

Date of Presentation
ICRI 2022 Spring Convention

Multiyear Restoration & Protection of 1969 CIP Post-Tensioned Parking Garage



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The ideas expressed in this ICRI hosted webinar are those of the speakers and do not necessarily reflect the views and opinions of ICRI, its Board, committees, or sponsors.

AGENDA

- Company Profile
 - THA Consulting, Inc.
 - Vector Corrosion Technologies, Inc.
- Garage History
- 2018 Critical Repair Program
- Multi-Year Restoration Program (2019 - 2024)
- Review Previously Installed Cathodic Protection System
- Discuss steps taken to determine performance for current CP System
- Review solutions for new CP system
- Installation of New Cathodic Protection System



DESIGN, ENGINEERING & MOBILITY CONSULTING FIRM

- Since 1994 - *Parking Consultants & Specialists*
- Multi-Disciplined Expertise
 - *Planning, Design, Operations, & Restoration of Parking Structures*
- 1,000 Parking Projects & 500,000 Parking Spaces
- Parking Study & Master Planning
 - *Complex Parking Issues*
 - *Practical Solution strategies*
 - *Hands on operating experience*

**ASSET
MANAGEMENT**

Adaptive Re-use
Condition Appraisal
Restoration Engineering
Life Cycle Cost Analysis
Operational Consulting
Owner Representation
Graphics & Wayfinding
Maintenance Program

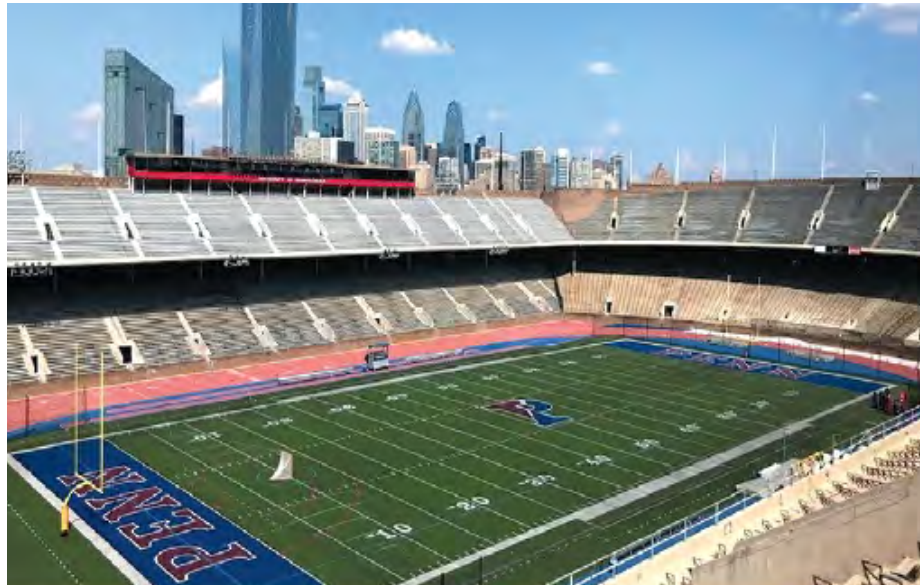
**ENGINEERING &
ARCHITECTURE**

Parking Structure Design
Mixed-Use Structure Design
Project Design Management
Functional Design
Architectural Design
Structural Engineering
Design Build Services
Sustainable Design



TECHNOLOGIES & RESTORATION SERVICES

- Vector Corrosion Technologies is the leading full-service supplier of technologies and restoration services for concrete and masonry corrosion.
- Experience: 1,000+ projects to control corrosion in structures around the world with innovative solutions.
- Many of these projects have been honored as award-winning projects by the International Concrete Repair Institute.



GARAGE HISTORY

Wilkes University Parking Garage

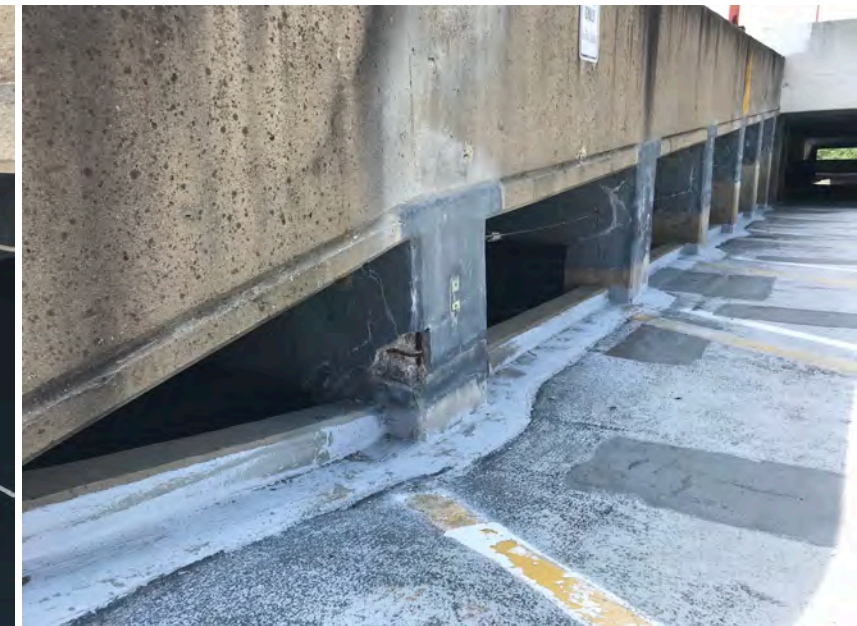
- Built ~ 1969
- CIP Post-Tensioned Beams and Slabs
- Beams Reinforced w/ Mild Reinforcing + Grouted Post-Tensioned Bars
- Slabs Reinforced w/ Unbonded Post-Tensioning Only; No Mild Reinforcing
- Cathodic Protection System – Zinc Arc Spray ~ 20 Years Old & Required Upgrades
- 7 Tier Garage
- Double Threaded Helix Functional Layout
- Student Parking + WU Police Department



2018 CRITICAL REPAIR PROGRAM

Wilkes University Parking Garage

- 2018 Critical Repair Program
 - PT Induced Shear Failure – Top Tier Ramp Columns



2018 CRITICAL REPAIR PROGRAM

Wilkes University Parking Garage

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MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Multi-Year Restoration Program (5 Year)

- Top-Down Approach
- Critical Structural Repairs Addressed Early
- Phase 1 (2019)
- Phase 2 (2021)
- Phase 3 (2022)
- Phase 4 (2023)
- Phase 5 (2024)

