



ANCHOR 201: TECHNOLOGY OF ADHESIVE ANCHORS

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Sr. Field Engineer | North Carolina

LEARNING OBJECTIVES

Upon completing this program, the participant should be able to:

1. Identify effects of varying field and loading conditions on the performance of adhesive anchors
2. Examine the rigorous testing methods used by manufacturers to address various jobsite conditions
3. Gain confidence in the suitability of adhesive anchors over a wide range of applications
4. Explore the various installation methods per manufacturer and options available

This course is registered for 1.0 Professional Development Hour with NCSEA



TIP OF THE DAY – Only with proper installation will you get proper performance



AGENDA

- **Advantages of adhesive anchors**
 - Effects of varying field and loading conditions
 - Testing methods
 - Suitability of adhesive anchors over a wide range of applications
 - Installation methods
 - New technologies



ADVANTAGES OF ADHESIVE ANCHORS

- 1** More flexibility vs. cast-in and post-installed mechanical anchors
- 2** Suitable for various construction project types and conditions
- 3** Well established technology
- 4** Superior capacity
- 5** Relatively cost effective
- 6** Relatively easy to install*



*If you have been trained to read and follow the Manufacturers Printed Installation Instructions (MPII)

Six strong advantages that make adhesive anchors a suitable solution for your application.



ADVANTAGES OF ADHESIVE ANCHORS

More flexibility vs. cast-in and post-installed mechanical anchors

- Wide variety of anchor elements: rebar, threaded rod, internally threaded inserts
- Greater spacing and edge distance flexibility
- Variable embedment depths

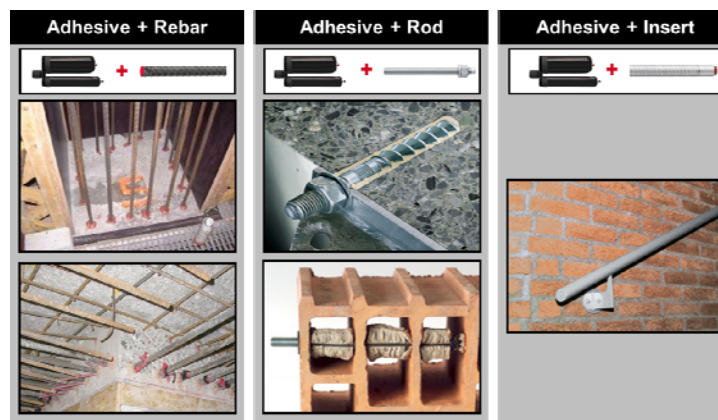


Adhesive can be combined with multiple anchor elements

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ADVANTAGES OF ADHESIVE ANCHORS

Adhesive anchors are suitable for various construction project types and conditions



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AGENDA

- Advantages of adhesive anchors
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EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

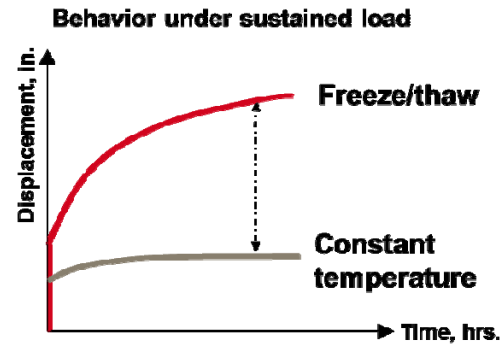
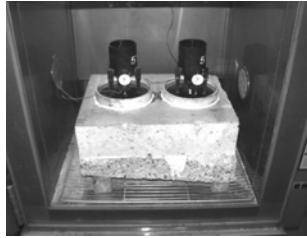
Cause		Effect
Freeze/Thaw	→	A large white question mark is centered within a dark brown rectangular box, which occupies the right side of the table's effect column.
Water (Wet Conditions)	→	
Seismic Load	→	
Sustained Load (Creep)	→	
Hole Cleaning	→	
Installation Orientation	→	
Temperature	→	
Diamond Cored Holes	→	



EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Freeze/Thaw

Expansion and contraction of materials due to temperature changes and expansion of water when it freezes tend to disrupt the equilibrium/compatibility of structural systems.



