NORTH AMERICAN PRODUCT TECHNICAL GUIDE

Cast-In Anchor Channel Fastening Technical Guide, Edition 1

A guide to design, specification, and installation
We are a company inspired to make a difference in our customers’ businesses. We want to help make your job faster, safer, and more productive. That’s why Hilti North America has over 3,600 highly trained team members in sales, engineering, marketing, and other support roles whom all work to help construction professionals solve their biggest challenges.

Hilti offers products, systems, and solutions for every application on the jobsite. Whether our customers work in construction, civil engineering, energy, mechanical, electrical, steel and metal, or interior finishing, Hilti is here to help them build a better future.

With over 60 years of experience in fastening systems, Hilti is your reliable partner for secure anchor solutions. We have now further extended our range of products to include a new generation of cast-in anchor systems for reliable load transfer to concrete structures — the Hilti HAC Anchor Channel.

Hilti’s extensive research and testing on anchor channels allowed the publication of the first ICC approval for anchor channels for seismic design categories C, D, E, and F. Hilti Anchor Channels are a value engineered solution that in addition of preserving the high product performance, they have improved the function and features of the traditional anchor channel system, creating differentiating and innovative solutions that bring added value to the cast-in industry. Every Hilti product and system is backed with research, training, software, service, and support. It’s the right way. And that’s the Hilti way.

Our Purpose
We passionately create enthusiastic customers and build a better future!

Enthusiastic Customers
We create success for our customers by identifying their needs and providing innovative and value-adding solutions.

Build a better future
We embrace our responsibility towards society and the environment.

Our Quality System
Hilti is one of a select group of North American companies to receive the ISO 9001 and ISO 14001 Certifications. This recognition of our commitment to quality ensures our customers that Hilti has the systems and procedures in place to maintain our position as the world market leader, and to continually evaluate and improve our performance.

That’s total customer satisfaction.
For Technical Support, contact Hilti, Inc. (US) at 1-877-749-6337 or Hilti (Canada) Corporation at 1-800-363-4458.

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HILTI ANCHOR CHANNEL — ONSITE PHOTOS

Curtain wall installation
HAC CRFsd U in composite slab
Box-out solution
Curtain wall bracket

Anchor channel in underside of T-beam
Underide view of face of slab corner configuration
Face of slab corner condition
Installation of curtain wall panels

Anchor channel fixed to form-work in face of slab
Anchor channel in top of slab corner
HAC in top of slab with box-out
HAC in face of slab spandrel beam

HAC in top of slab with installation aid
Corner configuration in top of slab
HAC in face of slab condition in PT slab
Anchor channel fixed to formwork in face of slab
1. CAST-IN ANCHOR CHANNEL SYSTEMS

A proven anchoring technology with approved design standards.

Anchor channel systems are a cost-effective cast-in anchoring to concrete technology. This technology provides a solution for job site tolerances and on-site adjustability when connecting structural and non-structural elements.

The system consists of a group of anchors connected to a channel profile (anchor channel) and a proprietary matching head channel bolt (t-bolt). The anchor channel is installed prior to casting of the concrete. The channel profile comes with a filler foam to prevent the concrete from getting inside the profile. To install the fixture, the filler foam is removed. This leaves the channel cavity exposed and the t-bolts can be installed along the channel profile. The fixture is secured once the washer and nuts are against the fixture and the required installation torque is applied.

Compared to traditional cast-in technologies, anchor channel systems provide added savings by not requiring skilled labor to connect the fixture since welding is not required. Moreover, anchor channels reduce the installation time per connection, improve the productivity of the installer, increase the structural reliability of the connection, and may improve the safety of the installer.

(For additional anchor channel applications, see chapter 3)
Anchor channels are installed before the concrete is poured. Proper planning between different trades is required for a successful project.

Proactivity goes a long way! By planning ahead, onsite complexities can be minimized thus allowing to take control of the project while it will leave more time to work on the unexpected.

Traditionally, anchor channel systems have been designed using manufacturer’s data and allowable stress design. Anchor channel systems are now easier to show compliance with the International Building Code (IBC) for design with strength design provisions. Providing model Code Compliant designs ensures the use of the product will be accepted by local authorities, jurisdictions, engineer of records, inspectors, etc.

The International Code Council Evaluation Service (ICC-ES) has developed the Acceptance Criteria for Anchor Channels in Concrete Elements (AC232) to show compliance of the anchor channel systems, and to assist in designing these systems using the provisions given in AC232 and in the anchoring-to-concrete provisions provided in the American Concrete Institute (ACI) publication Building Code Requirements for Structural Concrete (ACI 318).

Adjustability without drilling or welding

No certified welder needed
Faster installation
No damage of slab’s reinforcement or concrete by multiple drilling attempts
No toxic fumes (HDG)
Anchors with reinforcing bars allowed for superior performance
No electricity needed on site
No scanning needed
No welding sparks
No dust control requirements
Simpler inspections

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5. Base material
6. Loading
7. Anchor Channel Design Code
8. Reinforcing Bar Anchorage
9. Special Anchor Channel Design
10. Design Software
11. Best Practices
12. Instructions for Use
13. Field Fixes
14. Design Example
1.1 HILTI CAST-IN ANCHOR CHANNEL

**BENEFITS AND FEATURES**

**WELL SEALED SYSTEM**
- Well sealed system keeps concrete slurry out of the channel cavity
- Prevents t-bolts from being installed at the outer 1” of the channel profile

**PRODUCTIVITY GAINS ON THE JOB SITE**
- Continuous foam reduces the removal time
- Well-sealed system that keeps concrete out of the channel cavity
- Tear out band/strip integrated that eases the foam removal process
- Environmental friendly materials (PE/PP)

**RELIABILITY: MECHANICAL CONNECTION**
- Superior performance/quality control
- Less data/strength fluctuation
- Fully automated assembly

**PROFIS ANCHOR CHANNEL**
- Simplifies design
- Design based on American Standards
- Optimized and reliable anchor channel design
- Covers all typical applications in a building (i.e. Lightweight concrete, thin members, corners, corner zones, seismic applications)
- No extra cost
- ICC ESR-3820

**VALUE ENGINEERED PORTFOLIO**
- Synergized anchor channel design
- Optimum anchor channel geometry
- Optimum component size

**VERSATILE PORTFOLIO**
- Wider range of anchor channel sizes for optimum anchor selection

**OPTIMUM CHANNEL PROFILE DESIGN**
- Optimum amount of steel allocated to each profile size
- Simplifies logistical management inventory on site: 1 bolt head size that fits all anchor channels
- Flexibility via economies of scale: one bolt size for all applications
- Reduced channel width allows anchor channels to be installed up to a 2” edge distance
TAKE YOUR ANCHOR CHANNELS TO A NEW EDGE. ANCHOR CHANNEL SYSTEM FOR SUPERIOR CONCRETE EDGE PERFORMANCE

HAC EDGE (Patent pending)
Provides up to 5.6X higher concrete breakout strength in shear than traditional anchor channels

HAC S EDGE (Patent pending)

Corner Solutions

THE SERRATED HAC-T — THE BEST ANCHOR CHANNEL SYSTEM FOR SEISMIC AND 3D LOADS

HAC-T

PERFORMANCE
- High slip resistances at low installation torque.
- Rebar channels available on serrated.