- Goal to extend service life of garage to ~ 2040

Wilkes University Multi-Year Parking Garage Restoration Program															Wilkes University															
Order of Magnitude Cost Of Repairs																														
by Kevin Carrigan of THA Consulting, Inc.																														
Last Updated 3/1/2022																														
	2019	2022	2024	2019	2024	2021	2019	2023	2022	2019	2023	2019	2023	2023	2019	2022	2019	2021	2024	2019	2022	2024	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5			
	Ground Tier (Ascending)			1 & 2 (Ascending)			3 & 4 (Ascending)			5 & 6 (Ascending)		Top		5 & 4 (Descending)		3 & 2 (Descending)		1 (Descending)		Repairs @	Unit Price	Total	Total	Year 2020	Year 2021	Year 2022	Year 2023	Year 2024		
	R1.1			R1.2			R1.3			R1.4		R1.5		R1.6		R1.7		R1.8		Facade		Quantities	Cost							
Structural Repairs (Unit)																														
Full Depth Slab Repair/Replacement (SF)					12																\$150	12	\$1,200		\$1,200					
Partial Depth Slab Repair (SF)		230	313		280		596		372	4	515			217	395	302	1228				\$55	7795	\$428,725	\$102,245	\$218,360	\$67,945	\$30,000	\$11,000		
Exposed Rebar (SF)																					\$70	0	\$0	\$0	\$0	\$0	\$0	\$0		
Curb Repair (SF)					4		12														\$35	28	\$980	\$360	\$420	\$420	\$420	\$420		
Static Floor Crack Repair (LF)		103		280		2000		1818			2903			988	100		2300				\$5	15438	\$77,190	\$25,945	\$25,500	\$11,500	\$10,000	\$2,800		
Overhead Surface Repair (SF)			2	84		44		28	14				19	21	8	55					\$85	313	\$26,345	\$2,980	\$6,845	\$2,425	\$5,055	\$5,055		
Post Tension Anchor Repair (EA)			2	5		8		8	5	5			3		3	14					\$1,500	56	\$84,000	\$22,500	\$18,500	\$9,000	\$24,000	\$24,000		
Post Tension Anchor Repair @ Exterior (EA)																					\$2,000	0	\$0	\$0	\$0	\$0	\$0	\$0		
Post Tension Tendon Splice Repair (EA)					7		2				2				2		7				\$1,500	16	\$24,000	\$3,000	\$10,000	\$3,000	\$3,000	\$3,000		
Overhead Beam Repair (SF)					21		12														\$100	107	\$10,700	\$900	\$4,800	\$4,000	\$4,200	\$4,200		
Epoxy Injection (LF)					8			32	84					303	257		252				\$60	1094	\$71,130	\$28,955	\$10,200	\$0	\$25,855	\$25,855		
Galvanic Anodes in Slab Repairs (EA)		87	32		432		170		195	2	115			81	114	56	331				\$40	1710	\$68,400	\$14,700	\$30,600	\$13,950	\$6,800	\$2,280		
Column Spall Repair (SF)					18		2							8			5				\$385	45	\$15,525	\$3,850	\$340	\$1,530	\$1,530	\$1,530		
Vertical Spall Repair (SF)					45		46							21	4		38				\$40	36	\$1,440	\$27,000	\$5,600	\$3,200	\$4,800	\$4,800		
Static Vertical Crack Repair (LF)																					\$8.00	0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Barrel Cable Retention (EA)							1														\$900.00	3	\$2,700	\$900	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800	
Floor Drain Replacement (EA)																					\$1,200.00	1	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200
Clean and Paint Facade (SF)																					40000	\$2.75	45000	\$123,750					\$123,750	
Waterproofing & Corrosion Control (Unit)																														
Traffic Deck Coating Replacement (SF)		8500	313	1000	27000		27000	1963	27000	7200	27000	1264	100	8000	19340	382	27000	1836	775	13000		\$5.00	198072	\$990,360	\$318,160	\$370,000	\$167,513	\$177,318	\$56,600	
Vertical Waterproofing Membrane (LF)					28					18				450							\$10.00	515	\$5,150	\$570	\$60	\$4,000	\$4,000	\$4,000	\$4,000	
Cove & Joint Sealant Replacement (LF)		190		301		590		600		1133		1522		889	500		500				\$6.50	6983	\$45,389	\$22,840	\$6,500	\$5,200	\$3,250	\$1,950	\$1,950	
Miscellaneous Repairs (Unit)																														
New line striping and pavement marking (SF)		8500		1000	20000		27000	1963	27000	7200	27000	1264	100	8000	19340		27000	1836		13000		\$0.45	198602	\$89,475	\$28,035	\$24,300	\$15,075	\$15,958	\$5,161	
Trench Drain & CIP Wash at base of ramp (EA)		1																			\$25,000	1	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	
Cathodic Protection System Enhancements (EAF)				700	1980		1434	574		388		885		1424		143	1285				\$131	8883	\$1,294,650	\$669,074	\$774,850	\$353,278	\$300,549	\$300,549	\$300,549	
Cathodic Protection System Enhancements ³																						\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	
Lump Sum Allowance for Minimal Upgrades																														
Sub-Total																						\$3,426,814	\$298,835	\$1,373,290	\$660,530	\$770,552	\$604,513			
Inflation Deflated Work Factor (+5% per year)																						1%			-1%	+1%	+1%	+2%		
General Condition (+15%)																						\$514,052	\$60,720	\$160,961	\$98,961	\$115,583	\$90,966			
Contingency (20%)																						\$685,361	\$128,985.0	\$214,641.9	\$133,307.0	\$154,150.4	\$120,214.6			
Total Hard Cost (Non-Union labor)																						\$4,626,226	\$843,655	\$1,448,832	\$899,820	\$1,040,245	\$816,172			
Actual Hard Construction Cost Paid by WJ																						\$620,287	\$1,472,000							
Estimated Construction Time																							5 Months	5-6 Months	5-6 Months	5-6 Months	5-6 Months	8 Months		

Note:
 1. All floor repair quantities shall be re-evaluated after removal of deteriorated / delaminated traffic deck membrane.
 2. CP Enhancements includes galvanic anodes to recharge the existing zinc anode spray CP system and extend its life for an additional 20 years. The anodes will be embedded into the concrete and tied into the existing CP anchorage bars that are visible on the concrete surface.
 3. CP Enhancements were performed during Phase 1 by Vector Corrosion Services who worked under Meany. Work mainly consisted of replacing 14 reference electrodes and supporting basin to assure that the CP wiring was attached at post-tension repairs.



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Each Phase Includes
 - Structural Repairs
 - Concrete
 - Post-Tension
 - At floor / soffits / façade
 - Waterproofing
 - Sealants & Traffic Deck Membrane
 - Cathodic protection upgrades



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
 - PT Slab Failures at Façade
 - Primary Tendons
 - Broken Strand and/or Anchorage Zone Failure



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
 - PT Slab Failures at Façade
 - Primary Tendons
 - Broken Strand and/or Anchorage Zone Failure



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
 - PT Slab Failures at Façade
 - Primary Tendons
 - Broken Strand at Interior – Release of Energy Caused Exterior Spall
 - Not Anchorage Zone Failure



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

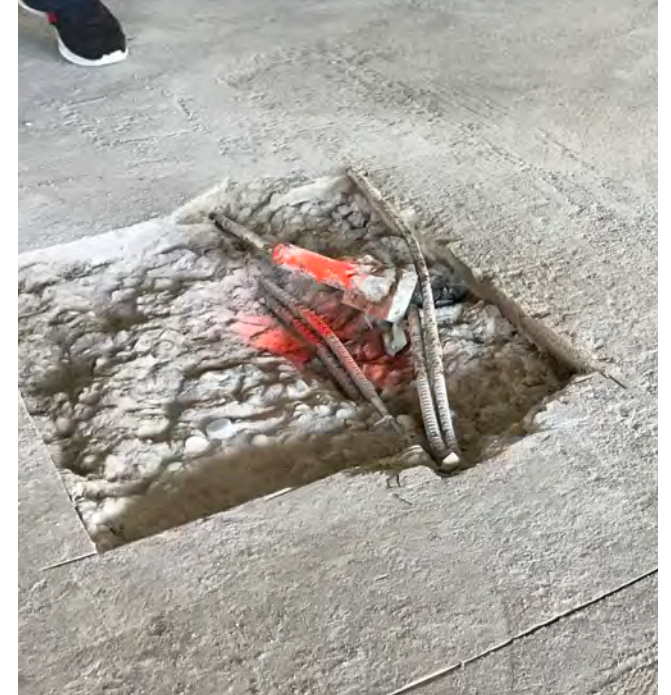
- Structural Repairs
 - PT Slab Failures at Interior Slab
 - Primary Tendons



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
 - PT Slab Failures at Interior Slab
 - Primary Tendons