Large displacement and low capacity over time

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EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Water (Wet Conditions)

A – Dry



Ideal conditions for adhesive anchors

B – Damp

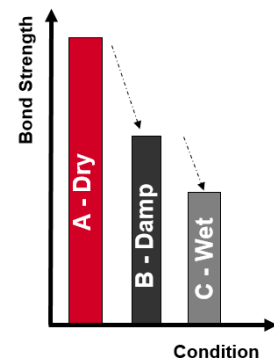


Inside a damp or water saturated hole, pores exposed during drilling and cleaning, or concrete which had been previously submerged, can trap pockets of water, impeding the migration of adhesive into the concrete

C – Wet



Wet or water-filled hole conditions represent an extreme case of a damp-hole



Potential reduction in mechanical interlock and bond strength

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EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Seismic Load

- Cyclic and seismic loadings can damage the concrete/adhesive anchor interface.
- Research continues to evaluate the most realistic testing protocols including small and large scale shake table tests.



UC San Diego shake table test

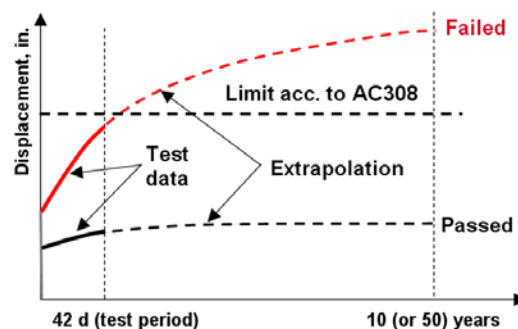
Reduced bond strength and greater variation in anchor performance



EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Sustained Load (Creep)

External loads applied to the anchor assembly (rebar or threaded rod) for a prolonged amount of time. Excessive displacement and/or failure can occur to an adhesive anchor system that is not resistant to creep.



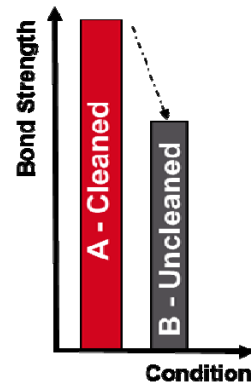
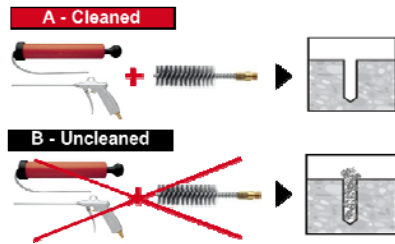
Increased displacement and variation in performance



EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Hole Cleaning

Products installed into uncleaned or partially cleaned holes generally experience decreased bond strength with increased variation in performance.

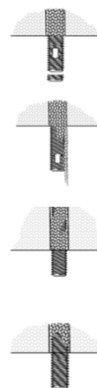
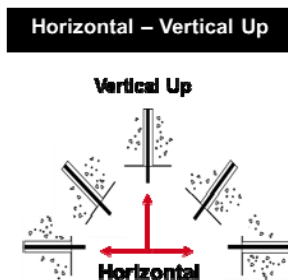


Lower bond strength and larger displacement



EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Installation Orientation



Sag of anchor element during anchor cure

Excessive run-out of adhesive during injection or installation of anchor element

Incomplete coverage of anchor element due to run out of adhesive

Entrapment of air during injection leading to voids along bonded length

Anchor orientation can require different installation procedures



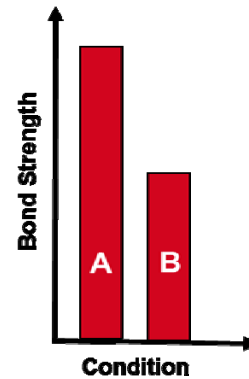
EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Temperature

Environmental conditions may impose sufficient heat energy to elevate the base material (and the cured adhesive) to a moderate temperature.

Temperature Range	Short Term Temperature	Long Term Temperature	Bond Strength*
A	130° F	110° F	2,130
B	176° F	110° F	1,470

* Characteristic bond strength (psi) based on Hilti HIT-RE 500 V3 (ICC ESR-3184), 3/4" threaded rod, 2,500 psi dry uncracked concrete in hammer drilled hole. Refer to manufacturers ICC ESR for the temperature range and bond strength for each product based on concrete condition, anchor element type/size and hole drilling method.



