



2008 CONSTRUCTION

LAS VEGAS, NEVADA MAY 7-9

Hilti Product Safety

Building with Hilti:
Limiting your Exposure

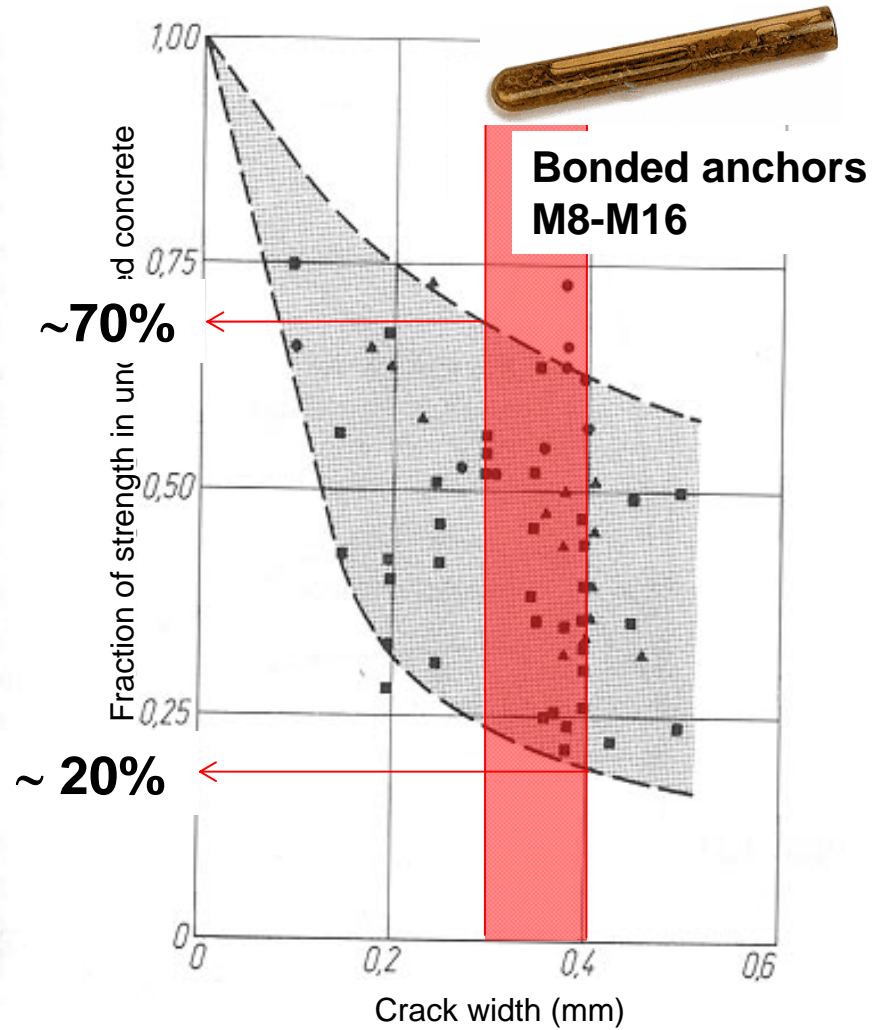
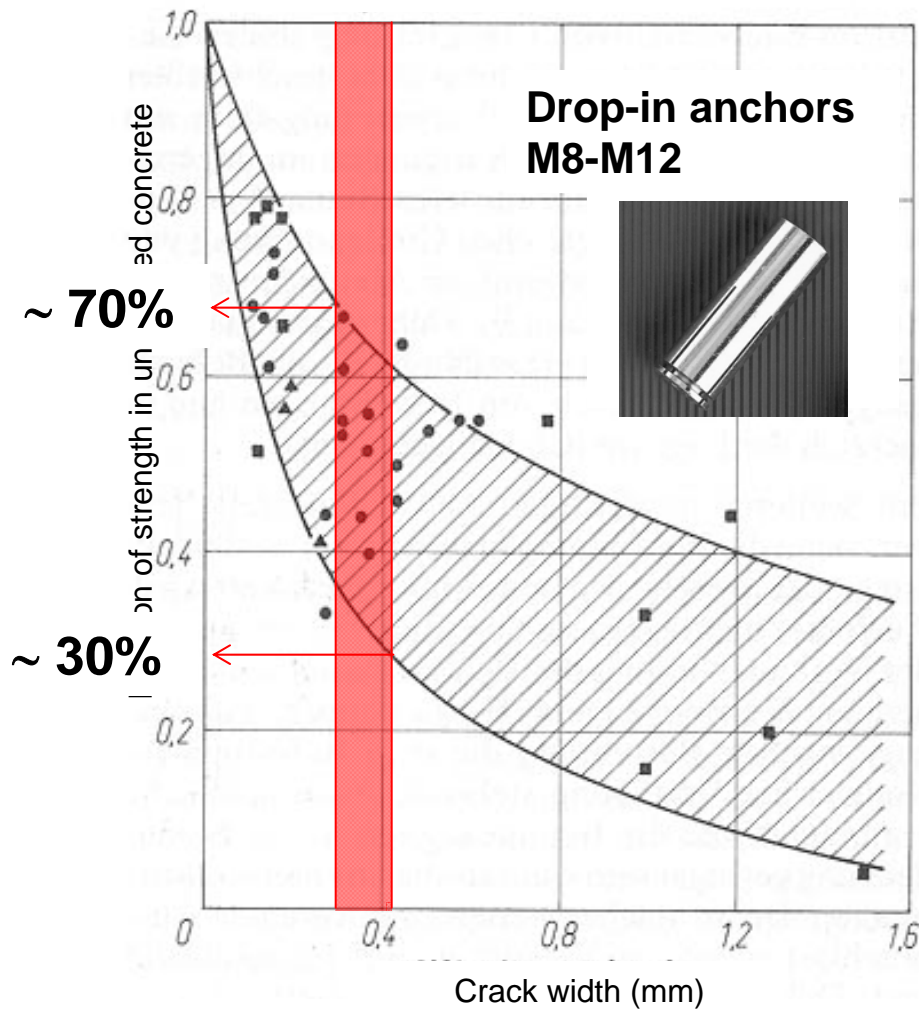
Lucas Floriani, P.E.
Southwest Engineering Manager
Hilti North America

