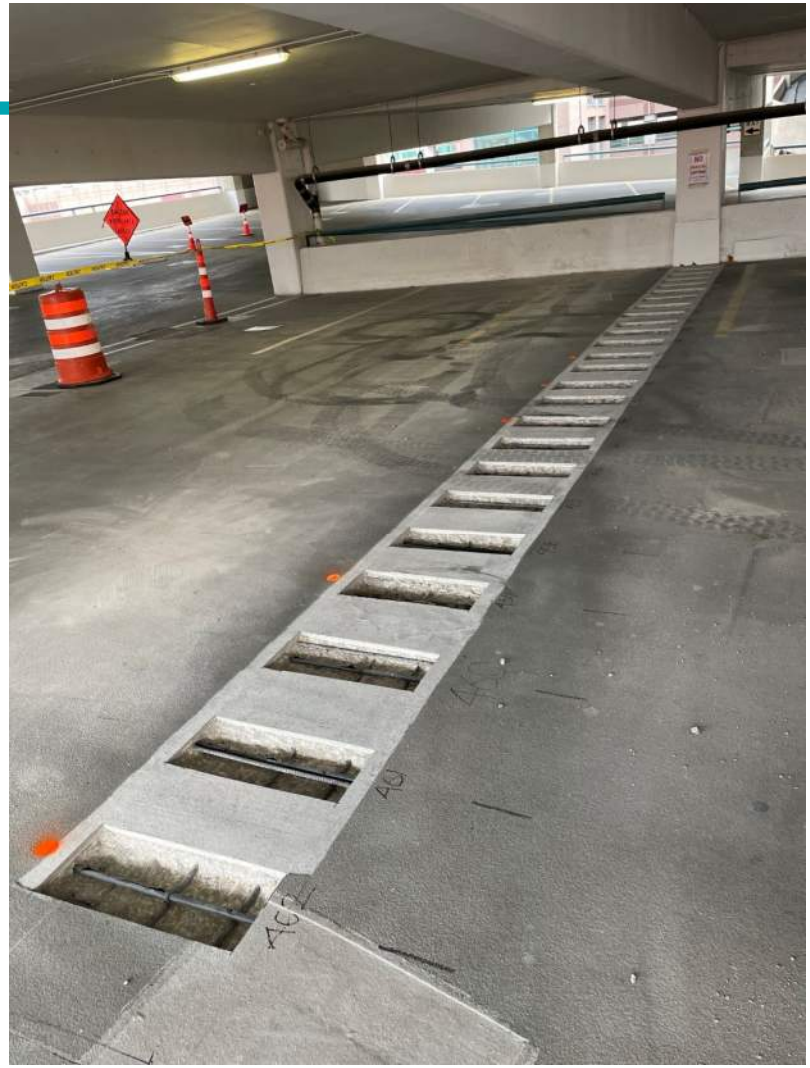
Case Study – Slab Repairs

Execution

- Analysis indicated that by removing the LL, slab would have capacity some PT loss w/o shoring (2 tendons in 10 ft)
- Captured segments one at a time
- Walker Located tendons via GPR and marked out removal areas
- Exposed 8” x 24” openings
- Cover was 1.5 in. to 2 in. deep / ¾”clear space all around tendon



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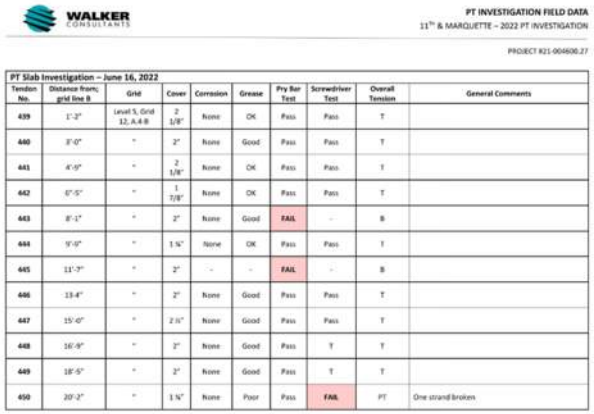
Case Study – Slab Repairs

