SAND • CEMENT

Back to Basics

WATER • AGGREGATE

ICRI
CONCRETE REPAIR
Restore | Repurpose | Renew

2024 FALL CONVENTION

DENVER, COLORADO | OCTOBER 22-25, 2024

www.icri.org

BASICS OF CONCRETE REPAIR AND SURFACE PREPARATION

Peter Dias, BASc, P.Eng.

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

AGENDA

- Codes, Standards, and Guidelines
- Concrete Delamination Principles
- Concrete Restoration
  - Products & Materials
  - Practices
- Special Considerations
- Additional Resources
- Q&A

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

Live Content Slide

When playing as a slideshow, this slide will display live content

Poll: What are deterioration factors that can make reinforcing more susceptible to corrosion, or drive further corrosion in nearby reinforcing?

CODES, STANDARDS, AND GUIDELINES

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

CODES, STANDARDS, AND GUIDELINES

- **Primary objective is to restore structure to condition consistent with current intended use and service life**
- Put another way, at minimum, maintain structural demand/capacity ratios
- Therefore, we want to meet (or exceed) Code-mandated loads, as well as design standards (e.g. local Building Code and/or bylaws, ACI 318, CSA A23.3, etc.)
- Standards and best practice guides have been developed by ICRI, ACI, and CSA for reinforced concrete restoration

CODES, STANDARDS, AND GUIDELINES

- For USA:
  - Local Building Code
  - ACI 318
- For Canada:
  - BCBC, VBBL, NBCC, etc.
  - CSA A23.3
  - CSA 413
  - CSA 448
- For Both:
  - IBC, IEBC
  - ACI 562/563
  - ICRI 310.1R

CODES, STANDARDS, AND GUIDELINES

- British Columbia Building Code 2024:

1.1.1.2. Application to Existing Buildings

1) Where a *building* is altered, rehabilitated, renovated or repaired, or there is a change in *occupancy*, the level of life safety and *building* performance shall not be decreased below a level that already exists. (See Note A-1.1.1.2.(1).)

- CSA S448.1:

7.1 Objective

When the need for repairs has been established, the engineer shall prepare a design specification that contains the directions and instructions necessary to ensure that the repairs restore the structure or structural component to a condition consistent with the current intended use for the defined service life.

CODES, STANDARDS, AND GUIDELINES

- ACI 562:

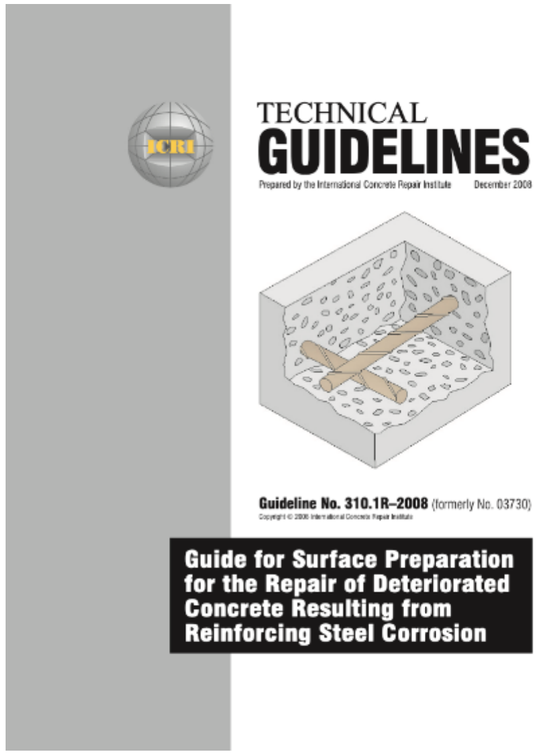
4.2.4 Detailing of the existing reinforcement within the work area need not comply with the current building code if the original building code is the design-basis criteria, and both of the following conditions are satisfied:

(a) The damage or deterioration to existing reinforcement is addressed; and

(b) The repaired work area has capacity equal to or greater than demand in accordance with 5.2.2 if using the original building code requirements or satisfies the requirements of 4.5.3 if using allowable stress design.

CODES, STANDARDS, AND GUIDELINES

- ICRI 310.1R:



CODES, STANDARDS, AND GUIDELINES

- Additional design considerations:
  - Don't assume the original design is correct
  - Consider shoring requirements after site assessment
  - Consider patch growth when estimating repair quantities and contingency allowances
  - Consider making reasonable detailing improvements where possible. For example:
    - Use ties/hoops/stirrups w/ 135° hooks
    - Add extra hairpins/crossties in columns, or to existing close ties/hoops/stirrups w/ 90° hooks
    - Add extra cover if existing is thin (or corrosion inhibitor/intumescent paint if no room for extra cover)
    - Add extra reinforcing if cracking has been an issue (i.e. closely spaced smaller bars)