History of Concrete Anchor Design

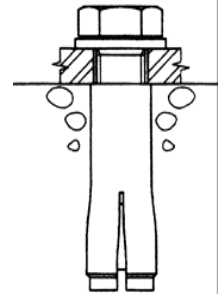
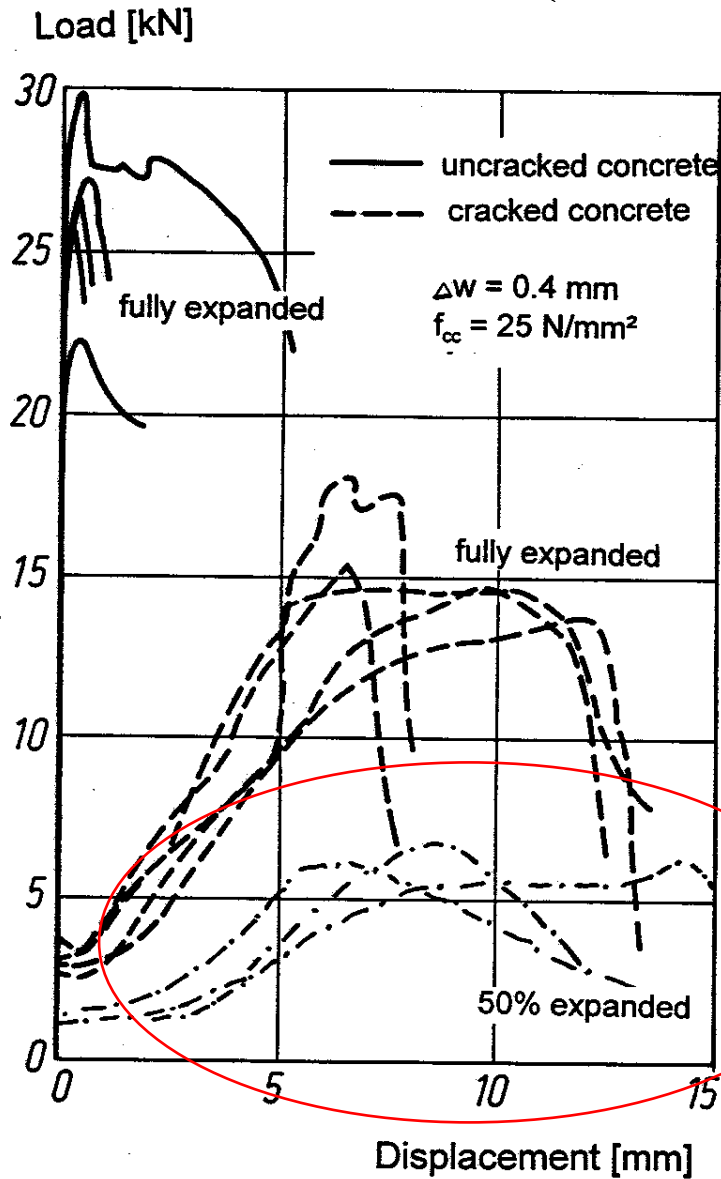
Until now, it has been implicitly assumed that concrete is uncracked (and unreinforced) for the purpose of anchor design. The state of the art, as reflected by various publications (Eligehausen, et al) that the state of cracking in concrete can have a measurable and predictable negative impact on the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



testing in flexural cracks



performance of anchors in cracked concrete



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

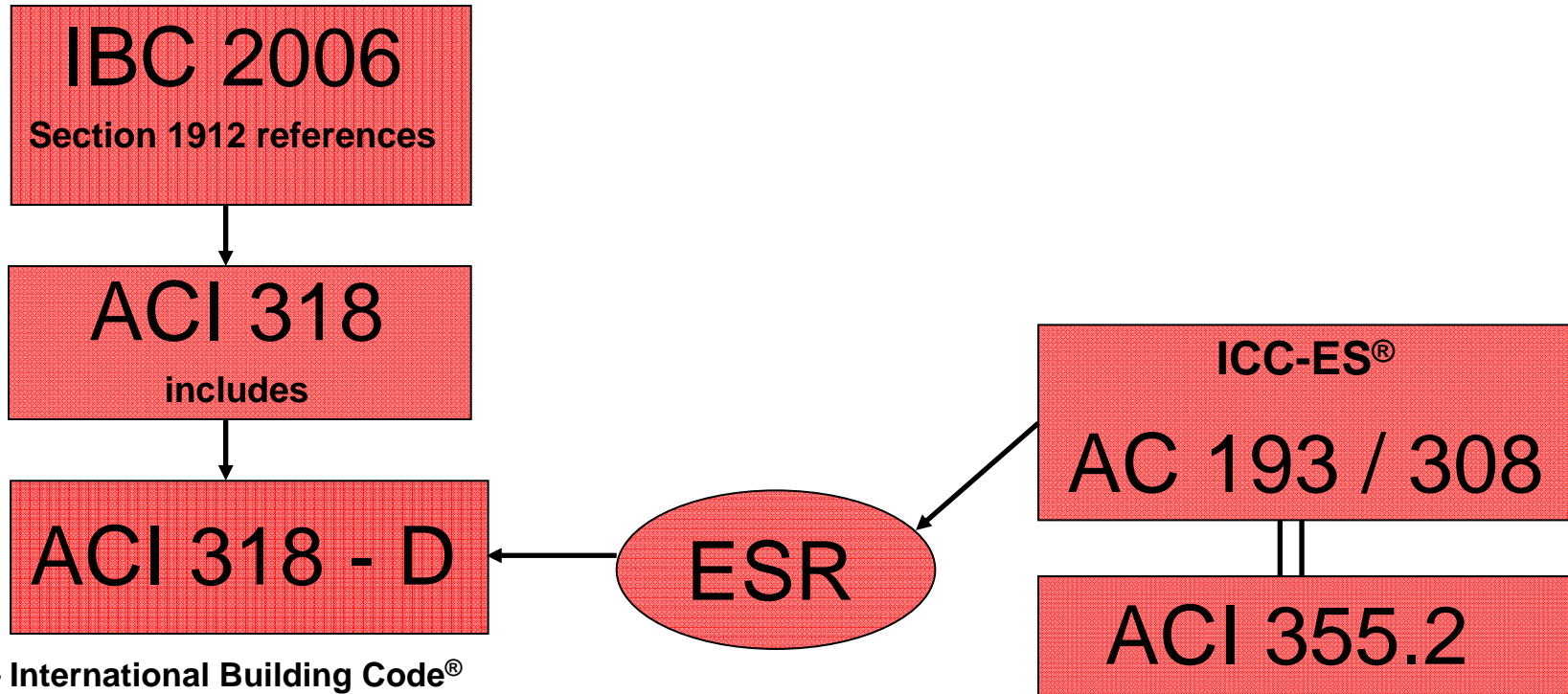
What are ICC-ES reports and why are they important?

