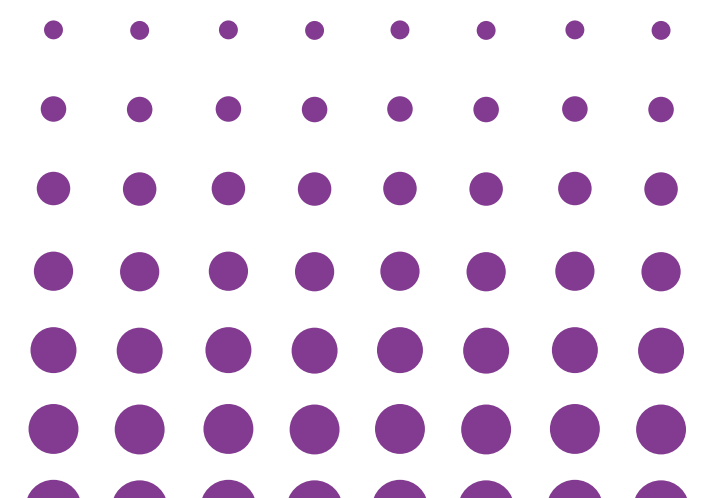


2024 FALL CONVENTION

DENVER, COLORADO | OCTOBER 22-25, 2024



www.icri.org



Fundamentals of Repair Design – Anchorage in Concrete

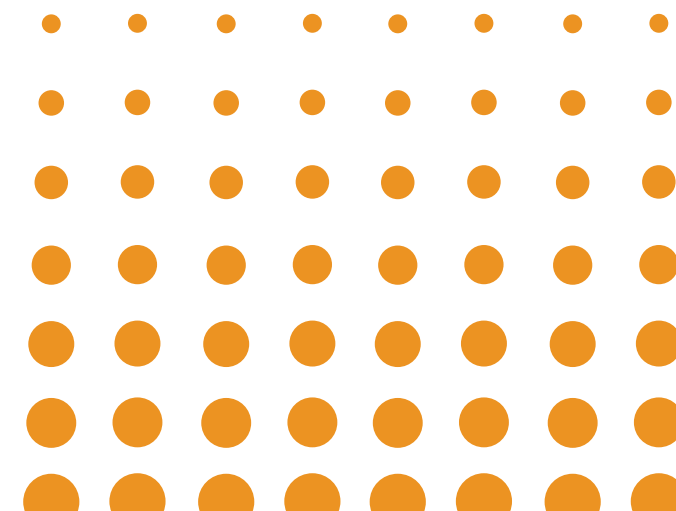
PRESENTED BY:

Jeffrey M. Owad, PE, PMP

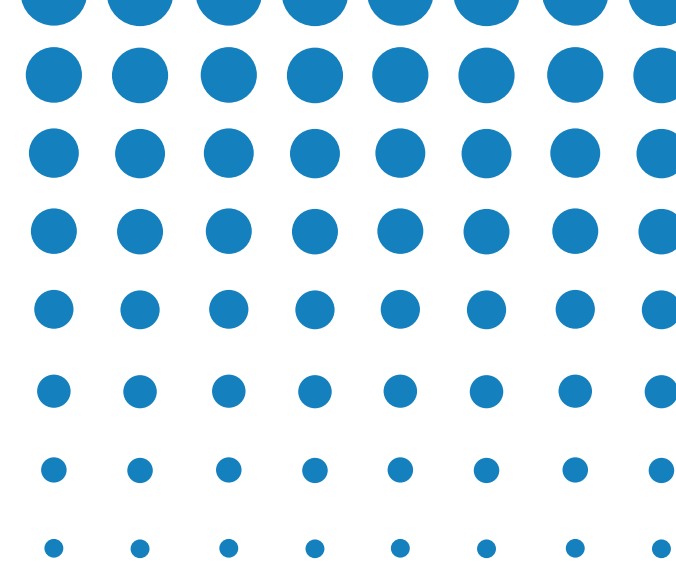
Luis R. Pelayo, PE, SE



www.icri.org



2024 FALL
CONVENTION
OCTOBER 22-25 2024



Objectives



- Review applicable codes and standards commonly used
- Review specific anchor design limit states and parameters considered
- Demonstrate common application of anchorages in repairs
- Discuss engineering best practices for repair design using anchorage

www.icri.org

2024
CONVENTION
OCTOBER 22-25 2024
FALL

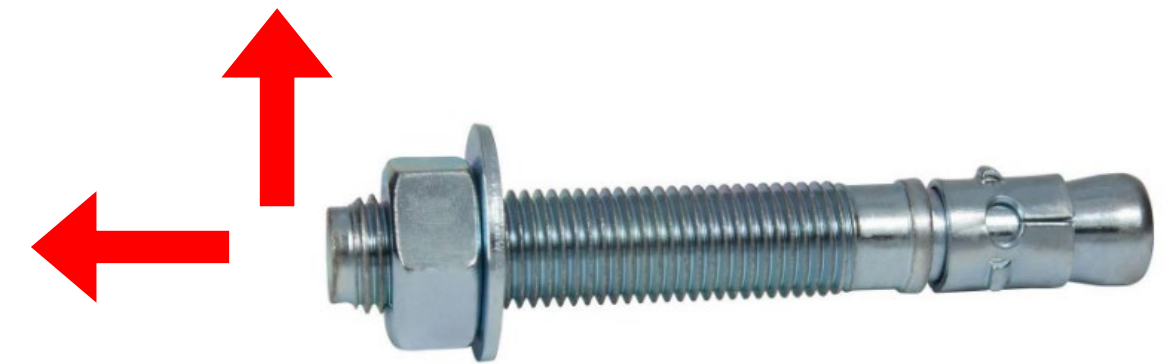
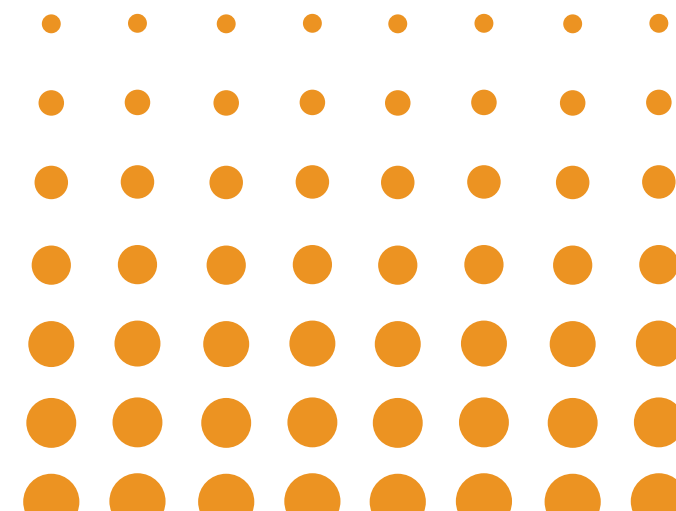


What is an Anchor?

anchor

a metal bolt, stud, threaded rod, or reinforcing steel, either cast in place, grouted in place, or drilled into hardened concrete, used to prevent dislodging of repairs from concrete substrate in the event of a bond failure; to hold various structural members or embedments in the concrete; and to resist shear, tension, and vibration loadings.

- **Anchor** – a steel element either cast into concrete or post-installed into a hardened concrete member and used to transmit applied loads to the concrete.
- **Cast in Anchor** - Headed bolt, headed stud, or hooked bolt installed before placing concrete
- **Post Installed Anchor** - Anchor installed in hardened concrete; adhesive, expansion, screw, and undercut anchors are examples of post installed anchors

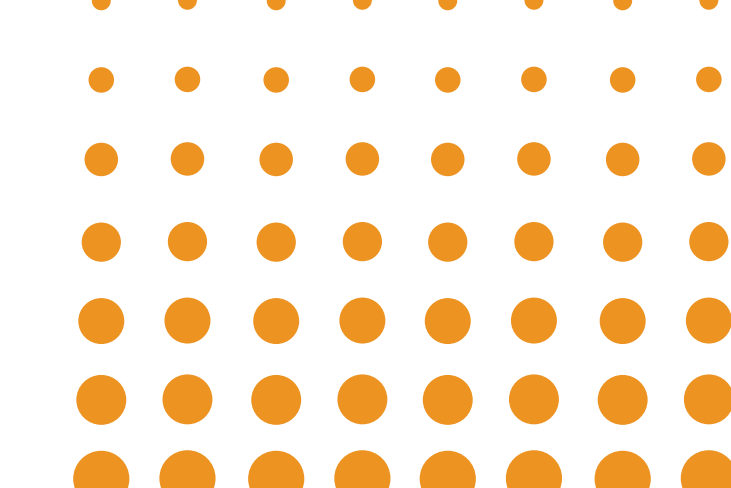




Classification:

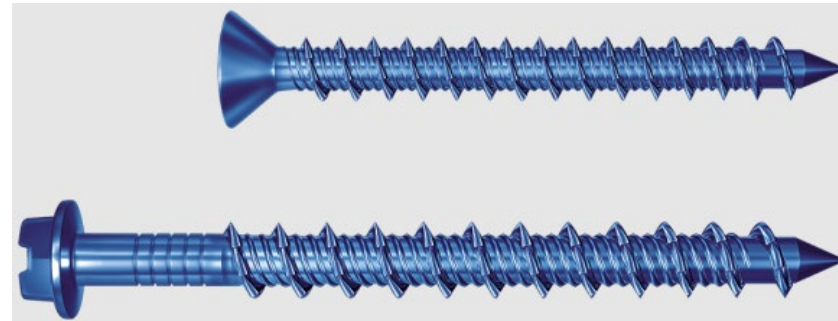


- Anchors further classified by mechanism of force transfer:
 - Expansion Anchors
 - » Friction
 - » Thread Engagement into Grooves
 - » Mechanical Interlock at End of Anchor
 - Screw Anchors
 - » Mechanical Interlock at End of Anchor
 - Undercut Anchor
 - » Adhesive Bond
 - Headed Stud, Headed Bolt
 - » Adhesive Bond (typical)
 - Adhesive Anchor
 - Steel Reinforcement





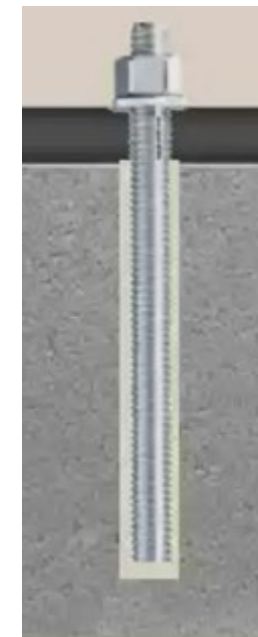
Examples:



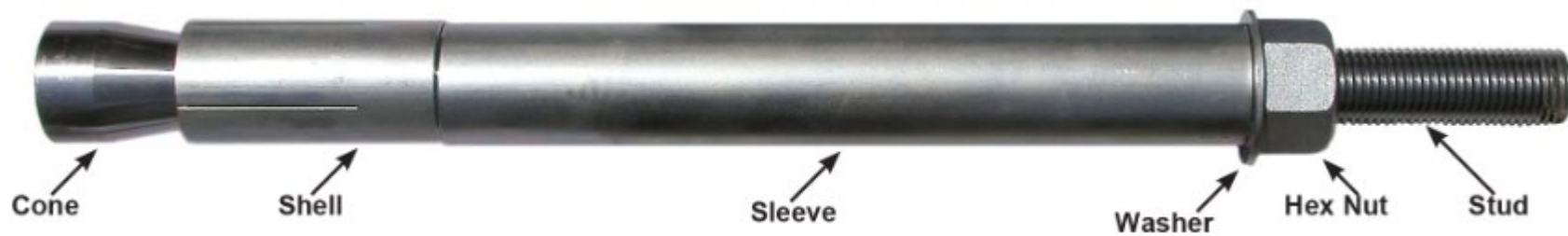
Screw Anchors



Expansion Anchor



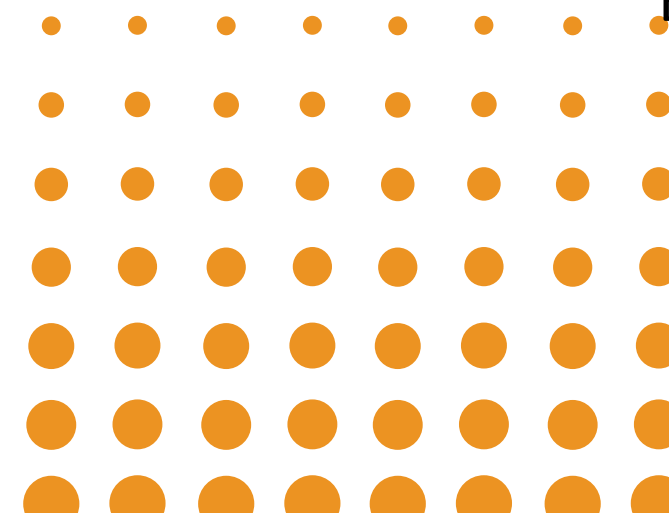
Epoxy Anchor



Undercut Anchor



Headed Bolt Anchors



Live Content Slide

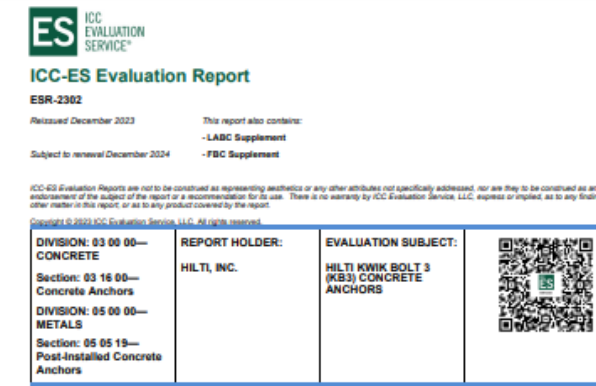
When playing as a slideshow, this slide will display live content

Poll: What type of concrete anchor do you use most often?