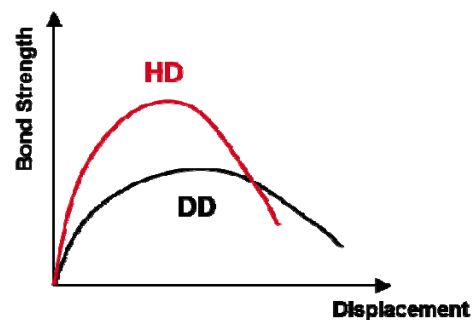
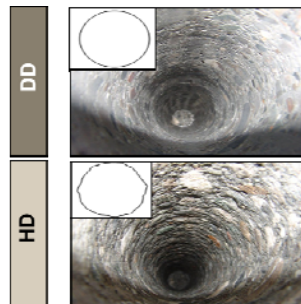
Decrease in bond strength with increased variation in performance

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EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Diamond Cored Holes

Diamond drilling produces a smooth, geometrically regular cylindrical hole



Lower bond strength and larger displacement

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EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

Cause		Effect
Freeze/Thaw	→	Large displacement and lower capacity
Water (Wet Conditions)	→	Reduction in mechanical interlock
Seismic Load	→	Reduced bond strength and increased variation
Sustained Load (Creep)	→	Increased displacement, variation and cracking
Hole Cleaning	→	Lower bond strength and larger displacement
Installation Orientation	→	Different installation procedures
Temperature	→	Decrease in bond strength
Diamond Cored Holes	→	Lower bond strength and larger displacement

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EFFECTS OF VARYING FIELD & LOADING CONDITIONS ON THE PERFORMANCE OF ADHESIVE ANCHORS

If an adhesive is not properly designed to resist all of the conditions presented, higher displacement, reduced capacity, cracking and large variations in performance can result.



Thus the importance of using products demonstrated to have suitable performance in accordance with the current test standards (ACI, ICC-ES) referenced in the model building codes

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CURRENT TEST STANDARDS

ACI 355.4

Design according to ACI 318-14, Chapter 17

- ACI 355.4 addresses adhesive anchors specifically so that ACI 318-14 can be used to design adhesive and mechanical systems.
- Previously, ACI 318-08 only addressed mechanical anchors.
- ACI 355.4 is available to address various conditions that affect the adhesive anchor system.

ICC-ES AC308

Design according to I-codes

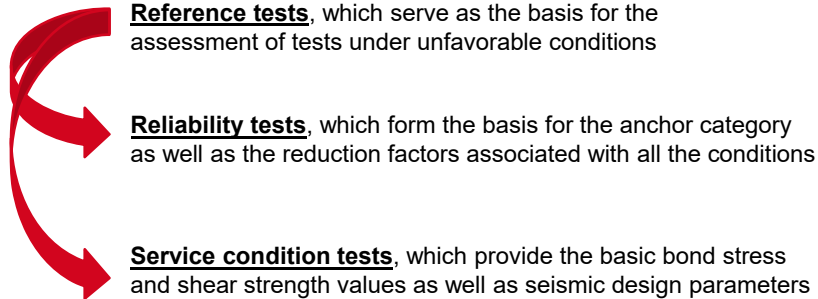
- ICC-ES AC308 is the state-of-the-art evaluation criteria to demonstrate an adhesive anchor's performance under all the various conditions previously discussed.
- ACI 355.4 and ICC-ES AC308 have been harmonized.