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

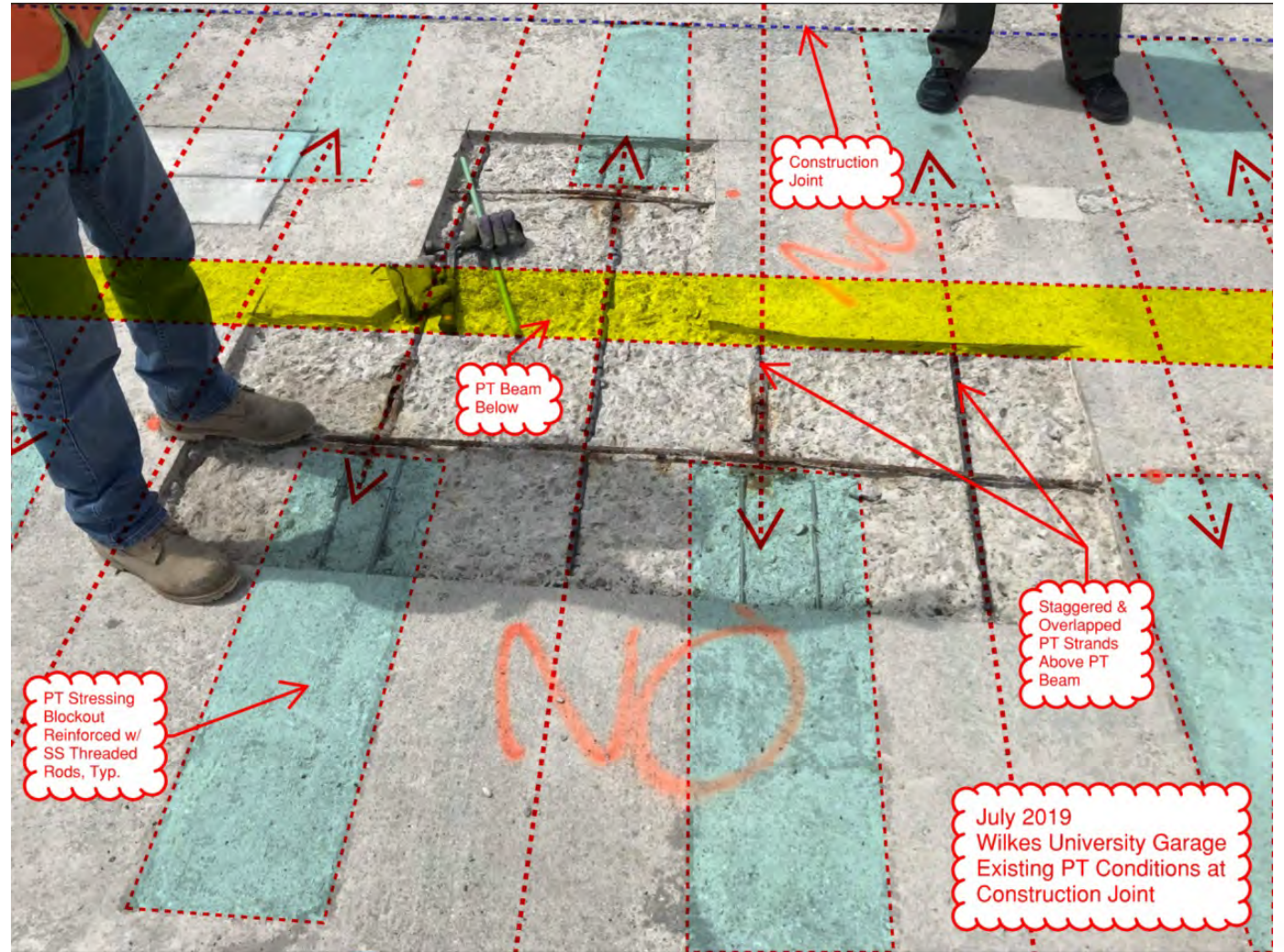
- Structural Repairs
 - PT Slab Failures at Interior Slab
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MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
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MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

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MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

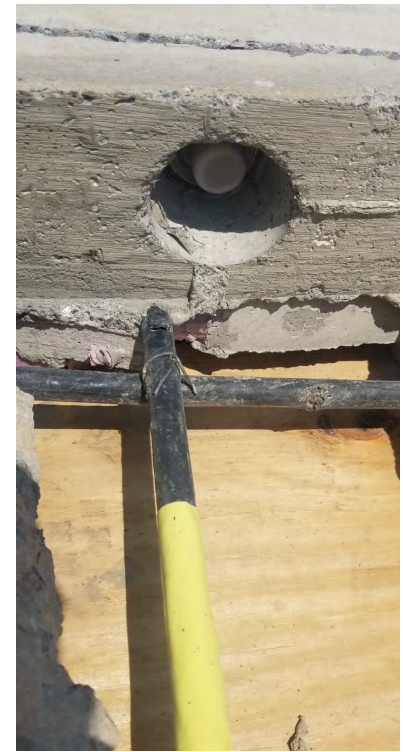
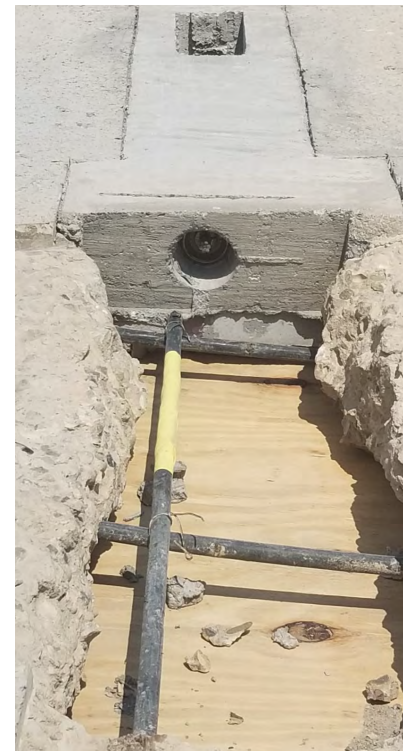
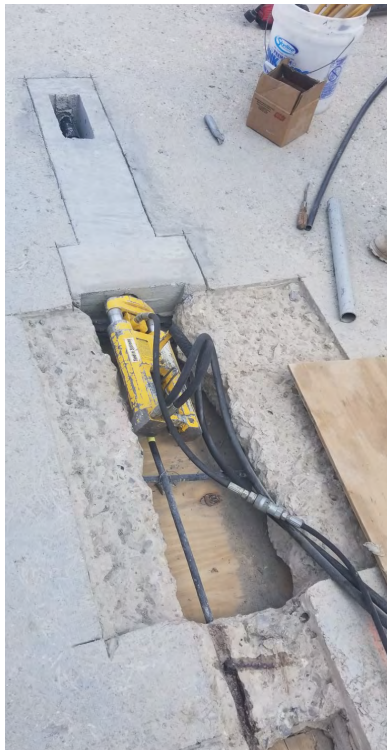
- Structural Repairs
 - PT Slab Failures at Interior Slab
 - Primary Tendons



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
 - PT Slab Failures at Interior Slab
 - Primary Tendons



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

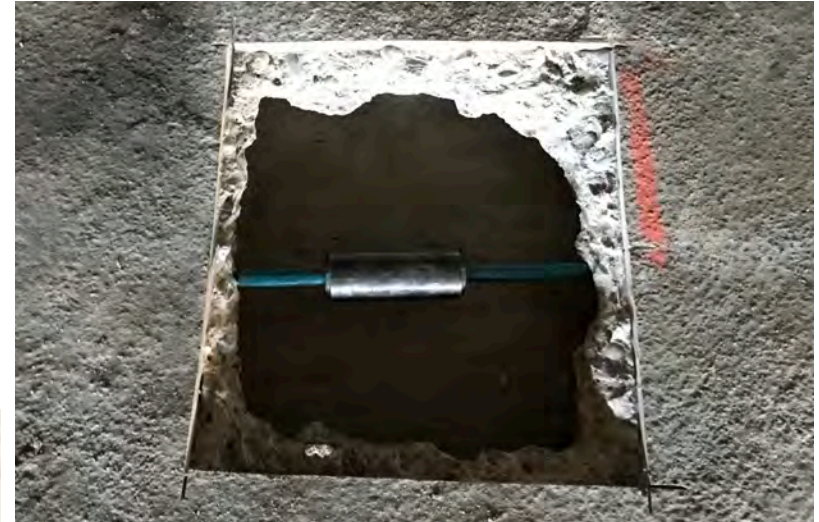
- Structural Repairs
 - PT Slab Failures at Interior Slab
 - Shrinkage & Temperature Tendons



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs
 - PT Slab Failures at Interior Slab
 - Shrinkage & Temperature Tendons



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Structural Repairs – PT Girder Repairs