Execution

- Performed Screwdriver test
  - Penetration = no tension / failure
- Pry Bar tests (4 ft bar)
  - Displacement = no tension / failure

Cut sheathing and characterized tendon and grease conditions – most were good…some no grease, corrosion, water



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PT INVESTIGATION FIELD DATA
11TH & MARQUETTE – 2022 PT INVESTIGATION

PROJECT K21-004600.27

PT Slab Investigation – June 16, 2022

Tendon No.	Distance from; grid line B	Grid	Cover	Corrosion	Grease	Pry Bar Test	Screwdriver Test	Overall Tension	General Comments
439	1'-2"	Level 5, Grid 12, A-4 B	2 1/8"	None	OK	Pass	Pass	T	
440	3'-0"	"	2"	None	Good	Pass	Pass	T	
441	4'-9"	"	2 1/8"	None	OK	Pass	Pass	T	
442	6'-5"	"	1 7/8"	None	OK	Pass	Pass	T	
443	8'-1"	"	2"	None	Good	FAIL	-	B	
444	9'-9"	"	1 ¾"	None	OK	Pass	Pass	T	
445	11'-7"	"	2"	-	-	FAIL	-	B	
446	13-4"	"	2"	None	Good	Pass	Pass	T	
447	15'-0"	"	2 ½"	None	Good	Pass	Pass	T	
448	16'-9"	"	2"	None	Good	Pass	T	T	
449	18'-5"	"	2"	None	Good	Pass	T	T	
450	20'-2"	"	1 ¾"	None	Poor	Pass	FAIL	PT	One strand broken

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Case Study – Slab Repairs

Each replaced tendon was rethreaded, stressed, and observed by Walker prior to tendon acceptance + patching

Results

- Over the first 4 years, 113 tendons were identified as failed, and replaced full-length

Year	Failed	Zones	Tendons	Broken %
2019	23	5	170	13.5%
2020	29	5.5	187	15.5%
2021	36	5.5	187	19.3%
2022	25	5.5	187	13.4%
Subtotal	**113**	21.5	**731**	**15.5%**
Remaining	Failed		Tendons	Broken %
2026	39	7.5	255	15.5%

- We anticipate 39 more for repair!

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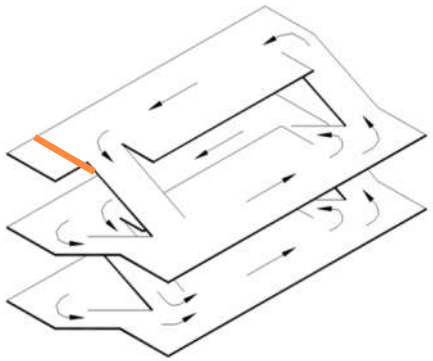
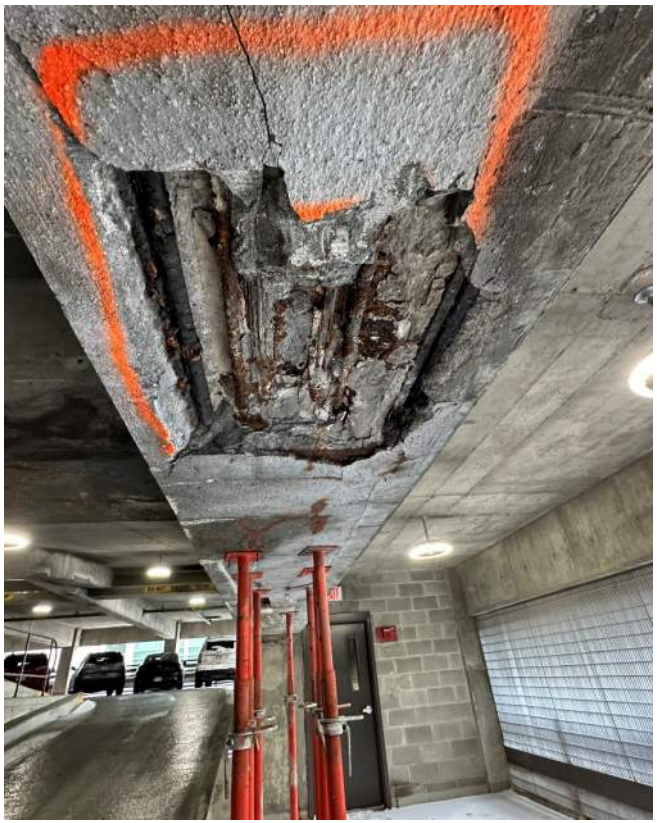
Case Study – Beam Repair