RELIABILITY
- Optimal t-bolt/channel lip interlocking for consistent performance.
- Redundant system due to multiple teeth engagement between t-bolt and channel lip’s serrations.

FEASIBILITY
- Innovative manufacturing process that brings serrations at minimal extra cost.
- Price of HAC-T is similar to it’s equivalent HAC size with HBC-C-N.

SAFETY
- Higher installation safety via lower installation torque.
- Lighter torque wrench, less muscle fatigue.

SIMPLICITY
- Higher slip resistances without continuous inspection requirements.
- One channel bolt size suitable for both channel sizes HAC-T50 and HAC-T70.
1.2 HAC OVERVIEW

1.2.1 HILTI ANCHOR CHANNEL PORTFOLIO AT A GLANCE

Hilti’s simplified and value engineered cast-in anchor channel system portfolio, in conjunction with PROFIS Anchor Channel, helps designers to easily provide model code compliant and cost-effective anchor channel system solutions.

Hilti Anchor Channel (HAC) design models are based on state-of-the-art compliance with International Council Code Evaluation Service Report 3520 (ICC ESR-3520). Design models of anchor channels not explicitly covered by ICC Acceptance Criteria 232 (AC232) are based on applicable provisions of U.S. Concrete Standard ACI 318 and AC232, and ESR-3520, as applicable. Moreover, all Hilti Anchor Channel have been tested following applicable AC232 testing protocols.

The Hilti Anchor Channel (HAC) portfolio consists of two different V-shape channel profile types; smooth and serrated lips. To feasibly cope with the typical and non-typical conditions encountered in a project, different channel profiles sizes (HAC-40, 50, 60, and 70), channel lengths, and a versatile configuration of anchors have been integrated into the standard HAC portfolio.

The standard HAC portfolio consists of predetermined anchor channel configurations which allow for shorter lead time. The standard portfolio consists of fixed channel lengths, number of anchors per channel, anchor type (rounded headed anchors, reinforcing bar anchors, and/or EDGE plate), anchor diameter, and anchor length.

HAC’s standard portfolio covers most of the extreme project conditions. For a broader application coverage range, custom solutions are offered upon request.

The Hilti Channel Bolts (HBC), commonly known as t-bolts are part of the HAC system. HBC have proprietary bolt head geometry compatible with HAC profiles. HBC are offered in different types, diameters, steel grades, finishing, and lengths. Although serrated t-bolts cannot be used with smooth lip channel profile or vice-versa, t-bolts for each profile type (smooth or serrated) can be used in all corresponding channel profile sizes.

The innovative manufacturing channel technology allows different channel profiles to have a relative constant channel width, permitting one t-bolt head size to be used in all different channel sizes, streamlining product portfolio and simplifying installation on the job site. This means more cost-effective t-bolts via economy of scale.

Hilti Anchor Channels are a value engineered solution that in addition of preserving the high product performance, they have improved the function and features of the traditional anchor channel system, creating differentiated and innovative solutions that bring added value to the cast-in industry.

1.2.2 HILTI ANCHOR CHANNEL PROFILES

Numerical simulations allowed Hilti to design a range of channel profiles with different anchor configurations, resulting in a synergized steel to concrete performance.

Hilti Anchor Channels with smooth lips (HAC) and serrated lips (HAC-T) are covered by ICC ESR-3520. The geometry of HAC versus its matching HAC-T profile (i.e. HAC-50 vs HAC-T50) is identical, with the main difference of the lip type. Generally, HAC and its equivalent HAC-T offer similar performance. The main advantage of HAC-T is that it offers higher slip resistance at a lower installation torque.

HAC profiles (40, 50, 60, and 70) and HAC-T profiles (50 and 70) are the backbones of the Hilti’s anchor channel portfolio. Such profiles are utilized in all different anchor channel types. It is only the type of anchor and connection that changes or additional accessories are incorporated. For instance, HAC-50 with rounded head anchors has the same channel profile as HAC-50 with reinforcing bar anchors (HAC-50 CRFs 0, U).

HAC and its equivalent HAC-T offer similar performance. The identical, with the main difference of the lip type. Generally, HAC and its equivalent HAC-T offer similar performance. The main advantage of HAC-T is that it offers higher slip resistance at a lower installation torque.
HAC and HAC-T

Hilti Anchor Channels with rounded head anchors are characterized by being the most cost-effective anchor channel type. Additionally, due to its lighter weight, they are generally easier to install than anchor channels with reinforcing bars. These are excellent anchor channel systems with optimized steel components. The HAC portfolio allows for a gradual increase in performance. Moreover, they can be installed as close as 2” away from an edge. This anchor channel type is covered by ICC ESR-3520.

HAC and HAC-T have optimized components (i.e. channel profile thickness) that allow the steel performance of the product (i.e. channel lip strength) to be similar to the concrete performance (i.e. concrete breakout strength in tension) when used in typical concrete compressive strength (4000 psi – 5000 psi).

The design of this type of anchor channel is generally limited by the tensile strength and fracture energy of the concrete. Therefore, concrete breakout strength in shear (top of slab applications), concrete breakout strength in tension (face of slab applications), or a combination of both are generally the governing failure modes. Technically speaking, the substrate’s strength tends to be the limiting factor.

The substrate’s strength may limit the use of these types of anchor channels in applications with high loads in low to medium concrete compressive strengths, lightweight concrete, thin substrate, close to an edge, and/or close to a corner.

The use of HAC CRFoS U is ideal for applications where the applied tensile force exceeds the concrete breakout strength in tension. Although concrete pry-out is precluded when reinforcing bars are used instead of rounded head anchors, the concrete breakout strength in shear is not impacted by the reinforcing bar anchors.

The design model of HAC CRFoS U is based on AC232 principles. All failure modes are based on AC232 except the pull-out strength of the reinforcing bar, which is calculated in accordance with ACI 318. Steel strengths not covered in ESR-3520 are based on ACI 318 and applicable testing protocols of AC232.

HAC CRFoS U comes with one diameter reinforcing bars offset/bend. This allows to position two CRFoS U in a corner. One channel is rotated 180° to avoid clashing of the reinforcing bar. Moreover, the offset of the reinforcing bar allows for extra rebar cover in composite slab applications where the reinforcing bars may extend into the metal deck zone. The use of HAC CRFoS U is not limited to corner applications.

HAC CRFoS U is commonly utilized in applications with high tension loads, thin slabs, lightweight concrete, low concrete compressive strength, and corners.
HAC EDGE Lite, HAC EDGE, HAC-T EDGE Lite, and HAC-T EDGE

Hilti Anchor Channel with a new rebar edge confinement plate (HAC EDGE) is a solution that offers superior concrete edge breakout performance in shear. HAC EDGE changes the traditional concept of anchor channels with welded reinforcing bars. Instead of relying on structural welds to transfer shear forces from the channel profile to the reinforcing bars, HAC EDGE takes advantage of the compressive strength of the concrete as a way to transfer the forces to the reinforcement attached to the edge plate. The rebar edge confinement plate (EDGE Plate) is not structurally connected to the anchor channel. HAC EDGE optimizes the shear load transfer from the channel profile to the reinforcing bars and overcomes the challenges with traditional anchor channels with welded reinforcing bars.