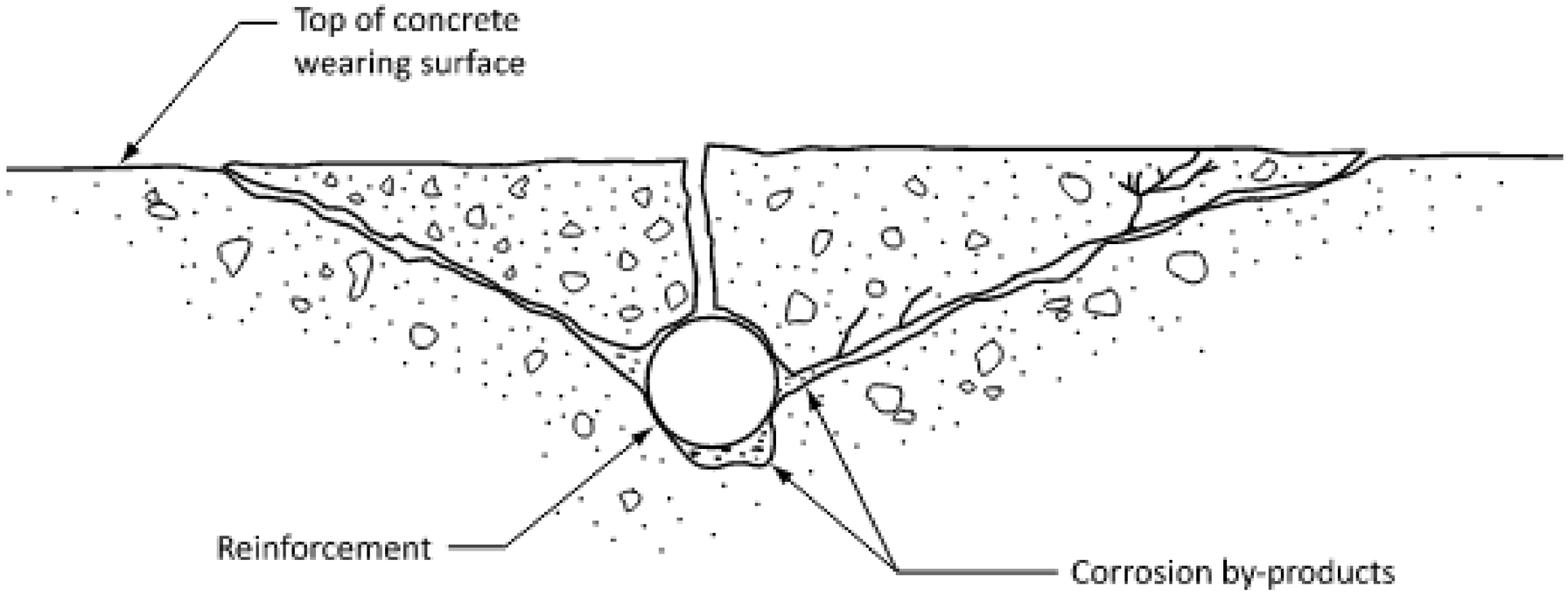
CONCRETE DELAMINATION PRINCIPLES

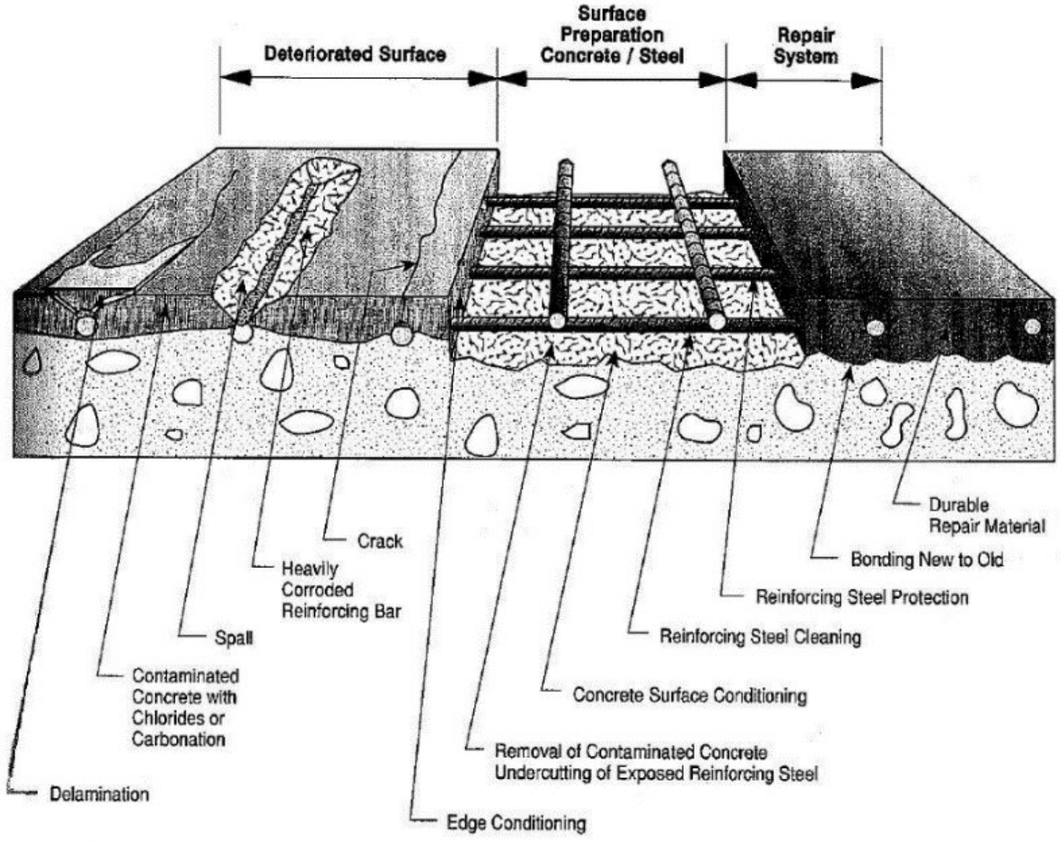
www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

CONCRETE DELAMINATION PRINCIPLES

- Moisture-induced corrosion of embedded reinforcing results in expansion of steel by the formation of corrosion products, eventually leading to delamination and spalling of concrete
- Chlorides (primarily from de-icing salts) disrupt natural passive layer around reinforcing (i.e. lower pH), making it more susceptible to corrosion
- Carbonation (reaction of carbon dioxide in the atmosphere, water, and calcium hydroxide, as well as calcium silicate in concrete) also causes passive layer to deteriorate, making element more susceptible to corrosion


Top of concrete
wearing surface
Reinforcement
Corrosion by-products



www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

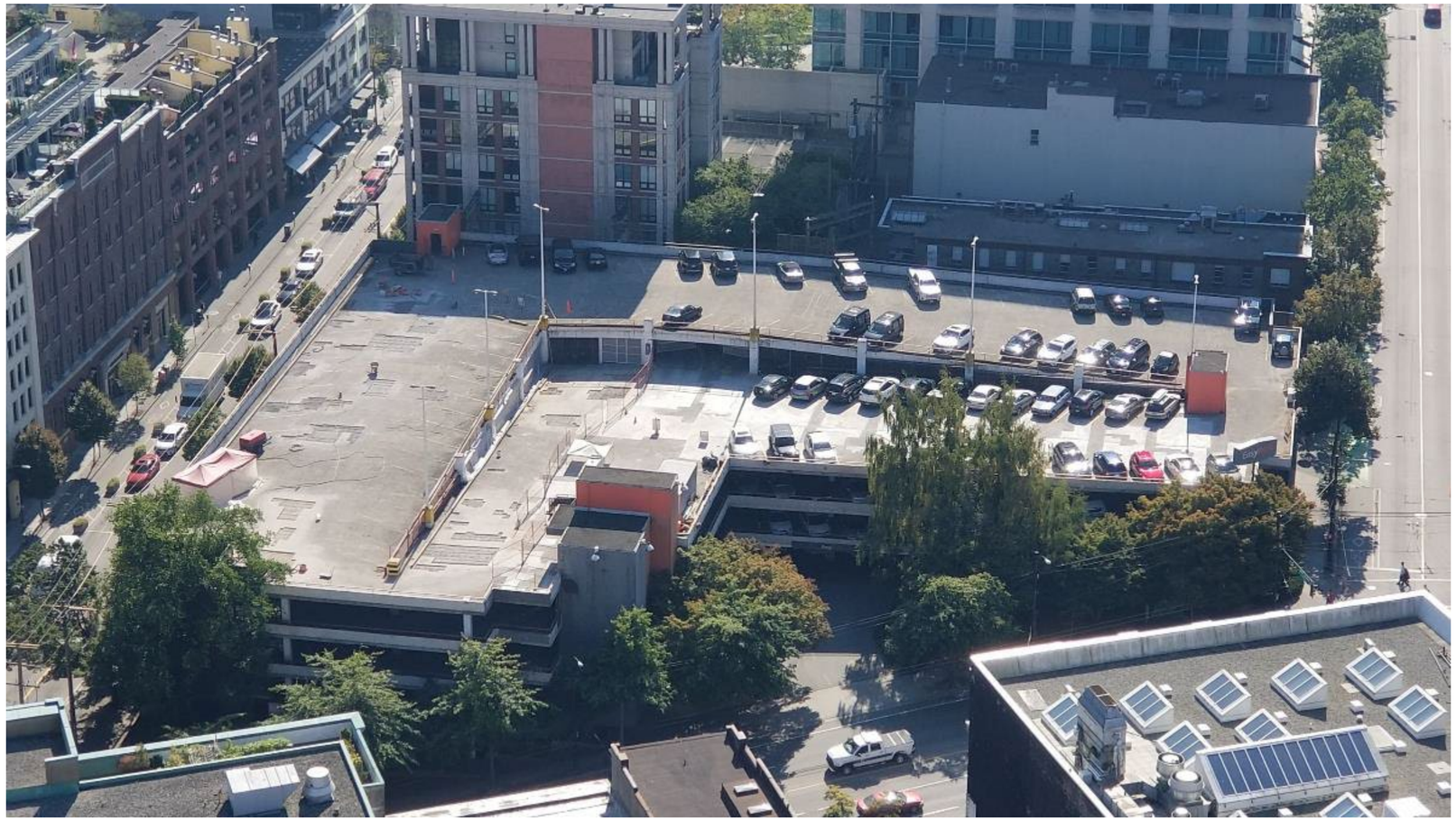
2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

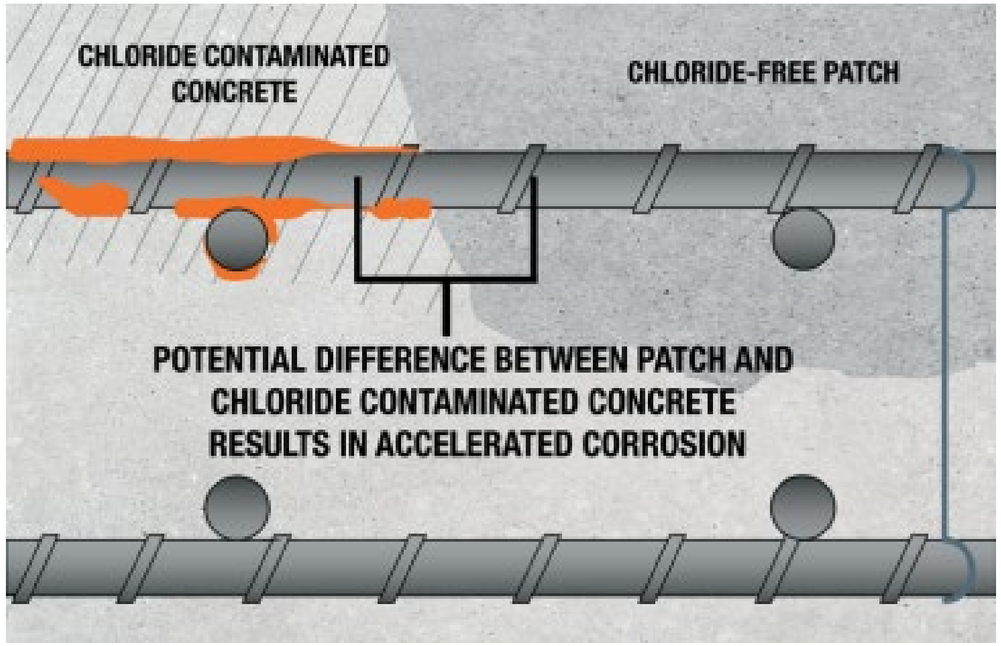
2024 FALL CONVENTION
OCTOBER 22-25, 2024



www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

- **“Ring Anode”/ “Incipient Anode” / “Halo Effect”**
  - A phenomenon where corrosion and deterioration of concrete around a patch repair can be accelerated due to the large electrical potential difference between the new (passive) and old (active) concrete
  - Can be addressed by expanding repair area to non-chloride-contaminated concrete, sacrificial anodes, impressed current



CONCRETE DELAMINATION PRINCIPLES

- Determining patch extents:
  - Use simple boxes as much as possible
  - Avoid excessive re-entrant corners
  - Join multiple small, close patch into larger patches (within reason)
  - Be mindful of structural system (e.g. flat plate, beams, slab bands, drop panels, pan joist, waffle slab, hollow core, post-tensioned, etc.)
  - Be mindful of slab thickness
  - Be mindful of critical zones (e.g. bar development zones, high shear/moment/torsion zones, etc.)