ACI 355.4 and AC308 are at the forefront of adhesive anchor test procedures



TEST GROUPINGS

- Organization of tests within standards:



Design parameters for all conditions previously discussed are determined through testing

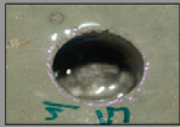
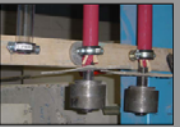
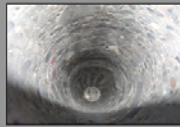


CRITICAL TESTS FOR LONG-TERM PERFORMANCE AND SUSTAINED TENSION LOADING

- Freeze/thaw
- Water-filled holes
- Seismic
- Sustained load
- Sensitivity to hole cleaning
- Sensitivity to installation orientation
- In-service behavior at elevated concrete temperatures
- Resistance to alkalinity and sulfur exposure
- Installation at decreased temperatures (for potential effects on long-term performance)
- Alternative drilling methods (supplement for diamond cored holes)



CRITICAL TESTS FOR LONG-TERM PERFORMANCE AND SUSTAINED TENSION LOADING

	Water-filled holes	Installation orientation	Diamond cored holes
Test Condition	Table 3.2, Test Series No. 2g	Table 3.2, Test Series No. 8	Test Series 1 and 2
Scope and/or Acceptance Criteria	COV≤30% Characteristic load compared to corresponding Reference test and used to establish anchor category	COV≤30% Characteristic load ≥ 90% of corresponding Reference test "Blind" installation to identify recommendations (use of wedges, i.e.) and potential issues	COV≤20% Determination of bond strength for diamond cored holes applications. Can include all hole conditions (damp, wet, etc.) as desired.
Image			

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THE PRODUCT SELECTION CAN BE BASED ON MANY PARAMETERS AND CONDITIONS

- **Base Material:** cracked and uncracked concrete, lightweight concrete, concrete compressive strength, water saturated or submerged concrete
- **Base Material Geometry:** thickness, edge distance, anchor spacing. These parameters may affect anchor diameter and embedment depth.
- **Load:** tension, shear, seismic
- **Temperature:** installation (gel and cure time), short and long term over the life of the anchor
- **Anchor Orientation:** downward, horizontal, overhead
- **Environment:** interior, exterior, freeze/thaw, exposure to chemicals, etc.
- **Hole preparation:** hammer drill, diamond coring

How do I know which product is suitable for my application?

Consult an anchor manufacturer for technical support by contacting their office, local field representative or reference their website and published literature.



HOW CAN YOU VERIFY THAT A PRODUCT CONFORMS WITH THE NEW MODEL CODE REQUIREMENTS?

EASY – look for an Evaluation Service Report (ESR) for that product.



What is an ESR?

- Product-specific ESRs, which verifies code compliance, are published by ICC-ES based on testing performed in accordance with appropriate acceptance criteria (AC).

ICC-ES Reports play an important role in providing clear evidence that products comply with codes and standards



ICC-ES ESR LAYOUT

ICC-ES Evaluation Report
ESR-4802
 Released March 1, 2017
 This report is subject to renewal February 1, 2017.
 A Subsidiary of the International Code Council®

DIVISION 05 80—THERMAL AND MOISTURE PROTECTION
 Section 05 80—Roofing Felt and Underlayment

REPORT HOLDER:
 ADRI INCORPORATED/ADRI UNLIMITED
 6300 FLOWER STREET
 CHICO, MONTANA 59701
 (406) 894-1917
 ADRI@ADRIINC.COM

EVALUATION SUBJECT:
 HIT-RE 500+ ADHESIVE FOR ASPHALT/SHINGLE ROOF COVERINGS IN SEVERE CLIMATE AREAS

1.0 EVALUATION SCOPE
 Compliance with the following codes:
 • 2012 and 2009 International Building Code® (IBC)
 • 2012 and 2009 International Residential Code® (IRC)

Properties evaluated:
 See Section 2.0

2.0 USES
 HIT-RE 500+ is a self-adhesive, substrate repair membrane. It is used to repair and seal concrete and masonry substrates in areas subject to water penetration. It is used in accordance with the instructions on the product label and the instructions on the product label.

3.0 DESCRIPTION
 The HIT-RE 500+ has a granule surface. The membrane has a thickness of 0.040 inch (1.02 mm) and is applied in rolls (36 inches/914 mm wide) and (20.3 m) long.

4.0 INSTALLATION
 The HIT-RE 500+ membrane must comply with the instructions on the product label and the instructions on the product label. The manufacturer's printed installation instructions and the report must be available at the jobsite at all times during the installation.