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

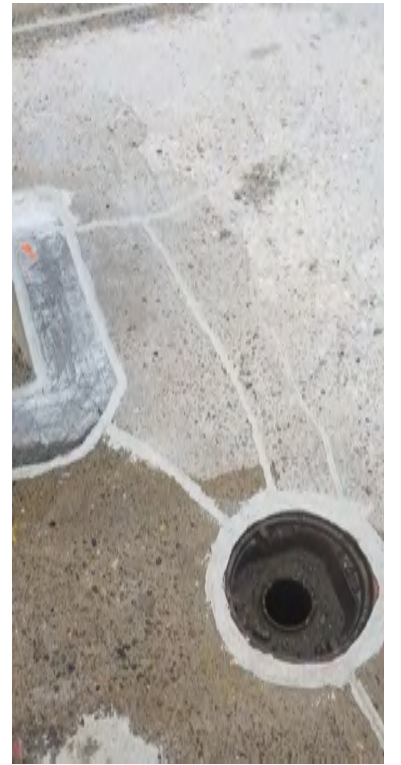
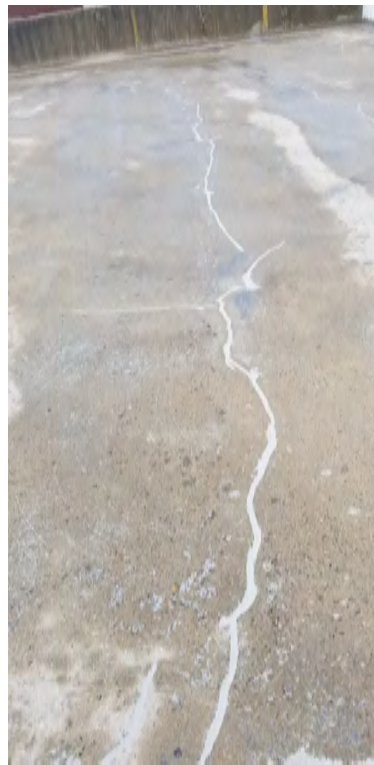
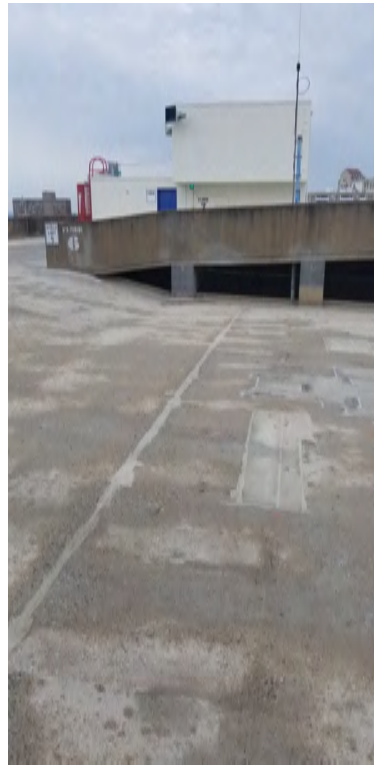
- Waterproofing
 - Sealants & Traffic Deck Membrane



MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

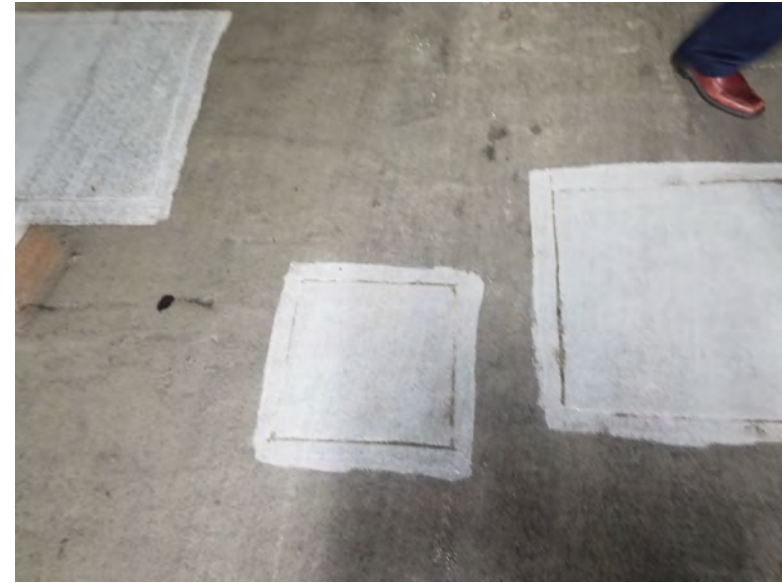
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MULTI-YEAR RESTORATION PROGRAM

Wilkes University Parking Garage

- Waterproofing
 - Sealants & Traffic Deck Membrane





Current Cathodic Protection System Zinc Arc Spray (ZAS)

- Installed approximately 20 years ago
- years ago
- CP system is comprised of Zinc Arc Spray (ZAS), which is a surface-applied galvanic CP system
- ZAS will sacrificially corrode to protect the embedded steel from corrosion activity

VISUAL INSPECTION OF ZAS SYSTEM

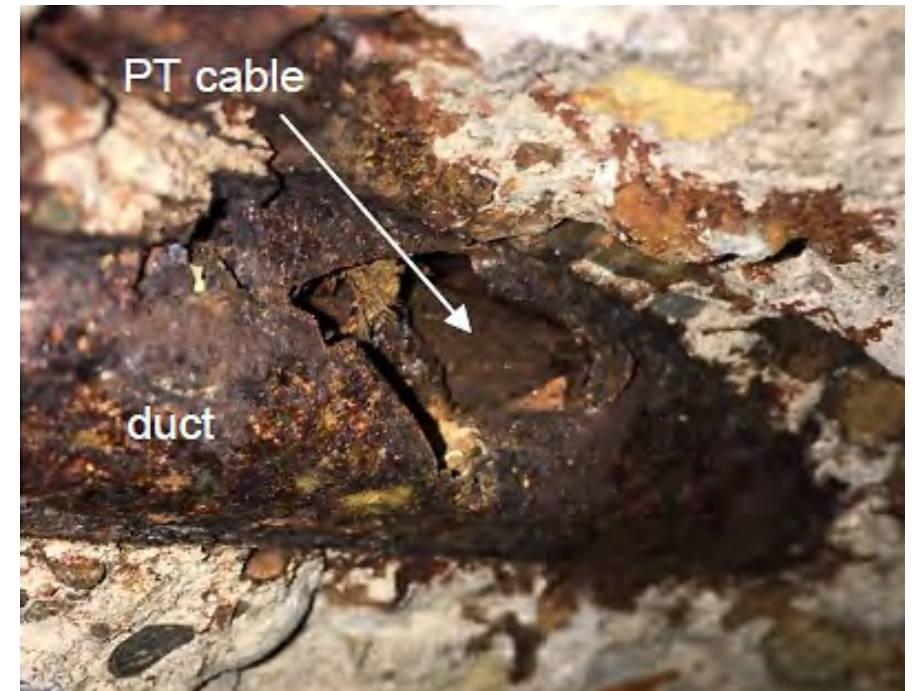
Spalling around CP System
White Zinc Oxide Film from corrosion of ZAS