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

CONCRETE RESTORATION

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

ICRI
CONCRETE REPAIR
Restore | Repurpose | Renew

Ready-Mix

Well-suited to large volume pours (e.g. wholesale slab/wall/column replacements)

Pre-Packaged

Well-suited to smaller, targeted repairs and when rapid turnaround needed

Admixtures

Typically used in ready-mix to improve working properties, performance, and reduce costs

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

ICRI
CONCRETE REPAIR
Restore | Repurpose | Renew

Plain

Most used and least expensive, however no environmental protection

Epoxy-coated

Improved environmental protection at a cost premium, as well as increased lead times. Damaged coating must be repaired, and development length must be increased too

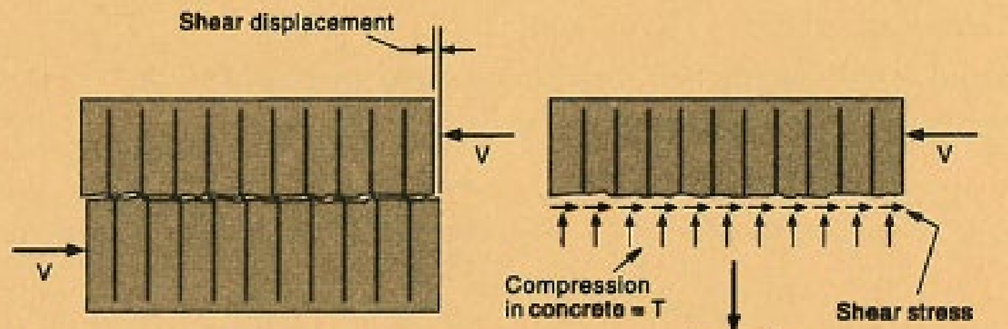
Galvanized & Stainless

Improved environmental protection at a cost premium, as well as increased lead times. Typically used in large infrastructure

CONCRETE RESTORATION PRACTICES

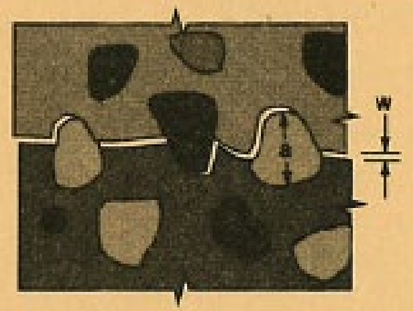
- Concrete removal:
  - Remove to a consistent minimum depth
  - Remove concrete around and behind reinforcing
  - Roughen concrete to ~4-6mm (3/16" – 1/4") amplitude for bond and shear friction (i.e. interface shear transfer) to structural engage patch
  - Roughness can be gauged on site with ICRI CSP chips

$$v_r = \lambda \phi_c (c + \mu \sigma)$$



(I) Shear Tension Causing Crack Opening

(II) Free-Body-Diagram



(III) Aggregate Interlock at Crack Interface

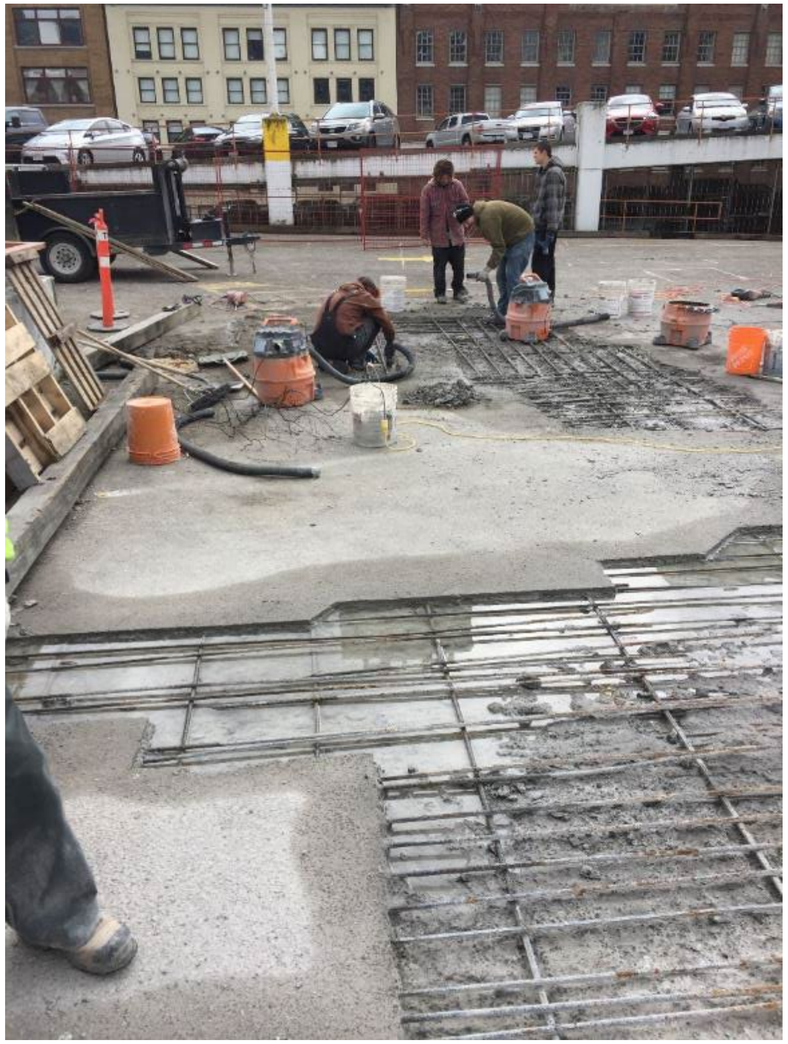
Fig. N11.5.1(a)
Shear friction concept

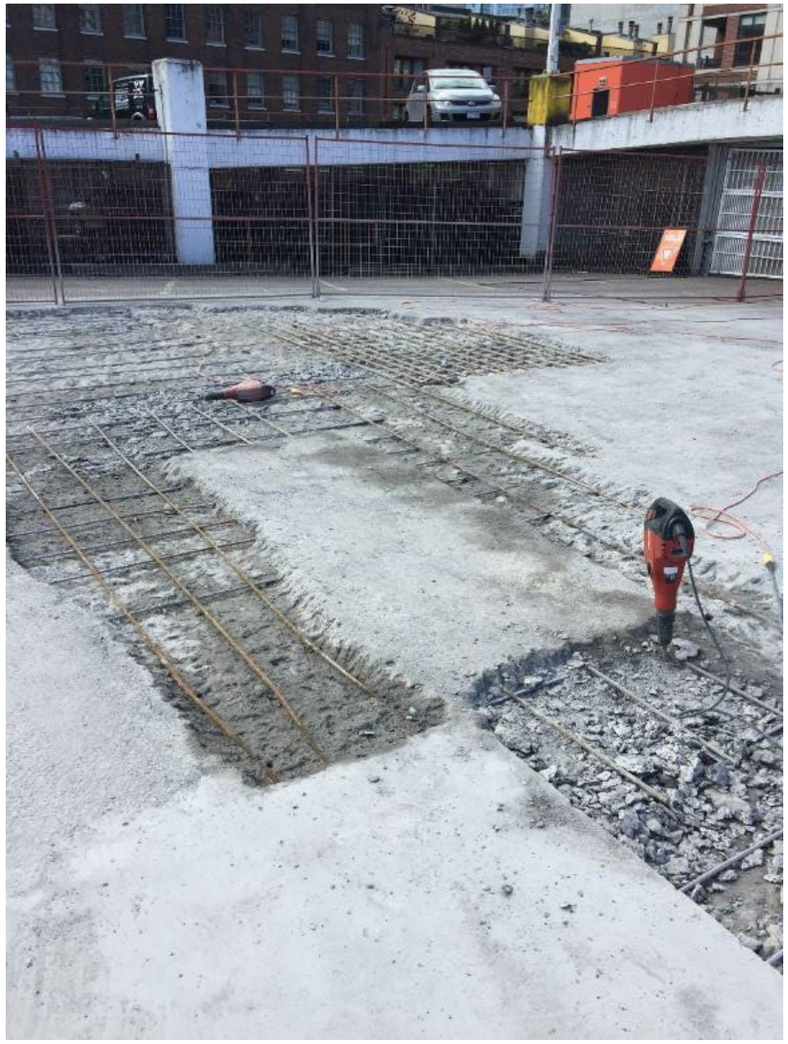
www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

