Hilti Product Safety

Building with Hilti:
Limiting your Exposure

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History of Concrete Anchor Design
Until now, it has been implicitly assumed that concrete is uncracked (and unreinforced) for the purpose of anchor design. The state of the art, as reflected by various publications (Eligehausen, et al) that the state of cracking in concrete can have a measurable and predictable negative impact on the performance of both cast-in-place and post-installed fasteners. \(^1\) testing in flexural cracks

\(^1\) ibid
Drop-in anchors  
M8-M12  

\[ \sim 70\% \]  
\[ \sim 30\% \]  

Bonded anchors  
M8-M16  

\[ \sim 70\% \]  
\[ \sim 20\% \]  

performance of anchors in cracked concrete

Eligehausen, et al. 1998
Drop-in anchors

Load-displacement curves for fully- and partially-expanded drop-in anchors in uncracked and cracked concrete

usual case

Fuchs, Eligehausen 1999
Changes to ICC-ES Anchoring Approvals
What are ICC-ES reports and why are they important?

- ICC-ES Evaluation Reports used to be called ICBO reports.
- ICC Evaluation Services Reports [ESR] are written for **building officials and inspectors**. Their main purpose is to give the inspection community a tool to evaluate where a product is safe to use in the construction of a structure.
- Many geographies in the Western United States [including CA, AZ, NV, WA, OR, AL, UT, NM and others] essentially require the concrete anchors have an ICC Evaluation Report in order to be used. Structural engineers or building officials will require these reports to be submitted before an anchoring product is approved for use.
Acceptance Criteria

- When a company like Hilti applies for an ICC Report, they have to test their product in a series of conditions.

- The results of these tests are evaluated to determine where the anchor can be used and what loads it is rated to hold.

- These testing guidelines and the rules for evaluating this data are called Acceptance Criteria or AC for short.

- The tests in an Acceptance Criteria may include seismic testing, testing in cracked concrete, edge distance testing and spacing effects.
Code requirements

**IBC 2006**
- Section 1912 references

**ACI 318**
- includes

**ACI 318 - D**

**ICC-ES®**
- AC 193 / 308
- ACI 355.2

**ESR**
- Evaluation Service Report => final approval document containing design data

IBC – International Building Code®
ACI 318-D – American Concrete Institute®; Design provisions
ACI 355.2 – American Concrete Institute®; Test provisions
AC 193 ICC-ES Acceptance Criteria; acceptance criteria for mechanical anchor in concrete elements
AC 308 ICC-ES Acceptance Criteria; acceptance criteria for post-installed adhesive anchors in concrete elements
ESR – Evaluation Service Report => final approval document containing design data
Strength Design

Influence of Cracked Concrete

cracks can cause a reduction in ultimate load

cracks can cause an increase in displacement at ultimate load
What is cracked and uncracked concrete?
What is cracked and uncracked concrete?

- For reinforced concrete to work, it has to crack.
- If the location of the fastening will be exposed to cracking at any time in the life of the structure, cracked concrete must be assumed.
- Common areas to assume cracked concrete
  - Seismic zones or seismic applications (Cat. C – F)
  - Overhead, Tension Zones
  - Areas where temperature cracking or shrinkage might occur
- The structural engineer and/or building official must ultimately decide on whether the application can be considered uncracked.
The Future

As of 1.1.08, all anchor manufacturers are required to conduct testing per AC308 and AC193, respectively, for recognition in jurisdictions using the 2003 and 2006 IBC.

At that time (1.1.08), there should be no states in the US using codes earlier than the 2003 IBC.
How can you verify that a product conforms with the new code requirements?
Reading the ICC Report

- **Section 1.0** – Evaluation Scope
- **Section 2.0** – Uses
- **Section 5.0** – Conditions of Use
- **Section 6.0** – Evidence Submitted
Section 1.0

• Make sure the IBC 2006 is listed
• However, IBC 2006 may be listed for CMU usage.
• Product may also be approved for IBC 2006 / CBC 2007 usage with no seismic approval.