- 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 – 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

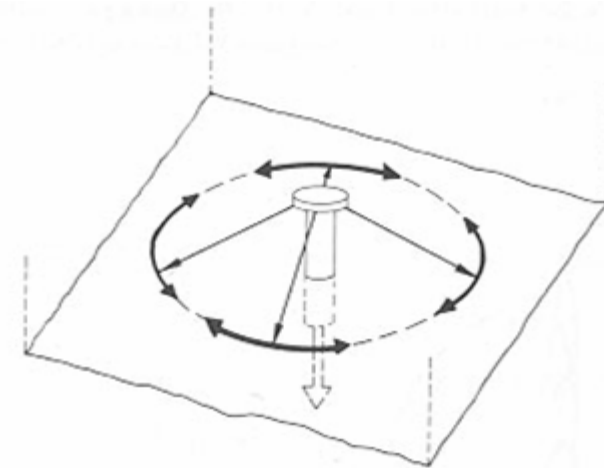
ESR – Evaluation Service Report => final approval document containing design data

Strength Design

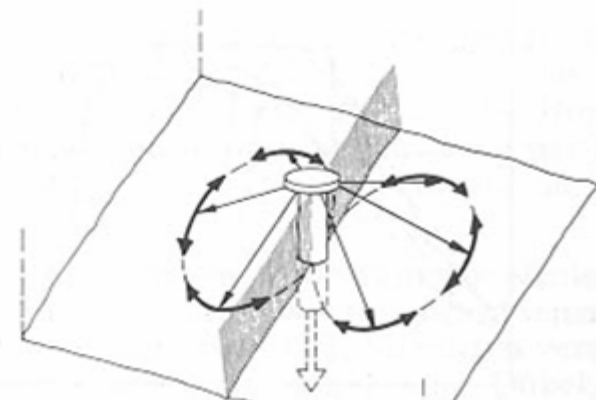
Influence of Cracked Concrete

cracks can cause a reduction in ultimate load

cracks can cause an increase in displacement at ultimate load

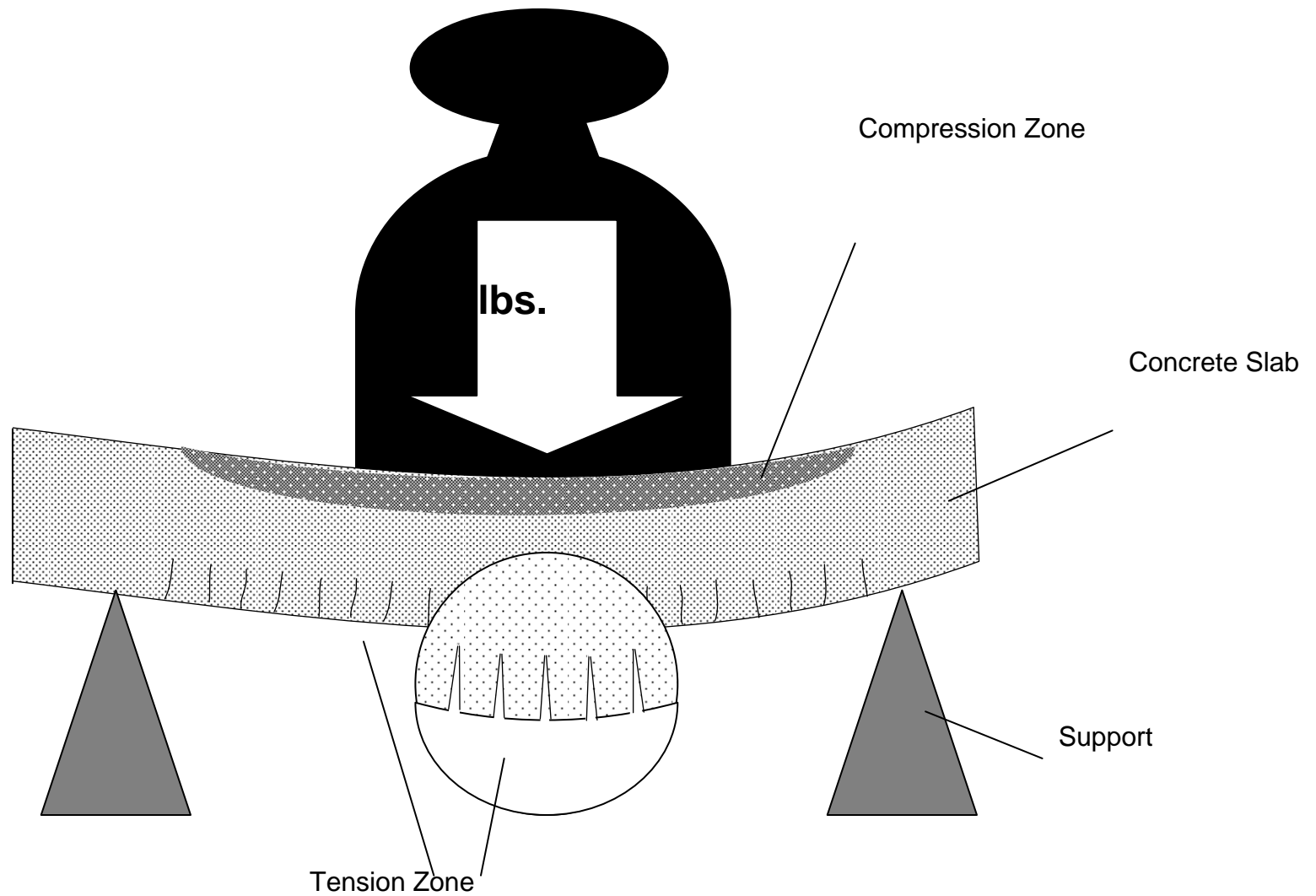


uncracked concrete



cracked concrete

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 ϕ)

Category 2: medium sensitivity to installation and medium reliability

Category 3: high sensitivity to installation and low reliability (lower ϕ)

Categories are only applicable to post-installed anchors !!

- ϕ 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.