CONCRETE RESTORATION PRACTICES

- Concrete removal methods:
  - Percussive (i.e. chipping)
  - Hydro-demolition
  - Abrasive blast (e.g. shot blast)





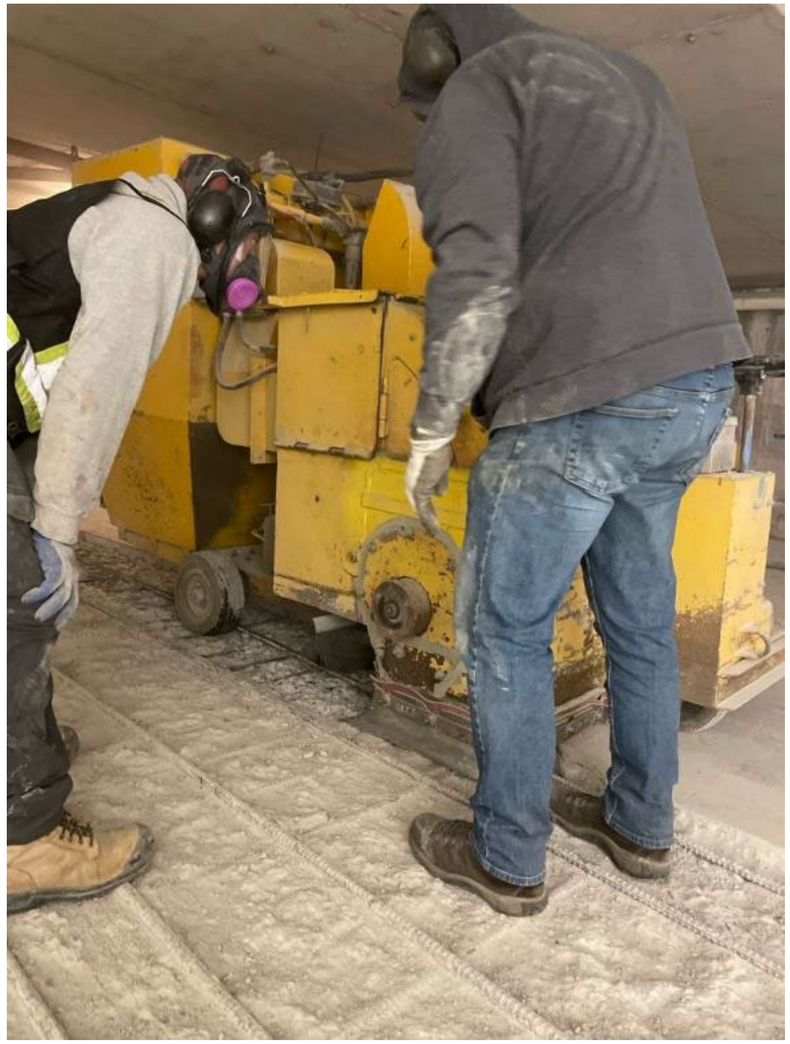
www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024


SLOW
5
M.P.H.