Section 6.0

• Make sure the product has been evaluated under AC 193 for expansion, undercut, and screw anchors.
• Make sure the product has been evaluated under AC 308 for adhesive anchors.
• Product may also be approved under AC 193 or AC 308 with no seismic approval. Be careful.
Section 2.0

2.0 USES

The Hilti Kwik Bolt TZ anchor (KB-TZ) is used to resist static, wind, and seismic tension and shear loads in cracked and uncracked normal-weight concrete and structural lightweight concrete having a specified compressive strength, \( f'_{c} \), of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa); and cracked and uncracked normal-weight or structural sand lightweight concrete over metal deck having a minimum specified compressive strength, \( f'_{c} \), of 3,000 psi (20.7 MPa). The anchoring system is an alternative to cast-in-place anchors described in Sections 1912 and 1913 of the IBC and Sections 1923.1 and 1923.2 of the UBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.2 of the IRC.
Strength Design

Anchor Categories

Category 1: low sensitivity to installation and high reliability (higher $\phi$)

Category 2: medium sensitivity to installation and medium reliability

Category 3: high sensitivity to installation and low reliability (lower $\phi$)

Categories are only applicable to post-installed anchors !!

• $\phi$ factors are given in the ESR
  • corresponding anchor category is listed in the ESR
Special Inspection

4.4 Special Inspection:

Special inspection is required, in accordance with Section 1704.13 of the IBC and Section 1701.5.2 of the UBC. The special inspector must be on the jobsite continuously during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, hole cleaning procedures, anchor spacing, edge distances, concrete thickness, anchor embedment, and tightening torque. Hilti Anchors for PT Slab.
Anchors Suitable for IBC 2006

Cracked Concrete Listings - Qualified Under AC193

- KB-TZ Expansion Anchor
  - ESR-1917

- HSL-3 Heavy Duty Sleeve Anchor
  - ESR-1545
  - Optimum Seismic, Shock and Fatigue Performance

- HDA Undercut Anchor
  - ESR-1546
  - High Load Capacities and Reduced Spacing

- HIT RE 500-SD Epoxy Adhesive
  - ESR 2322
  - The only Chemical Anchor with ICC approval for the new AC308
Kwik Bolt TZ Expansion Anchor

Impact Section (Dog Point)

Nut

Washer

Wedges

Expansion Cone

Carbon Steel

Stainless Steel

Kwik Bolt 3
KB-TZ Expansion Anchor

Fire –resistance-rated construction

5.12 Where not otherwise prohibited in the code, KB-TZ anchors are permitted for use with fire-resistance-rated construction provided that at least one of the following conditions is fulfilled:

- Anchors are used to resist wind or seismic forces only.
- Anchors that support a fire-resistance-rated envelope or a fire-resistance-rated membrane are protected by approved fire-resistance-rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards.
- Anchors are used to support nonstructural elements.

Cracked concrete

5.10 Anchors may be installed in regions of concrete where cracking has occurred or where analysis indicates cracking may occur \( f_t > f_r \), subject to the conditions of this report.
KB-TZ Expansion Anchor

Concrete over metal deck

FIGURE 5—INSTALLATION IN THE SOFFIT OF CONCRETE OVER METAL DECK FLOOR AND ROOF ASSEMBLIES
Anchors Not Suitable For IBC 2006 - Concrete

- **Drop In Anchors – Any Manufacture**
- **HDI-P – Hilti Anchors for PT Slab**
- **Powers Spike Anchor**
- **Powers Drive Anchors**
- **Tapcon Screw Anchors**
- **No approved screw anchors yet**
- **No Shot Pins**
The Big Dig Tunnel

Key message of the synopsis of NTSB report HAR-07-02 regarding the fatal accident in the Big Dig tunnel:

“Insufficient understanding among designers and builders of the nature of adhesive anchoring systems”
Creep behavior of Adhesive Anchoring Systems

What is creep?

How was the creep behavior tested?

How do Hilti products perform in creep tests?

What changes with AC308 - what are the reasons?

“Everything flows…” (Heraclitus ~500 BC)
What is creep?

Creep is the slow and continuous deformation of a material under a sustained stress and is mainly influenced by:

- material / product
- load level & duration of loading
- temperature
- installation

Creep can occur in various construction materials such as steel and concrete and is considered e.g. in reinforced concrete design.