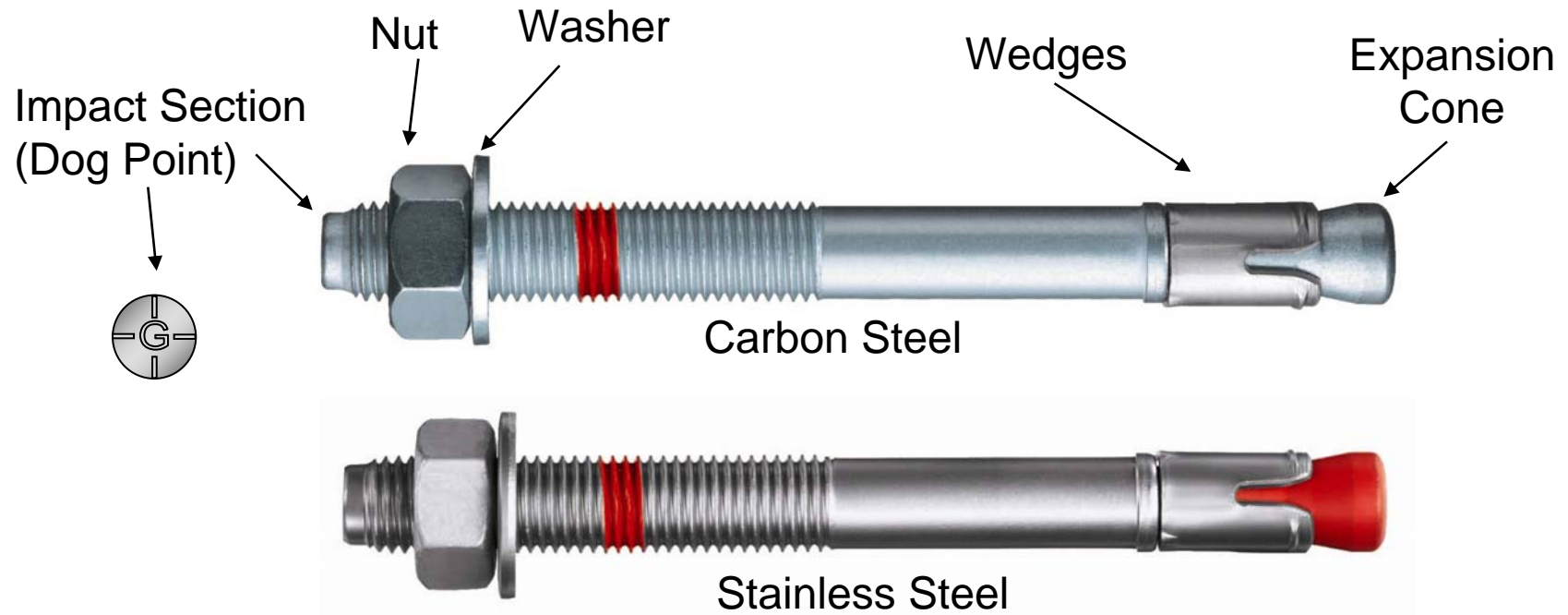
Anchors Suitable for IBC 2006

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

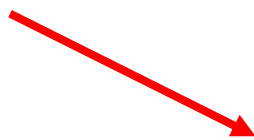


Kwik Bolt 3



KB-TZ Expansion Anchor

Fire –resistance-rated construction



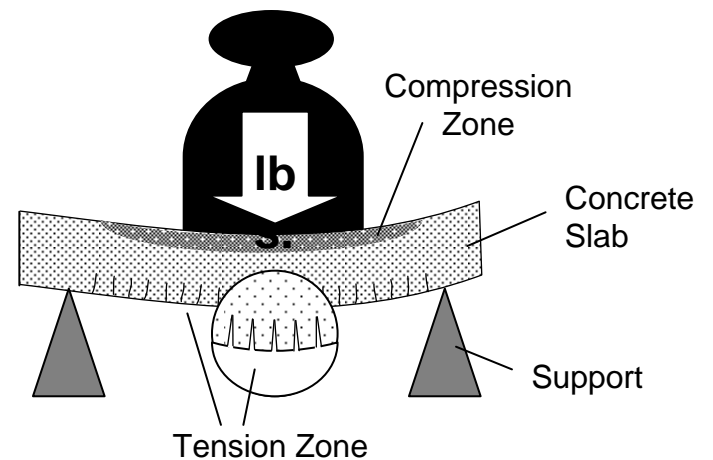
5.12 Where not otherwise prohibited in the code, KB-TZ anchors are permitted for use with fire-resistance-rated construction provided that at least one of the following conditions is fulfilled:

- 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

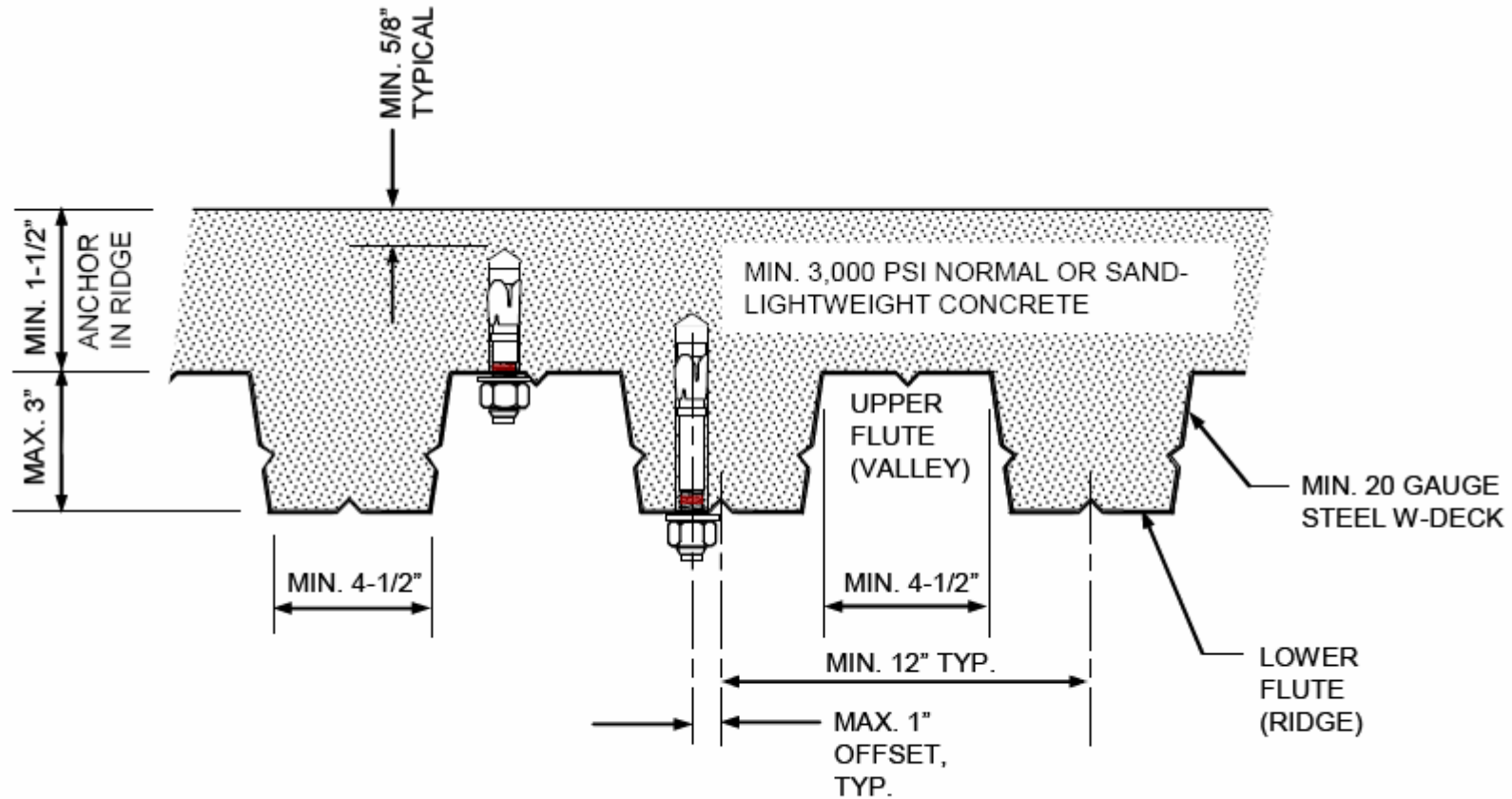


FIGURE 5—INSTALLATION IN THE SOFFIT OF CONCRETE OVER METAL DECK FLOOR AND ROOF ASSEMBLIES

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?