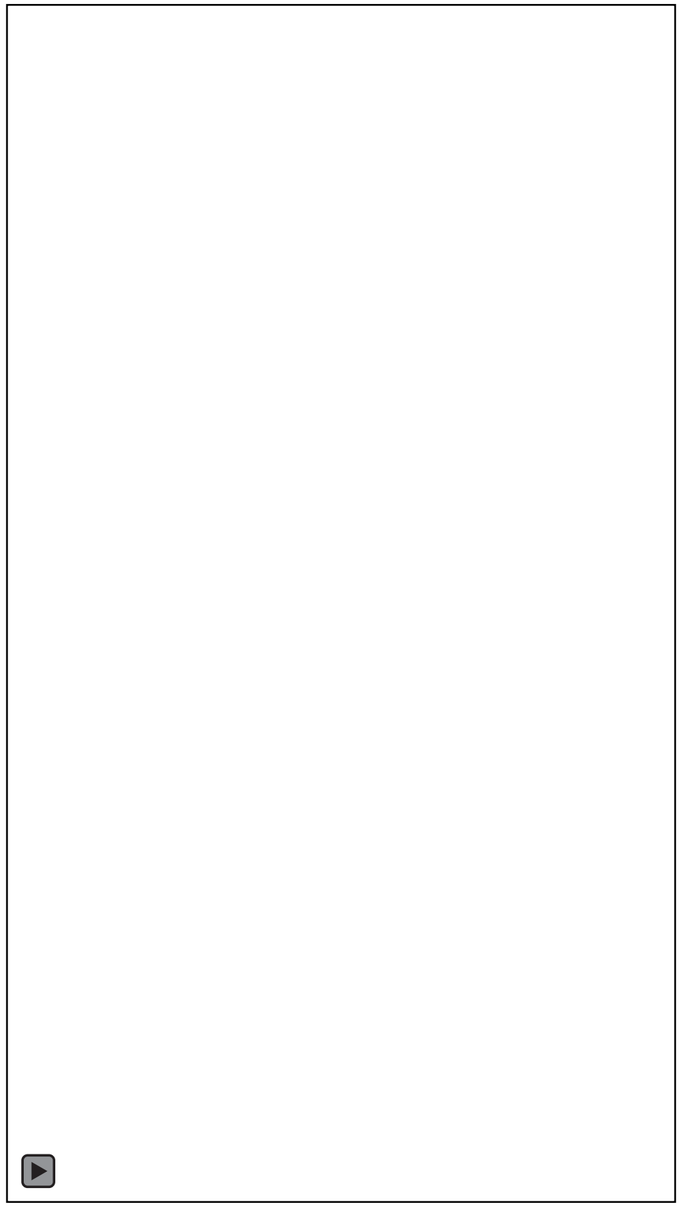


www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

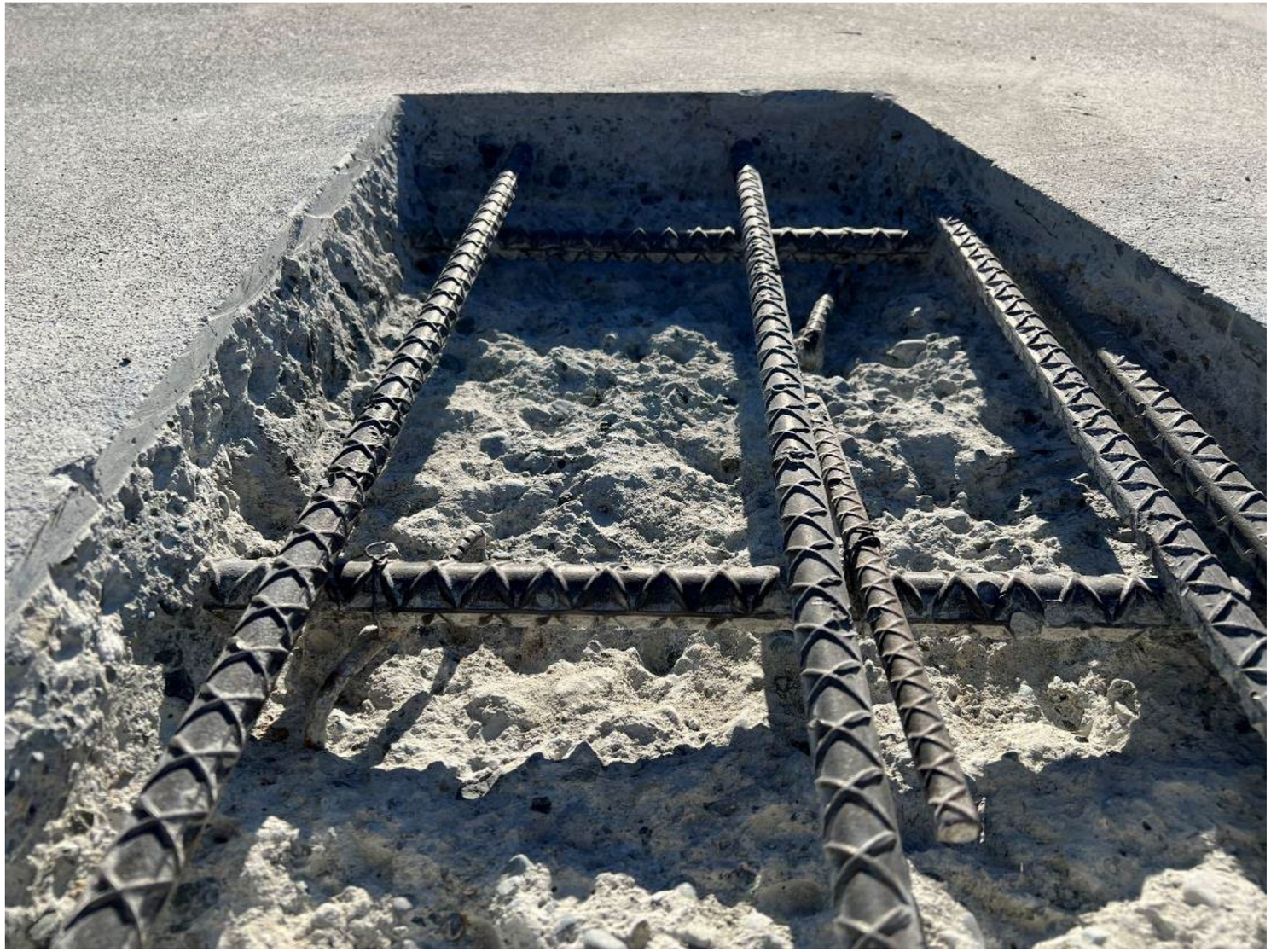
CONCRETE RESTORATION PRACTICES

- Reinforcing preparation:
  - Common methods:
    - Abrasive blast (e.g. sand blast)
    - Hydro-demolition
    - Grinding (e.g wire wheel)
  - Common methods, as well as quality of work can vary with region/contractor
  - Intent is to remove concrete, cement paste, corrosion, dirt/debris, oils, etc. to clean metal
  - Supplement reinforcing if needed after preparing reinforcing



www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024



www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

CONCRETE RESTORATION PRACTICES

- Patch wetting:
  - Intent is to hydrate host concrete to avoid pulling moisture from patch material (to prevent poor bond and curing)
  - Avoid standing water that can create localized poor bond and/or weaknesses (i.e. achieve SSD condition)
- Bond coat/slurry coat:
  - Instead of traditional “slurry coat”, scrub repair material into prepared patch with stiff brush or gloved hands
  - Slurry coat has high w/c ratio and can create a plane of weakness
  - Manufacturers of pre-packaged material recommend scrub coat as well

CONCRETE RESTORATION PRACTICES

- Concrete placement
  - Intent is to avoid aggregate segregation and cold joints
  - Place concrete as close to final position as possible, avoid re-handling
  - Place in a continuous manner from starting point (i.e. “keep a wet edge”)
  - No re-tempering of concrete
- Consolidating
  - Intent is to produce monolithic concrete elements with uniform properties and without voids, rock pockets/honeycomb, etc.
  - Work concrete well around reinforcing, embeds, etc.
  - Consider higher slump mix for more congested elements

CONCRETE RESTORATION PRACTICES

- Finishing:
  - Intent is to create uniform, consistent finish appropriate for application
  - Avoid overworking finish in general or working bleed water back in
  - Avoid hard troweling air-entrained concrete
- Curing:
  - Intent is to maintain moisture to drive the hydration process
  - Burlap acts as a sponge to keep moisture on patch
  - Plastic sheets slow evaporation to keep moisture on patch
  - Consider additional curing requirements in extreme weather (e.g. high/low temperatures, high winds, etc.)
  - Become familiar with hot weather concrete requirements as climate changes

CONCRETE RESTORATION PRACTICES

- Testing:
  - Intent is to confirm air content, slump, compressive and bond strength meet specifications
  - Acoustic sounding can be used for basic field testing on site
  - Coring can be completed afterwards for testing and to review bond, reinforcement encapsulation, etc.

SPECIAL CONSIDERATIONS

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

SPECIAL CONSIDERATIONS

- Lightweight aggregate:
  - Corrosion products fill voids in porous aggregate before bursting
  - Corrosion levels can therefore be much higher than with normal aggregate
  - Extent of delamination is likely not reflective of extent of corrosion
  - Consider exploratory chipping during design to review actual corrosion levels

- Reinforcing splicing:
  - Use lap splices wherever as possible
  - Mechanical bar couplers can be used where not enough room for lap splices
  - Welding can also be used, though often as a last resort

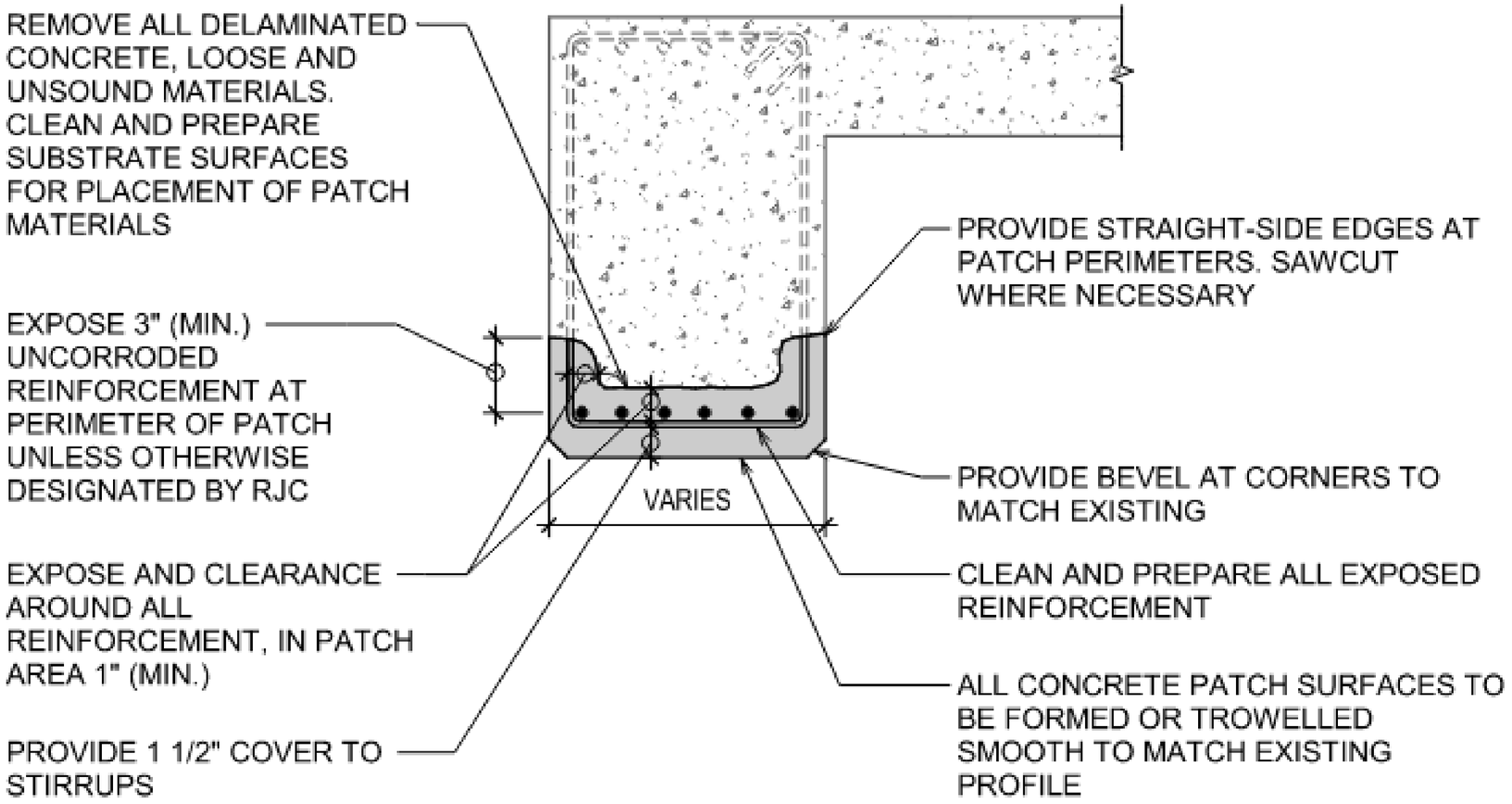
Patent no.: 7,107,735 / 7,093,402.
Additional patents in other countries.