- 1977 Parking Structure, 6 levels
- Long-span one-way beam/slab
- Older split-level design
- CIP, PT – 5” slabs
- Unbonded PT = 240ksi wires (not tendons)
- Owner/Contractor concerned w/spalling & corrosion
- Had been previously strengthened





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Case Study – Beam Repair

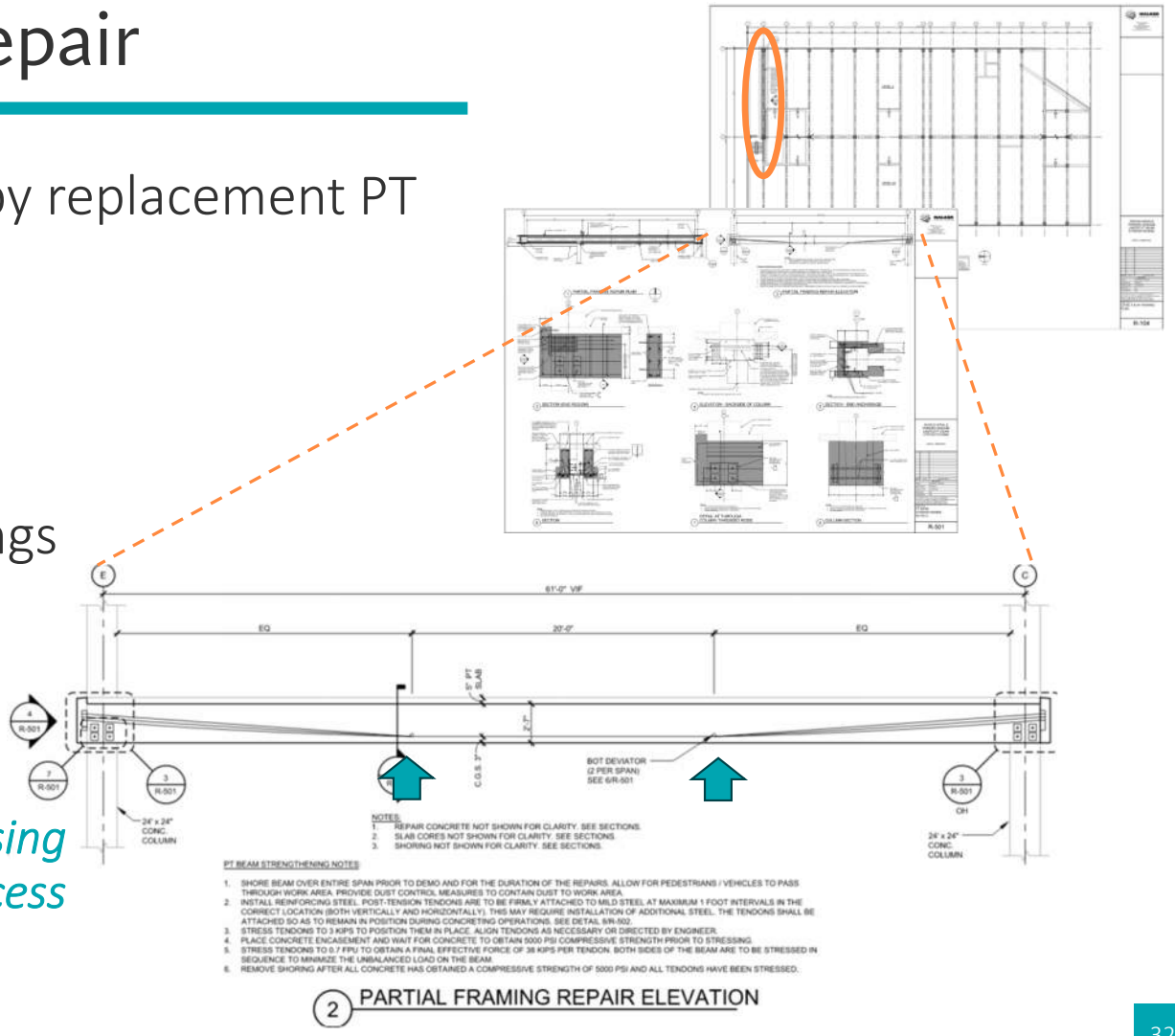
Field assessment indicated poor condition of original beam and strengthening