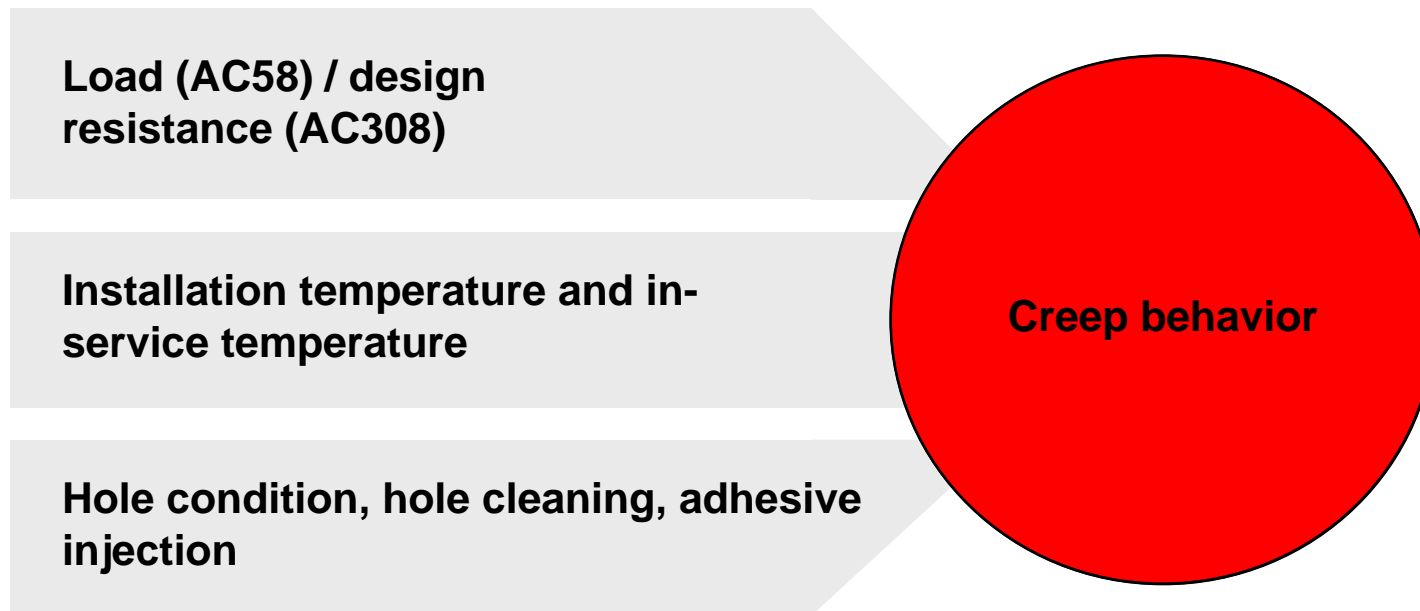
Creep is the slow and continuous deformation of a material under a sustained stress and is mainly influenced by:

- 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

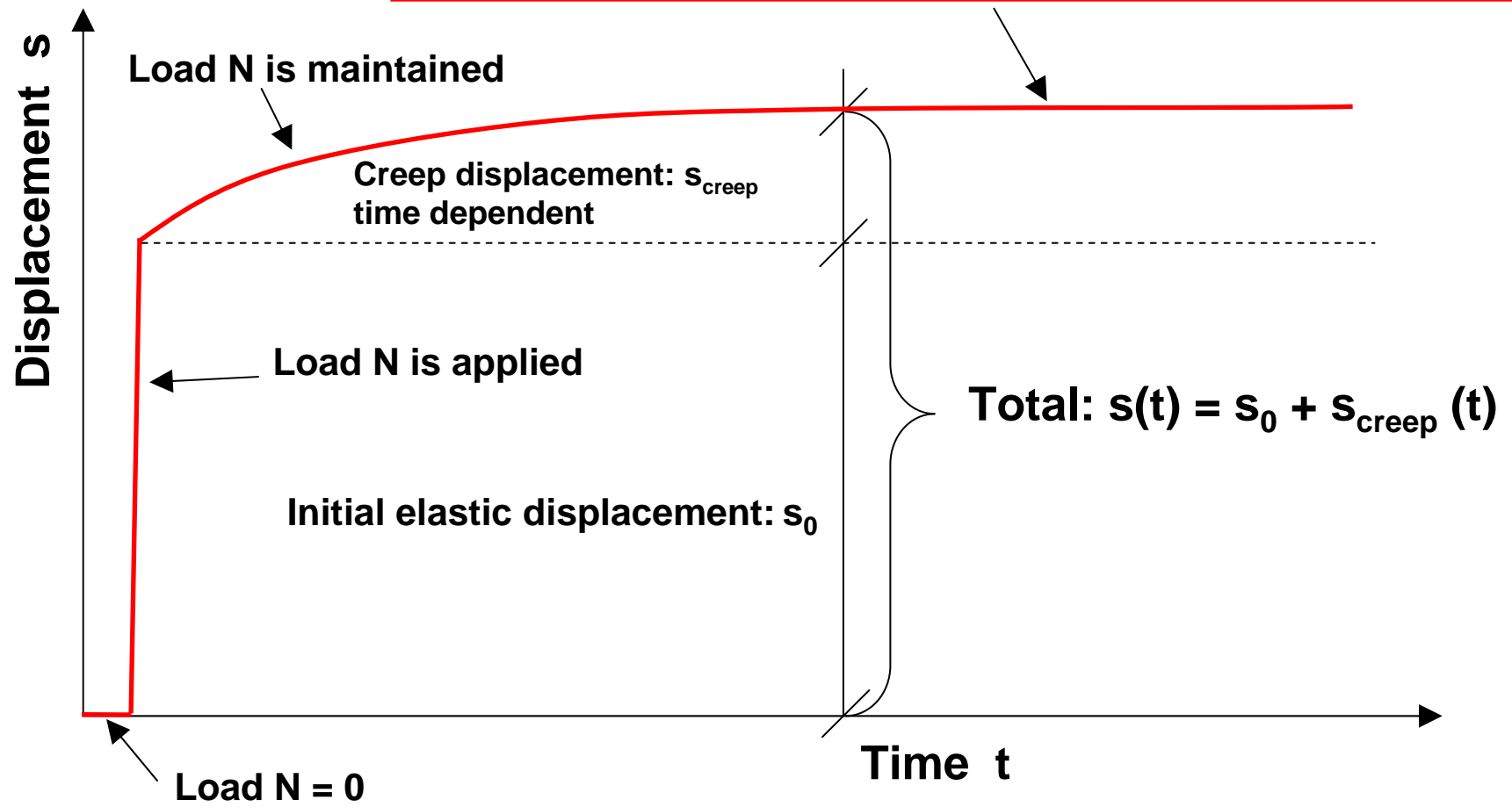


Properly installed adhesive anchors in properly designed applications are extremely reliable

What is creep?