Spalled Concrete in the Metalized Area Showing Corroding Rebar



Corrosion of Post Tension System



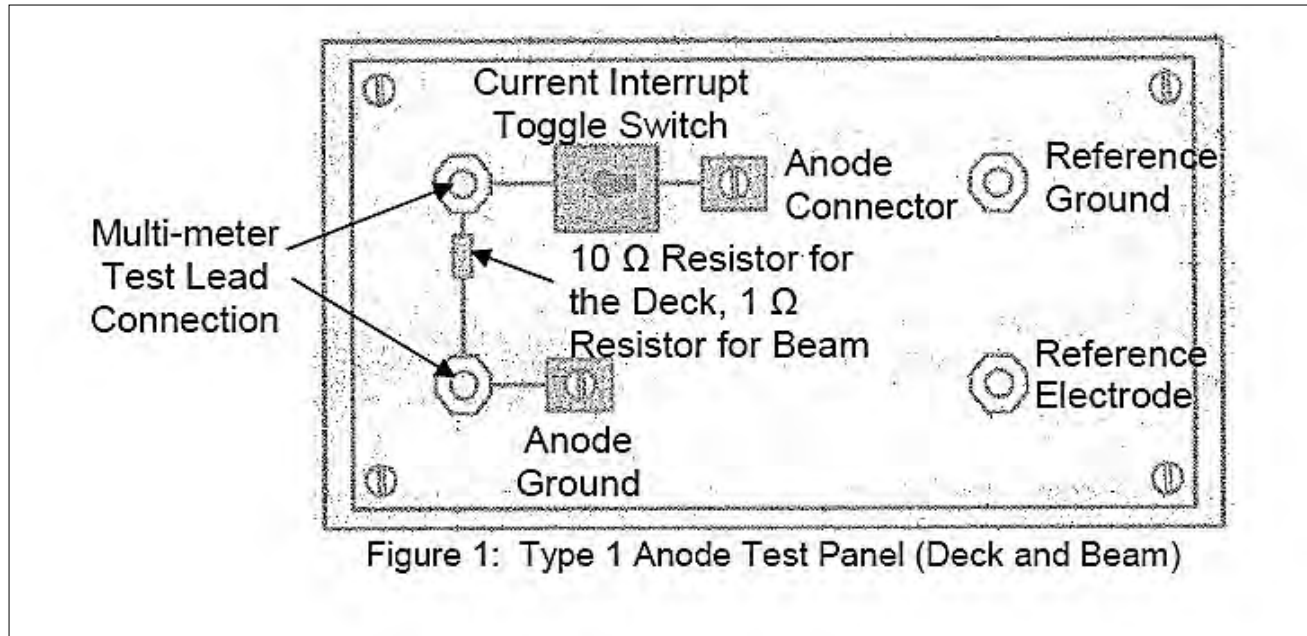
MULTI-YEAR RESTORATION PROGRAM

INSPECTION OF ZINC ARC SPRAY (ZAS) - CONT...



- PVC boxes that are attached to the ZAS system
- These boxes are test stations which provide the ability to determine if the ZAS is working properly

INSPECTION OF ZINC ARC SPRAY (ZAS) - CONT....



- 20 boxes in total within the garage – 11 were found to be in working condition (failed Reference Electrode)
- NACE criteria of a minimum of 100 mV of cathodic polarization criterion was primarily used for evaluation of the effectiveness of the CP system
- Only 1 out of 11 test panels displayed a polarization shift of at least 100 mV over the 24-hour period
- ZAS is still providing some current, though not sufficient to provide adequate corrosion protection

SOLUTIONS FOR NEW CATHODIC PROTECTION SYSTEM

Replace Current ZAS w/ new ZAS

Targeted Protection using Type 2 Embedded Anode

- Two Stage Anode
- Type 2A Galvanic



Embedded Type 2A Galvanic Anode



Self-Powered Two Stage Anode



OPTION 1 – REPLACE ZINC ARC SYSTEM (ZAS)



INSPECTION OF ZINC ARC SPRAY (ZAS) - CONT....



- Clean surface with light abrasive blasting
- Achieve sufficient profile which maximizing the amount of cement paste in contact with the zinc coating
- Dry compressed air used to clean any residual dust and blast media

APPLICATION OF ZINC ARC SPRAY



CONSIDERATIONS FOR THIS OPTION



- Have to Clean off existing ZAS system to apply to concrete surface
- Removing system that is still providing some protection
- Economical advantages occur when large areas can be completed at one time
 - Due to phasing of the project (1-2 levels per year) this option loses some its cost effectiveness

OPTION 2 – Targeted Protection using EMBEDDED TYPE 2 ANODES

PRODUCT RANGE

**Embedded Type 2A
Galvanic Anode**

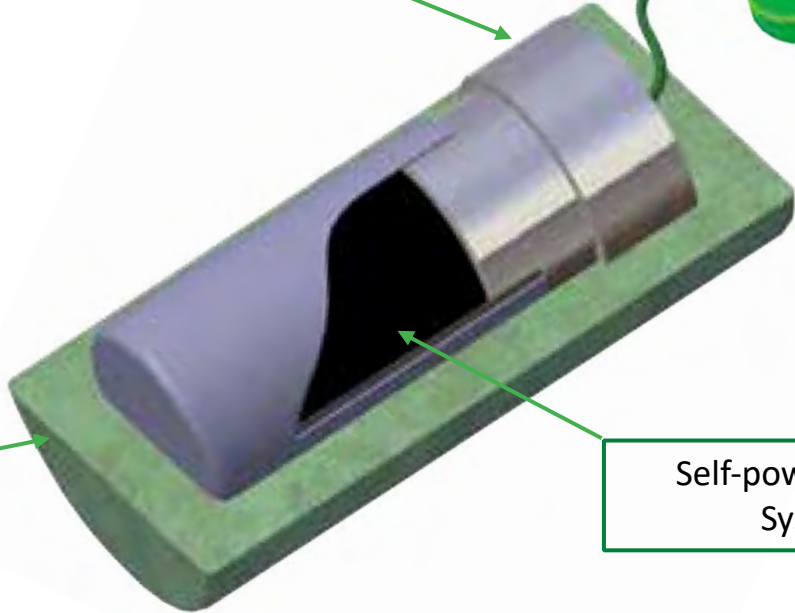


Alkali-activated Galvanic Anode

Single wire installation

Self-powered ICCP
System

Fully Alkali-Activated



**Self Powered Two
Stage Anode**

OPTION 1 – SELF POWERED TWO STAGE ANODE

Stage 1 Electrochemical Treatment
50+ Days



PASSIVATION

- Concrete repairs carried out as required
- High charge density delivered
- Alkalinity restored around steel
- Chlorides pushed away from steel surface
- Corrosion mitigated in pits
- Steel passivity is restored
- Stage 1 can be repeated

Stage 2 Cathodic Prevention
30+ Years

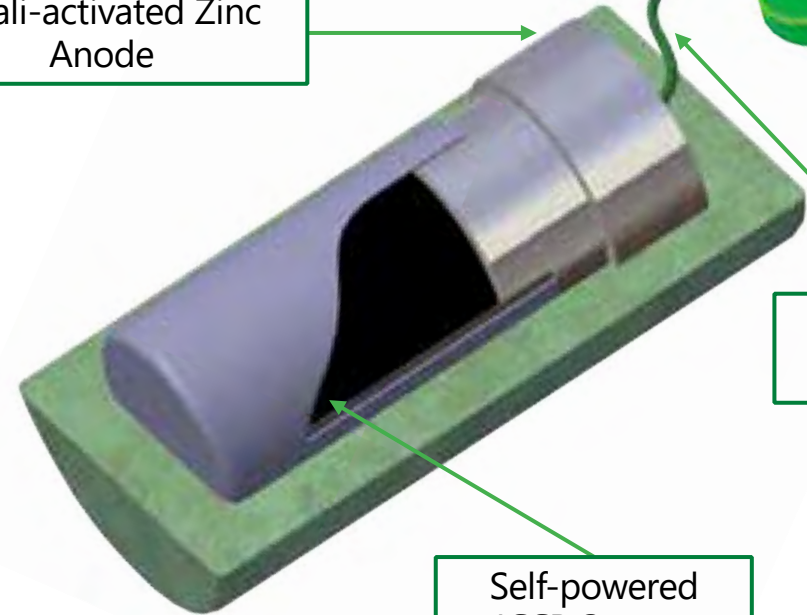


MAINTENANCE

- On-going protective current delivered to steel
- Steel passivity is maintained
- Chloride continues to be repelled
- Alkalinity continues to increase