HAC EDGE is a new anchoring system that brings value innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as innovation.

HAC EDGE Lite is the latest addition to the HAC portfolio. It offers a gradual increase in performance and cost between the HAC and HAC EDGE. HAC EDGE Lite is offered in HAC-40, HAC-50, and HAC-T50.

The design model of HAC EDGE is based on ESR-3520, ACI 318, and principles of AC232 and ACI 318. The anchor channel itself is covered by ICC ESR-3520. The verification of the concrete edge due to perpendicular shear loads is based on a Hilti method; see section 9.6.1 for additional design information.

The use of HAC EDGE and HAC EDGE Lite is ideal for applications with high shear loads, thin slabs, small edge distances, lightweight concrete, low concrete compressive strength, and corners.

Shear Performance Index

Comparison based on the lowest strength considering the anchor, anchor-channel connection, and channel lip.

Comparison based on 4" thick slab, edge distance of 4", 4000 psi NWC, 11.8" long HAC with no influence of a corner.

State-of-art design model based on ICC ESR-3520 and principles of AC232 and ACI 318. 19 out of 20 possible failure modes are calculated in accordance with ESR-3520.
1.4 HILTI CHANNEL BOLTS: HBC-C AND HBC-T

Hilti Channel Bolts (HBC and HBC-T) are part of the cast-in anchor channel system. HBC come in a variety of diameters, grades, and corrosion protection. The T-bolt head shape works with all four different channel HAC sizes (HAC-40, HAC-50, HAC-60, and HAC-70) simplifying logistical management on the jobsite. Moreover, because the size of the head of the bolt does not get bigger as the anchor channel profile gets bigger, optimizing the amount of steel used per bolt, bringing economy of scale.

**HBC-C**
Loads in 2D only (tension and perpendicular shear)

**HBC-C-N**
For tension, perpendicular and longitudinal shear loads

**HBC-T**
For tension, perpendicular and longitudinal shear loads

Hilti Cast-in Anchor Channel: HAC and HAC-T

**Textile Tape**
Eases the removal of the foam by allowing the entire foam length to be removed from the channel cavity

**Foam Filler**
Environmentally friendly, low density polyethylene foam filling. It prevents fresh concrete from entering the channel cavity

**Rivet**
Carbon steel and hot-dip galvanized ≥ 45 μm steel grade

**End cap**
End caps help keep concrete slurry out of the channels

**Lectite-type Agent**
Applied at the threads of the anchor to avoid movement and unscrewing of the anchor

Hilti Cast-in Anchor Channel: HAC CRFoS U

**Textile Tape**
Eases the removal of the foam by allowing the entire foam length to be removed from the channel cavity

**Foam Filler**
Environmentally friendly, low density polyethylene foam filling. It prevents fresh concrete from entering the channel cavity

**Rivet**
Carbon steel and hot-dip galvanized ≥ 45 μm steel grade

**End cap**
End caps help keep concrete slurry out of the channels

**Lectite-type Agent**
Applied at the threads of the reinforcing bar to avoid movement and unscrewing of the reinforcing bar

**Jam Nut**
Non-structural stainless steel nut

**Threaded End Reinforcing Bar**
Alloks reinforcing bar to be mechanically connected to channel profile

**Zinc Rich Paint**
Zinc rich paint is applied at the thread of the reinforcing bar and adjacent surface, for up to 2” to provide corrosion protection of connection

**Reinforcing Bar**
Reinforcement steel according to DIN 488-1, Bst 500 B
fy = 72.50 ksi

**Environmentally freindly, low density polyethylene foam filling. It prevents fresh concrete from entering the channel cavity**

**Carbon steel and hot-dip galvanized ≥ 45 μm steel grade**

**End caps help keep concrete slurry out of the channels**

**Applied at the threads of the anchor to avoid movement and unscrewing of the anchor**

**Non-structural stainless steel nut**

**Alloks reinforcing bar to be mechanically connected to channel profile**

**Zinc rich paint is applied at the thread of the reinforcing bar and adjacent surface, for up to 2” to provide corrosion protection of connection**

**Reinforcement steel according to DIN 488-1, Bst 500 B**
fy = 72.50 ksi
Hilti Cast-in Anchor Channel: HAC EDGE Lite, HAC EDGE, HAC-T EDGE Lite, and HAC-T EDGE

Environmentally friendly, low-density polyethylene foam filling. It prevents fresh concrete from entering the channel cavity.

**Foam Filler**

**Rivet**
Carbon steel and hot dip galvanized ≥ 45 μm

**EDGE Plate**
(S) Carbon steel, S355
Hot dip galvanized (F) ≥ 45 μm

**Loctite-type Agent**
Applied at the threads of the anchor to avoid movement and unscrewing of the anchor.

**Anchor**
Carbon steel, grade S235
Hot dip galvanized (F) ≥ 45 μm

**Self drilling screw**
Carbon steel, grade 1018 to 1022 according to ASTM A510

**Fixture**
Carbon steel, metal sheet DX510+Z

**Loctite-type Agent**
Applied at the threads of the anchor to avoid movement and unscrewing of the anchor.

**Anchor**
Carbon steel, grade S235
Hot dip galvanized (F) ≥ 45 μm

**Self drilling screw**
Carbon steel, grade 1018 to 1022 according to ASTM A510

**Fixture**
Carbon steel, metal sheet DX510+Z

Hilti Cast-in Anchor Channel: HAC S EDGE and HAC-T S EDGE

Environmentally friendly, low-density polyethylene foam filling. It prevents fresh concrete from entering the channel cavity.

**Foam Filler**

**Rivet**
Carbon steel and hot dip galvanized ≥ 45 μm

**S Bracket**
(S) Carbon steel, S355
Hot dip galvanized (F) ≥ 45 μm

**EDGE Plate**
(S) Carbon steel, S355
Hot dip galvanized (F) ≥ 45 μm

**Loctite-type Agent**
Applied at the threads of the anchor to avoid movement and unscrewing of the anchor.

**Anchor**
Carbon steel, grade S235
Hot dip galvanized (F) ≥ 45 μm

**Self drilling screw**
Carbon steel, grade 1018 to 1022 according to ASTM A510

**Fixture**
Carbon steel, metal sheet DX510+Z

**Loctite-type Agent**
Applied at the threads of the anchor to avoid movement and unscrewing of the anchor.

**Anchor**
Carbon steel, grade S235
Hot dip galvanized (F) ≥ 45 μm

**Self drilling screw**
Carbon steel, grade 1018 to 1022 according to ASTM A510

**Fixture**
Carbon steel, metal sheet DX510+Z

**Unique markings for reliable identification**

**Markings on Hilti Anchor Channels and HBC Channel Bolts**

Hilti Anchor Channels have distinct markings on the outside and inside surface that allow correct identification before and after casting in concrete. The marking consist of the Hilti logo, the channel type designation, and the type of corrosion protection. The channels bear a unique production number that indicates the production lot as well as the channel type, to aid identification.