Creep basics:

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



How was the creep behavior tested?



(Spring pots for sustained loading)

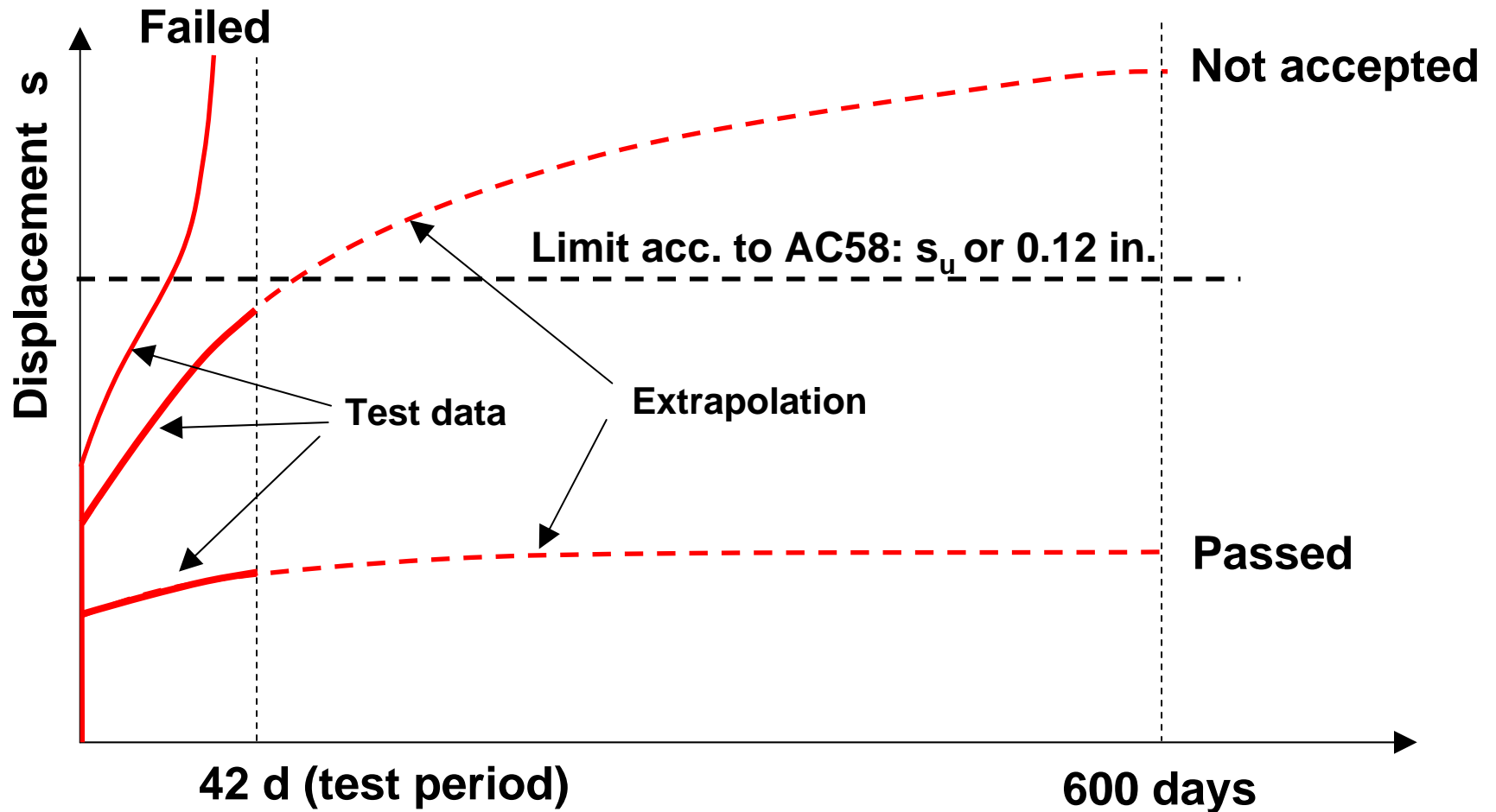
How was the creep behavior tested?

- 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



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:**

Evidence Submitted
ESR → Section 6
ER → Section 3

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, $c = c_{min}$ (AC58 Test Series 5); axial tension testing of a group of two anchors, establishing minimum spacing distance, $s = s_{min}$ (AC58 Test Series 9); shear testing of single anchors, establishing critical edge distance, $c = c_{cr}$ (AC58 Test Series 13); shear testing of single anchors, establishing minimum edge distance, $c = c_{min}$ (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)

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TABLE 8—HILTI, INC., RECOMMENDED CURE TIMES FOR HIT HY 150 MAX ADHESIVE

MINIMUM BASE-MATERIAL TEMPERATURE		APPROXIMATE GEL TIME ¹	APPROXIMATE CURE TIME ²
°F	°C		
54	-10	100 min	12 hours
25	-5	40 min	4 hours
32	0	20 min	2 hours
50	10	8 min	1 hour
68	20	6 min	30 min
85	30	5 min	25 min
104	40	2 min	20 min

For SI: °C = (°F - 32) ÷ 1.8.

¹Section 4.2.1.1 of this report describes significance of gel time and gel time in anchor installations.

TABLE 9—ALLOWABLE TENSION AND SHEAR VALUES IN NORMAL-WEIGHT CONCRETE FOR THREADED RODS INSTALLED WITH HILTI HIT HY 150 MAX ADHESIVE (pounds)^{1,2,3,4}

ANCHOR DIAMETER (inches)	EMBEDMENT DEPTH (inches)	TENSION						SHEAR			
		BASED ON BOND OR CONCRETE		BASED ON STEEL STRENGTH		BASED ON BOND OR CONCRETE		BASED ON STEEL STRENGTH			
		F _t = 2,000 psi	F _t = 4,000 psi	ISO 888 Class 5.8	ASTM A 193 B7	AISI 304 SS	F _t = 2,000 psi	F _t = 4,000 psi	ISO 888 Class 5.8	ASTM A 193 B7	AISI 304 SS
1/4	1 1/2	725	1450				1,255	1,770			
	2 1/2	2110	3255	2,040	4,555	3,045	2,355	3,345	1,380	2,345	1,875
	4 1/2	2150	3255				3,640	5,145			
3/8	2 1/2	1385	2090				2,080	2,815			
	4 1/2	4300	4900	4,700	8,100	6,480	4,325	5,350	2,420	4,170	3,335
	6	4705	4900				6,475	9,155			
1/2	2 1/2	1945	2755				3,075	4,245			
	4 1/2	5965	8410	7,340	12,855	10,125	6,570	9,295	3,780	6,520	5,215
	7 1/2	7230	8410				10,120	14,310			
5/8	3 1/2	2625	4295				4,580	6,475			
	6 1/2	4460	6935	10,570	18,225	12,390	8,490	13,260	5,445	9,390	8,385
	9	11175	11175				14,575	20,500			
3/4	4	3375	5300				5,750	8,130			
	7 1/2	9910	14815	14,385	24,805	16,885	12,880	18,215	7,410	12,780	8,690
	10 1/2	14385	15345				18,830	26,040			
1	4 1/2	5210	8510				7,490	12,590			
	9	11955	17475	18,710	32,410	22,030	18,825	27,790	9,880	16,890	11,350
	12	17540	19655				25,900	36,620			
1 1/4	5 1/2	6985	9935				8,885	13,860			
	11 1/2	16345	30065	29,260	50,820	34,425	28,285	37,875	15,125	26,660	17,735
	15	29275	30065				49,470	57,225			

For SI: 1 inch = 25.4 mm, 1 lb = 0.454 kg, 1 psi = 6.895 kPa.