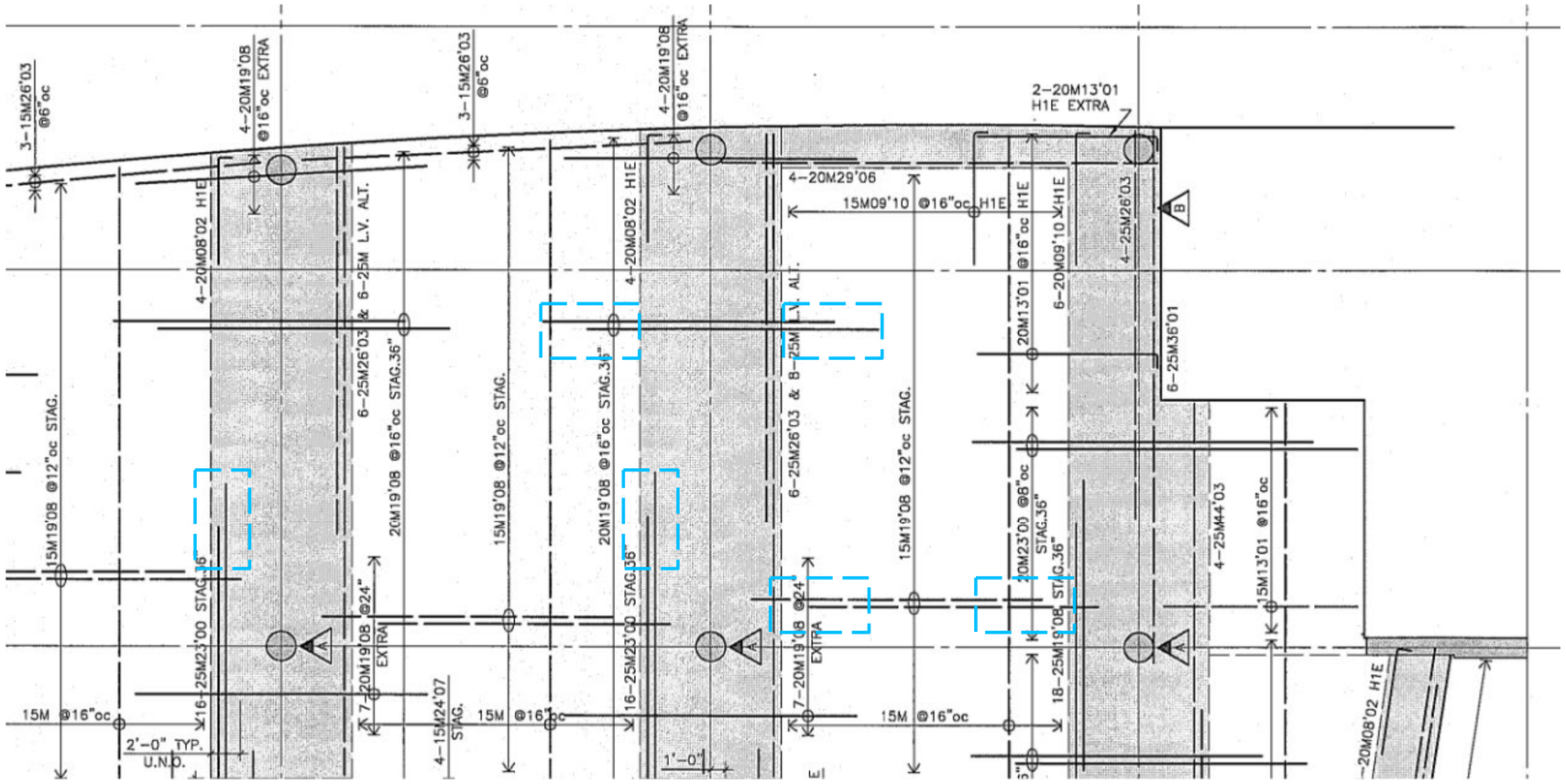
This cutaway shows Lock's patented gripping technology on the inside of the coupler and patented round bolts on the outer edges of the coupler.

SPECIAL CONSIDERATIONS

- High shear/moment zones:
  - Be mindful of “critical sections” in structures and their current condition (e.g. bottom bars heavily deteriorated at mid-span, top bars heavily deteriorated near supports, heavily deteriorated stirrups near supports, top mats, raft slabs, punching shear zones, etc.)
  - Beware of reducing the capacity/cross section at critical sections while doing restoration work (e.g. significant chipping of columns, corbels, beam/slab band/slab near supports, etc.)

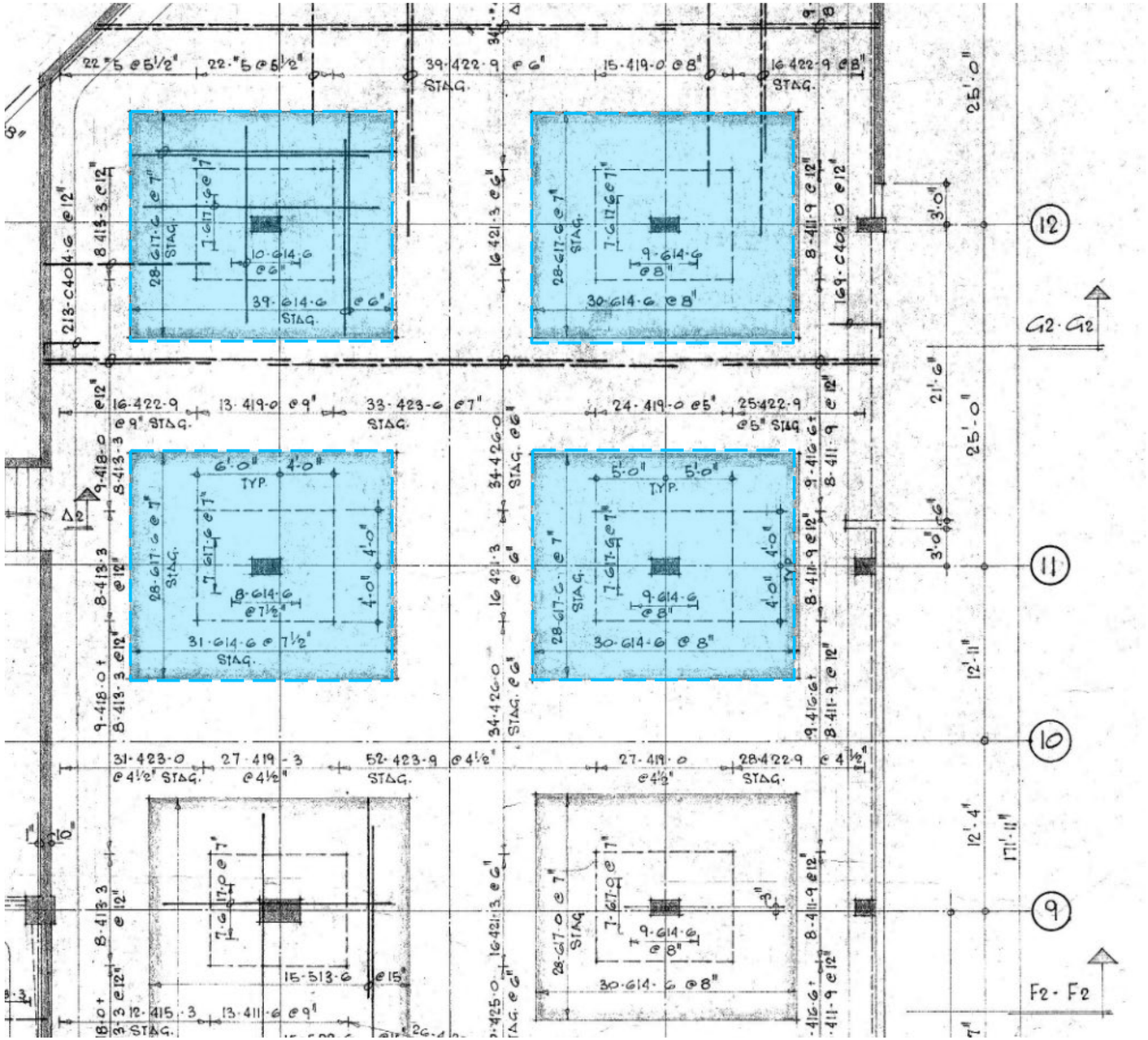
- Bar development zones:
  - Avoid chipping out/disengaging bar ends where development occurs
  - If necessary to chip out, consider phasing work, limiting load, or shoring to suit