Hilti T-bolts bear marks on the head indicating the bolt type, strength class, corrosion class, and also include a manufacturing mark. The outside face of the bolt includes a unique mark for proper bolt identification after installation.

**Traceability**

A unique feature offered by our anchor channels is traceability. The lot number and our q-systems allow to trace the product back to the raw material and provide a 3.2 certificate of the raw material of each component if required.

**Labeled anchor channels is our new standard**

To simplify the anchor channel identification process and avoid confusion, all Hilti Anchor Channels come labeled. A fast and accurate channel identification saves times and can help the installer to ensure the anchor channel been installed matches the specified one. Pictures on the right illustrate a Hilti Anchor Channel with a label on the back of the channel profile.

The label provides product name, item number, lot number, country of fabrication, bar code, and approval (if applicable).

Custom labels can be provided upon request.
1.4 HAC SELECTION

1.4.1 HILTI ANCHOR CHANNEL SELECTION VIA PROJECT NEEDS

Hilti’s Anchor Channel portfolio present solutions for today’s construction challenges. The Hilti Anchor Channel (HAC) system portfolio includes anchor channels with rounded head anchors (HAC and HAC-T), rebar anchors (HAC CRFoS U), and a combination of rounded head anchors and rebars (HAC-EDGE Lite, HAC-T EDGE Lite, HAC-EDGE, HAC-T EDGE, HAC S EDGE, and HAC-T S EDGE).

### HAC SELECTION

**Product** | Main Features | Channel Type and Size
--- | --- | ---
HAC | Product covered by ICC ESR-3350. Most feasible anchor channel solution. Ease of installation | HAC-40, HAC-50, HAC-70
HAC CRFoS U | Anchor Channel for superior concrete performance in tension | HAC-50 CRFoS U, HAC-60 CRFoS U, HAC-50 EDGE Lite, HAC-50 EDGE, HAC-50 EDGE Lite, HAC-40 EDGE Lite
HAC EDGE Lite and HAC EDGE | Anchor Channel for superior concrete edge shear confinement plate | HAC-40 EDGE Lite, HAC-50 EDGE Lite, HAC-50 EDGE
HAC S EDGE | Anchor Channel with concrete edge shear confinement plate and superior steel performance | HAC-50 S EDGE, HAC-50 S EDGE

### HAC CRFoS U

**Table**: Channel, Units, \( h_0 \), \( h_{min} \), NWC & SLWC, ALWC

<table>
<thead>
<tr>
<th>Channel</th>
<th>Units</th>
<th>( h_0 )</th>
<th>( h_{min} )</th>
<th>NWC &amp; SLWC</th>
<th>ALWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td>in (mm)</td>
<td>2.68 (68)</td>
<td>3.15 (80)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50</td>
<td>in (mm)</td>
<td>3.56 (90)</td>
<td>4.13 (105)</td>
<td>1.97 (50)</td>
<td>2.95 (75)</td>
</tr>
<tr>
<td>HAC-70</td>
<td>in (mm)</td>
<td>5.80 (146)</td>
<td>6.61 (168)</td>
<td>2.95 (75)</td>
<td></td>
</tr>
</tbody>
</table>

### HAC EDGE Lite and HAC EDGE

**Table**: Channel, Units, \( h_0 \), \( h_{min} \), NWC & SLWC, ALWC

<table>
<thead>
<tr>
<th>Channel</th>
<th>Units</th>
<th>( h_0 )</th>
<th>( h_{min} )</th>
<th>NWC &amp; SLWC</th>
<th>ALWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40 EDGE Lite</td>
<td>in (mm)</td>
<td>3.58 (91)</td>
<td>3.94 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE Lite</td>
<td>in (mm)</td>
<td>3.70 (94)</td>
<td>3.94 (100)</td>
<td>1.97 (50)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>HAC-70 EDGE</td>
<td>in (mm)</td>
<td>4.17 (106)</td>
<td>4.92 (125)</td>
<td>3.94 (100)</td>
<td></td>
</tr>
</tbody>
</table>

HAC EDGE can be used in 3.125” thick slabs. Please contact Hilti at US+CA.HAC@Hilti.com for information.

### HAC S EDGE

**Table**: Channel, Units, \( h_0 \), \( h_{min} \), NWC, SLWC, & ALWC

<table>
<thead>
<tr>
<th>Channel</th>
<th>Units</th>
<th>( h_0 )</th>
<th>( h_{min} )</th>
<th>NWC</th>
<th>SLWC</th>
<th>ALWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-50 S EDGE</td>
<td>in (mm)</td>
<td>3.70 (94)</td>
<td>3.94 (100)</td>
<td>3.94 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-70 S EDGE</td>
<td>in (mm)</td>
<td>4.17 (106)</td>
<td>4.92 (125)</td>
<td>3.94 (100)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**:
- \( c_{min} \), \( c_{max} \), \( c_{slw} \), and \( c_{alw} \) are measured from an edge to the center of the anchor.
## 1. Anchor Channel Systems

### 2. HAC Portfolio

### 3. HAC Applications

### 4. Design Introduction

### 5. Base Material

### 6. Loading

### 7. Anchor Channel Design Code

### 8. Reinforcing Bar Anchorage

### 9. Special Anchor Channel Design

### 10. Design Software

### 11. Best Practices

### 12. Instructions for Use

### 13. Field Fixes

### 14. Design Example

#### 1.1 Anchor Channels Benefits and Features

<table>
<thead>
<tr>
<th>Base Material</th>
<th>Load Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncracked concrete</td>
<td>HAC-30</td>
</tr>
<tr>
<td>Cracked concrete</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Lightweight concrete</td>
<td>HAC-(T)50</td>
</tr>
<tr>
<td>Concrete over metal deck</td>
<td>HAC-60</td>
</tr>
<tr>
<td>Post-tension concrete</td>
<td>HAC-(T)70</td>
</tr>
<tr>
<td>Hollow-core concrete</td>
<td>HAC-50 CRFoS U</td>
</tr>
<tr>
<td>Concrete over metal deck</td>
<td>HAC-60 CRFoS U</td>
</tr>
<tr>
<td>Hollow-core block</td>
<td>HAC-70 CRFoS U</td>
</tr>
<tr>
<td>Unreinforced concrete</td>
<td>HAC-40 EDGE Lite</td>
</tr>
<tr>
<td>Serrated</td>
<td>HAC-(T)50 EDGE Lite</td>
</tr>
<tr>
<td>Smooth</td>
<td>HAC-(T)50 EDGE</td>
</tr>
<tr>
<td>Serrated</td>
<td>HAC-(T)50 S EDGE C</td>
</tr>
<tr>
<td>Smooth</td>
<td>HAC-(T)50 S EDGE</td>
</tr>
<tr>
<td>HBC-C</td>
<td>HBC-C-N</td>
</tr>
<tr>
<td>HBC-T</td>
<td>HBC-B</td>
</tr>
</tbody>
</table>