ICC-ES Reports:

- Free documents available in addition to published manufacturer data
- Qualification reports with summary of:
 - Code compliance
 - Detailed description of anchor including dimensional data
 - Design data (codes, tables, etc.)
 - Installation instructions
 - Testing qualifications
 - Identification
- ICC-ES Acceptance Criteria:
 - AC 193 (Mechanical Anchors)
 - AC 308 (Adhesive Anchors)
 - Refers back to ACI qualification requirements



1.0 EVALUATION SCOPE
 Compliance with the following codes:
 • 2021, 2018, 2015, and 2012 [International Building Code® \(IBC\)](#)
 • 2021, 2018, 2015, and 2012 [International Residential Code® \(IRC\)](#)
 For evaluation for compliance with codes adopted by the [Los Angeles Department of Building and Safety \(LADBS\)](#), see [EBR-2302 LABC and LARC Supplement](#).
Properly evaluated:
 Structural

2.0 USES
 The Hilti Kwik Bolt 3 Concrete Anchor (KB3) is used as anchorage to resist static, wind and earthquake (Seismic Design Categories A and B only) tension and shear loads in uncracked normal-weight concrete and uncracked lightweight concrete having a specified compressive strength, f_c , of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).
 The anchoring system complies with anchors as described in Section 1901.3 of the 2021, 2018 and 2015 IBC, Section 1909 of the 2012 IBC, and is an alternative to cast-in-place anchors described in Section 1908 of the 2012 IBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

3.0 DESCRIPTION
3.1 KB3 Anchors:
 The KB3 anchors are torque-controlled, mechanical expansion anchors. KB3 anchors consist of a stud (anchor body), expansion element (wedge), nut, and washer. The stud is manufactured from medium carbon steel complying with the manufacturer's quality documentation, or AISI Type 304 or 316 stainless steel materials.
 The carbon steel anchors are available in diameters of 1/2 inch through 1 1/8 inch (6.4 mm through 19.1 mm) and an example is illustrated in [Figure 1](#) of this report. Carbon steel KB3 anchors and components have a minimum 5-micrometer (0.0002 inch) zinc plating. The expansion elements (wedges) for the carbon steel anchors are made from carbon steel, except all 1/2-inch (6.4 mm) anchors and the 1/2-inch-by-12-inch (19.1 mm by 305 mm) anchor have expansion elements made from AISI Type 316 stainless steel.



ACCEPTANCE CRITERIA FOR MECHANICAL ANCHORS IN CONCRETE ELEMENTS
AC193
 Approved October 2017
 (Editorially revised April 2024)
 Previously revised October 2015, June 2012, March 2012, October 2011, June 2011, October 2010, February 2010, October 2009, February 2009, May 2008, February 2008, December 2007, June 2007, October 2006, June 2006, October 2005, June 2005, February 2004, October 2003, June 2003, April 2002
 (Previously editorially revised December 2020, April 2018, April 2015, April 2014, May 2013)

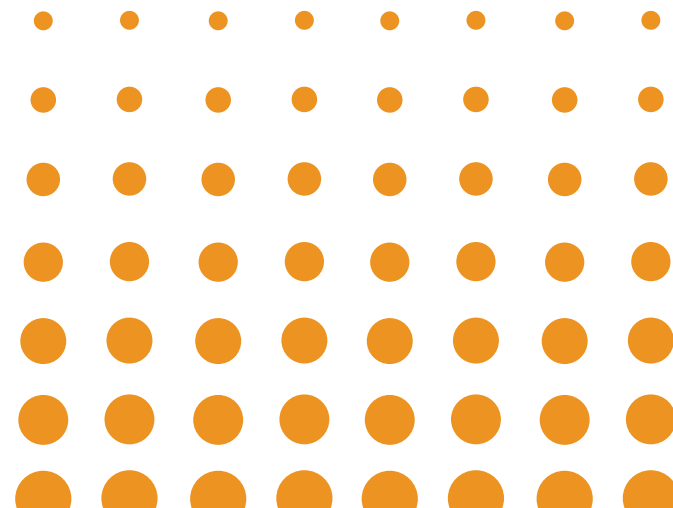
PREFACE
 Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes, and may include other codes, as applicable.
 For alternative materials, design and methods of construction and equipment, see Section 104.2.3 of the 2021 International Building Code® (IBC), Section 104.2.2 of the 2018 International Residential Code® (IRC), Section 104.11 of the 2021 IRC and earlier editions, and Section R104.11 of the 2012 IRC and earlier editions.
 This acceptance criteria has been issued to provide interested parties with guidelines for demonstrating compliance with performance features of the codes referenced in the criteria. The criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or on-line postings where public comment was solicited.
 New acceptance criteria will only have an "approval" date, which is the date the document was approved by the Evaluation Committee. When existing acceptance criteria are revised, the Evaluation Committee will decide whether the revised document should carry only an "approval" date, or an "approval" date combined with a "compliance" date. The compliance date is the date by which revised evaluation reports must comply with the requirements of the criteria. See the ICC-ES web site for more information on compliance dates.
 If the criteria is a revised edition, a solid vertical line (|) in the margin within the criteria indicates a change from the previous edition. A dashed indicator (---) is provided in the margin where any significant wording has been deleted.
 ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either chemical or fire resistance or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.
 Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports.
 ICC EVALUATION SERVICE® and ICC-ES® (and their associated logos) are registered trademarks and service marks of ICC Evaluation Service, LLC, an INTERNATIONAL CODE COUNCIL®, ICC®, INTERNATIONAL BUILDING CODE® and IRC® (and their associated logos) are registered trademarks and service marks of its parent company, International Code Council, Inc.
 No portion of this document (ICR100) may be copied, reproduced, republished, distributed, transmitted, or modified in any form or manner without the express prior written permission of ICC-ES. Any request for such permission should be addressed to ICC-ES at 3000 Sateen Street, Suite 100, Brea, California 92621. Any of the foregoing expressly authorized by ICC-ES must include all the copyright, trademark, service mark and other proprietary rights notices contained herein.



ACCEPTANCE CRITERIA FOR POST-INSTALLED ADHESIVE ANCHORS AND REINFORCING BARS IN CONCRETE ELEMENTS
AC308
 Approved February 2023
 (Editorially revised February 2024)
 Previously approved October 2022, February 2022, February 2022, June 2019, October 2017, October 2016, June 2016, January 2016, June 2015, February 2015, September 2014, May 2014, December 2013, June 2013, February 2013, February 2012, June 2011, November 2009, June 2009, October 2008, August 2008, May 2008, February 2008, January 2008, October 2007, June 2007, February 2007, June 2006
 (Previously editorially revised February 2021, March 2018, April 2014, October 2013, August 2013)

PREFACE
 Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes, and may include other codes, as applicable.
 For alternative materials, design and methods of construction and equipment, see Section 104.2.3 of the 2021 International Building Code® (IBC), Section 104.2.2 of the 2018 International Residential Code® (IRC), Section 104.11 of the 2021 IRC and earlier editions, and Section R104.11 of the 2012 IRC and earlier editions.
 This acceptance criteria has been issued to provide interested parties with guidelines for demonstrating compliance with performance features of the codes referenced in the criteria. The criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or on-line postings where public comment was solicited.
 New acceptance criteria will only have an "approval" date, which is the date the document was approved by the Evaluation Committee. When existing acceptance criteria are revised, the Evaluation Committee will decide whether the revised document should carry only an "approval" date, or an "approval" date combined with a "compliance" date. The compliance date is the date by which revised evaluation reports must comply with the requirements of the criteria. See the ICC-ES web site for more information on compliance dates.
 If the criteria is a revised edition, a solid vertical line (|) in the margin within the criteria indicates a change from the previous edition. A dashed indicator (---) is provided in the margin where any significant wording has been deleted.
 ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either chemical or fire resistance or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.
 Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports.
 ICC EVALUATION SERVICE® and ICC-ES® (and their associated logos) are registered trademarks and service marks of ICC Evaluation Service, LLC, an INTERNATIONAL CODE COUNCIL®, ICC®, INTERNATIONAL BUILDING CODE® and IRC® (and their associated logos) are registered trademarks and service marks of its parent company, International Code Council, Inc.
 No portion of this document (ICR100) may be copied, reproduced, republished, distributed, transmitted, or modified in any form or manner without the express prior written permission of ICC-ES. Any request for such permission should be addressed to ICC-ES at 3000 Sateen Street, Suite 100, Brea, California 92621. Any of the foregoing expressly authorized by ICC-ES must include all the copyright, trademark, service mark and other proprietary rights notices contained herein.

www.icri.org



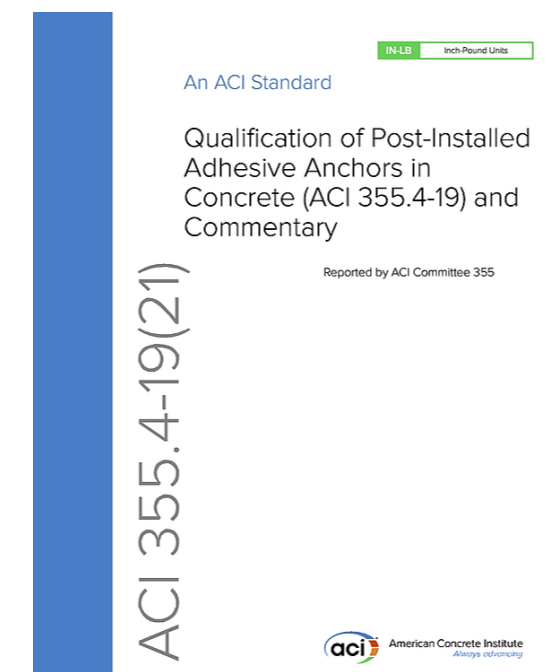
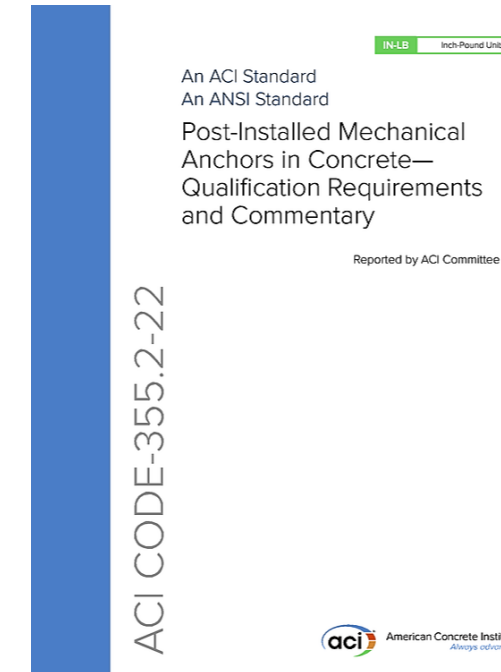
2024 FALL CONVENTION OCTOBER 22-25 2024



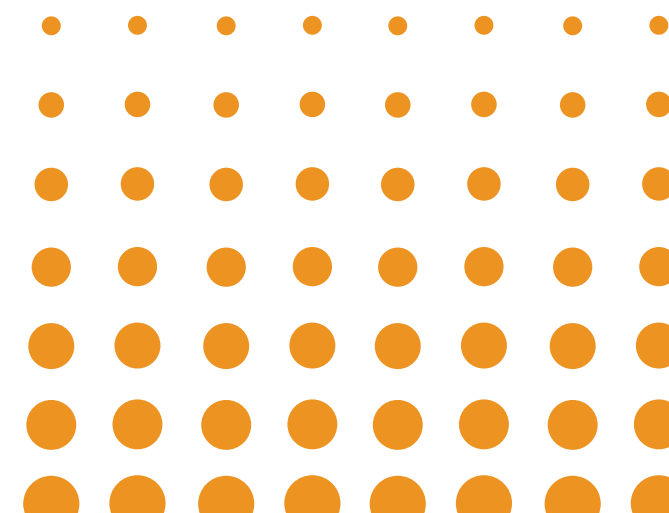
Post-Installed Anchors



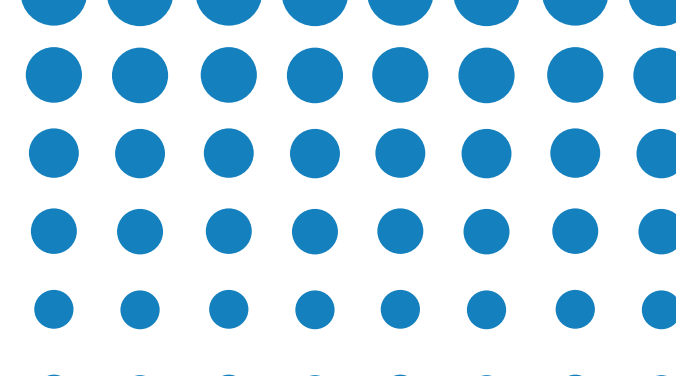
- Post Installed anchors are of particular interest for repairs
 - Substantial product catalogs
 - Versatile installation (physical install/timing)
 - Cost effective
- Mechanical Anchors must meet ACI 355.2
 - Pullout failures must have acceptable load-displacement characteristics
 - OR prove pullout is precluded by different failure
- Adhesive Anchors must meet ACI 355.4
 - Must establish characteristic bond strength
 - Prove suitability for structural use



www.icri.org

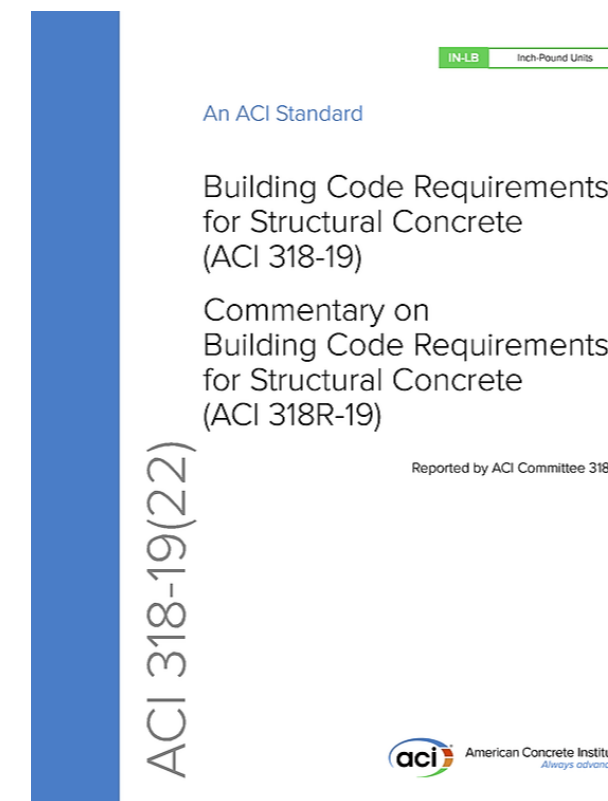


2024 FALL
CONVENTION
OCTOBER 22-25 2024



Design Requirements:

- Design must meet requirements of codes adopted
 - Model codes like International Building Code (IBC, IRC, etc.)
 - Other site specifications
- IBC 1901.3 Anchoring to Concrete
 - references ACI 318 for anchorage design (with amendments)
- ACI 318 – Building Code Requirements for Structural Concrete
 - Requirements within **Chapter 17 – Anchoring to Concrete** ←
 - ACI 562 – Assessment, Repair, and Rehabilitation of Existing Concrete Structures
 - ASCE Anchorage Design for Petrochemical Facilities

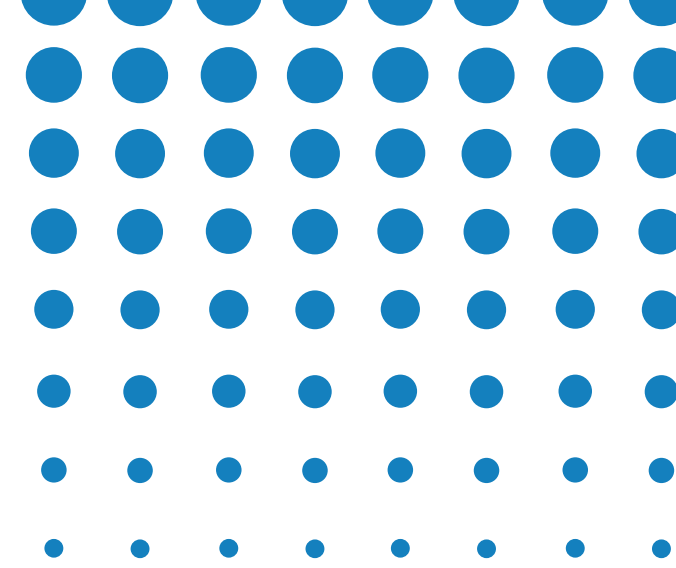


www.icri.org

2024 FALL
CONVENTION
OCTOBER 22-25 2024



ACI 318



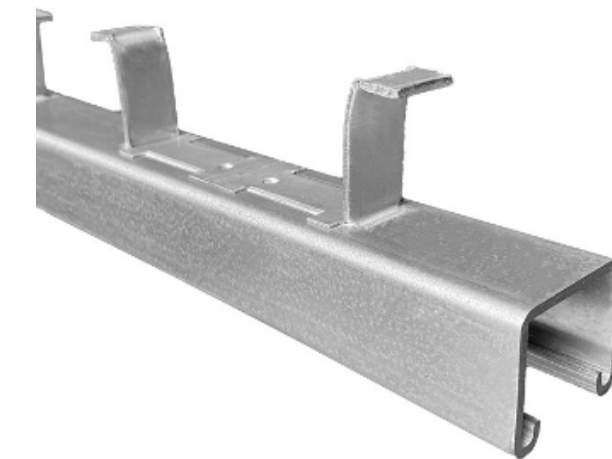
ACI 318 – Scope (17.1.2-17.1.3)

- Covers:
 - Headed Studs, Headed Bolts, & Hooked Bolts
 - Expansion Anchors
 - Undercut Anchors
 - Adhesive Anchors
 - Screw Anchors meeting ACI 355.2
 - Attachments with Shear Lugs

COMMON
REPAIR
ANCHORS

Excluded/ Not directly addressed:

- Specialty inserts (too many types, need testing)
- Through-bolts
- Anchors with plate at embedded end (not recommended)
- Grouted anchors
- Direct anchors (Powder actuated, pneumatic)
- High cycle fatigue or impact related



www.icri.org

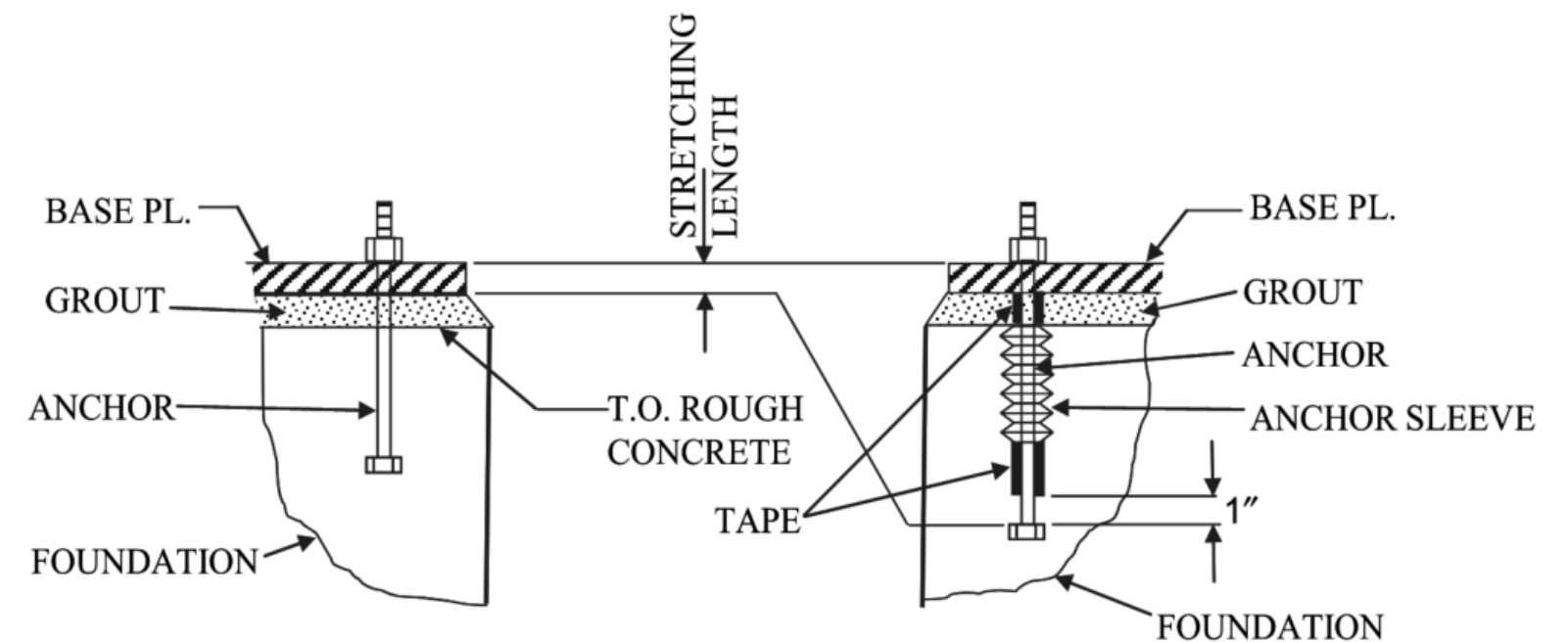
2024
CONVENTION
OCTOBER 22-25 2024
FALL



Tensioned Anchors

ASCE - Anchorage Design for Petrochemical Facilities

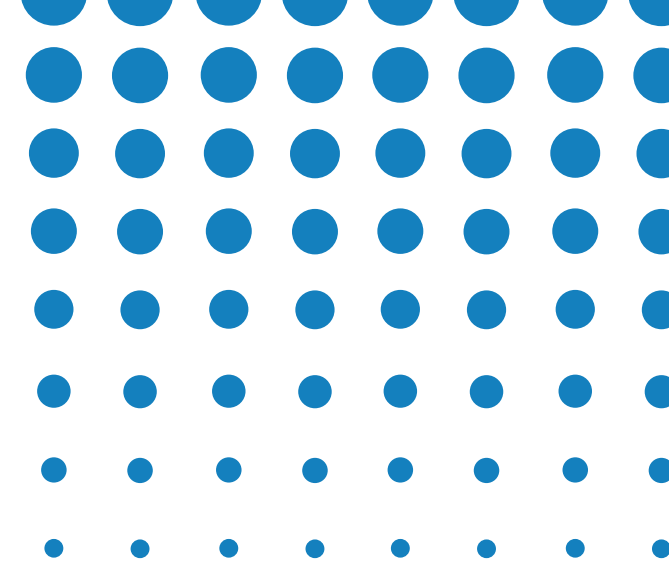
- Typically Cast-In Place
- Anchor tensioned through longitudinal elongation
- Sleeve provided for stretch
- Used with vessels when:
 - Additional frictional resistance is needed
 - Vibrations or deflections need to be reduced
 - Stress reversals need to be reduced
- Challenges:
 - Not covered by codes
 - May be difficult/costly to install
 - Proper tensioning not guaranteed
 - Creep/relaxation over time



NOTE: Stretching Length = That portion of anchor allowed to freely stretch



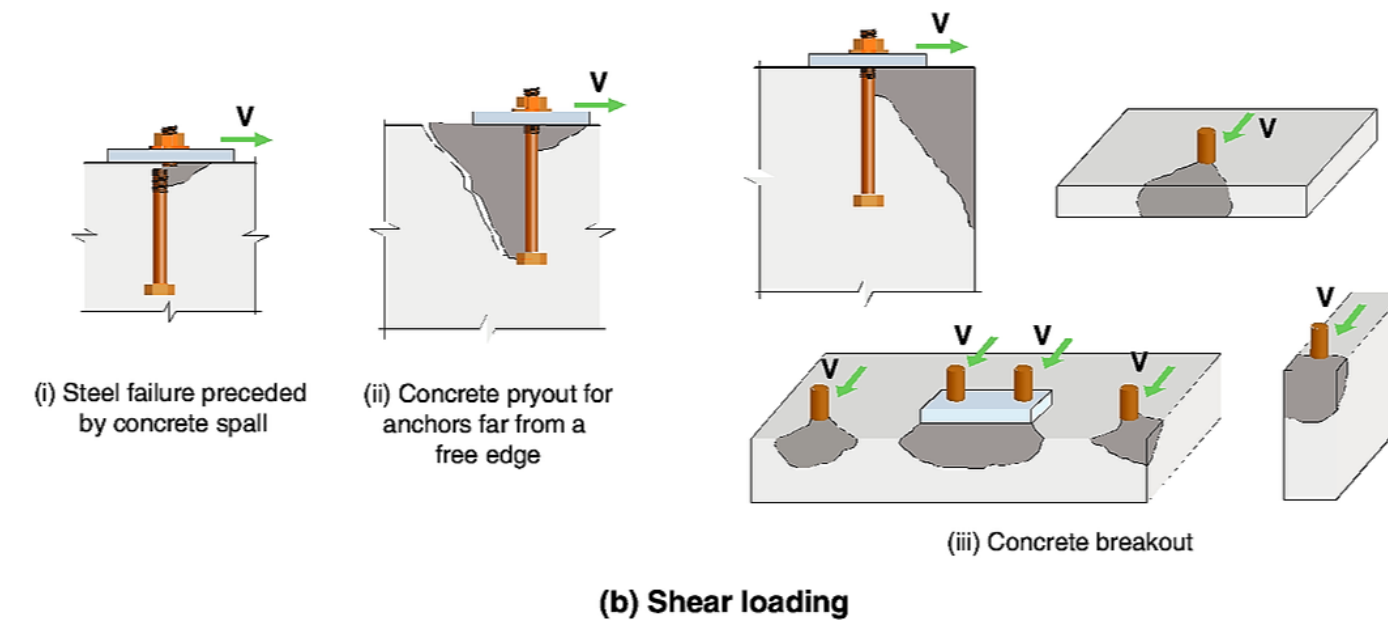
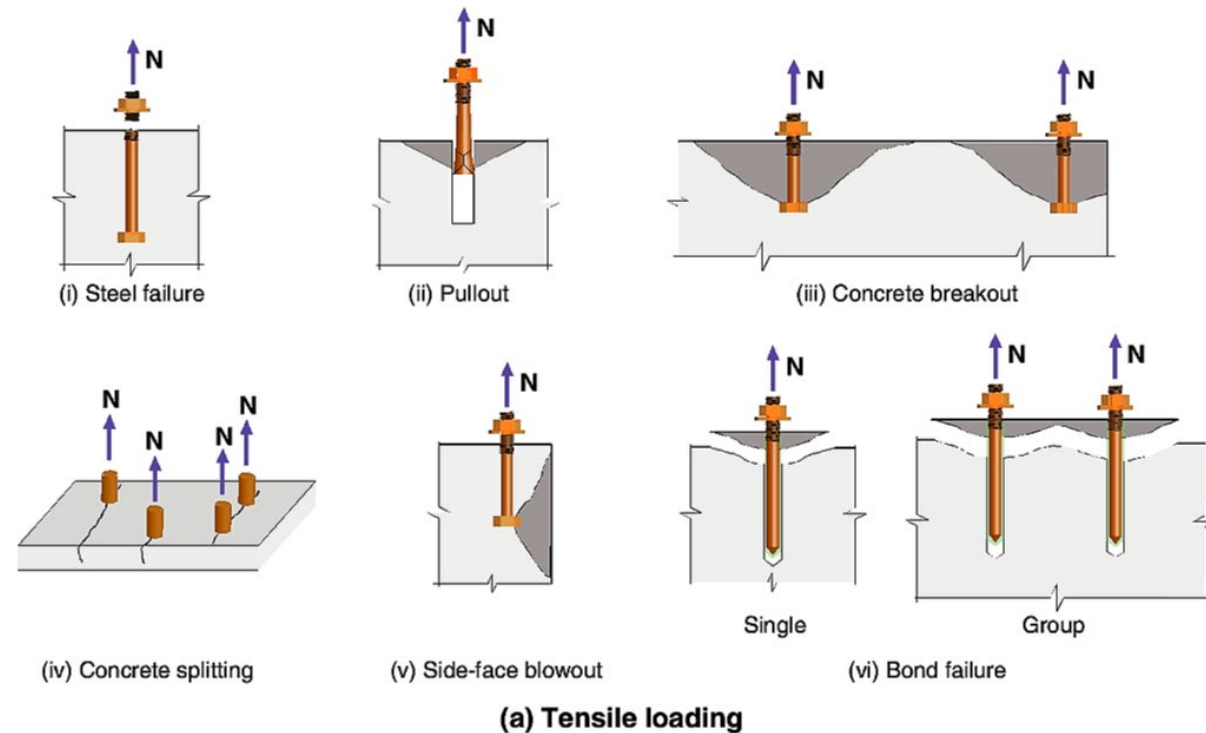
ACI 318