- Severe corrosion of original PT
- Replacement PT was poorly affixed to beam/column

Case Study – Beam Repair

Restoration of beam selected by replacement PT

- New analysis performed
- Details Developed
- Constructability Studied
- Demolition & Repair Drawings
- Shoring Criteria Established

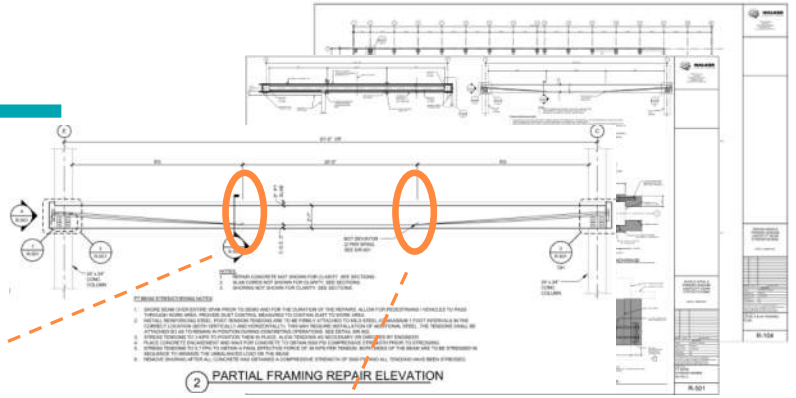