- **1. Technical data based on CEN/TS.
- 2. Anchor channel system may be suitable, contingent to minimum edge distance requirements within solid concrete. HAC-(T) indicates product is available in smooth and serrated channel profile.**

#### Approvals

<table>
<thead>
<tr>
<th>Codes</th>
<th>Corrosion resistance</th>
<th>Anchor Channel Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICC-ES</td>
<td>COLA</td>
<td>FL</td>
</tr>
<tr>
<td>End Caps</td>
<td>End Caps with nail holes</td>
<td>Nail holes</td>
</tr>
</tbody>
</table>

- **1. Refer to updated section 5.3 for a more detailed discussion on corrosion and corrosion resistance.
- 2. Anchor channel and Reinforcement Edge Confinement Plate (EDGE plate) are hot dip galvanized. HAC-(T) indicates product is available in smooth and serrated channel profile.**
2. HAC PORTFOLIO

This chapter provides product, geometrical, structural, and general information about the Hilti Anchor Channel Systems. It is intended to provide all relevant information about the product. It provides explanation about the nomenclature of the product, geometrical properties, minimum substrate requirements, and steel strengths. Moreover, this chapter provides item numbers and lead times for standard, non-standard, and information about custom solutions.

2.1 HILTI ANCHOR CHANNEL NOMENCLATURE

Hilti Anchor Channel Profile type and size Effective embedment depth in mm Anchor channel length in mm Finish or material

<table>
<thead>
<tr>
<th>Hilti Anchor Channel</th>
<th>Profile type and size</th>
<th>Effective embedment depth in mm</th>
<th>Anchor channel length in mm</th>
<th>Finish or material</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E1) HAC 50</td>
<td></td>
<td>106 [4.17 in.]</td>
<td>300 [11.81 in.]</td>
<td>F (HDG)</td>
</tr>
<tr>
<td>(E2) HAC T50</td>
<td></td>
<td>106 [4.17 in.]</td>
<td>350 [13.78 in.]</td>
<td>F (HDG)</td>
</tr>
</tbody>
</table>

Example 1 (E1): HAC-50 106/300 F

Example 2 (E2): HAC-T50 106/350 F
2.1 HAC Nomenclature

2.2 Geometric Parameters

2.3 Structural Performance

2.4 Ordering Information

2.5 Standard Portfolio

2.6 HAC Custom Solutions

Nomenclature of HAC CRFoSU

HAC-profile h nom /length Finish CRFoSU

<table>
<thead>
<tr>
<th>HAC</th>
<th>Profile</th>
<th>h nom</th>
<th>Length</th>
<th>Finish</th>
<th>CRFoSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilti Anchor Channel</td>
<td>Profile type and size</td>
<td>Nominal channel height in mm</td>
<td>Anchor channel length in mm</td>
<td>Finish or material</td>
<td>Corner Rebar Face of Slab</td>
</tr>
<tr>
<td>(E1)</td>
<td>HAC</td>
<td>70</td>
<td>420 [16.54 in.]</td>
<td>350 [13.78 in.]</td>
<td>F (HDG)</td>
</tr>
<tr>
<td>(E2)</td>
<td>HAC</td>
<td>70</td>
<td>420 [16.54 in.]</td>
<td>300 [11.81 in.]</td>
<td>F (HDG)</td>
</tr>
</tbody>
</table>

Example 1 (E1): HAC-70 420/350 F CRFoSU

Example 2 (E2): HAC-70 420/300 F CRFoSU

Nomenclature of HAC CRFoSU at Corners

HAC-profile h nom /length Finish CRFoSU

<table>
<thead>
<tr>
<th>HAC</th>
<th>Profile</th>
<th>h nom</th>
<th>Length</th>
<th>Finish</th>
<th>CRFoSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilti Anchor Channel</td>
<td>Profile type and size</td>
<td>Nominal channel height in mm</td>
<td>Anchor channel length in mm</td>
<td>Finish or material</td>
<td>Corner Rebar Face of Slab</td>
</tr>
<tr>
<td>(E1)</td>
<td>HAC</td>
<td>70</td>
<td>420 [16.54 in.]</td>
<td>300 [11.81 in.]</td>
<td>F (HDG)</td>
</tr>
</tbody>
</table>

Example 1 (E1): HAC-70 420/300 F CRFoSU

Example 2 (E1): HAC-70 420/300 F CRFoSU

Note: HAC CRFoSU can be used in intermediate and corner conditions. A corner condition requires the use of (2) HAC CRFoSU. For ordering purposes, two (2) units need to be ordered. See section 2.4 for item numbers.
### Nomenclature of HAC EDGE Lite, HAC EDGE, HAC-T EDGE Lite, and HAC-T EDGE

<table>
<thead>
<tr>
<th>HAC-profile h_e</th>
<th>Length</th>
<th>Finish</th>
<th>Edge distance, c_e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilti Anchor Channel Profile type and size</td>
<td>Effective embedment depth in mm</td>
<td>Anchor channel length in mm</td>
<td>Finish or material</td>
</tr>
</tbody>
</table>

**Example 1 (E1):** HAC- 50 106/300 F EDGE Lite 4.000 in.

**Example 2 (E2):** HAC-T 50 94/300 F EDGE 3.000 in.

### Nomenclature of HAC EDGE C, HAC-T EDGE C at Corners

<table>
<thead>
<tr>
<th>HAC-profile h_e</th>
<th>Length</th>
<th>Finish</th>
<th>Edge distance, c_e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilti Anchor Channel Profile type and size</td>
<td>Effective embedment depth in mm</td>
<td>Anchor channel length (mm)</td>
<td>Finish or material</td>
</tr>
</tbody>
</table>

**Example 1 (E1A):** HAC- 50 106/300 F EDGE 4.000 in.

**Example 2 (E1B):** HAC- 50 106/300 F EDGE C 4.000 in.
Nomenclature of HAC S EDGE and HAC-T S EDGE

<table>
<thead>
<tr>
<th>Hilti Anchor Channel</th>
<th>Profile type and size</th>
<th>Superior Steel Performance</th>
<th>Effective embedment depth in mm</th>
<th>Anchor channel length (mm)</th>
<th>Finish or material</th>
<th>Specified edge distance from edge of slab to C/L of HAC in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E1) HAC 50</td>
<td>S</td>
<td>106 (4.17 in.)</td>
<td>300 (11.81 in.)</td>
<td>F (HDG)</td>
<td>EDGE</td>
<td>4.000 in. (102 mm)</td>
</tr>
<tr>
<td>(E2) HAC T50</td>
<td>S</td>
<td>94 (3.70 in.)</td>
<td>300 (11.81 in.)</td>
<td>F (HDG)</td>
<td>EDGE</td>
<td>4.000 in. (102 mm)</td>
</tr>
</tbody>
</table>

Example 1 (E1): HAC- 50 S 106/ 300 F EDGE 4.000 in.

Example 2 (E2): HAC- T50 S 94/ 300 F EDGE 4.000 in.