Structure protected for up to **30+ YEARS**

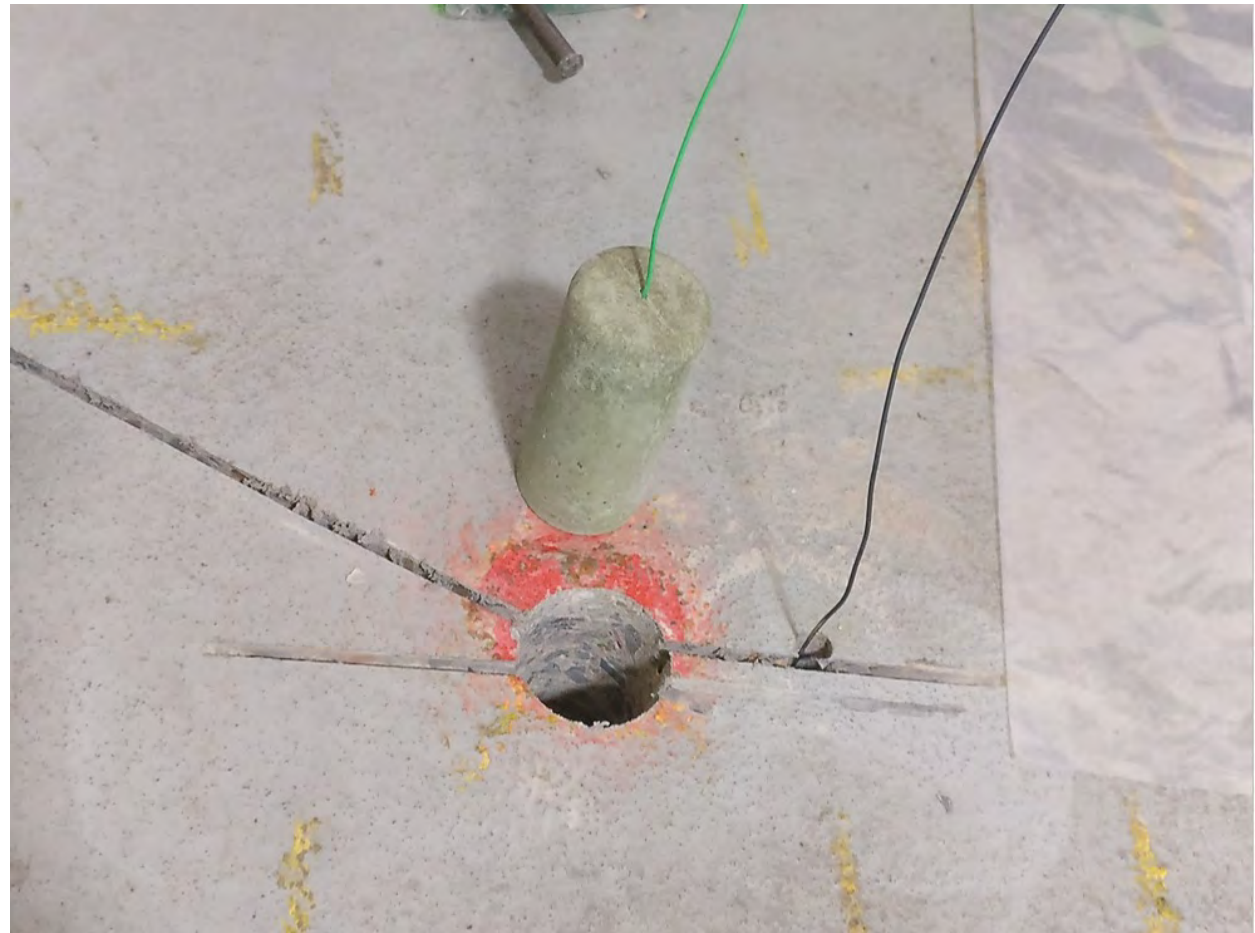
Alkali-activated Zinc Anode



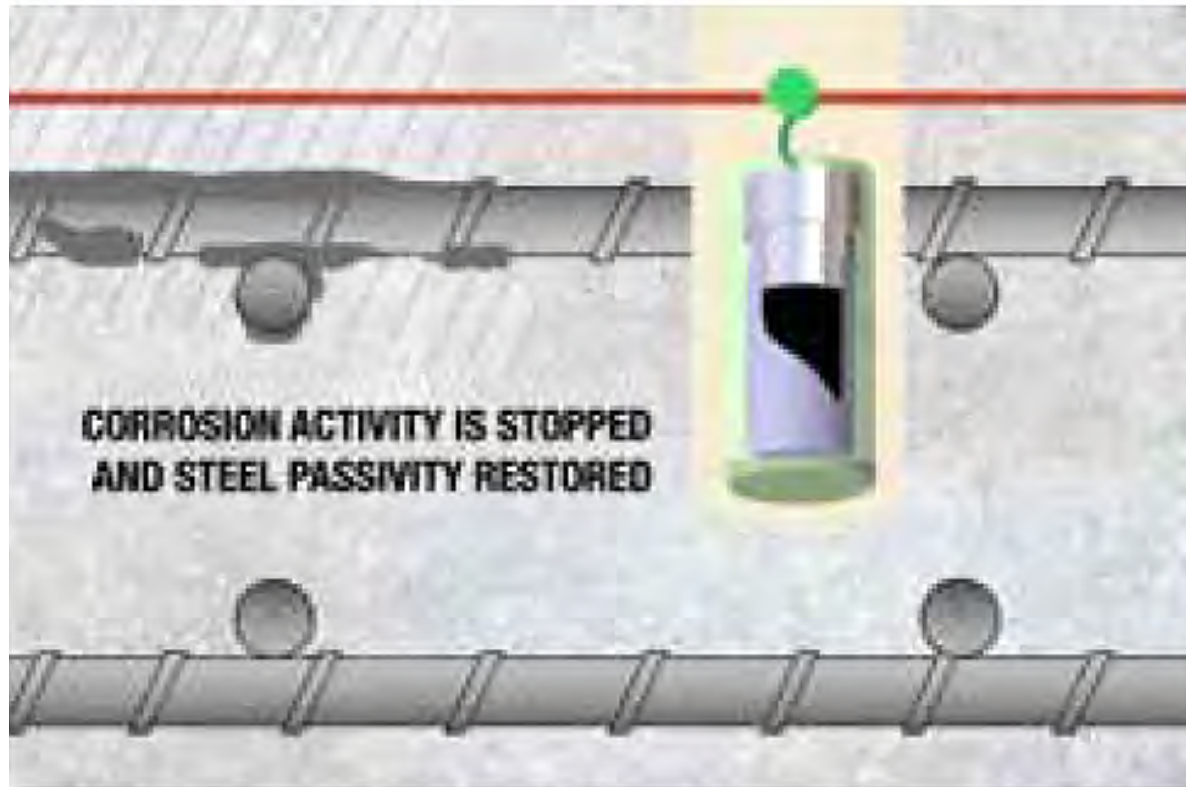
Single Wire Installation

Self-powered ICCP System

TYPICAL INSTALLATION – INSTALL IN SOUND CONCRETE - "HOT SPOT" AREAS



CONSIDERATIONS FOR THIS OPTION



TYPICAL INSTALLATION

Benefits of Two Stage Embedded Anode

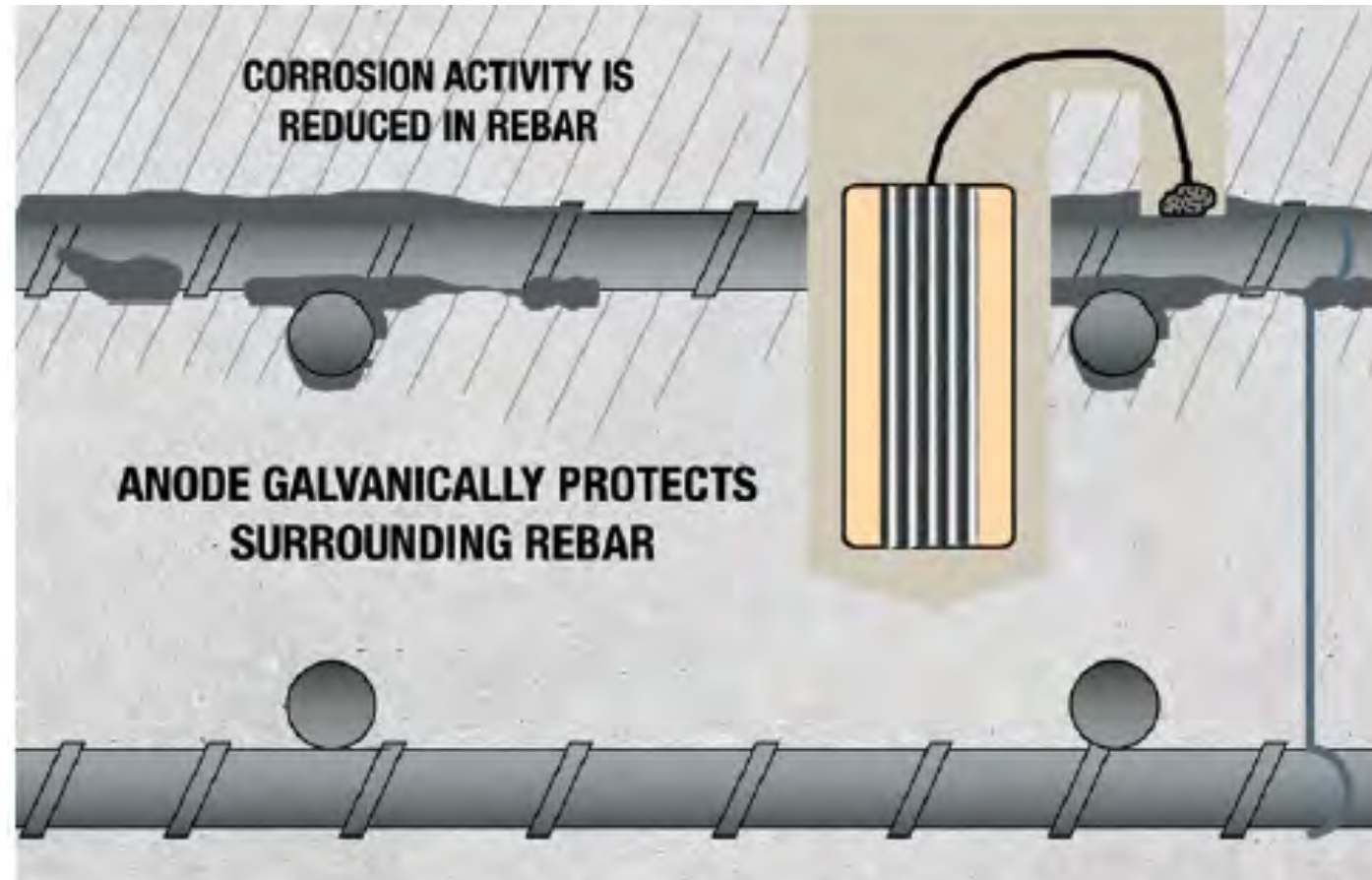
- Self Powered ICCP Phase can provide cathodic protection to steel in Phase 1 w/ out the use of outside power
- Due to ICCP Phase, wider spacing compared to galvanic Type 2 Anodes (Less Anodes, install time etc.)
- Potentially provide longer service life if desired due to ICCP Phase protection steel up front – Galvanic Stage does not work nearly as hard

Consideration