EVIDENCE SUBMITTED
 6.1 Data in accordance with the ICC-ES Acceptance Criteria for Self-Adhesive Roof Underlayment for Concrete and Masonry (ICC-ES ESR-1040), dated February 2012.
 6.2 Report of testing in accordance with ASTM D1970.

7.0 IDENTIFICATION
 The membrane is identified by labels on the rolls or packaging, including the name, logo, and address of the manufacturer, and the product name, the evaluation report number ESR-4802.

1. CSI Division Number
2. Report Holder
3. Evaluation Subject
4. Evaluation Scope
5. Properties Evaluated
6. Uses
7. Description
8. Installation
9. Conditions of Use
10. Evidence Submitted
11. Identification

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ICC-ES ESR LAYOUT

I. Installation Parameters

II. Design Tables

III. Example Calculations

IV. *Manufacturer's Printed Installation Instructions (MPII) or Instructions for Use (IFU)

V. Supplemental Data and Certifications

- I. Installation Parameters
- II. Design Tables
- III. Example Calculations
- IV. *Manufacturer's Printed Installation Instructions (MPII) or Instructions for Use (IFU)
- V. Supplemental Data and Certifications

*Always reference the MPII or IFU included in the adhesive anchor packaging.

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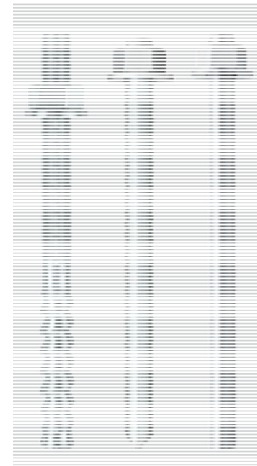
HOW TO READ AN ICC-ES EVALUATION REPORT

1. **CSI Division Number** - ICC-ES Evaluation Reports, and the building products represented in them, are organized according to the Construction Specifications Institute's (CSI) MasterFormat system.
2. **Report Holder** - The name and address of the company or organization that has applied for the Evaluation Report.
3. **Evaluation Subject** - The specific product(s) covered by the report.
4. **Evaluation Scope** - The code(s) that were used to evaluate the product.
5. **Properties Evaluated** - A brief description of the properties the product was evaluated against such as fire resistance and wind resistance. This section also shows if the product can be used for structural purposes.
6. **Uses** - Identifies the scope of the Evaluation Report and relates the product evaluated to code provisions.
7. **Description** - Provides a general description of the product and its features, such as length, thickness, etc.
8. **Design and Installation** - Provides design parameters and strength reduction factors. Identifies general and often specific requirements to help the inspector ensure the product is installed properly.
9. **Conditions of Use** - Statement that the product complies with or is a suitable alternative to the requirements of the applicable code.
10. **Evidence of Submitted** - Data (i.e. test reports, calculations, installation instructions) that was used in evaluating the product. Typically references the applicable Acceptance Criteria.
11. **Identification** - Information that can be used to identify the product, including the manufacturers name, product code, Evaluation Report number, etc.



SELECTING THE RIGHT STEEL ELEMENT IS AS IMPORTANT AS THE ADHESIVE

- Material properties – Steel strength and ductility
 - ASTM F1554 standard specifies all mechanical properties that are relevant for carbon steel structural fasteners, includes compatible nuts and washers
 - Ductility in carbon steel for seismic applications
- Corrosion resistance
 - Protective coating or stainless steel may be suitable for exterior applications or corrosive environments
- Reliable material finish and identification
 - Pre-cut and cut-to-length rod programs offer threaded rod of the proper dimensions, without oil or debris, and chamfered
 - ASTM F1554 requires specific head markings for ease of identification