Nomenclature of HAC S EDGE C and HAC-T S EDGE C at Corners

<table>
<thead>
<tr>
<th>Hilti Anchor Channel</th>
<th>Profile type and size</th>
<th>Superior Steel Performance</th>
<th>Effective embedment depth in mm</th>
<th>Anchor channel length in mm</th>
<th>Finish or material</th>
<th>Corner rebar edge confinement plate (EDGE plate)</th>
<th>Specified edge distance from edge of slab to C/L of HAC in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E1A) HAC 50</td>
<td>S</td>
<td>106 (4.17 in.)</td>
<td>300 (11.81 in.)</td>
<td>F (HDG)</td>
<td>EDGE</td>
<td>4.000 in. (102 mm)</td>
<td></td>
</tr>
<tr>
<td>(E1B) HAC 50</td>
<td>S</td>
<td>106 (4.17 in.)</td>
<td>300 (11.81 in.)</td>
<td>F (HDG)</td>
<td>EDGE C</td>
<td>4.000 in. (102 mm)</td>
<td></td>
</tr>
</tbody>
</table>

Example 1 (E1A): HAC- 50 S 106/ 300 F EDGE C 4.000 in.

Example 2 (E1B): HAC- 50 S 106/ 300 F EDGE C 4.000 in.
### 2.2 HAC GEOMETRIC PARAMETERS

#### 2.2.1 HAC

Hilti Anchor Channels (HAC) with smooth channel lips are offered in an array of four channel profile sizes; HAC-40, HAC-50, HAC-60, and HAC-70. Hilti Channel Bolts C (HBC-C) are suitable for all four HAC profiles. Hilti Locking Channel Bolts (HBC-C-N) provide slip resistances via interlocking between t-bolt head and channel lip. Figure 2.2.1.1 illustrates the different channel profile sizes and t-bolt types.

The standard HAC portfolio consists of pre-defined channel lengths, embedment depths, number of anchors, anchor spacing, and defined anchor diameter. Figure 2.2.1.2 illustrates standard HAC-40 to HAC-70 anchor channels. Table 2.2.1.1 provides geometric parameters of HAC portfolio.

Non-standard anchor channels (i.e. custom channel length, custom anchor spacing, etc.) can be provided upon request. Longer lead times can be expected for custom channels. See sections 2.4, 2.5, and 2.6 for standard and custom anchor channels lead times.

#### Table 2.2.1.1 — Geometric parameters of HAC portfolio

<table>
<thead>
<tr>
<th>Hilti Channel Bolt</th>
<th>Bolt type</th>
<th>Steel grade</th>
<th>Finish or material</th>
<th>Diameter</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E1) HBC C</td>
<td>C</td>
<td>8.8</td>
<td>F (HDG)</td>
<td>M12</td>
<td>50 [1.97 in.]</td>
</tr>
<tr>
<td>(E2) HBC C</td>
<td>C</td>
<td>50</td>
<td>R (stainless steel)</td>
<td>M16</td>
<td>60 [2.36 in.]</td>
</tr>
<tr>
<td>(E3) HBC C-N</td>
<td>C-N</td>
<td>8.8</td>
<td>F (HDG)</td>
<td>M16</td>
<td>60 [2.36 in.]</td>
</tr>
<tr>
<td>(E4) HBC T</td>
<td>T</td>
<td>8.8</td>
<td>F (HDG)</td>
<td>M16</td>
<td>60 [2.36 in.]</td>
</tr>
</tbody>
</table>

Example 1 (E1): HBC- C 8.8 F M12x 50

Example 2 (E2): HBC- C 50 R M16x 60

Example 3 (E3): HBC- C-N 8.8 F M16x 60

Example 4 (E4): HBC- T 8.8 F M16x 60

Matching with smooth lip channel profile only

Matching with serrated lip channel profile only

Figure 2.2.1.1 HAC profiles with matching channel bolts

Figure 2.2.1.2 — Section view of HAC-40, HAC-50, HAC-60, and HAC-70.
Minimum substrate requirements

The minimum edge distance and member thickness for anchor channels are established via testing. It is the interaction between minimum member thickness and minimum edge distance that determines the minimum edge distance. If the anchor channel is installed closer than the minimum edge distance, cracking of the concrete may occur while applying the required installation torque to the t-bolts. Testing to determine the minimum edge distance considers unfavorable site conditions. The test is based on having the anchor channel recessed 1/8" in unreinforced concrete. Splitting/cracking may occur. Therefore, minimum substrate requirements vary depending on the anchor channel size. HAC substrate requirements are provided in Table 2.2.1.2 and 2.2.1.3.

Table 2.2.1.2 — Minimum substrate dimensions for HAC in normal weight and sand-lightweight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>(c_{a1})</th>
<th>(c_{a2})</th>
<th>(h_{min})</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td>in</td>
<td>1.97</td>
<td>1.97</td>
<td>4.13</td>
</tr>
<tr>
<td>HAC-50</td>
<td>in</td>
<td>1.97</td>
<td>1.97</td>
<td>4.13</td>
</tr>
<tr>
<td>HAC-60</td>
<td>in</td>
<td>1.97</td>
<td>1.97</td>
<td>4.13</td>
</tr>
<tr>
<td>HAC-70</td>
<td>in</td>
<td>1.97</td>
<td>1.97</td>
<td>4.13</td>
</tr>
</tbody>
</table>

Table 2.2.1.3 — Minimum substrate dimensions for HAC in all lightweight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>(c_{a1})</th>
<th>(c_{a2})</th>
<th>(h_{min})</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td>in</td>
<td>2.95</td>
<td>2.95</td>
<td>7.72</td>
</tr>
<tr>
<td>HAC-50</td>
<td>in</td>
<td>2.95</td>
<td>2.95</td>
<td>7.72</td>
</tr>
<tr>
<td>HAC-60</td>
<td>in</td>
<td>2.95</td>
<td>2.95</td>
<td>7.72</td>
</tr>
<tr>
<td>HAC-70</td>
<td>in</td>
<td>2.95</td>
<td>2.95</td>
<td>7.72</td>
</tr>
</tbody>
</table>

Minimum substrate dimensions for HAC in normal weight and sand-lightweight concrete

Minimum substrate dimensions for HAC in all lightweight concrete

Edge distance facts:

- Any edge which the distance perpendicular to the long axis of the anchor channels is considered an edge.
- For determination of the minimum edge distance of concrete breakout strength in tension, \(c_{a2} = \min(c_{a2,1}, c_{a2,2})\), and \(c_{a1} = \min(c_{a1,1}, c_{a1,2})\).
- For analysis purposes of concrete edge breakout strength in shear, \(c_{a2} = \min\) always measured in the direction of the applied shear load.
- Corner distances are always measured from the center of the anchor under consideration.

Corner distance facts:

- Any edge which the distance parallel to the long axis of the anchor channels is considered a corner.
- For determination of the minimum corner distance, \(c_{a2} = \min(c_{a2,1}, c_{a2,2})\).
- Corner distances are always measured from the center of the anchor under consideration.

Table 2.2.1.1 provides geometric parameters for HAC. This information is based on ICC ESR-3520 Table 8.1.