¹Allowable load must be the lesser of tabulated bond and steel values. Load reduction factors given in Table 7 for reduced edge distance (e) and spacing (s) must be applied to values in the bond or concrete capacity column. Linear interpolation may be used for intermediate spacing, edge distances, embedments and concrete strengths. Load reduction factors are cumulative for anchors with multiple anchor spacings or base-material edge distances.

²The tabulated values must be for anchors installed in concrete complying with Section 3.2.5 and having the designated compressive strength (f'_c) or higher at the time of installation.

³Allowable loads based on bond strength have been calculated using a safety factor of 4.0 applied to the mean ultimate strength.


⁴Concrete thickness must be equal to or greater than 1.5 times the anchor embedment depth.

Use allowable tension and shear values for threaded rods to resist short-term loads, such as wind or seismic, must be calculated in accordance with Sections 5.3, 5.5 or 5.6, and 5.7, and Table 6, of this report.

AC308 versus AC58

What changes with AC308 - what are the reasons?

- **AC58 evolved into AC308. The main developments:**

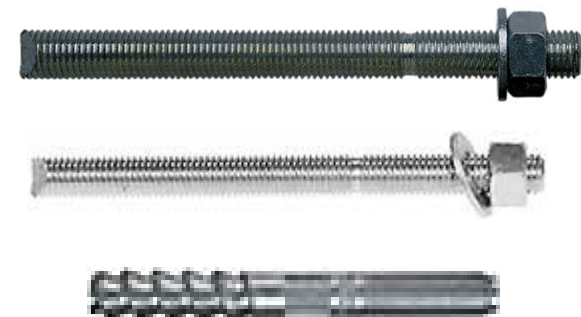
AC58	 AC308	Benefit
Extrapolation to 600 days only	Extrapolation to 10 years (elevated temp.) 50 years (normal ambient temp)	better coverage of relevant time periods
Test temperature fixed (110F)	Test temperature determined through published service temperature range	Wider temperature ranges possible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

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 Anchoing 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)

Project Name: _____
 Project Location: _____
 Weather: _____ Air Temperature: _____ (°F / °C)

CODES <input type="checkbox"/> UBC 1997 <input type="checkbox"/> IBC 2000 <input type="checkbox"/> IBC 2003 <input type="checkbox"/> IBC 2006	Seismic Zone/ Seismic Design Category
---	--

Product Name/Manufacturer: _____
 Lot No.: _____
 ICC-ES Report No.: _____
 Adhesive expiration Date: ___/___/___ Specified Dispenser Specified Mixer
 Discard Initial Adhesive: _____ (# trigger pulls)
 Adhesive Temperature: _____ (°F / °C)
 Gel Time: _____ Cure Time: _____
(per manufacturers installation instructions)

Type: All-Thread Internally Threaded Torque-Controlled Rebar Other _____
 Material: Standard Stainless Steel High Strength
 Steel Grade/Coating: _____
 Length: _____ (in/mm)
 Rod Diameter: 3/8" 1/2" 5/8" 3/4" 7/8" 1" 1 1/4"
 Rebar: #3 #4 #5 #6 #7 #8 #9 #10
 #11 Other _____

Base Material Type: NW Concrete LW Concrete Brick CMU Other _____
 Base Material Strength: 2000psi 3000psi 4000psi Other _____
 Base Material Thickness: _____ (in/mm)
 Base Material Temperature: _____ (°F / °C)

Drill Bit Diameter: _____ (in/mm) Hole Depth: _____ (in/mm)
(core bit diameter, if approved)
 Drill Bit Type: Carbide-Tip Drill Bit Diamond Core Bit Other _____
(ANSI B212.15-1994) (if appropriate and allowed)
 Hole Condition: Dry Water Saturated Water Filled Under Water
 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: Twisting motion Annular gap filled with adhesive Air Void Free Injection
 Anchor Spacing: _____ (in/mm) Edge Distance: _____ (in/mm)
 Embedment (h_{ef}): _____ (in/mm) Installation Torque (if required): _____ (ft.-lb./Nm)

Completed by: _____ (Signature) Date: ___/___/___
 _____ (Print) Company: _____
 _____ (Title)

Version 09.2007

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)

Project Name: _____
 Project Location: _____
 Weather: _____ Air Temperature: _____ (°F / °C)

CODES <input type="checkbox"/> UBC 1997 <input type="checkbox"/> IBC 2000 <input type="checkbox"/> IBC 2003 <input type="checkbox"/> IBC 2006	Seismic Zone/ Seismic Design Category
---	--

Product Name/Manufacturer: _____
 Lot No.: _____
 ICC-ES Report No.: _____
 Head Configuration: Hex Nut/Threaded Hex Bolt Head Torque Cap Countersunk
 Diameter/Dimension: 1/4" 3/8" 1/2" 5/8" 3/4" 1"
 M8 M10 M12 M16 M20 M24
 Overall Anchor Length: _____ (in/mm)
 Steel Grade/Coating: _____

Base Material Type: NW Concrete LW Concrete LWC over Steel Deck CMU Block
 Other _____
 Base Material Strength: 2000psi 3000psi 4000psi Other _____
 Base Material Thickness: _____ (in/mm)

Drill Bit Diameter: _____ (in/mm)
 Hole Depth: _____ (in/mm)
 Drill Bit Type: Carbide-Tip Drill Bit Diamond Core Bit Other _____
(ANSI B212.15-1994) (if appropriate and allowed)
 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: _____ (in/mm)
 Edge Distance: _____ (in/mm)
 Embedment (h_{ef}): _____ (in/mm)
 Installation Torque: _____ (ft.-lb./Nm)