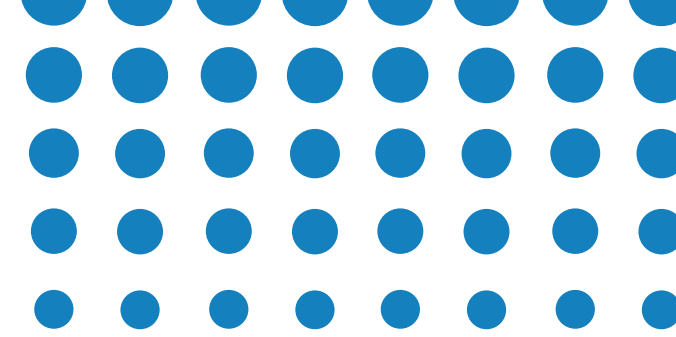


- 17.5 – Design Strength Requirements:
 - Meet min. edge distances, preventing splitting (17.7)
 - Satisfy 17.2.3 for Earthquake Loadings
 - Satisfy 17.3.1.2 for sustained loading
 - Design:
 - Concrete Capacity Design (CCD) Method
 - Testing (Required for some anchors)

KEY CONCEPTS:

- 1. Anchor capacity proportional to volume of concrete engaged by anchors. (edge distance, spacing, bolt heads sizes)**
- 2. Concrete substrate is essential to capacity. (compressive strength, weight, cracked/uncracked, reinforcement)**



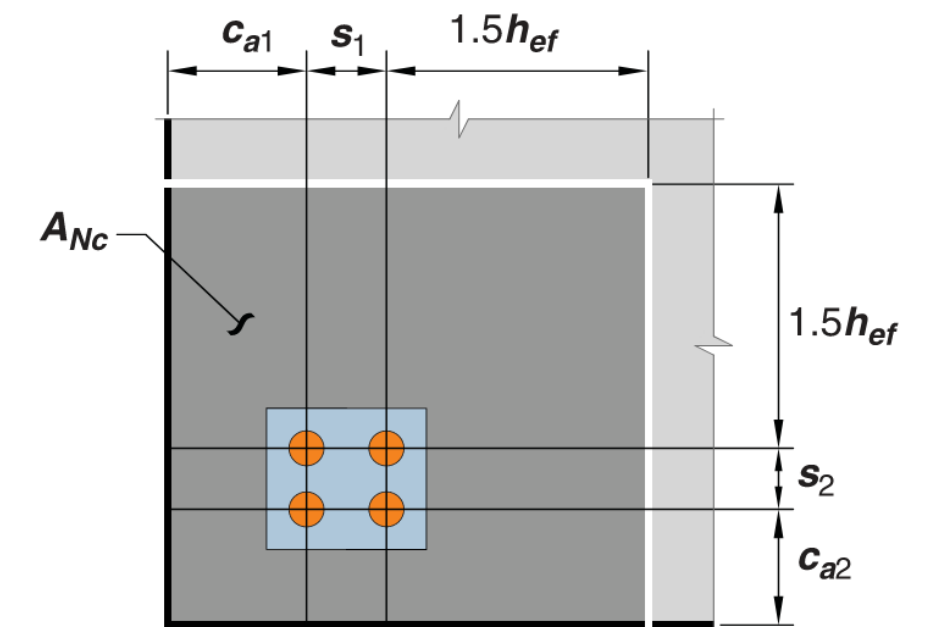
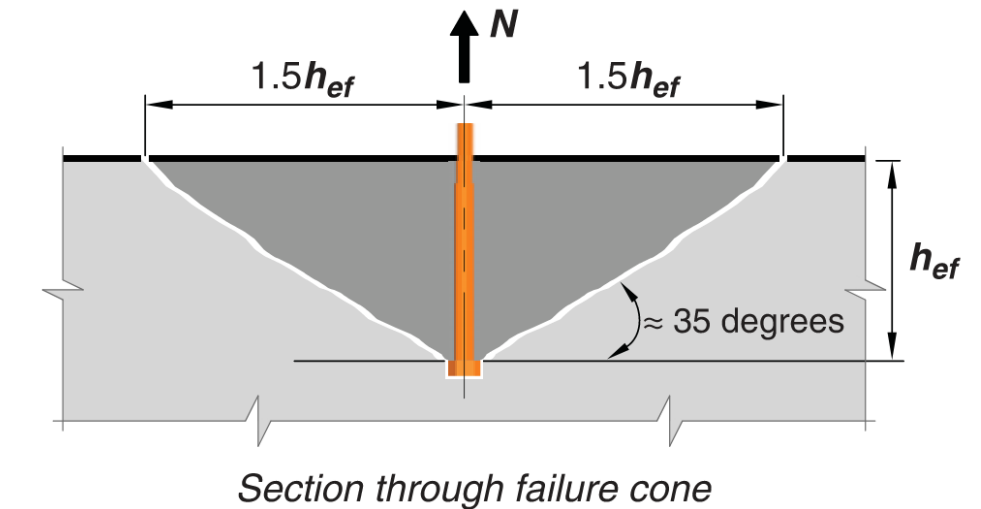


“Can’t we just go deeper?”

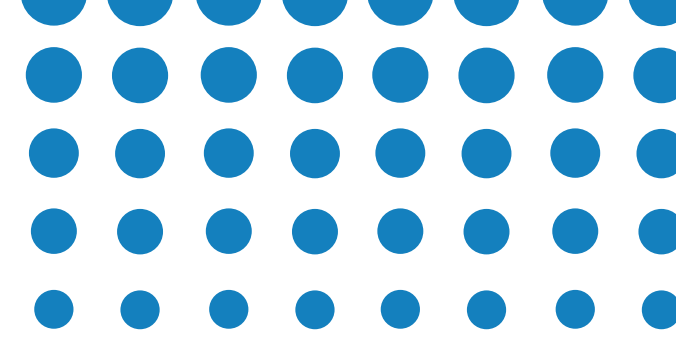
- Deeper embedment usually means more capacity (more engaged mass)**

Answer: It depends...

- Embedment depth limited by depth of member (ACI 17.9.4)
 - Embedment < max{ 2/3*member depth or depth-4”}
- ** For single anchors not near edges
 - Groups of Anchors – Spacing more important
- Deeper embedments run higher risk of impacting member reinforcement
- Time of installation increases significantly (coring or drilling)
- Deeper embeds most likely use epoxy anchors – higher cost



If c_{a1} and $c_{a2} < 1.5h_{ef}$
and s_1 and $s_2 < 3h_{ef}$
 $A_{Nc} = (c_{a1} + s_1 + 1.5h_{ef}) \times (c_{a2} + s_2 + 1.5h_{ef})$



“What if we add more anchors?”

- Increasing number of anchors:
 - Load sharing decreases effective forces per anchor
 - More volume of concrete engaged – higher capacity overall



- **Answer: It depends...**
- Yes, if we can increase volume:
 - Avoid closely spaced anchors
 - Avoid edges of concrete
- Limited by the connection and what its used for
- More likely to hit reinforcement in member
- Higher install time and cost

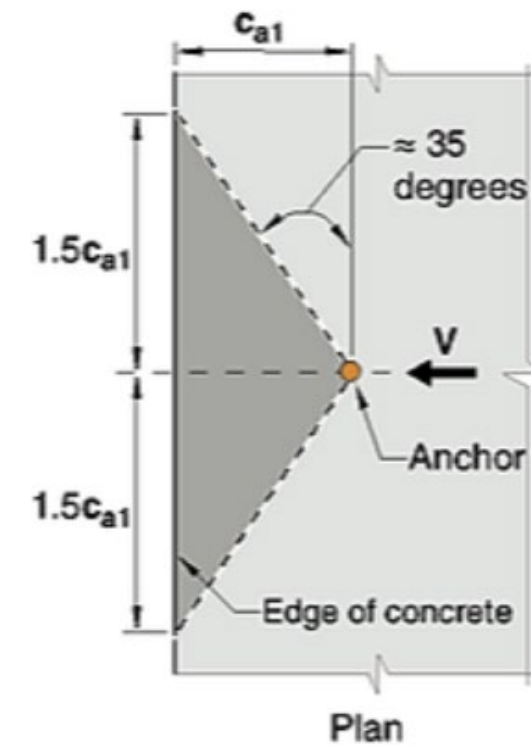
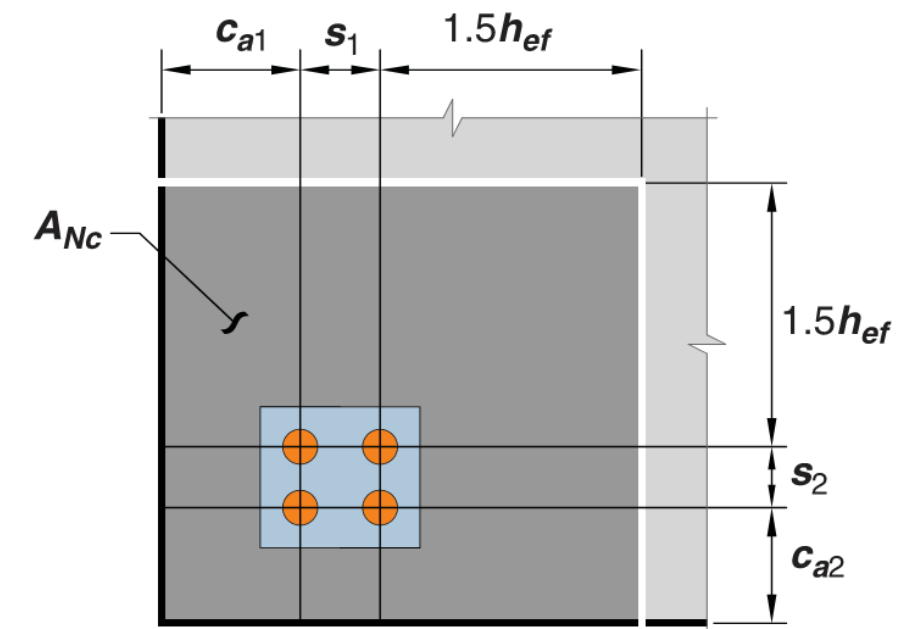
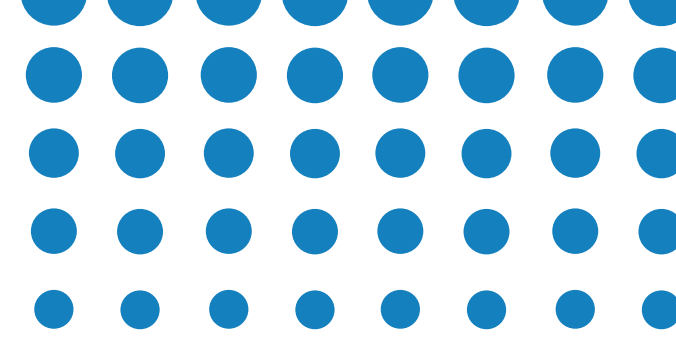


Fig. R17.5.1.3b—Breakout cone for shear.



If c_{a1} and $c_{a2} < 1.5h_{ef}$
and s_1 and $s_2 < 3h_{ef}$
 $A_{Nc} = (c_{a1} + s_1 + 1.5h_{ef}) \times (c_{a2} + s_2 + 1.5h_{ef})$



Existing Concrete Info

- Depth of element
 - Must be known in most cases (minimum depth)
- Condition of Element
 - Steel and concrete condition and what can be counted on for design
- Plan locating anchors on the plan dimensions of element
 - Design can assume minimum edge distance – more RFI
- Structural use of the element
 - Cracked concrete assumed typically
- Concrete compressive strength
 - Can be assumed using ACI 562 – will be conservative
- Reinforcement layout of element
 - Avoid cutting reinforcement during anchor installation
 - Possible to use reinforcement to prove breakout not possible
 - Connections can use slotted holes or double holes to avoid reinforcement

Table 6.3.2a—Default compressive strength of structural concrete, psi

Time frame	Footings	Beams	Slabs	Columns	Walls
1900-1919	1000	2000	1500	1500	1000
1920-1949	1500	2000	2000	2000	2000
1950-1969	2500	3000	3000	3000	2500
1970-present	3000	3000	3000	3000	3000



Note: Adopted from ASCE/SEI 41.