Table 2.2.1.1 – Geometric parameters for HAC

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel profile height</td>
<td>(h_{w})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Channel profile width</td>
<td>(b_{w})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Channel profile moment of inertia</td>
<td>(I_{w})</td>
<td>in(^2)</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Channel profile opening</td>
<td>(d)</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Channel tip flange thickness</td>
<td>(t)</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Channel tip thickness (top)</td>
<td>(t_{nom,t})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Channel tip thickness (bottom)</td>
<td>(t_{nom,b})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Min. effective channel profile opening</td>
<td>(d)</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Min. effective channel profile height</td>
<td>(h_{ch})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Anchor length</td>
<td>(l_{A})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Spacing</td>
<td>(s_{min})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Minimum anchor spacing</td>
<td>(s_{nom})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Maximum anchor spacing</td>
<td>(s_{max})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Net bearing area of the anchor head</td>
<td>(A_{net})</td>
<td>in(^2)</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Matching channel bolt</td>
<td>(x_{k})</td>
<td>HBC-C, HBC-C-50R, HBC-C-N</td>
<td></td>
</tr>
<tr>
<td>Minimum channel bolt spacing</td>
<td>(x_{w})</td>
<td>in</td>
<td>HAC-40</td>
</tr>
<tr>
<td>Nail hole location</td>
<td></td>
<td>in</td>
<td>HAC-40</td>
</tr>
</tbody>
</table>

1. Longer anchors can be offered upon request; longer lead time is expected.
2. Manufacture tolerance of up to ±3 mm (0.118 in.).
3. The head diameter is the inner diameter of the hexagonal shaped head, and does not fully reflect the cross sectional area of the anchor head.
4. Nail hole diameter is 4 mm (0.16 in.).
2.2.2 HAC IN FACE OF SLAB CORNERS

Single HAC in face of slab corners
AC232 provides design guidelines to account for the influence of corners where only one anchor channel is present. The design of this type of application is covered in ESIR-3520. Table 2.2.2.1 provides the minimum edge and corner distances for HAC.

Table 2.2.2.1 — Minimum substrate edge and corner distances for single HAC in a corner in normal weight, sand-lightweight and all light-weight concrete

<table>
<thead>
<tr>
<th>Channel</th>
<th>Units</th>
<th>Minimum c_{a1}</th>
<th>Minimum c_{a2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td>in (mm)</td>
<td>2.95 (75)</td>
<td>2.95 (75)</td>
</tr>
<tr>
<td>HAC-50</td>
<td>in (mm)</td>
<td>1.97 (50)</td>
<td>1.97 (50)</td>
</tr>
<tr>
<td>HAC-60</td>
<td>in (mm)</td>
<td>2.95 (75)</td>
<td>2.95 (75)</td>
</tr>
<tr>
<td>HAC-70</td>
<td>in (mm)</td>
<td>2.95 (75)</td>
<td>2.95 (75)</td>
</tr>
</tbody>
</table>

For all-lightweight concrete, c_{a1} = c_{a2} = 2.95" (75 mm)

Table 2.2.2.2 and figure 2.2.2.2 provide information about the minimum corner distance for pair of HAC. See chapter 9, Anchor Channel Design for additional design information.

Table 2.2.2.2 — Minimum substrate edge and corner distances for pair of HAC in corners in normal weight, sand-lightweight and all light-weight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>Minimum c_{a1}</th>
<th>Minimum c_{a2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40 In (mm)</td>
<td>1.97 (50)</td>
<td>3.70 (94)</td>
<td></td>
</tr>
<tr>
<td>HAC-50 In (mm)</td>
<td>1.97 (50)</td>
<td>4.31 (109.50)</td>
<td></td>
</tr>
<tr>
<td>HAC-60 In (mm)</td>
<td>2.35 (75)</td>
<td>6.70 (170.50)</td>
<td></td>
</tr>
<tr>
<td>HAC-70 In (mm)</td>
<td>2.95 (75)</td>
<td>7.09 (180.50)</td>
<td></td>
</tr>
</tbody>
</table>

Pair of HAC in a corner
AC232 does not include provisions to account for the influence of an adjacent channel in a face of slab corner. Technically, HAC can be used in both sides of the corner, if there is no overlapping of the anchors.

Additional measurements shall be taken in consideration to account for the negative influence of the adjacent anchor channel, if both channels are to be loaded simultaneously. See chapter 9, Anchor Channel Design for additional design information. Although this solution is technically feasible, installing HAC at 4 to 7 inches away from the corner typically results in unpractical bracket sizes, large eccentricities, large forces, and consequently, inadequate concrete strengths.

Corner distance c_{a2} is measured to the center of the anchor.

Design of Top of Slab Corners
Hilti has developed a model to account for the influence of adjacent and corner channels. The model follows the fundamentals of AC232 and allows to analyze more complex but typical applications encountered in a project such as the conditions shown in Figure 2.2.3.3. See chapter 9, Special Anchor Channel Design for additional design information.

2.2.3 HAC IN TOP AND BOTTOM OF SLAB CORNERS

Single HAC in top of slab corner
AC232 provides design guidelines to account for the influence of corners where only one anchor channel is present. The design of this type of application is covered in ESIR-3520. Table 2.2.3.1 provides the minimum edge and corner distances for HAC. HAC requirements for top and bottom of slab corners are equal.

Table 2.2.3.1 — Minimum substrate edge and corner distances for single HAC in a corner in normal weight, sand-lightweight and all light-weight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>Minimum c_{a1}</th>
<th>Minimum c_{a2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40 In (mm)</td>
<td>1.97 (50)</td>
<td>1.97 (50)</td>
<td></td>
</tr>
<tr>
<td>HAC-50 In (mm)</td>
<td>1.97 (50)</td>
<td>1.97 (50)</td>
<td></td>
</tr>
<tr>
<td>HAC-60 In (mm)</td>
<td>2.35 (75)</td>
<td>2.35 (75)</td>
<td></td>
</tr>
<tr>
<td>HAC-70 In (mm)</td>
<td>2.95 (75)</td>
<td>2.95 (75)</td>
<td></td>
</tr>
</tbody>
</table>

Corner distance c_{a2} is measured to the center of the anchor.

Pair of HAC in top of slab corners
AC232 does not include provisions to account for the influence of an adjacent channel and/or corner channel. Technically, HAC can be used in both sides of the corner.

Additional measurements shall be taken into consideration to account for the negative influence of the adjacent anchor channel, if both channels are to be loaded simultaneously. See chapter 9, Special Anchor Channel Design for additional design information.

The minimum corner distances for pair of HAC in top of slab corners (c_{a2}) are consistent with table 2.2.3.1. These minimum distances are based on installation requirements. Both HAC at corners cannot be installed at the minimum corner distance due to physical constraints (plashing of HAC will occur).

However, two HAC can be installed next to each other in a corner configuration where the anchor channels are installed perpendicular to each other; see Figure 2.2.3.3.

Figure 2.2.3.2 illustrates a pair of HAC in a corner. Corner distances greater than the minimum corner distance may be required based on the structural adequacy of the concrete at the corner.