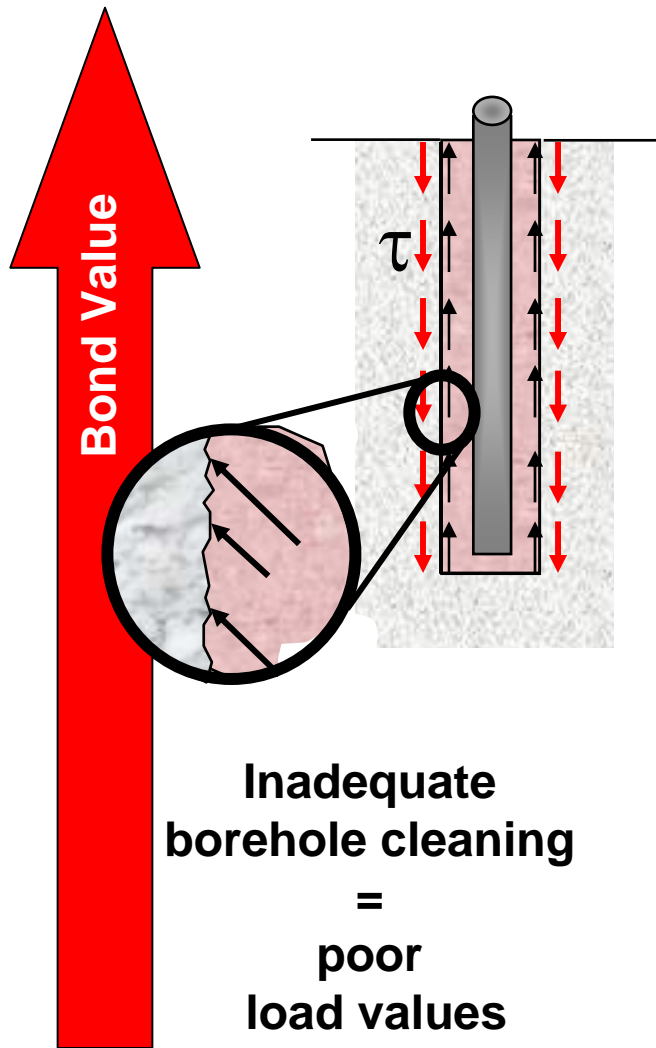
h_{ef} = Effective embedment depth, measured from the concrete surface to the deepest point at which the anchor tension load is transferred to the concrete, measured prior to applying torque to the anchor.

Completed by: _____ (Signature) Date: ___/___/___
 _____ (Print) Company: _____
 _____ (Title)

Version 09.2007

Installation of Post-Installed Anchoring Systems

Installation Accessories



Blowing out



**Compressed-air+
Hilti HIT-DL
air nozzle
attachment**



**Compressed-air
90 psi**



Hand Pump

Brushing

Round Brush



Bristle Brush

Injecting

Piston plugs



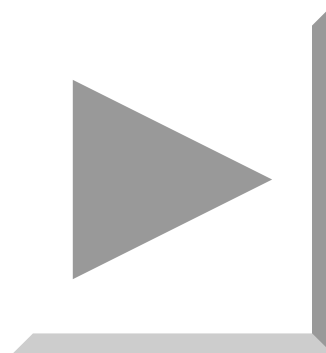
**Injection
extension**



**Hilti HIT-RE-M
Nozzle**



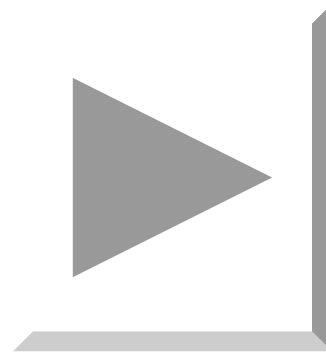
Adhesive Anchor Hole Preparation



Adhesive Product Installation Overhead w/o Piston



Adhesive Product Installation Overhead With Piston



RE 500 SD Installation



RE 500 SD Installation

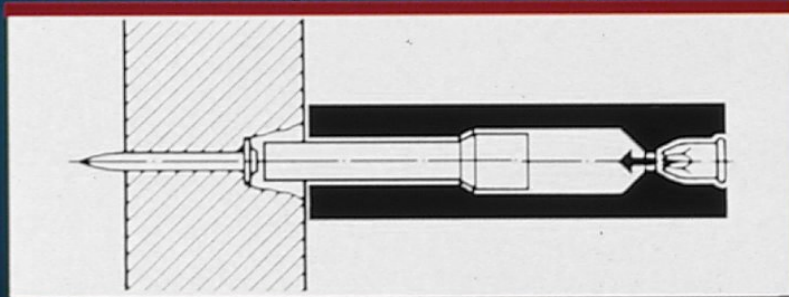


Operating Principles – Power Actuated

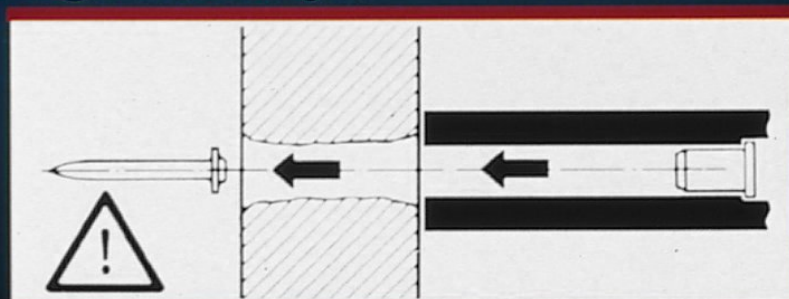


Powder Actuated

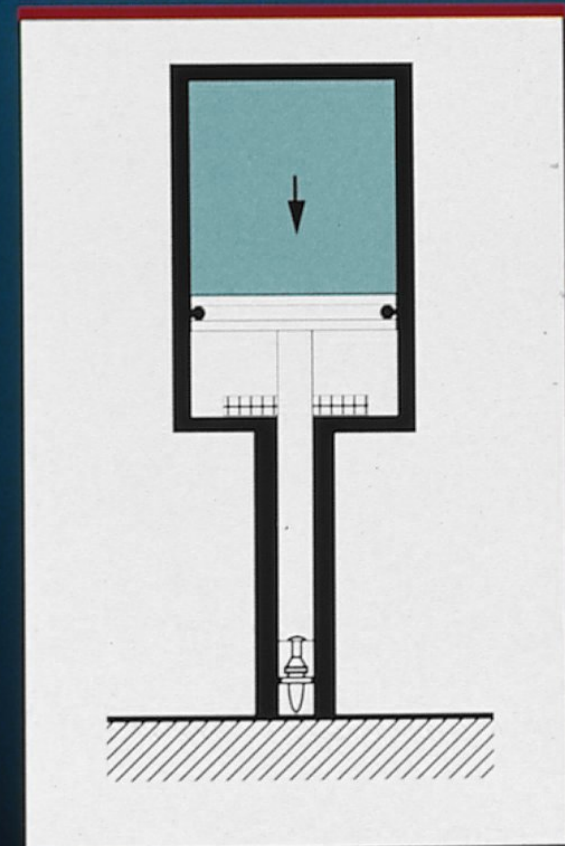
Low Velocity (Hilti Tools)



High Velocity



Pneumatic



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**





What did we cover ?

- > *IBC 2006 Anchor Code* ➤ *The 1, 2, 6 rule !!!*
- > *Cracked Concrete Life Safety Issues* ➤ *Adhesive Creep Issues*
- > *Approved Anchors* ➤

QUESTIONS ???