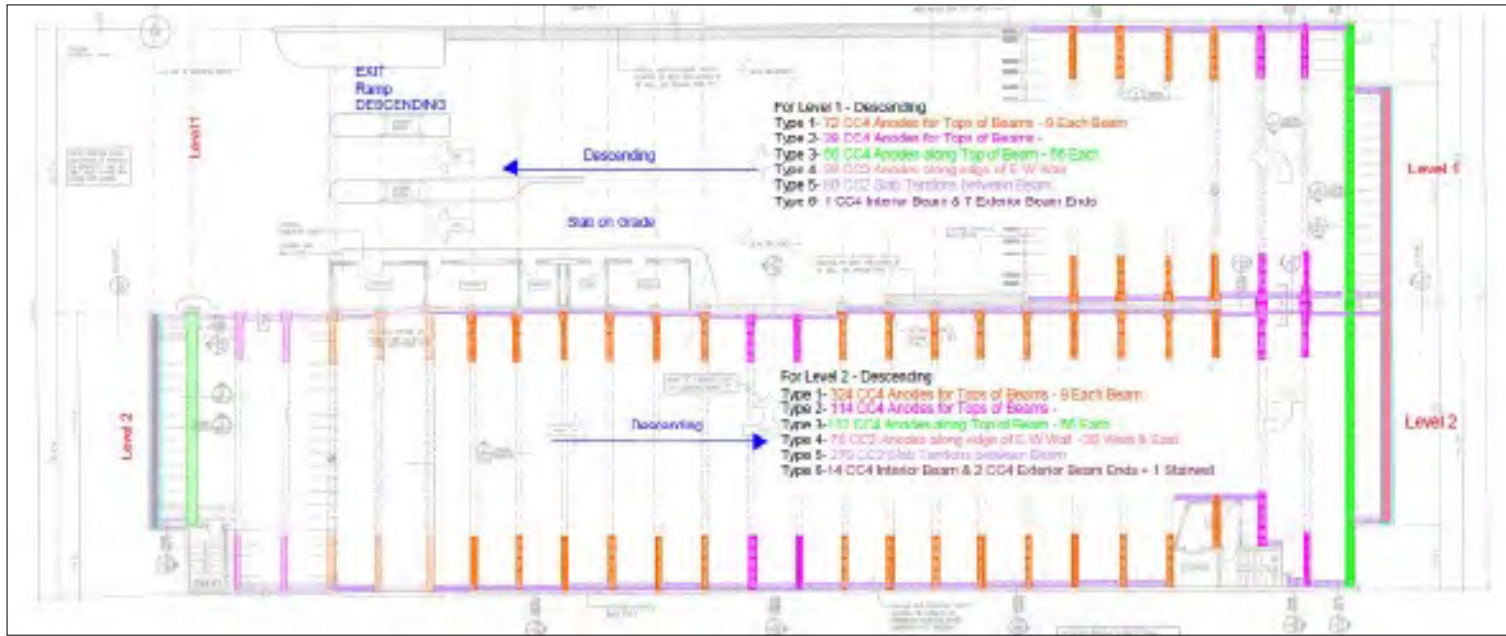
- Not just protecting mild Steel
- Existing reinforcing attached to Post Tension system as well
- Risk of Hydrogen Embrittlement

SOLUTION 2 – EMBEDDED TYPE 2A GALVANIC ANODES

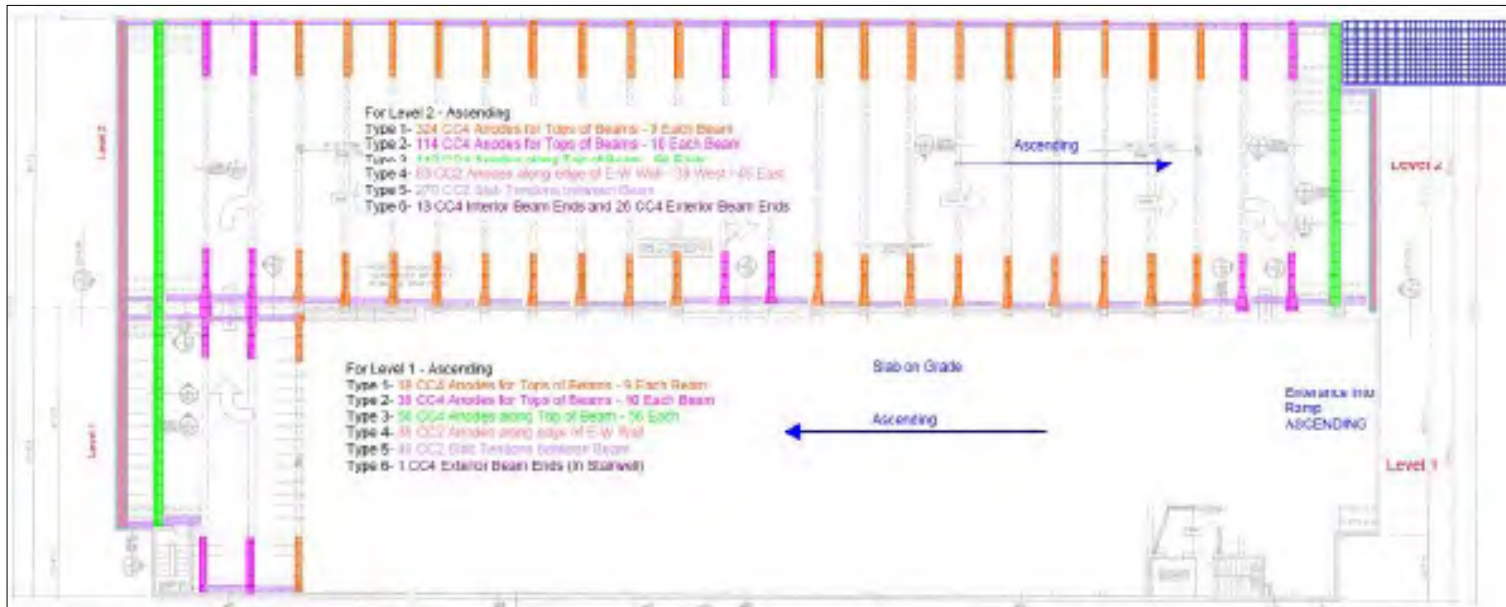
- Control on-going corrosion /prevent the initiation of new corrosion
- Type 2A Embedded anodes are alkali-activated and consist of a sacrificial zinc anode core
- Installed into concrete that is mechanically sound but has ongoing corrosion activity
- Once installed, the zinc anode corrodes preferentially to the surrounding steel



INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM (ANODE LAYOUT MAP)



Descending Ramps



Ascending Ramps

INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM - CONT...