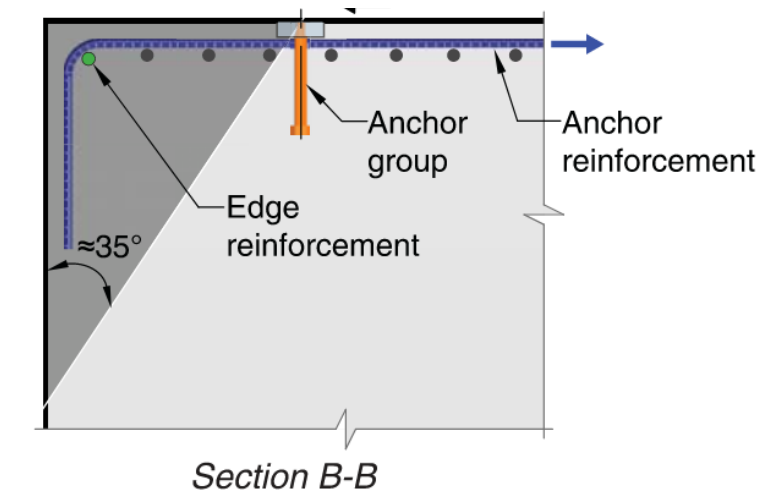


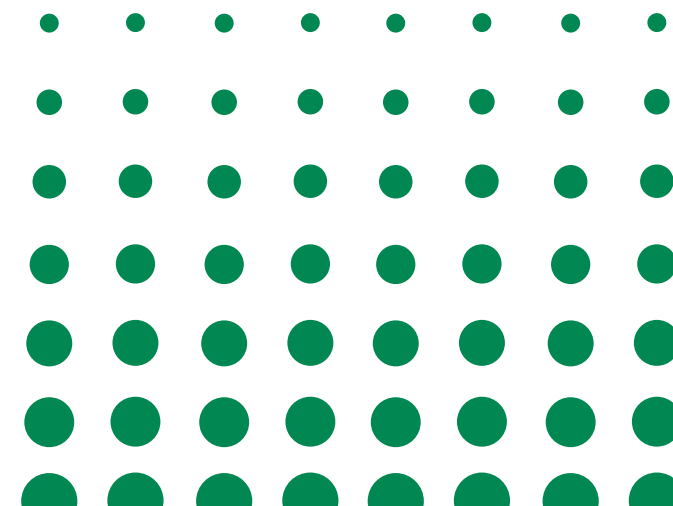
Fig. R17.5.2.1b(ii)—Edge reinforcement and anchor reinforcement for shear.



Types of Repairs/ Case Studies

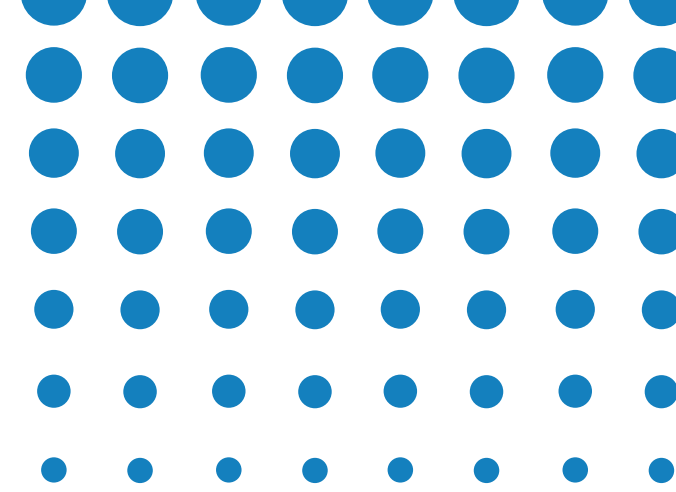


www.icri.org



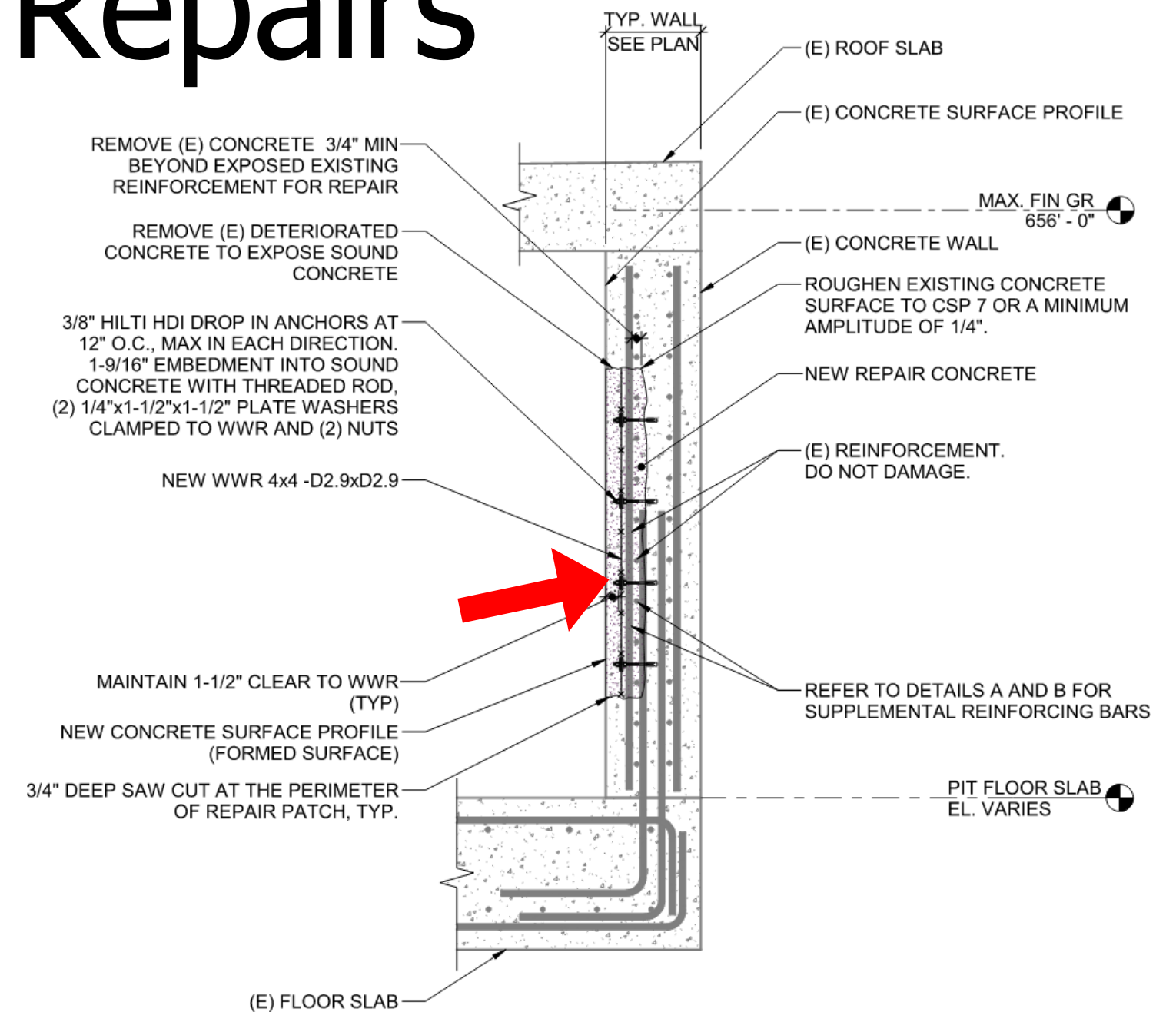
2024 CONVENTION
OCTOBER 22-25 2024

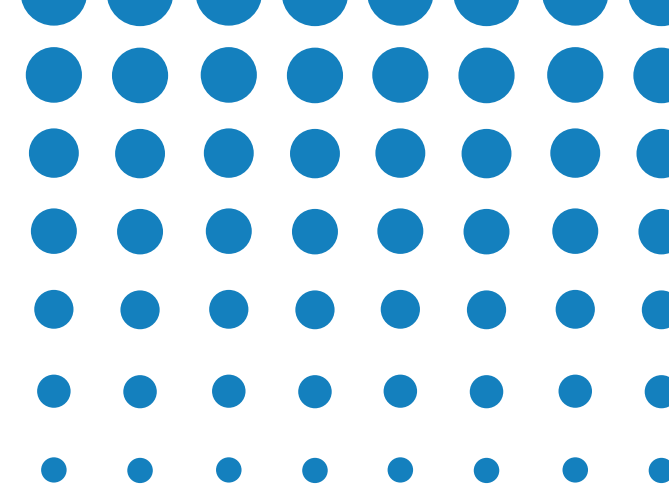
FALL



Type 1 - Partial Depth Repairs

- Common repair for restoring section loss on concrete section
 - Honeycombing, delaminations, spalling, etc.
- Repair needs to consider:
 - Loading during repair (partial section)
 - Loading after repair (full section)
 - Partial section capacity, full section capacity
- Role of Anchors:
 - Mechanical anchorage at new/old interface
 - Hold mesh/small rebar if needed in repair
 - Transfer loading to original section