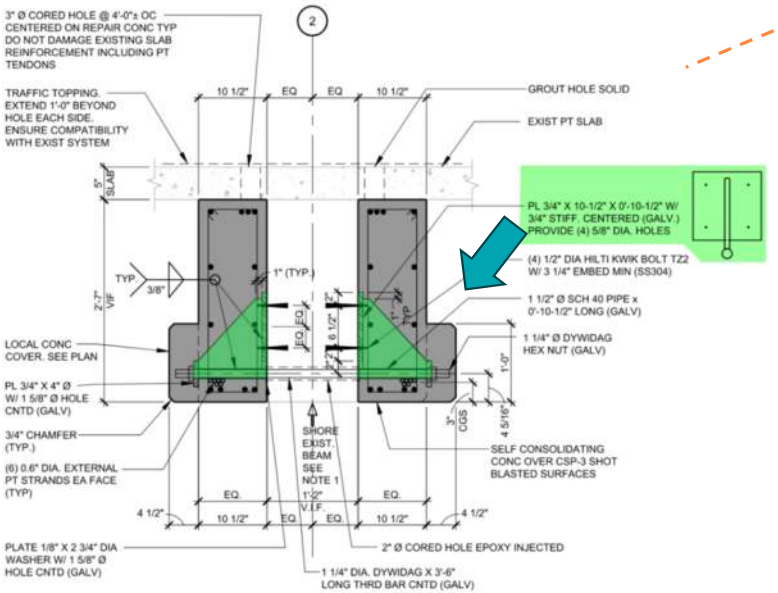
No Stressing Access

Case Study – Beam Repair

Repair

- (12) new 0.6” tendons (38k/tendon)
- Hold-downs @ L/3





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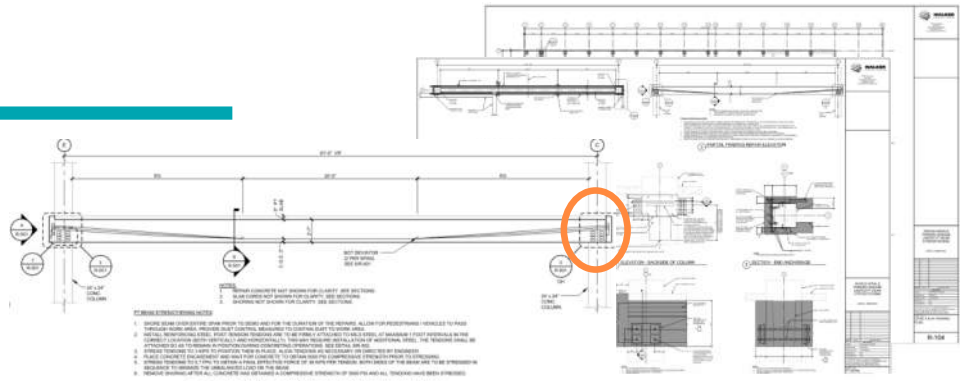
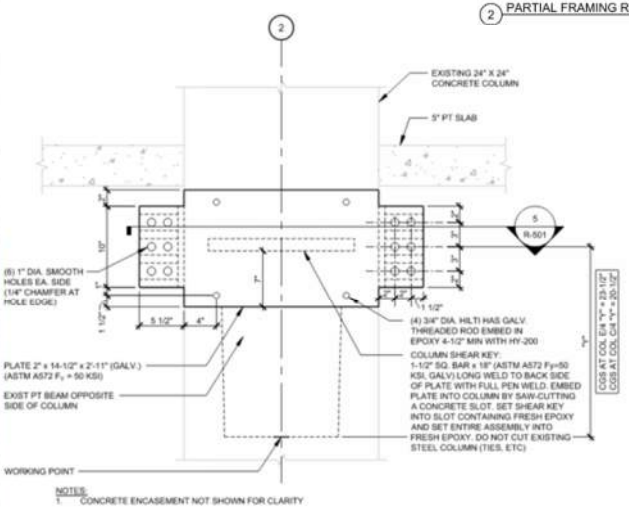
Case Study – Beam Repair