- Example of Initial Layout of Anode Grid
- Does not include rebar or Post Tension Strands

INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM - CONT...



- Use GPR verify locations, ensuring no rebar or PT is in the drill location
- These will be slightly different due to location of existing reinforcing steel and post tension system

INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM - CONT...



Type 2A Embedded Anode



Type 2A Embedded Anode
Next to Drilled Hole

INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM - CONT...

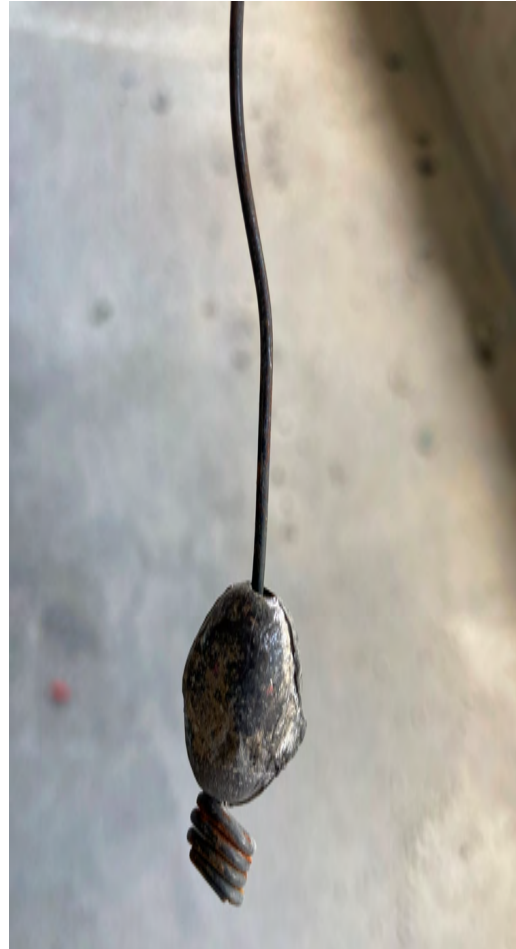


- Holes being drilled for installation of Type 2A Embedded Anodes
- Saw cut made between each drilled hole to run header wire
- Connection to the steel made at each end – max of 8-10 anodes

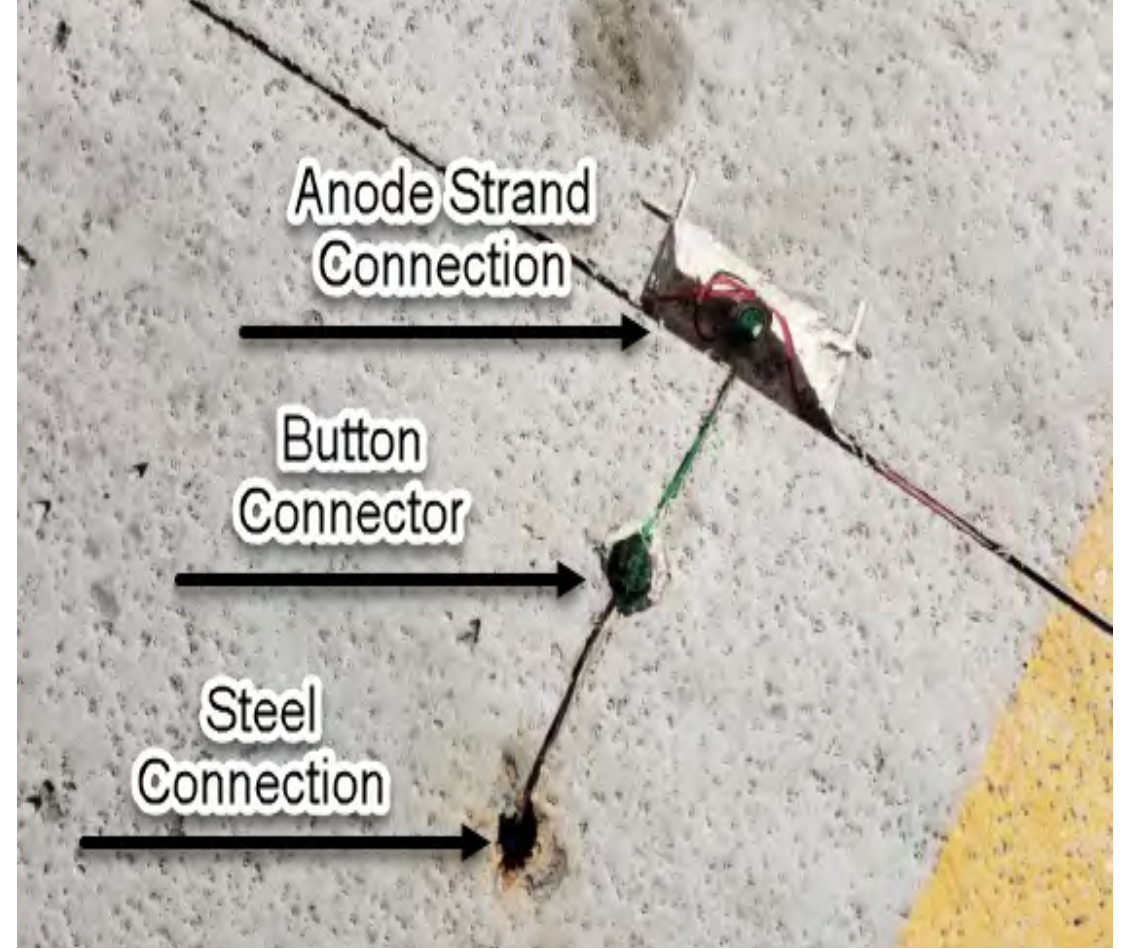
INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM - CONT...



Two Series Of Anodes
Ready to be tied to steel



Lead Steel Connector



Connection from header wire to steel
Example

INSTALLATION OF TYPE 2 A EMBEDDED ANODE SYSTEM - CONT....



- Type 2A Embedded Anodes Grouted in Place
- Traffic Coating then installed over top of the anode system throughout the two levels of the garage

PERFORMANCE OF ANODE SYSTEM



- Continuity checks for steel and post tension system were conducted
- New Anode system was connected back to existing monitoring boxes from previous system
- New reference electrodes were installed so potential measurements could be taken

Test Box #	NACE Criteria		
	"Instant Off" Potential E_{off} (mV CSE)	Native Potential E_n (mV CSE)	Polarization E_p (mV)
#18	-235	-243	8
#19	-308	-250	-58

- Two Test Boxes were initially monitored
- Installed galvanic system is operating as designed
- The two zones presently do not meet NACE criteria for cathodic protection (-100mV Shift), but this will take time to achieve

CATHODIC PROTECTION SYSTEM REVIEW



- Original CP System near end of service life
- New CP System chosen on variety of factors (service life, protection level, project constructability)
- Embedded Type 2A have capability to monitored in future to determine overall performance
- Installation of Cathodic Protection System will occur at each phase

Questions?



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