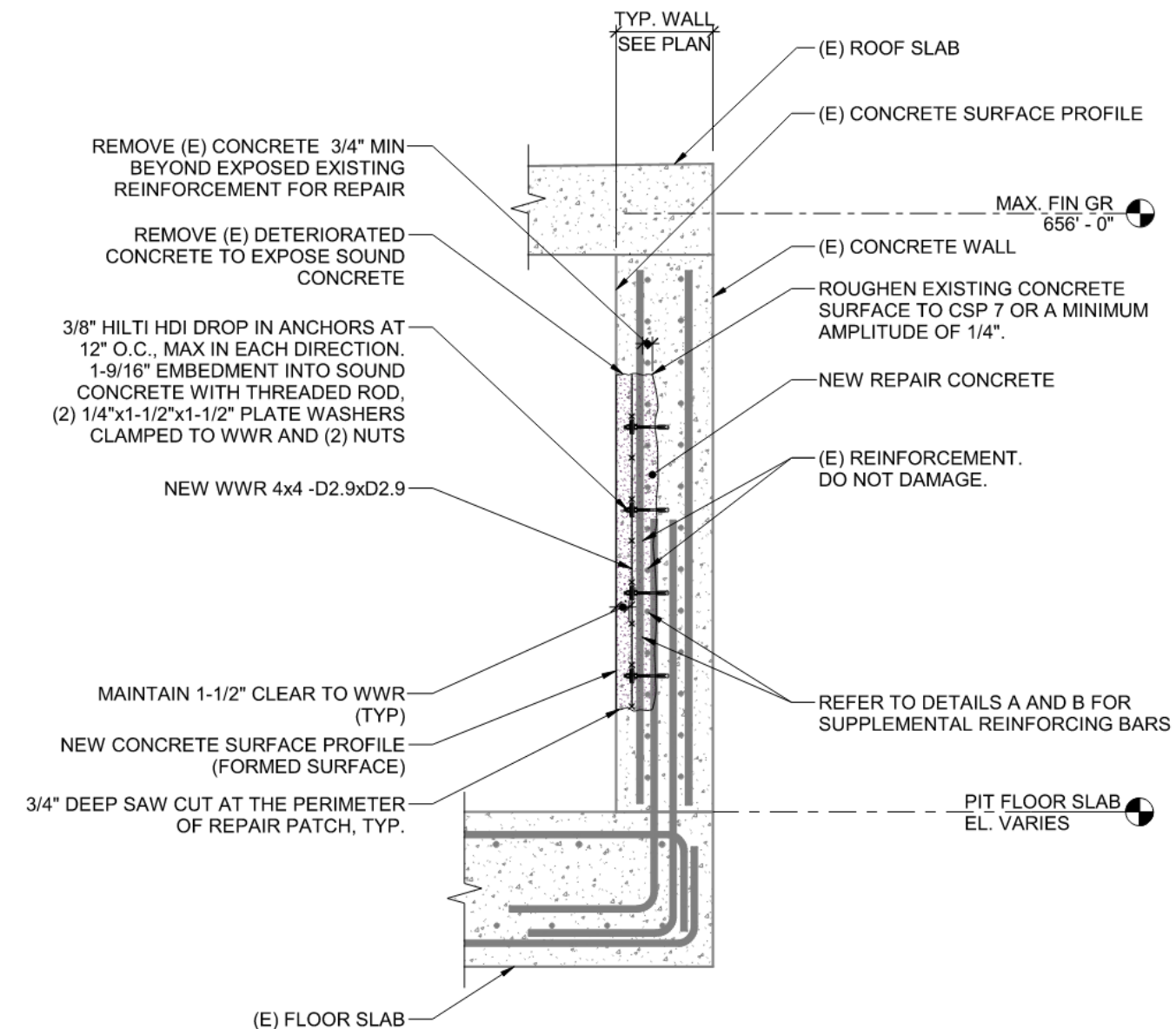


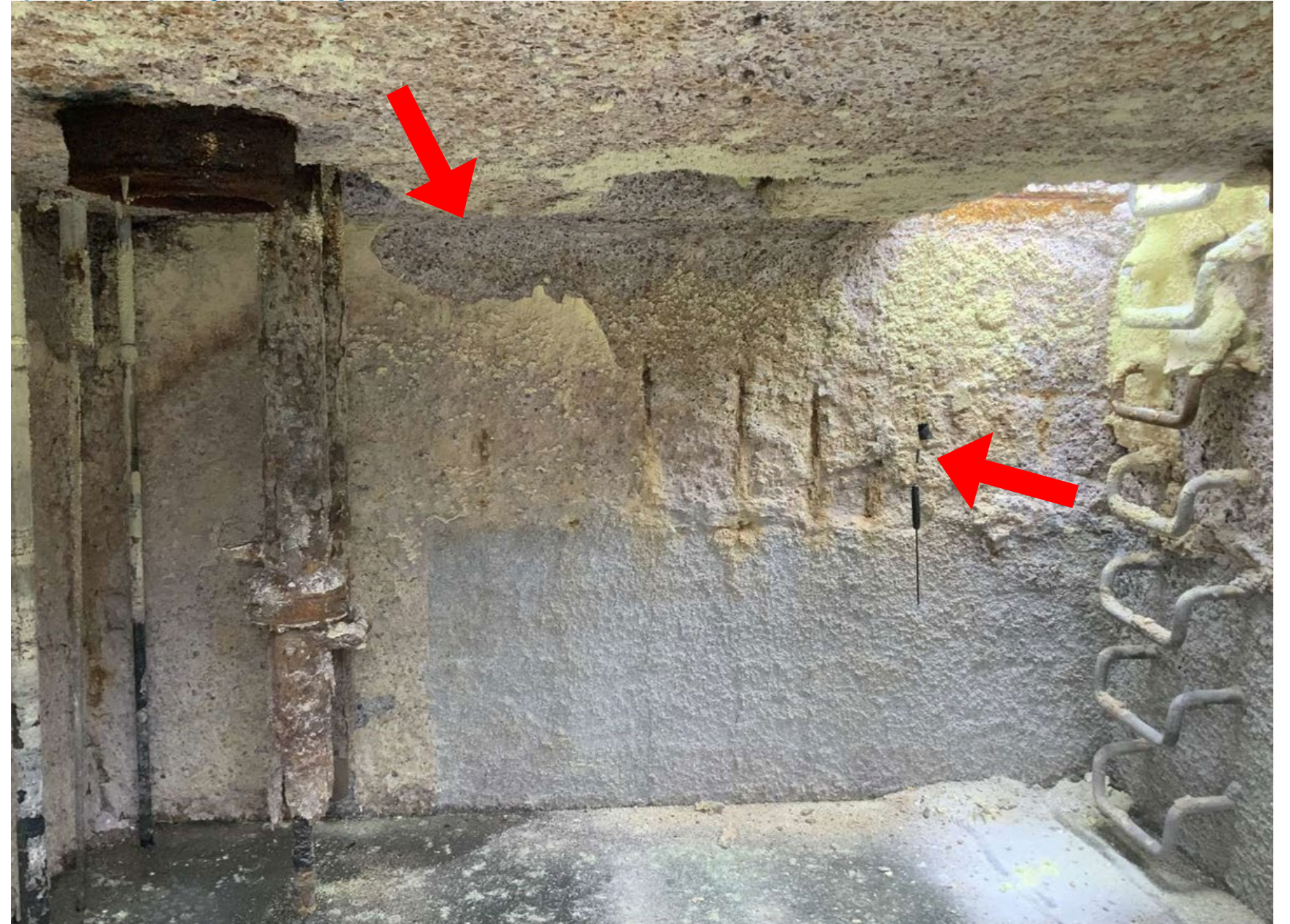
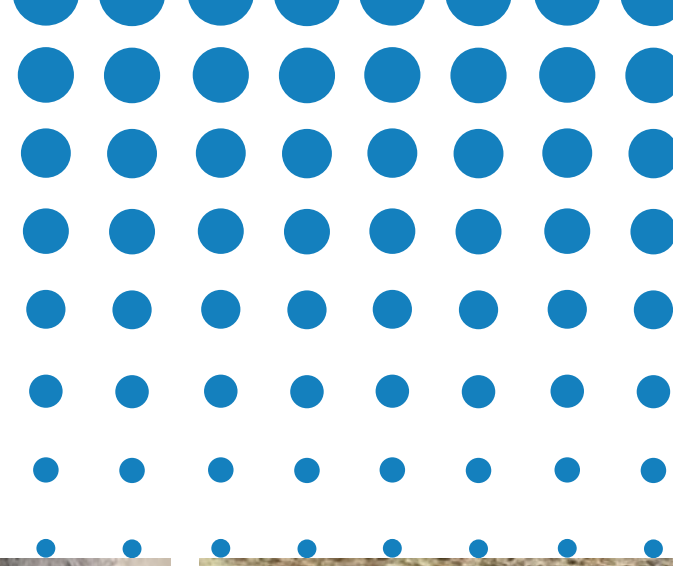


Pit Wall PD Repairs



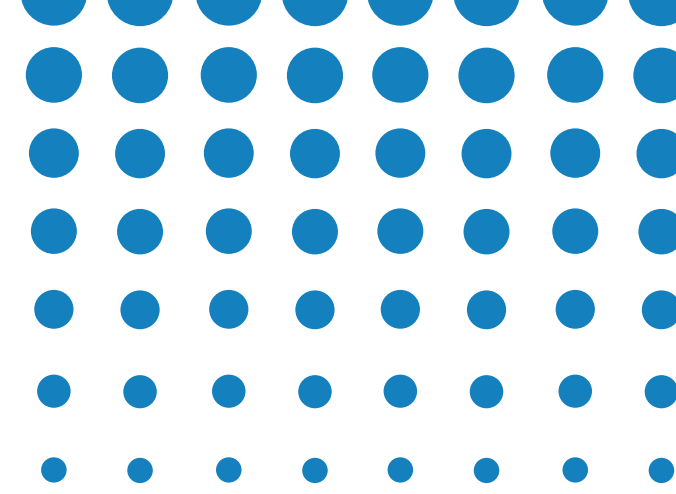
- Scope:
 - Subgrade pit wall partial depth repair in-kind
- Condition of Walls:
 - Depth of spalling varied from cover depth to 5"
 - Pit emptied during repairs
 - Surcharge around pit limited during repairs
 - Compressive strength data, reinforcement available
- Design Approach:
 - Design remaining section to carry reduced load
 - Check for redistribution of forces to "good" sections
 - Supplement existing reinforcement as needed





www.icri.org

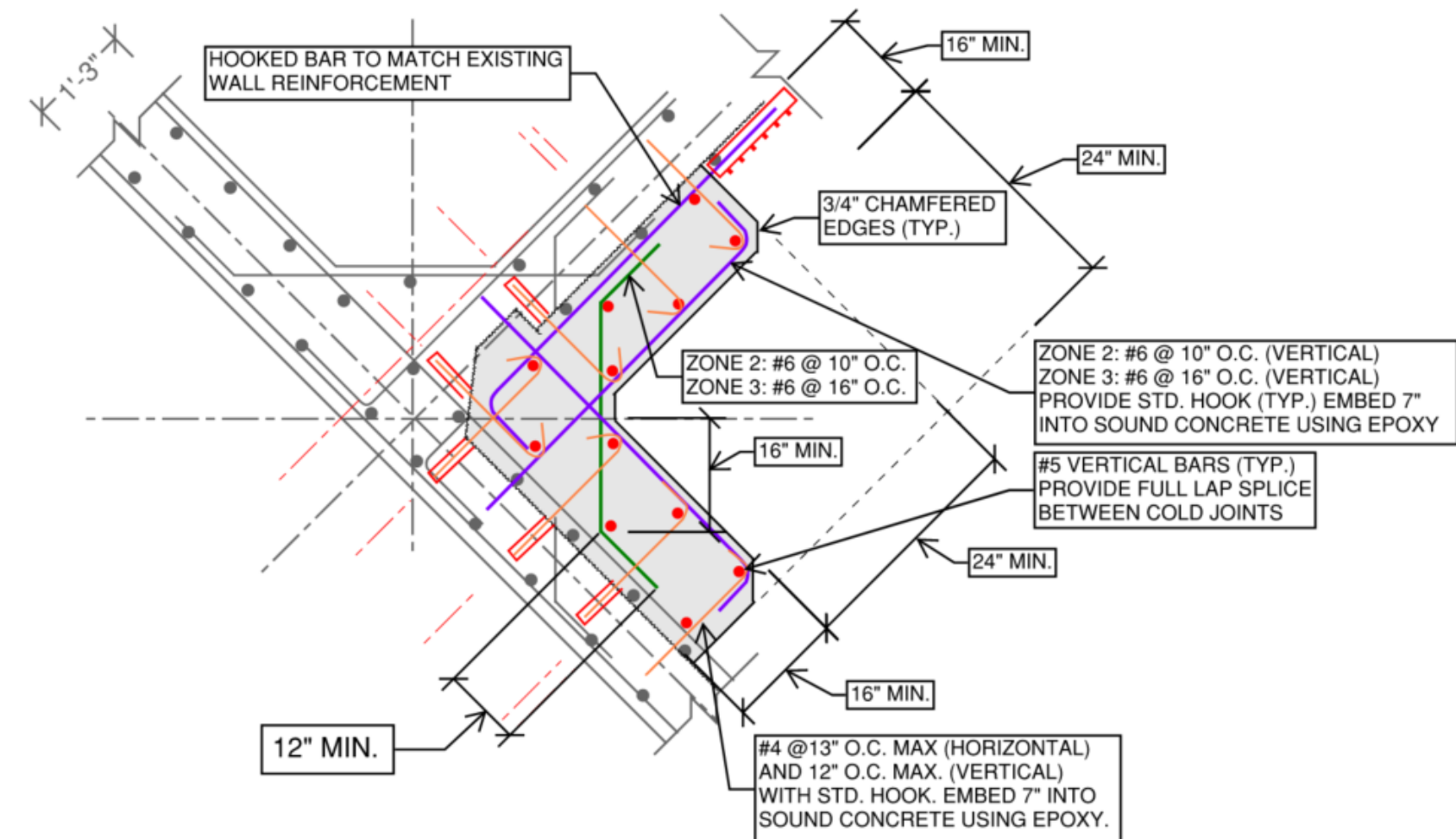
2024 FALL
CONVENTION
OCTOBER 22-25 2024

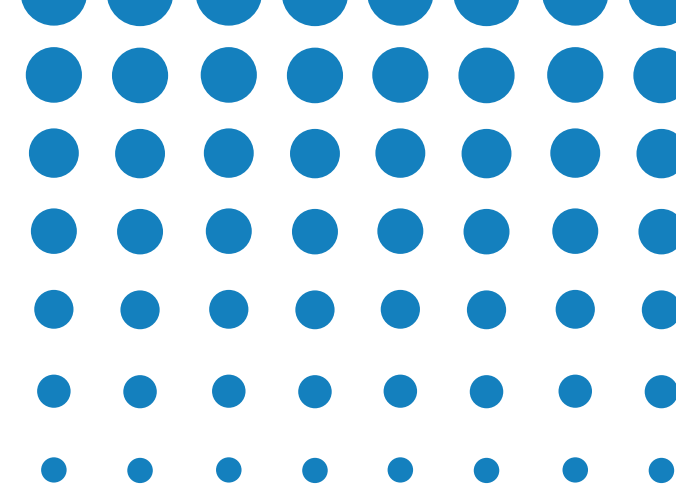


Type 2 - Section Enlargement



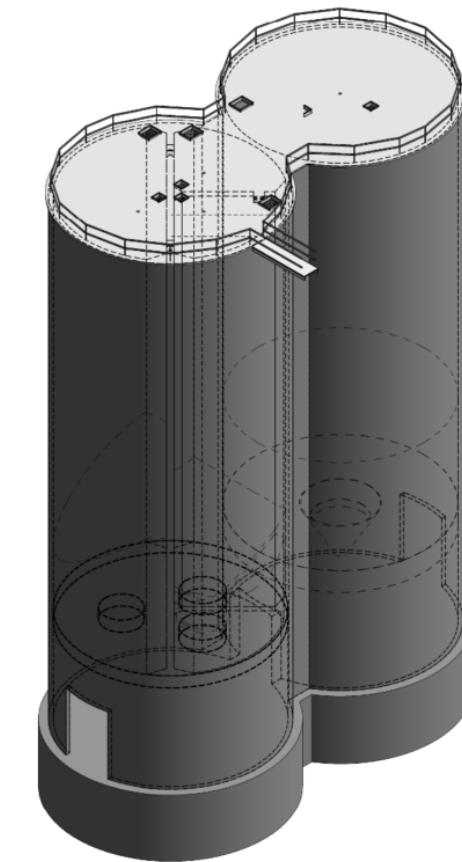
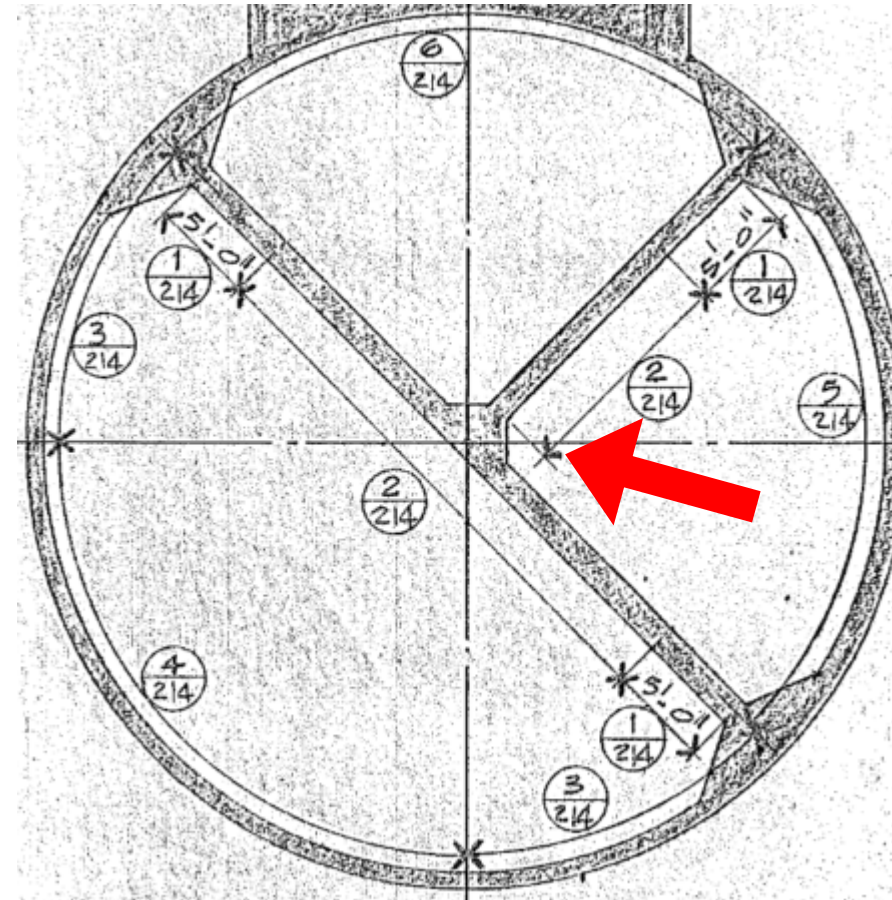
- Common repair when deteriorated element not sufficient
 - Adding capacity to element
 - Need more room for installation of repair
- Repair needs to consider:
 - Loading during repair (partial section)
 - Loading after repair (full section)
 - Partial section capacity, full section capacity
- Role of Anchors:
 - Mechanical anchorage at new/old interface
 - Hold mesh/small rebar if needed in repair
 - Transfer loading to composite section (shear flow, shear friction, etc.)