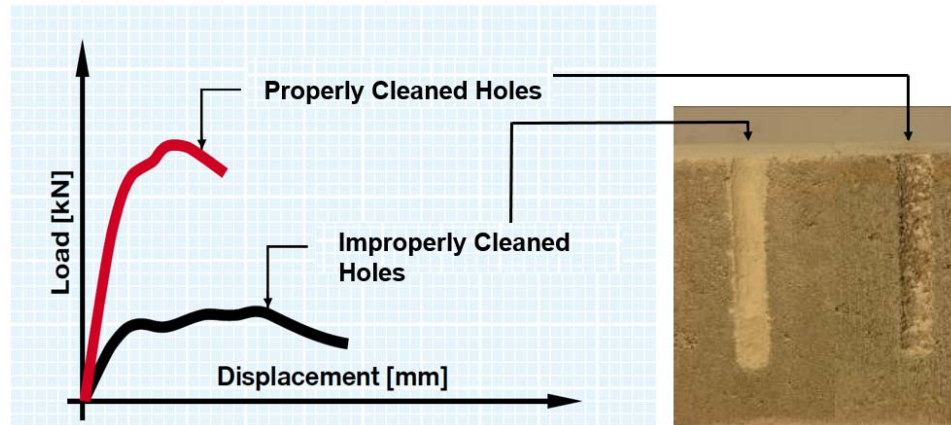
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IS THIS INSTALLATION METHOD CORRECT?



ONLY WITH PROPER INSTALLATION WILL YOU GET PROPER FUNCTION



Clean holes matter!



A FIELD STUDY OF ADHESIVE ANCHOR INSTALLATIONS

A Field Study of Adhesive Anchor Installations

Theory and practice

BY PHILIPP LANGE, WOLFGANG FUCHS, AND ROLF ELIGEHAUSEN

In every building application, the starting point is choosing the correct product. This requires understanding the loads to be resisted and following a defined design method. It also requires establishing the exact location of the fixing point, anticipating the environmental conditions during installation and service, and observing the installation procedures for the fastener or anchor.

For adhesive anchors, the designer must select a product that is adequate for the conditions in service and that has been evaluated for compliance with code requirements. Once an appropriate system has been selected and designed, the installation process has to be considered. To ensure correct installation, the installer must follow the manufacturer's instructions precisely. Furthermore, the installer must follow the requirements of the relevant evaluation service report (ESR)—added to the anchor. Detailed information on the installation and inspection of adhesive anchors is given by Weber/Chemur and Maritz, and summarized on factors influencing the behavior of adhesive anchors can be found in Reference 2.

In theory, the knowledge is available to ensure reliable fastenings with adhesive anchors and to give designers and installers confidence and flexibility in various applications. With the debate of adhesive anchors in Boston, MA, however, the installation and use of these types of anchors has been called into question. The figures

FIELD RESEARCH PROJECT

The installation of adhesive anchor systems was investigated at concrete test sites in California, Florida, Illinois, New York, and Pennsylvania. In total, 23 sites were visited. 26 applications were investigated, and 33 installers were interviewed (Table 1). Various different adhesive systems (either epoxy-based or hybrid mortars) were installed. None of these products had an ESR. The steel anchors were continuously threaded steel rods or deformed steel reinforcing bars. Anchors were used for strengthening bridge structures, seismic retrofitting, connecting structural elements to structural walls, anchoring steel elements to existing concrete members, anchoring precast elements, installing bracing systems, or anchoring liquid elements. The anchors were installed downward in 13 applications, horizontally in 11 applications, and overhead in two applications.

All information relevant to the field study was gathered on site by the first author, and the detailed findings were recorded by general installers who were interviewed to determine their professional and educational backgrounds, training and experience levels with pre-installed anchors, general anchor installation experience level, and general experience concerning the pros and cons to regard to the installation of adhesive-bonded anchors.

TABLE 1: DETAILS OF THE SURVEY

Location	Illinois	Florida	California	Pennsylvania	New York	Total
Job sites	6	7	5	2	3	23
Applications	7	8	5	3	3	26
Surveys	8	6	8	5	4	31

Magazine	Concrete International, V.33, No 1, pp. 57-63.
Date	January 2011
Authors	Grosser, P. ; Fuchs, W. and Eligehausen, R. University of Stuttgart

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A FIELD STUDY OF ADHESIVE ANCHOR INSTALLATIONS

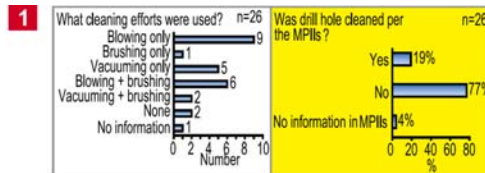


Fig. 2: Results of the field study of adhesive anchor installations. (n = number of observed applications)