REMOVE ALL DELAMINATED CONCRETE, LOOSE AND UNSOUND MATERIALS. CLEAN AND PREPARE SUBSTRATE SURFACES FOR PLACEMENT OF PATCH MATERIALS
EXPOSE 3" (MIN.) UNCORRODED REINFORCEMENT AT PERIMETER OF PATCH UNLESS OTHERWISE DESIGNATED BY RJC
EXPOSE AND CLEARANCE AROUND ALL REINFORCEMENT, IN PATCH AREA 1" (MIN.)
PROVIDE 1 1/2" COVER TO STIRRUPS
VARIES
PROVIDE STRAIGHT-SIDE EDGES AT PATCH PERIMETERS. SAWCUT WHERE NECESSARY
PROVIDE BEVEL AT CORNERS TO MATCH EXISTING
CLEAN AND PREPARE ALL EXPOSED REINFORCEMENT
ALL CONCRETE PATCH SURFACES TO BE FORMED OR TROWELLED SMOOTH TO MATCH EXISTING PROFILE



www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024



ICRI
CONCRETE REPAIR
Restore | Repurpose | Renew

www.icri.org

2024 FALL
CONVENTION
OCTOBER 22-25, 2024

ICRI
CONCRETE REPAIR
Restore | Repurpose | Renew

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

SPECIAL CONSIDERATIONS

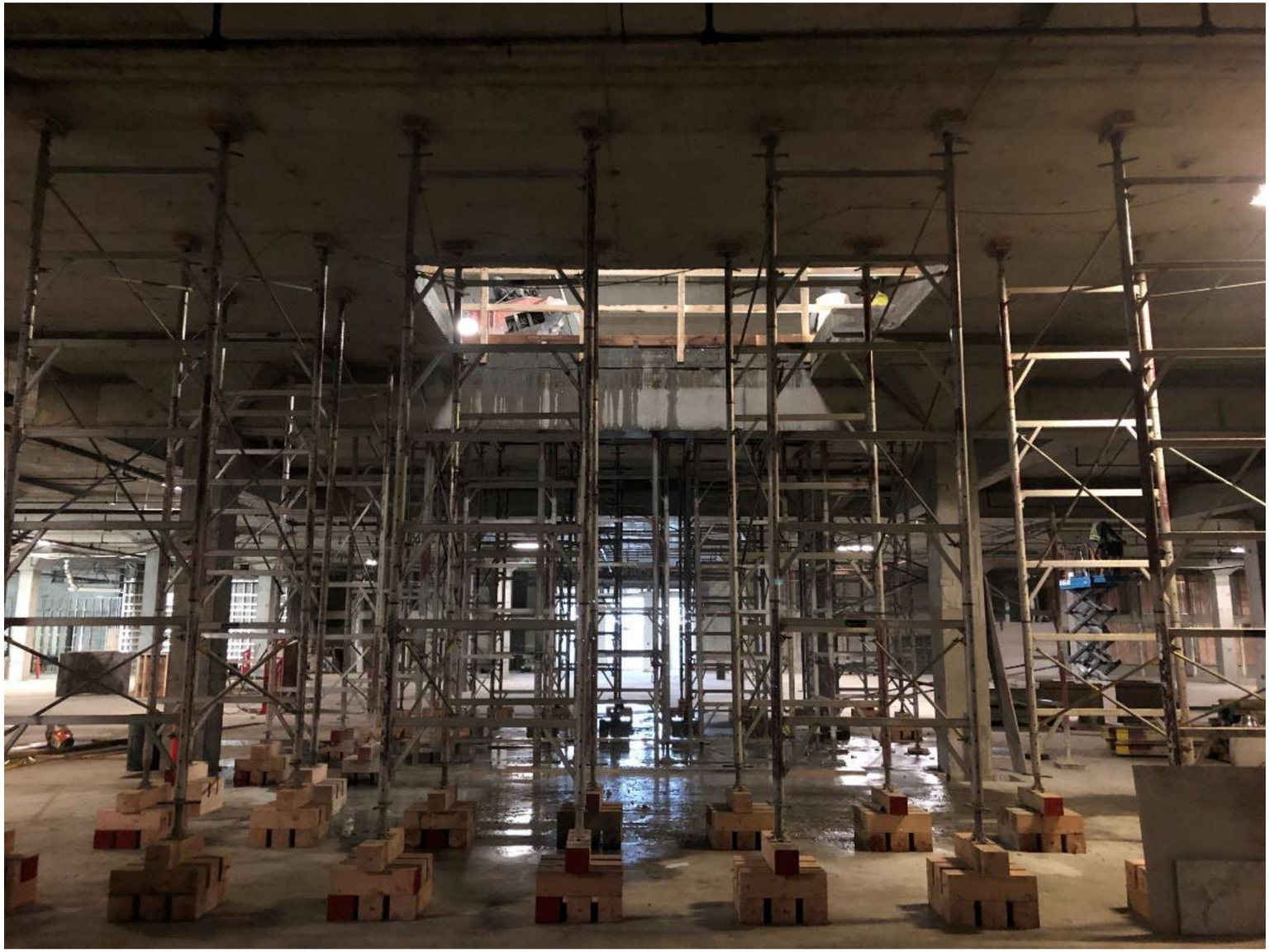
- Bracing/Shoring
  - Shoring may be needed for various situations (e.g. reduced member capacity due to deterioration, chipping out reinforcing in development zones, etc.)
  - Review capacity vs. actual loading (e.g. are design live/snow loads currently being applied, or just self weight? Construction loads?)
  - Lateral bracing may also be needed for vertical elements (e.g. columns, walls), if the element providing lateral support (e.g. beam/slab band/slab) is being removed, or if resisting significant lateral loads (e.g. retaining wall)

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

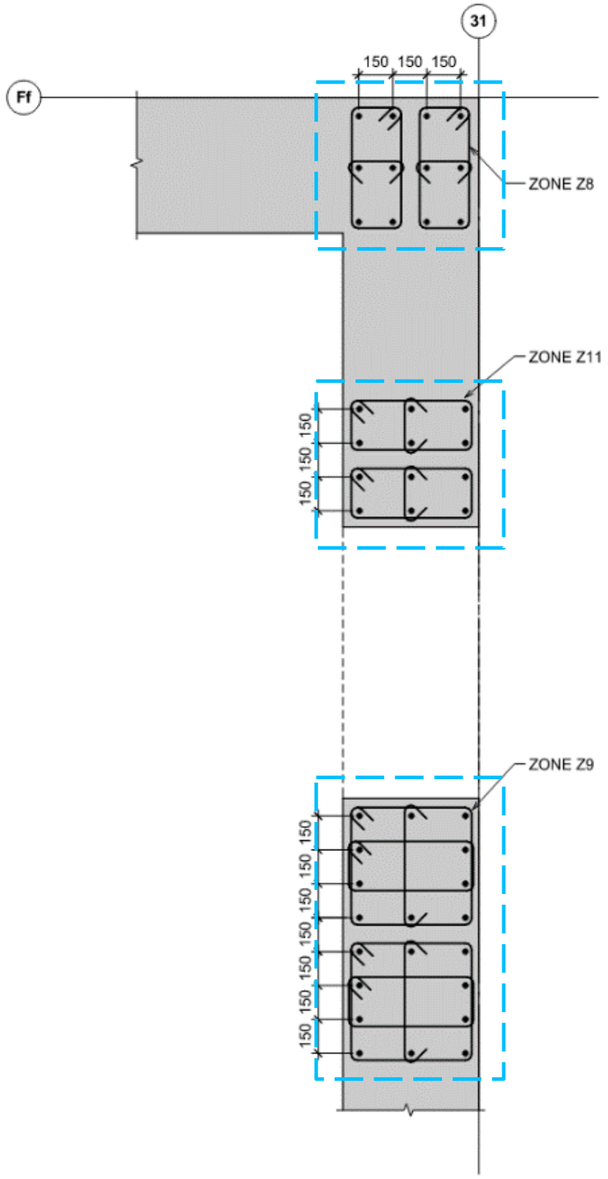


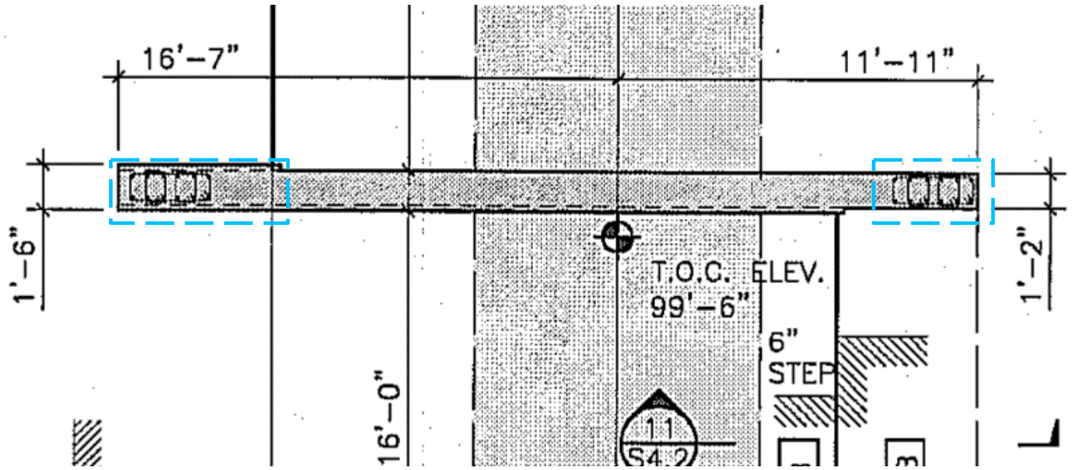
www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