Creep is a typical behavior of construction materials that needs to be considered for design.
Key pillars of Creep behavior

- Load (AC58) / design resistance (AC308)
- Installation temperature and in-service temperature
- Hole condition, hole cleaning, adhesive injection

Properly installed adhesive anchors in properly designed applications are extremely reliable
**What is creep?**

**Creep basics:**

The creep displacement rate significantly decreases over time → the displacement stabilizes

**Displacement**

Load $N$ is maintained

Creep displacement: $s_{\text{creep}}$

time dependent

Load $N$ is applied

Initial elastic displacement: $s_0$

Load $N = 0$

Total: $s(t) = s_0 + s_{\text{creep}}(t)$
How was the creep behavior tested?

(Spring pots for sustained loading)
How was the creep behavior tested?

• A standard method to test and evaluate the creep behavior of Adhesive Anchoring Systems can be found in ICC-ES AC58

• AC58 was introduced in January 1995

• More than 25 different products from various manufacturers have been tested and evaluated

• The NTSB expressed no concern or criticism in AC58 qualifying suitable creep-resistant adhesives, instead stating that failing AC58 testing indicated an adhesive's inappropriateness for sustained-loading applications

• The creep test was optional

The test method under AC58 is appropriate for identifying the general suitability of Adhesive Anchoring Systems for sustained tension loads
How was the creep behavior tested?

Examples for possible creep test curves

- **Failed**
- **Not accepted**
- **Passed**

- Limit acc. to AC58: $s_u$ or 0.12 in.
- Extrapolation
- Test data

Displacement $s$

42 d (test period)  \[ \rightarrow \]  600 days
How was the creep behavior tested?

- If a creep test report (Series 17) was passed / submitted
- can be found in an ICC-ES ER / ESR in accordance with AC58:

3.0 EVIDENCE SUBMITTED

Data in accordance with the ICBO ES Acceptance Criteria for Adhesive Anchors in Concrete and Masonry Elements (AC58), dated November 2001, including test reports for the following optional tests: axial tension testing of single anchors, establishing minimum edge distance, \( c = c_{\text{min}} \) (AC58 Test Series 5); axial tension testing of a group of two anchors, establishing minimum spacing distance, \( s = s_{\text{min}} \) (AC58 Test Series 9); shear testing of single anchors, establishing critical edge distance, \( c = c_{\text{cr}} \) (AC58 Test Series 13); shear testing of single anchors, establishing minimum edge distance, \( c = c_{\text{min}} \) (AC58 Test Series 14); creep testing (AC58 Test Series 17); dampness testing (AC58 Test Series 19); freezing and thaw testing (AC58 Test Series 20); and seismic shear and tension testing of threaded rods and rebar (AC58 Test Series 21).
How was the creep behavior tested?

- Other locations in an ER / ESR where information can be found:
  - Footnotes in load tables stating Factors of Safety (FS):
    - FS = 4 → creep test passed,
    - FS = 5.33 (UBC) or
    - FS = 6.67 (IBC) → creep test not submitted
  - Other locations:
    - “Findings” (ER - Section 4)
    - “Design” (ER - Section 2)
    - “Conditions of Use” (ESR – Section 5)
AC308 versus AC58
What changes with AC308 - what are the reasons?

- AC58 evolved into AC308. The main developments:

<table>
<thead>
<tr>
<th>AC58</th>
<th>AC308</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrapolation to 600 days only</td>
<td>Extrapolation to 10 years (elevated temp.) 50 years (normal ambient temp)</td>
<td>better coverage of relevant time periods</td>
</tr>
<tr>
<td>Test temperature fixed (110F)</td>
<td>Test temperature determined through published service temperature range</td>
<td>Wider temperature ranges possible</td>
</tr>
<tr>
<td>Pass / Fail</td>
<td>Product can pass with reduced published load and or published temperature range</td>
<td>Application oriented evaluation</td>
</tr>
<tr>
<td>Creep test optional</td>
<td>Creep test mandatory</td>
<td>No “backdoor” or misunderstanding</td>
</tr>
</tbody>
</table>