Fig. 12: Training of installers. Although the installers wanted to do a good job, their training was inadequate. (n = number of installers interviewed)

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A FIELD STUDY OF ADHESIVE ANCHOR INSTALLATIONS

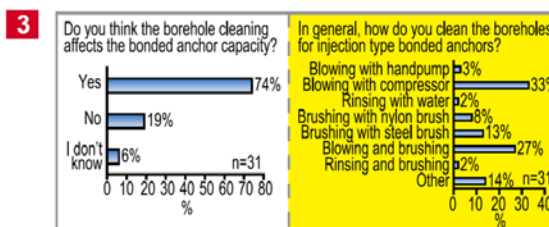


Fig. 13: Many installers were not aware of the influences of significant factors on anchor capacity: Although almost three out of four installers thought that the borehole cleaning method has an effect, less than a third were using blowing and brushing



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INSTALLERS MUST FOLLOW THE MANUFACTURERS PRINTED INSTALLATION INSTRUCTIONS

Each manufacturer has specific requirements upon which their testing and published load values are based:

- Hole cleaning methods: Compressed air and brushing, hollow drill bit and vacuum systems, torque-controlled adhesive anchors which require no hole cleaning.
- Initial dispensing of adhesive to equalize the "A" and "B" components to ensure proper mixing. Dispense "x" number of trigger pulls vs. dispensing until adhesive is a uniform color.
- Overhead and deep embedment: Specific accessories such as modular wire brushes that can be connected to a drill, extension hoses, piston plugs and battery-operated dispensers.



Manufacturer-provided training of installers and inspectors can facilitate proper installation



ADHESIVE ANCHOR INSTALLER CERTIFICATION

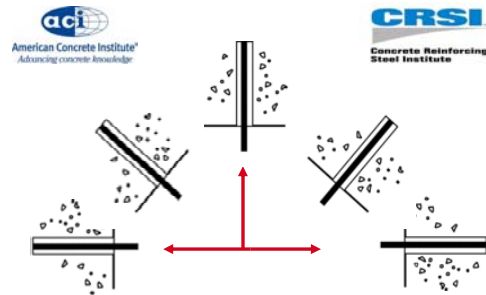
Codes and Standards Overview

- The 2014 edition of the American Concrete Institute Building Code and Commentary (ACI 318-14, Chapter 17) contains anchor design provisions.
- ACI 318-14, part 17.8.2.2 references Adhesive Anchor Installer Certification.
 - Installation of adhesive anchors horizontally or upwardly-inclined to support sustained tension loads shall be performed by personnel certified by an applicable certification program. Certification shall include written and performance tests in accordance with the ACI/CRSI Adhesive Anchor Installer Certification program, or equivalent.
- IBC 2015 references the provisions of ACI 318-14 for both cast-in-place and post-installed anchor design in Section 1901.3 Anchoring to Concrete.



ACI/CRSI ADHESIVE ANCHOR INSTALLATION CERTIFICATION PROGRAM

- The 90-minute written examination consists of 75 multiple-choice questions.
- The performance examination consists of two parts, Part 1 (vertical down) and Part 2 (vertical up)



www.concrete.org/certification

Anchor manufacturer training is an effective alternative to the ACI/CRSI Certification program with approval from the Engineer of Record (EOR)

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HOLLOW DRILL BIT AND VACUUM SYSTEMS

- Manufacturer specific systems consisting of:
 - Hollow drill bit
 - Vacuum
 - Adhesive anchor
 - Adhesive dispenser
- The requirements for each anchor system will be included in the ICC-ES Report and MPII



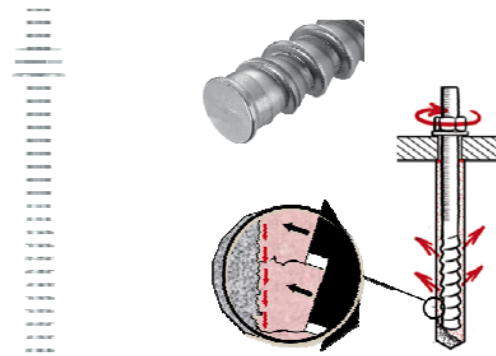
The industry is trending towards the use of hollow drill bit and vacuum systems to facilitate correct anchor installation and control silica dust