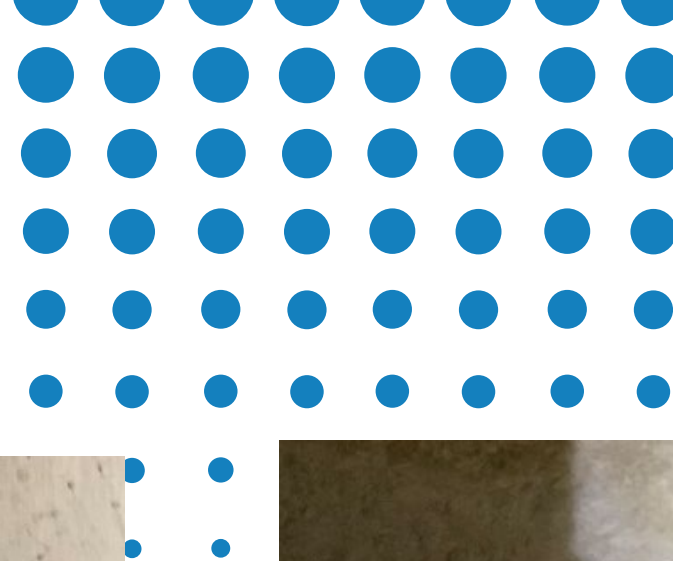




Rock Silo Wall Joint Enlargement

- Scope:
 - Segmented rock silo wall partial depth repairs
- Condition of Walls:
 - Wear from rock up to 8" from original surface
 - Adjacent quadrants in operation during repairs
 - Remaining wall thickness of 9" (Impact Echo)
 - Reinforcement sheared off
 - Compressive strength, reinforcement data available
- Design Approach:
 - Dowels create enlarged composite section to resist loading
 - Couplers to re-tie existing wall reinforcement into joint



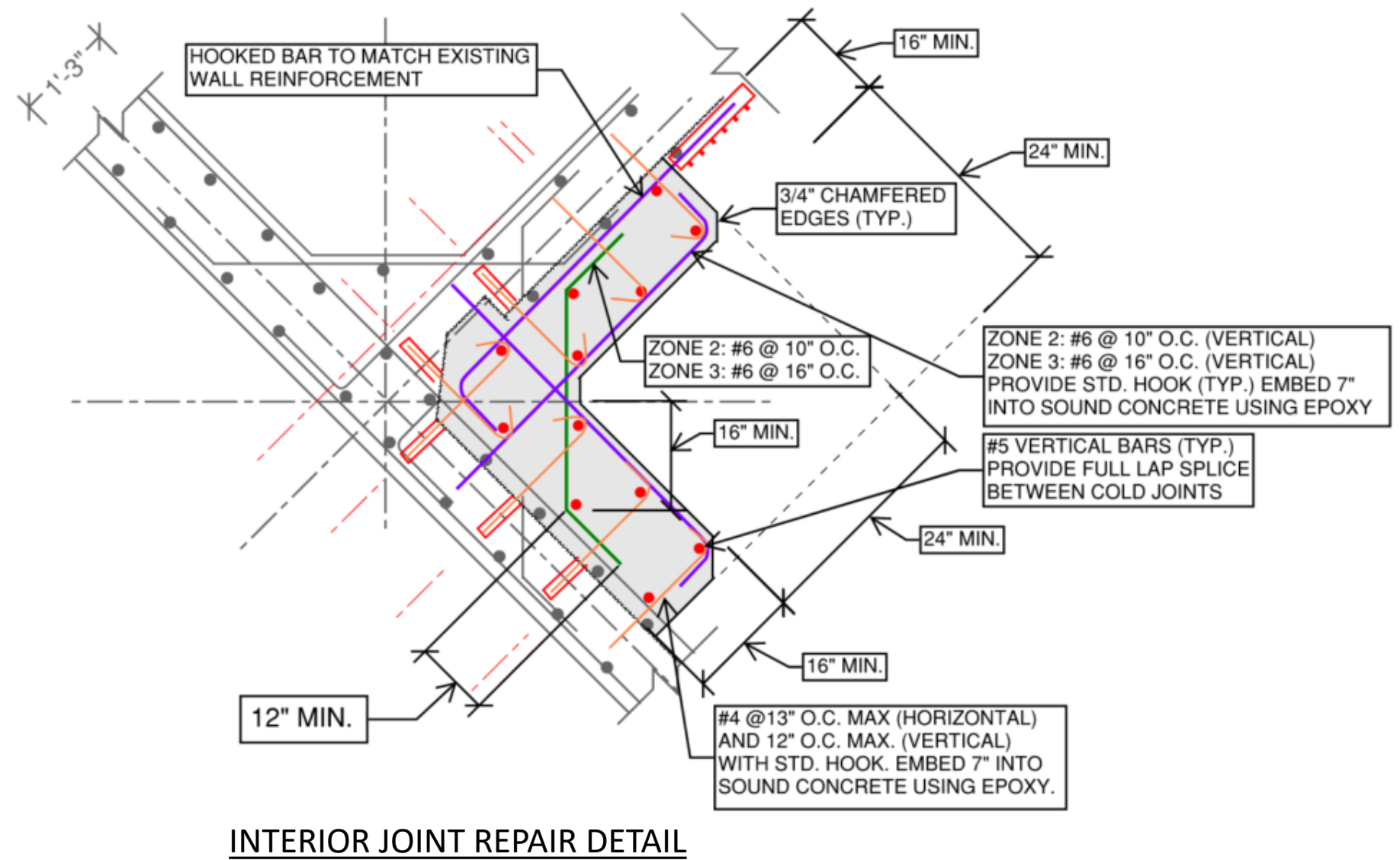
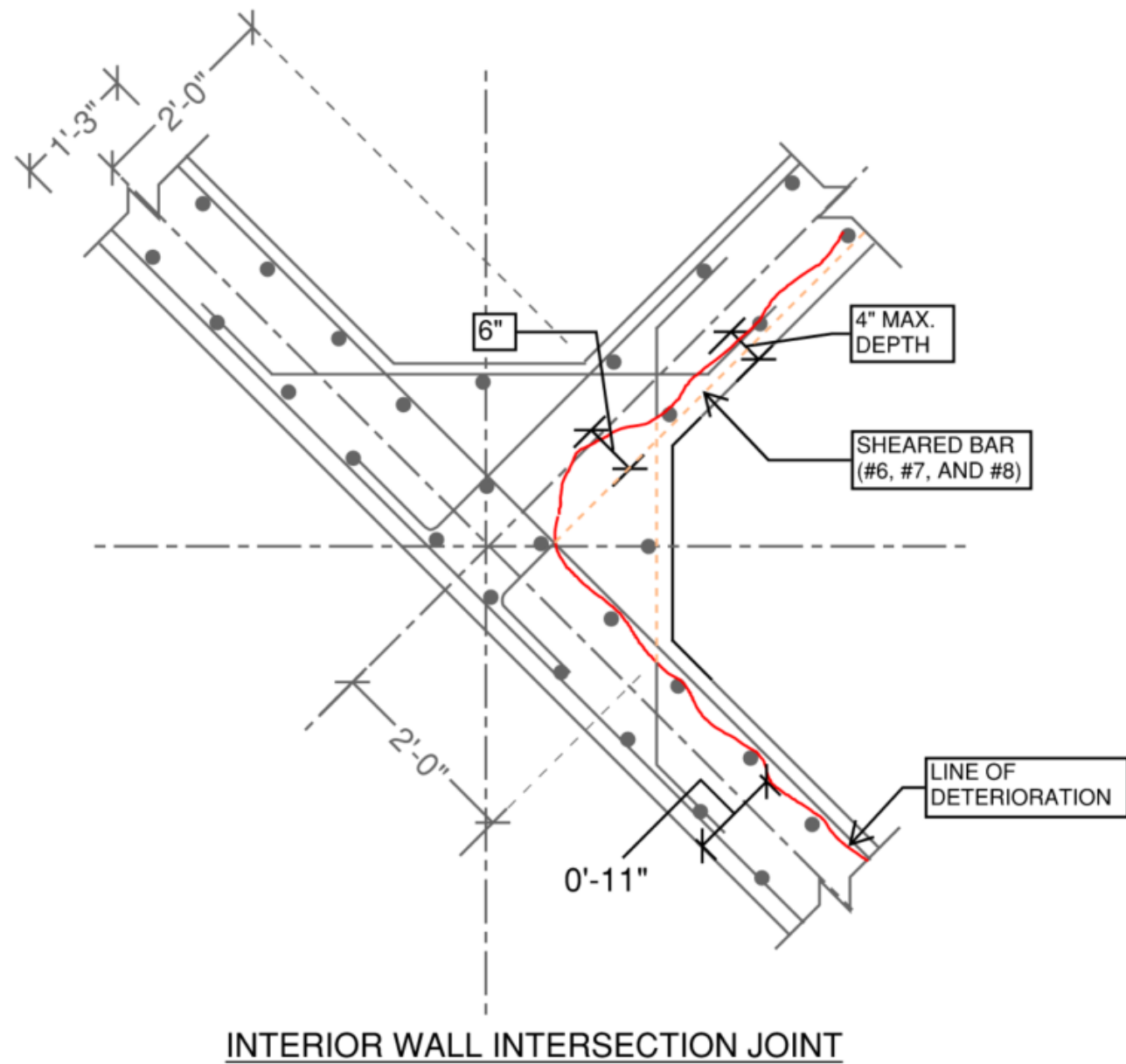
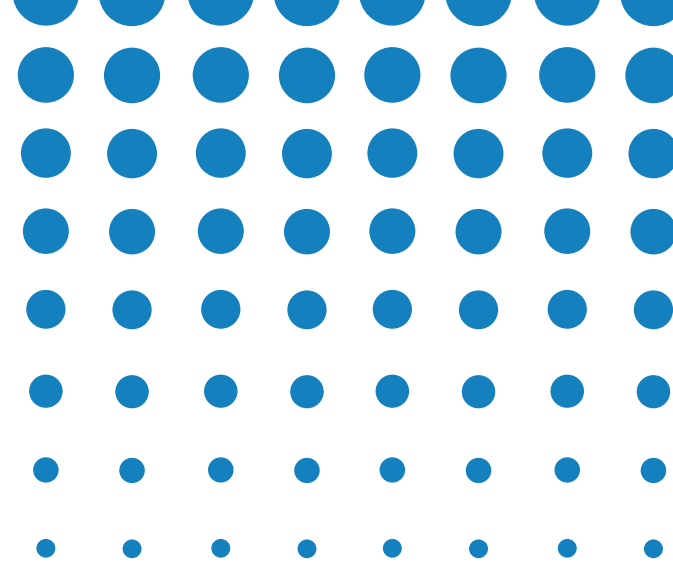