AC308 creep test is mandatory and published technical data directly depend on the result of creep tests
RE 500 / RE 500 SD
HIT RE 500 / 500 SD Epoxy Anchoring System

- Approved in accordance with AC 308 for threaded rods
- ESR 2322
- NSF Certification for potable water
- Suitable for design in cracked concrete and seismic conditions using the Concrete Compressive Design method
- Approved with cored holes
- Approved with rebar and threaded rod
- Approved with internally threaded inserts
Installation of Post-Installed Anchoring Systems

ICC-ES ESR Inspection Checklists

Adhesive Anchors Inspection Checklist for Concrete & Masonry

Special inspection shall be in compliance with Section 1701 of the UBC and Section 1704 of the IBC as described below. (See Structural Drawings for inspection requirements)

<table>
<thead>
<tr>
<th>Project Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Location:</td>
<td></td>
</tr>
<tr>
<td>Weather:</td>
<td>Air Temperature: °F / °C</td>
</tr>
</tbody>
</table>

**Product Name/Manufacturer:**
Lot No.:
ICC-ES Report No.:
Adhesive expiration Date: __/__/____
Specified Dispenser: Yes/No
Specified Mixer: Yes/No
Discard Initial Adhesive: __/__/____ (if trigger pull)

**Adhesive Temperature:** °F / °C
Cal Time: __/__/____
Cure Time: __/__/____
Per manufacturer installation instructions:

**Type:**
- [ ] All-Thread
- [ ] Internally Threaded
- [ ] Torque-Controlled
- [ ] Rebar
- [ ] Other

**Material:**
- [ ] Standard
- [ ] Stainless Steel
- [ ] High Strength

**Steel Grade/Coating:**

**Adhesive Insert:**
- [ ] Red Diameter: 3/8”
- [ ] 1/2”
- [ ] 5/8”
- [ ] 3/4”
- [ ] 7/8”
- [ ] 1”
- [ ] 1 1/4”
- [ ] Not Specified

**Rebar:**
- [ ] #8
- [ ] #10
- [ ] #12
- [ ] Other

**Base Material Type:**
- [ ] NW Concrete
- [ ] LW Concrete
- [ ] Concrete over Steel Deck
- [ ] CMU Block
- [ ] Other

**Base Material Strength:**
- [ ] 2000 psi
- [ ] 3000 psi
- [ ] 4000 psi
- [ ] Other

**Base Material Thickness:**”

**Base Material Temperature:** °F / °C

**Drill Bit Diameter:**”

**Hole Depth:**”

**Drill Bit Type:**
- [ ] Carbide-Tip Drill Bit
- [ ] Diamond Core Bit
- [ ] Other

**Hole Condition:**
- [ ] Dry
- [ ] Water Saturated
- [ ] Water Filled
- [ ] Wet
- [ ] Other

**Hole Cleaning:**
- [ ] Compressed Air
- [ ] Hand Pump
- [ ] Wire Brush
- [ ] Nylon Brush
- [ ] Other

**Hole cleaning in accordance with manufacturers’ printed installation instructions:**
- [ ] Yes
- [ ] No

**Anchor Application:**
- [ ] Please check all that apply
- [ ] Tension
- [ ] Shear
- [ ] Overhead
- [ ] Other

**Anchor Insertion:**
- [ ] Tapping motion
- [ ] Annular gap filled with adhesive
- [ ] Air Void Free Injection

**Anchor Spacing:**”

**Embedment (Bfl):”

**Installation Torque:**" (If required)

**Completion:**
Completed by: ____________________________
Date: ______/____/____
Company: ____________________________

**Mechanical Anchors Inspection Checklist for Concrete & Masonry**

Special inspection shall be in compliance with Section 1701 of the UBC and Section 1704 of the IBC as described below. (See Structural Drawings for inspection requirements)

<table>
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<tr>
<th>Project Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Location:</td>
<td></td>
</tr>
<tr>
<td>Weather:</td>
<td>Air Temperature: °F / °C</td>
</tr>
</tbody>
</table>