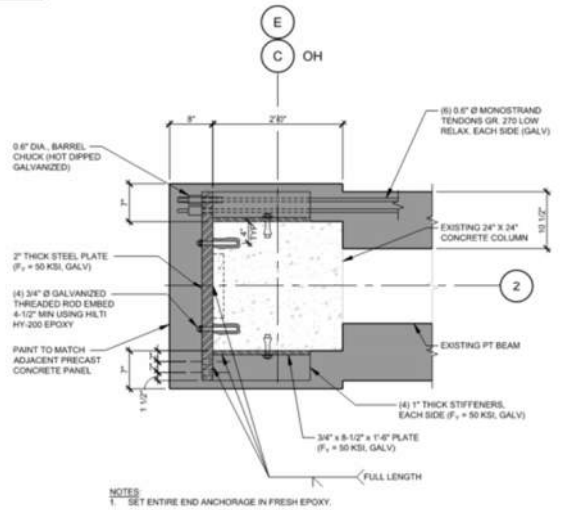
- Anchorage Blocks



2 PARTIAL FRAMING REPAIR ELEVATION



4 ELEVATION - BACKSIDE OF COLUMN



5 SECTION - END ANCHORAGE

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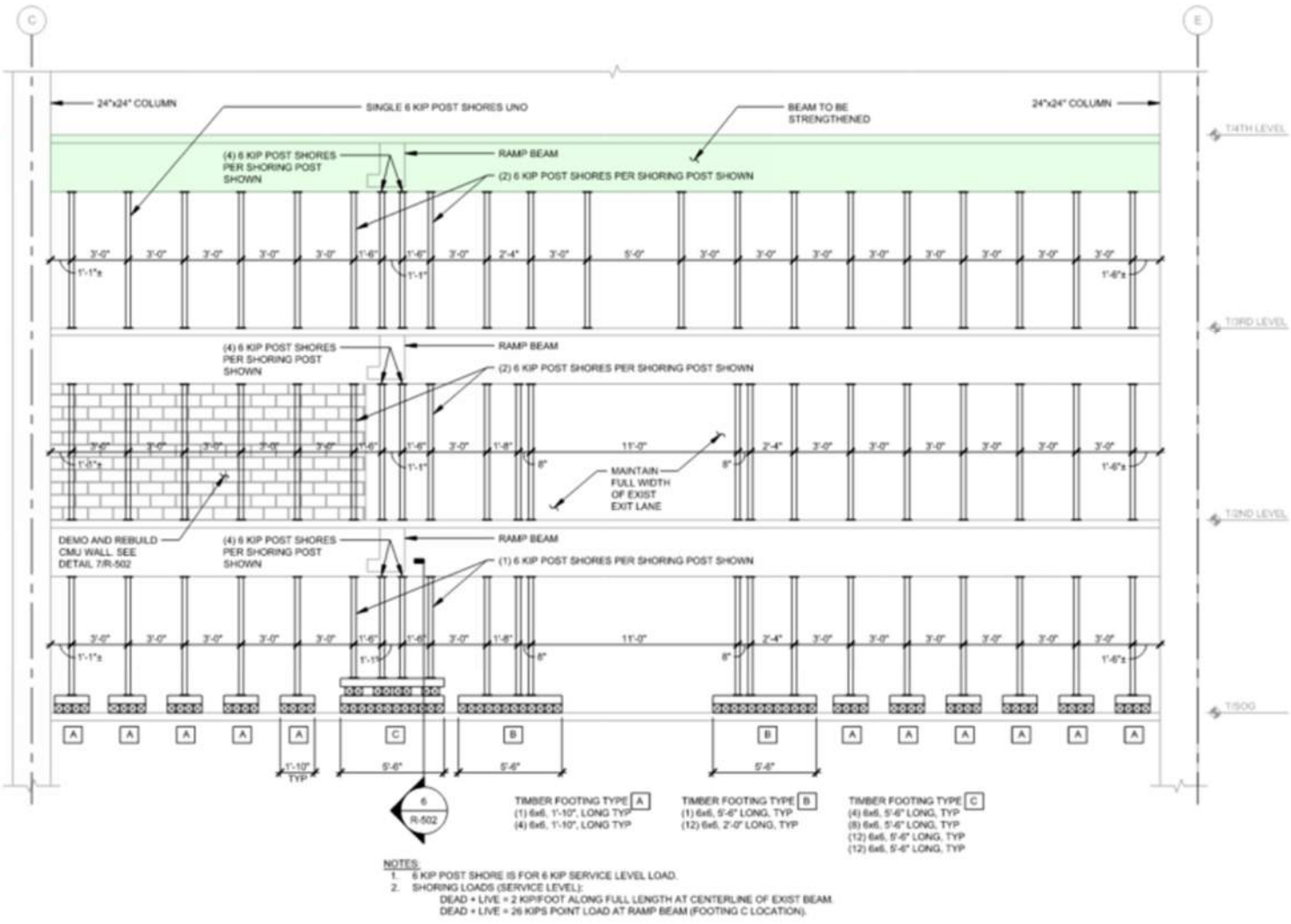
Case Study – Be

- Min. Shoring Criteria Established
- Provided layout and Dead + Live criteria
- Contractor engineer to provide final design



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Thank you!

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