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TORQUE CONTROLLED ADHESIVE ANCHORS

- Anchor working mechanism:
 - Coating on helix end of anchor elements prevents bonding between adhesive and anchor
 - Applied torque actuates expansion anchor characteristics and takes up initial displacement
 - Expansion forces increase friction to concrete significantly



Cleaning is not required due to the special design of the helix and the expansion forces generated by torquing the anchor

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POST-INSTALLED REBAR CONNECTIONS IN ICC-ES AC308

Reinforcing bars that are designed in accordance with the provisions ACI 318-14 Chapter 25, rebar development theory, are recognized in ICC-ES AC308.

- ICC-ES AC308 provides criteria for post-installed reinforcing bar systems in lieu of cast in place lap splices.
- ICC-ES AC308 Table 3.8 details the full range of tests for the evaluation and qualification of post-installed adhesive anchor systems for post-installed reinforcing bar applications.
- ACI 355.4 does not specifically address the use of adhesive anchor systems for post-installed reinforcing bars.



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ANCHOR DESIGN, SPECIFICATION AND DETAILING

- **Design Software:** Simple and accurate calculation in accordance with code provisions
- **General Structural Notes:**
 - Include product name and ESR number
 - Include required installation training by manufacturers direct representative
 - Include design parameters like moisture condition, temperature, and drilling methods
 - Note which manufacturer is the basis of design
- **Statement of Special Inspection:**
 - Note upwardly-inclined and overhead applications where applicable
 - Note critical connections and testing requirements where proof loading is required
- **Connection details:**
 - Include adhesive anchor identification, anchor element diameter, steel type and embedment depth

Consult manufacturers' website and technical personnel for additional information

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REVIEW - LEARNING OBJECTIVES

Upon completing this program, the participant should be able to:

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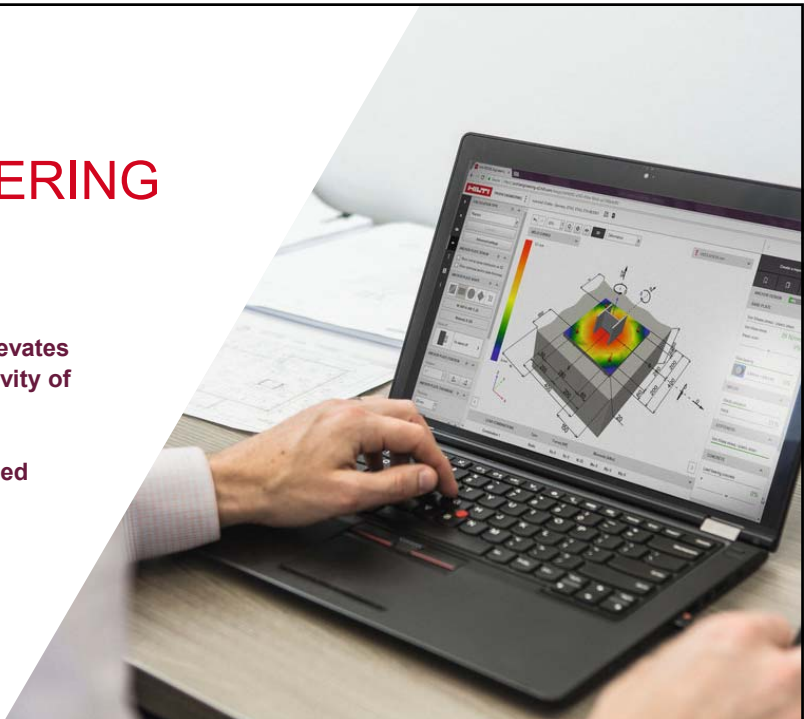
TIP OF THE DAY – Only with proper installation will you get proper function



PROFIS ENGINEERING SUITE

Comprehensive fixture design that elevates the accuracy, simplicity, and productivity of your design.

- Cloud-based software with enhanced user functionality
- Load Engine
- Masonry module
- Concrete-over-metal-deck module
- Base plate analysis



THANK YOU

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