**Product Name/Manufacturer:**
Lot No.:
ICC-ES Report No.:
Head Configuration:
- [ ] Hex Nut/Threaded
- [ ] Hex Bolt Head
- [ ] Torque Cap
- [ ] Countersunk

**Diameter/Dimension:**
- [ ] 1/4”
- [ ] 5/8”
- [ ] 1/2”
- [ ] 5/8”
- [ ] 3/4”
- [ ] 1”

**Overall Anchor Length:**”

**Steel Grade/Coating:**

**Base Material Type:**
- [ ] NW Concrete
- [ ] LW Concrete
- [ ] Concrete over Steel Deck
- [ ] CMU Block
- [ ] Other

**Base Material Strength:**
- [ ] 2000 psi
- [ ] 3000 psi
- [ ] 4000 psi
- [ ] Other

**Base Material Thickness:**”

**Drill Bit Diameter:**”

**Hole Depth:**”

**Drill Bit Type:**
- [ ] Carbide-Tip Drill Bit
- [ ] Diamond Core Bit
- [ ] Other

**Hole Cleaning:**
- [ ] Compressed Air
- [ ] Hand Pump
- [ ] Wire Brush
- [ ] Nylon Brush
- [ ] Other

**Hole Condition:**
- [ ] Dry
- [ ] Water Saturated

**Anchor Application:**
- [ ] Please check all that apply
- [ ] Tension
- [ ] Shear
- [ ] Overhead
- [ ] Other

**Anchor Spacing:**”

**Embedment (Bfl):”

**Installation Torque:**” (If required)

**Completion:**
Completed by: ____________________________
Date: ______/____/____
Company: ____________________________

ABC Hilti Safety Seminar May 8 2008 39
Installation of Post-Installed Anchoring Systems

Installation Accessories

Blowing out
- Compressed-air+
  Hilti HIT-DL
  air nozzle
  attachment

Brushing
- Round Brush
- Compressed-air
  90 psi
- Bristle Brush
- Hand Pump

Injecting
- Piston plugs
- Injection
  extension
- Hilti HIT-RE-M
  Nozzle

Inadequate borehole cleaning = poor load values
Adhesive Anchor Hole Preparation
Adhesive Product Installation Overhead w/o Piston
Adhesive Product Installation Overhead With Piston
RE 500 SD Installation
RE 500 SD Installation
Operating Principles – Power Actuated

Powder Actuated

Low Velocity (Hilti Tools)

Pneumatic

High Velocity
Power Actuated Fastening Safety Issues

- Wear protective eyewear
- Remove boosters from tool when not in use
- Do not attempt to extract a trapped nail when boosters are loaded in tool
- Do not attempt to extract booster strip that will not easily unload
- If Hilti tools are dropped, they will not drop fire
- Hilti PAT tools will not engage if applied at an angle to fastening surface
- Hilti PAT tools will not bump fire, and will not fire unless depressed with 11 pounds of pressure prior to trigger pull
Hilti offers more than just product - PAT

- Over 50 Field Engineers in U.S. (2 Las Vegas)
- Onsite power actuated training free of charge
- AIA and NCSEA accredited training for engineers
- State of the art testing facilities in both U.S. and Europe
- Over 10 ICC Evaluation Services reports to support all varieties of power actuated fastening applications
- Online Direct Fastening Design Center
**Hilti Engineering Support**

- 105+ Technical Field Support (4 Las Vegas)
  - Anchor design/application consulting
  - Jobsite installation/inspection support

- 4 TS Engineers and 6 Fire Protection Engineers
  - Available to answer general questions
  - 1-800-879-6000, ext 6337
  - HiltiTechEng@us.hilti.com

- Fastening Design Tools
  - Technical Manuals & Approval Reports
  - Easy-To-Use Reference Tables
  - Computer-based Design Software
  - Installer Training Program
  - Test Reports

- [WWW.US.HILTI.COM](http://WWW.US.HILTI.COM)
What did we cover?

- IBC 2006 Anchor Code ➢ The 1, 2, 6 rule !!!
- Cracked Concrete Life Safety Issues ➢ Adhesive Creep Issues
- Approved Anchors
QUESTIONS ???