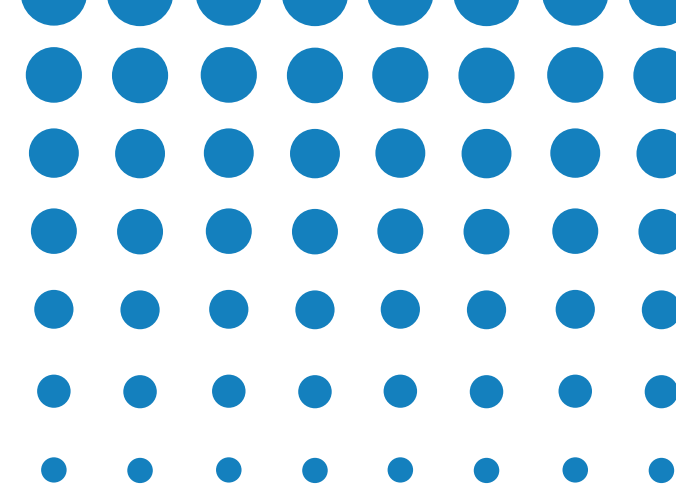
FACING JOINT AT TOP OF SILO



LOOKING DOWN AT JOINT







Type 3 - Full Replacement

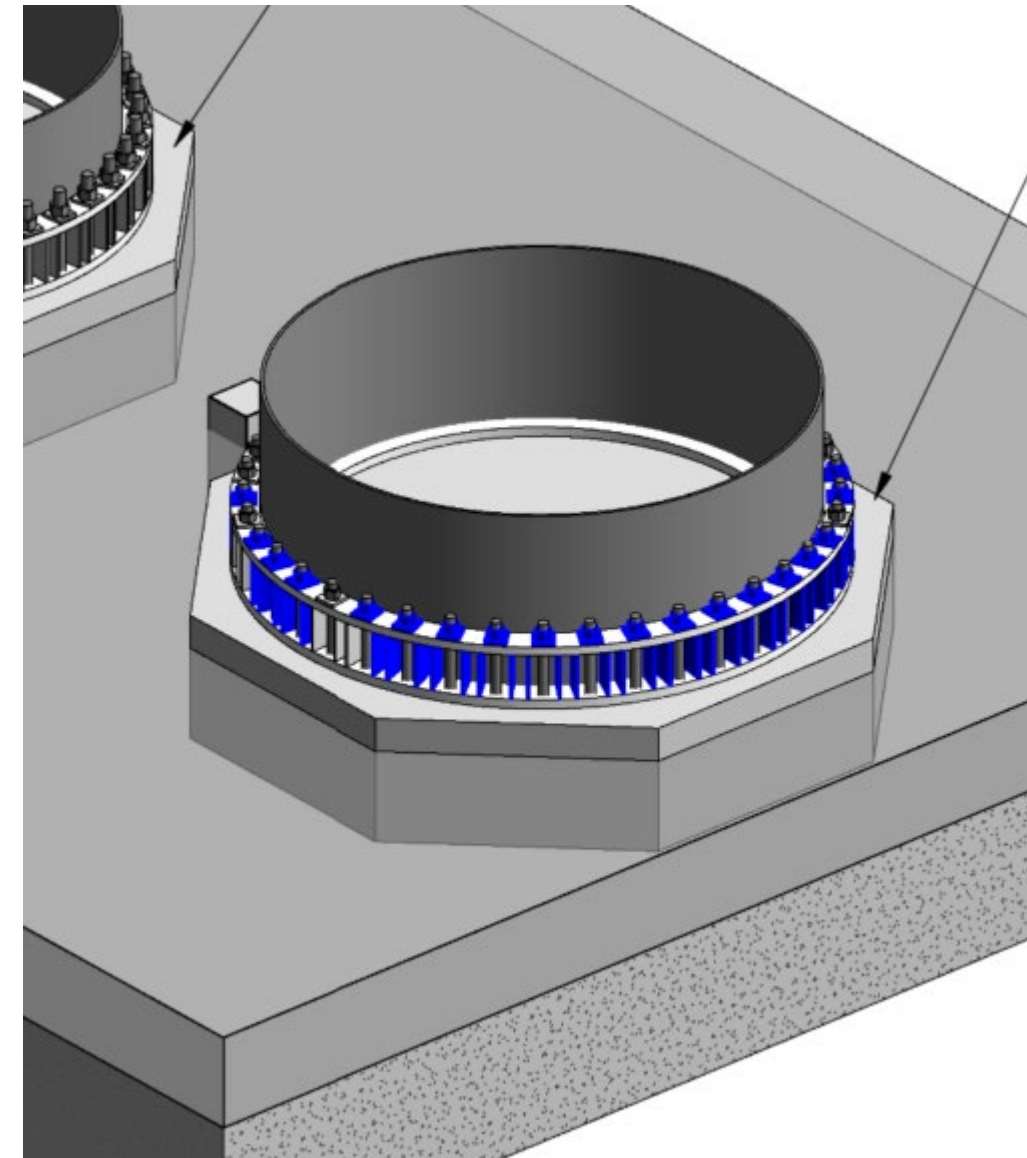
- Common repair when a new element/connection required
 - Existing fully deteriorated
 - Modifications require reinstallation of member
 - Constructability (less shoring, etc.)
- Repair needs to consider:
 - Loading during repair
 - Loading after repair (service condition)
- Role of Anchors:
 - Transfer loads from new members to the existing structure





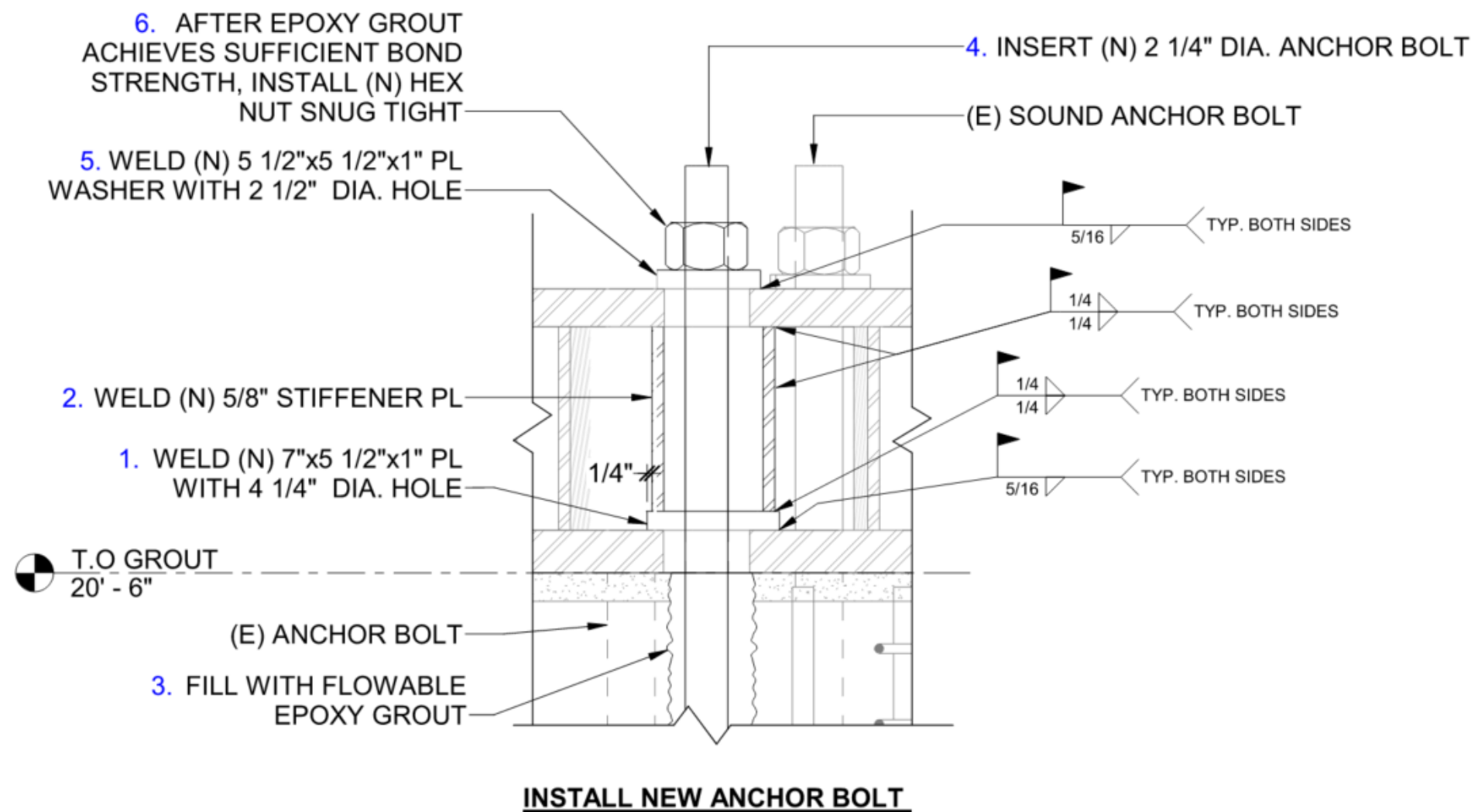
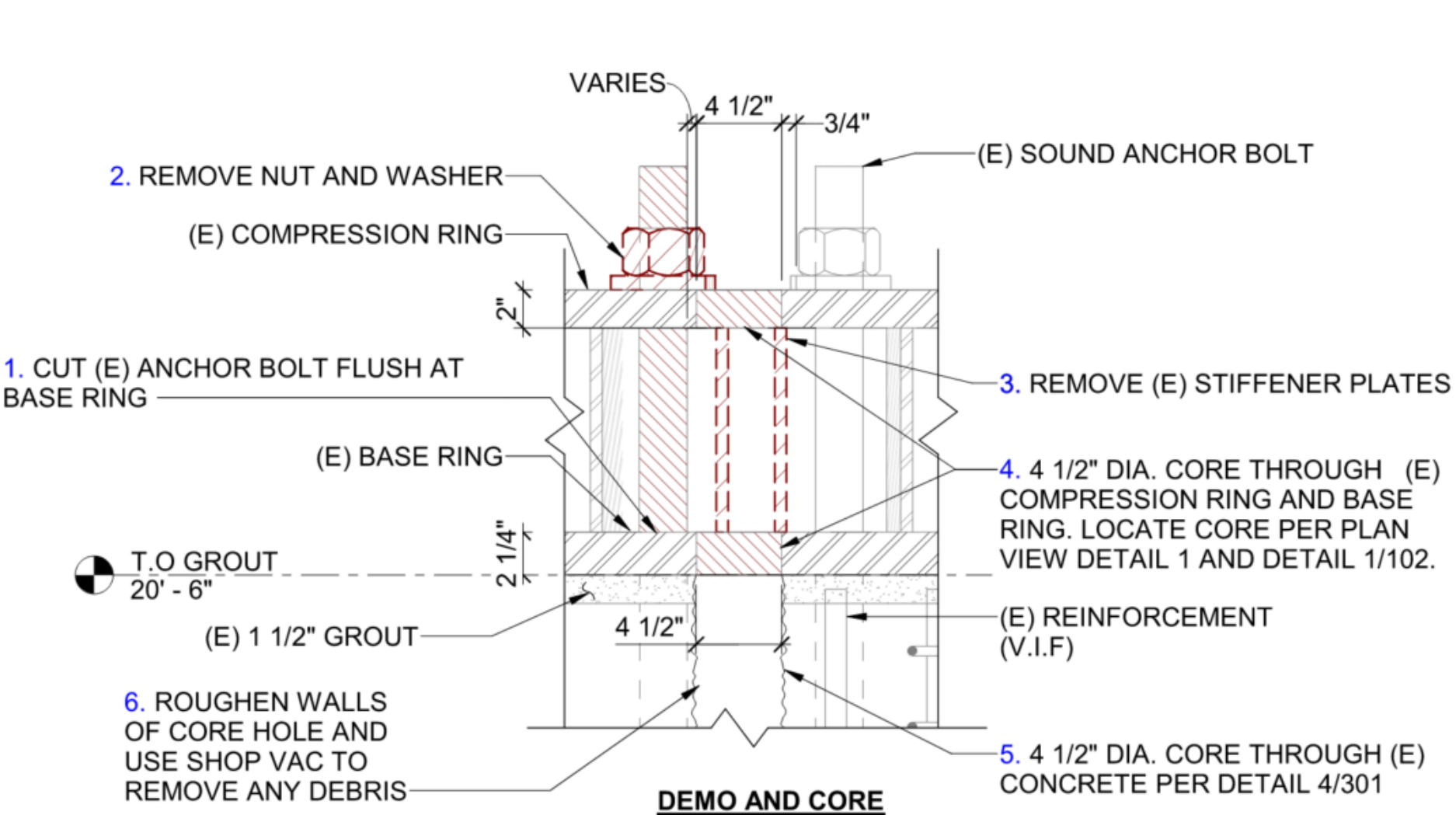
Vessel Anchor Replacement

- Scope:
 - Replacement of deteriorated anchor bolts of (3) existing vertical vessel
- Condition of Bolts:
 - Corrosion of existing anchor bolts, base ring, and stiffener plates as a result of age, exposure, and environmental condition
- Design Approach:
 - Optimized to replace a minimum number of anchor bolts to maintain safety until the vessel is replaced.
 - No replacements on (1) vessel
 - (1) anchor bolt replacement on (1) vessel
 - New anchor bolts located between existing anchor bolts to minimize removal of existing anchor bolts and stiffener plates to minimize costs





Vessel Anchor Replacement





Vessel Anchor Replacement



www.icri.org

2024 FALL
CONVENTION
OCTOBER 22-25 2024



Presenters:



Jeffrey M Owad, PE, PMP

Director of Engineering
jowad@structuraltec.com



Luis R. Pelayo, PE, SE

Engineer II
lpelayo@structuraltec.com



www.icri.org

2024 FALL
CONVENTION
OCTOBER 22-25 2024



SESSION EVALUATION

Resources

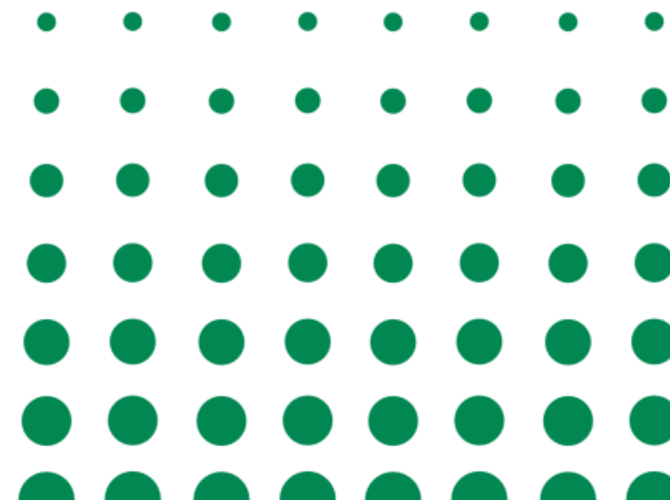
Evaluate this Session



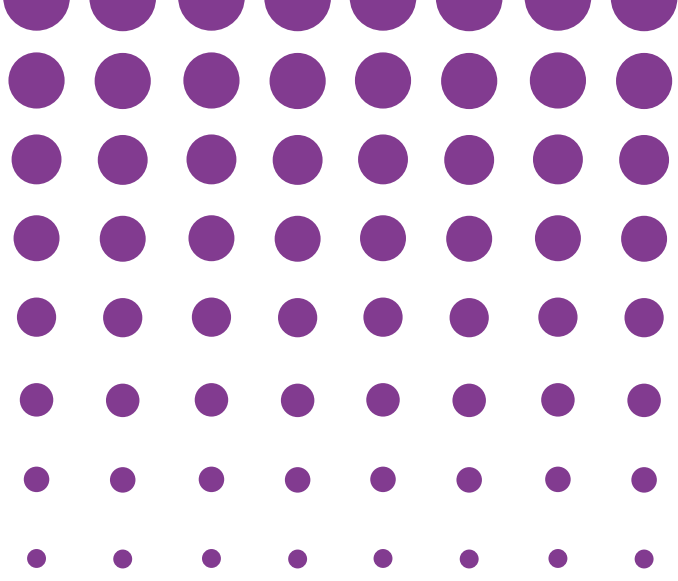
To complete the session evaluation, open the ICRI Convention App.

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**



THANK YOU FOR YOUR ATTENTION



www.icri.org



2024
CONVENTION
OCTOBER 22-25 2024

FALL