SPECIAL CONSIDERATIONS

- Lateral Force-Resisting Systems (LFRSs)
  - Careful consideration and detailing needed for repairs of LFRS elements such as shear walls, elevator/stair cores, moment frames, etc. (e.g. maximum concrete strength, seismic hooks on ties/hoops/stirrups, lap splice length reductions not permitted, requirements for welded/mechanical splices, etc.)
  - Be mindful of changing strength, stiffness, or ductility of LFRS members being repaired (see ASCE 41)
  - Reinforcing more congested, making preparation and placing more complex


31
Ff
150 150 150
ZONE Z8
ZONE Z11
150 150 150
ZONE Z9
150 150 150 150 150

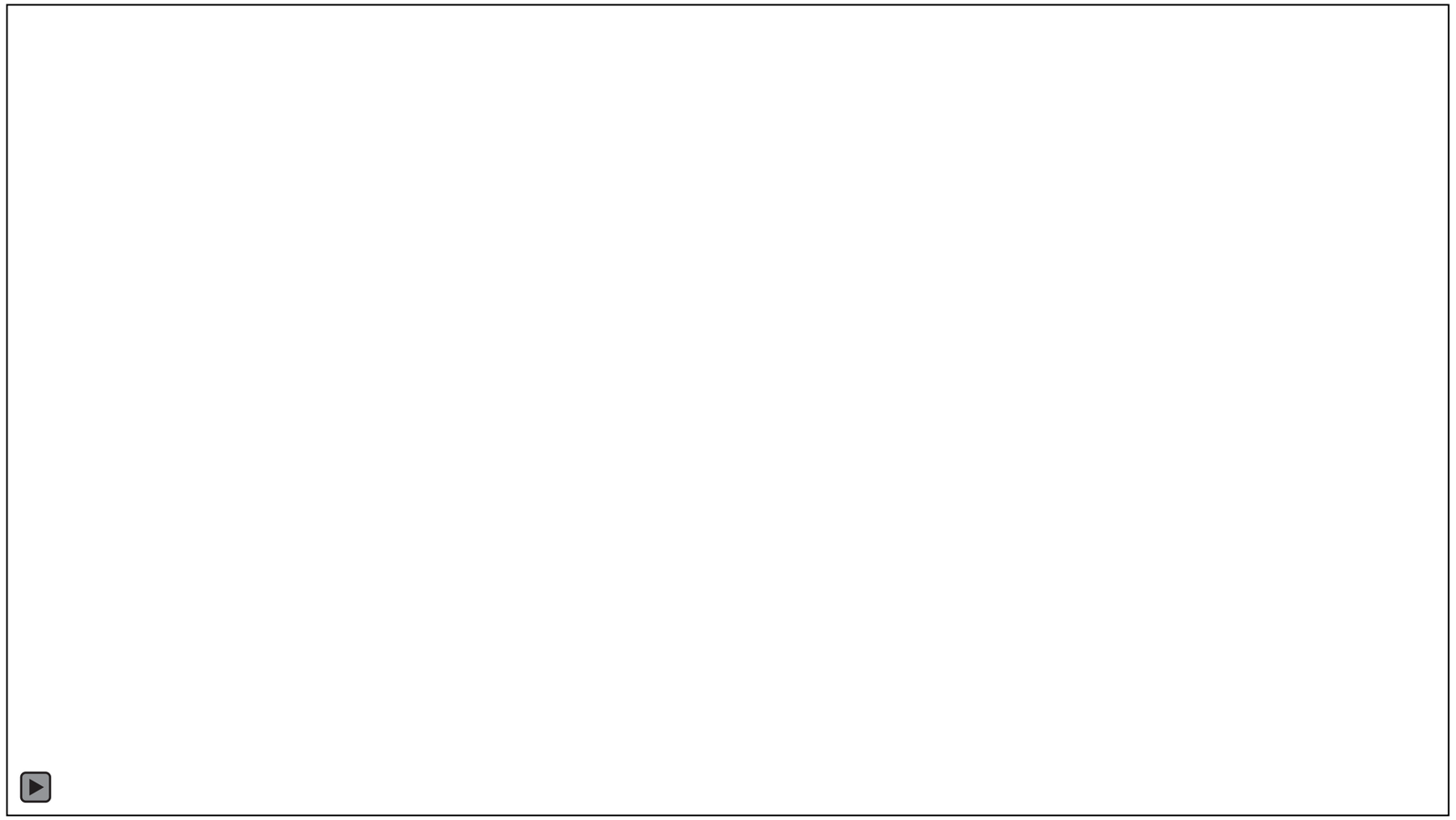

16'–7"
11'–11"
1'–6"
T.O.C. ELEV.
99'–6"
6"
STEP
16'–0"
1'–2"
11
S4.2

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

SPECIAL CONSIDERATIONS

- Shotcrete
  - Less common, but well-suited to large areas of vertical and overhead repairs
  - Nozzle person to be ACI-certified
  - Shoot mock-up test panels and test to confirm results
  - Watch for full encapsulation of reinforcing/shadow zones behind reinforcing
  - Beware of rebound being re-incorporated
  - Beware of sloughing of larger overhead patches when screeding



www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

Cores from Panel 2 – Andreas Rubabclava – Very Good

Table 1 – Visual Shotcrete Core Quality Evaluation

Core ID	Nozzleman	Visual Inspection			Interface Bond Inspection
		Criteria A	Criteria B	Rating	
P1-A	Jason Felter	>90%	<25%	Very Good	Good
P1-B	Jason Felter	>90%	<25%	Very Good	Good
P1-C	Jason Felter	>90%	<25%	Very Good	Good
P1-D	Jason Felter	>90%	<25%	Very Good	Good
P1-E	Jason Felter	>90%	<25%	Very Good	Good
P1-F	Jason Felter	>90%	<25%	Very Good	Good
P2-A	Andreas Rubaclava	>90%	<25%	Very Good	Good
P2-B	Andreas Rubaclava	>90%	<25%	Very Good	Good
P2-C	Andreas Rubaclava	>90%	<25%	Very Good	Good
P2-D	Andreas Rubaclava	>90%	<25%	Very Good	Good
P2-E	Andreas Rubaclava	>90%	<25%	Very Good	Good
P2-F	Andreas Rubaclava	>90%	<25%	Very Good	Good
P3-A	Cody Hagedorn	>90%	<25%	Very Good	Good
P3-B	Cody Hagedorn	>90%	<25%	Very Good	Good
P3-C	Cody Hagedorn	>90%	<25%	Very Good	Good
P3-D	Cody Hagedorn	>90%	<25%	Very Good	Good
P3-E	Cody Hagedorn	>90%	<25%	Very Good	Good
P3-F	Cody Hagedorn	>90%	<25%	Very Good	Good

SPECIAL CONSIDERATIONS

- Coating or waterproofing patches
  - Beware if repairs being coated shortly after (e.g. paint, waterproofing membrane)
  - Consider using specialized repair mortar (e.g. Sika MasterEmaco T430)
  - Adhere to manufacturer recommended curing times as much as possible
  - Use poly sheet test (ASTM D4263)

- Aesthetics
  - Can be a bigger consideration for clients/owners, especially with architecturally exposed finishes
  - Advise clients/owners that repairs likely won't match and will be noticeable
  - Consider having mock-ups done in discrete location with several mixes and allow client/owner choose closest match

ADDITIONAL RESOURCES

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

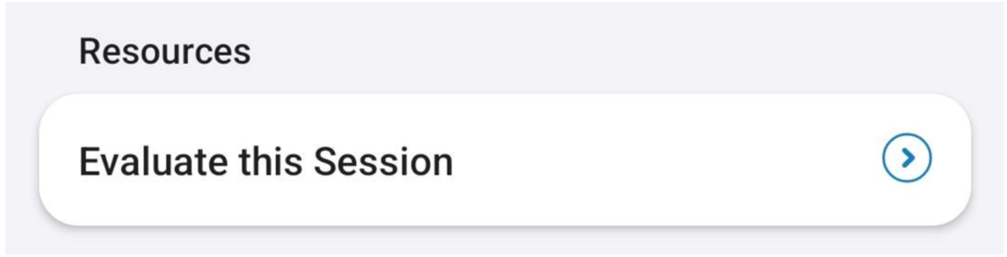
ADDITIONAL RESOURCES

- ICRI Guidelines
- ACI Standards and Guidelines
- CSA Standards and Guidelines
- Concrete Preservation Alliance

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

SESSION EVALUATION



To complete the session evaluation, open the ICRI Convention App.

Under **Plan Your Event,** select Schedule, and then the Technical Session you are attending. Select the sub-session you are attending, scroll down to Resources, and select Evaluate this Session.

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

QUESTIONS?

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024

THANK YOU

FOR YOUR ATTENTION

Peter Dias, BASc, P.Eng.
RJC Engineers
pdias@rjc.ca

www.icri.org

2024 FALL CONVENTION
OCTOBER 22-25, 2024