Corner distance c_{a2} is measured to the center of the anchor.

Figure 2.2.3.2—Minimum corner distance for pair of HAC in top of slab, plan view.
Hilti Anchor Channel Rebar Face of Slab with smooth channel lips (HAC CRFoS U) are offered in three channel profile sizes; HAC-50, HAC-60, and HAC-70. Hilti Channel Bolts C (HBC-C) are suitable for all HAC CRFoS U.

The standard portfolio consists of HAC-50, HAC-60, and HAC-70 channels profiles with pre-defined channel length, rebar lengths, number of anchors, and defined rebar diameter. Non-standard anchor channels (i.e. custom channel length, rebar length, number of rebars etc.) can be provided upon request. Refer to sections 2.4 and 2.5 for additional information about standard items and lead times.

### Table 2.2.4.1 — Geometric parameters for HAC CRFoS U

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>units</th>
<th>HAC-50 CRFoS U</th>
<th>HAC-60 CRFoS U</th>
<th>HAC-70 CRFoS U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel profile height</td>
<td>hch</td>
<td>in</td>
<td>1.22 (31)</td>
<td>1.40 (35.5)</td>
<td>1.57 (40)</td>
</tr>
<tr>
<td>Channel profile width</td>
<td>bch</td>
<td>in</td>
<td>1.65 (41.9)</td>
<td>1.71 (43.4)</td>
<td>1.79 (45.4)</td>
</tr>
<tr>
<td>Channel profile moment of inertia</td>
<td>lch</td>
<td>in²</td>
<td>0.0795 (32.125)</td>
<td>0.1392 (57.930)</td>
<td>0.2293 (85.457)</td>
</tr>
<tr>
<td>Channel profile opening d</td>
<td>d</td>
<td>in</td>
<td>0.11 (19.50)</td>
<td>0.14 (21.60)</td>
<td>0.18 (27.00)</td>
</tr>
<tr>
<td>Channel lip / flange thickness</td>
<td>f</td>
<td>in</td>
<td>0.21 (3.30)</td>
<td>0.25 (3.60)</td>
<td>0.30 (4.50)</td>
</tr>
<tr>
<td>Channel lip thickness (top)</td>
<td>ft</td>
<td>in</td>
<td>0.11 (2.70)</td>
<td>0.14 (3.50)</td>
<td>0.18 (4.50)</td>
</tr>
<tr>
<td>Channel lip thickness (bottom)</td>
<td>ftb</td>
<td>in</td>
<td>0.11 (2.70)</td>
<td>0.14 (3.50)</td>
<td>0.18 (4.50)</td>
</tr>
<tr>
<td>Rebar length</td>
<td>ℓd</td>
<td>in</td>
<td>12.80 (325)</td>
<td>14.17 (360)</td>
<td>14.96 (380)</td>
</tr>
<tr>
<td>Rebar kink/offset height</td>
<td>kh</td>
<td>in</td>
<td>0.47 (12)</td>
<td>0.55 (14)</td>
<td>0.63 (16)</td>
</tr>
<tr>
<td>Nominal anchor channel depth</td>
<td>hnom</td>
<td>in</td>
<td>14.02 (356)</td>
<td>15.60 (396)</td>
<td>16.54 (420)</td>
</tr>
<tr>
<td>Minimum end spacing</td>
<td>xnom</td>
<td>in</td>
<td>0.98 (20)</td>
<td>0.98 (21)</td>
<td>0.98 (21)</td>
</tr>
<tr>
<td>Rebar diameter</td>
<td>dbr</td>
<td>in</td>
<td>0.67 (17)</td>
<td>0.55 (14)</td>
<td>0.63 (16)</td>
</tr>
<tr>
<td>Minimum rebar spacing</td>
<td>xmin</td>
<td>in</td>
<td>3.94 (100)</td>
<td>3.94 (100)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>Maximum rebar spacing</td>
<td>xmax</td>
<td>in</td>
<td>5.84 (250)</td>
<td>9.84 (250)</td>
<td>9.84 (250)</td>
</tr>
<tr>
<td>Bar effective cross-sectional area</td>
<td>Aeff</td>
<td>in²</td>
<td>0.18 (51.33)</td>
<td>0.24 (61.71)</td>
<td>0.31 (92.16)</td>
</tr>
<tr>
<td>Matching channel bolt</td>
<td></td>
<td></td>
<td>HBC-C, HBC-C-50R, and HBC-C-N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum channel bolt spacing</td>
<td>xmin</td>
<td>in</td>
<td>3 x bolt diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nail hole location</td>
<td>xnom</td>
<td>in</td>
<td>1&quot; offset from rebar (25.4 mm from rebar)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Custom rebar lengths can be offered upon request. Longer rebars may require longer lead times. Refer to sections 2.4 and 2.6 for information about lead times of custom channels.

1 Nail hole diameter is 4 mm (0.16 in.)
Minimum substrate requirements for HAC CRFoS U

Similarly to HAC, the minimum edge distances for HAC CRFoS U are established via testing. Although HAC CRFoS U are not explicitly covered by AC232, ESN-3502 provides the minimum edge and corner distance for the minimum member thickness. The minimum member thickness for HAC CRFoS U is larger than the minimum member thickness for HAC. However, the channel profile is the same for HAC and HAC CRFoS U. Therefore, it is conservative to use the minimum HAC edge and corner distances for HAC CRFoS U.

- **Table 2.2.4.2** — Minimum edge and corner distances for HAC CRFoS U in normal weight and sand-lightweight concrete

- **Table 2.2.5.2** — Minimum edge and corner distances for HAC CRFoS U in all-lightweight concrete

2.2.5 HAC CRFoS U in face of slab corners

HAC CRFoS U are ideal for face of slab corner applications. The Hilti face of slab corner solution utilizes two independent anchor channels. The use of two independent anchor channels eases the installation in congested conditions. This minimizes clashes of the anchors with the rebar cage, preventing damage of the anchors during installation. Moreover, two independent anchor channels allows de-coupling of the loads applied on each corner channel, preventing the anchors from experiencing undesired loads.

The use of anchor channels with rebar anchors (HAC CRFoS U) allows the anchor channels to be installed as close as 2-1/8" (from end of channel profile) away from the corner, without penalizing the concrete tensile strengths in tension, as is the case for HAC.

HAC CRFoS U comes with specially bent rebars. Thus, allowing both corner channels to be installed at the same elevation without clashing of the rebars of both corner channels.

Due to the HAC CRFoS U configuration, the anchor channel used at both corners is the same type. At corners, one HAC CRFoS U is rotated 180 degrees. Therefore, one channel has the bent rebars going up while the other are going down.

Anchor channel steel strengths are provided in sections 2.3.3 and 2.3.4. For design of channels at corners, refer to chapter 9.

**Figure 2.2.5.1** — HAC CRFoS U at corners.

**Figure 2.2.5.4** — Pair of HAC CRFoS U in an acute corner, plan view.

**Figure 2.2.5.3** — Minimum corner distance for pair of HAC CRFoS U in a corner, plan view.

**Figure 2.2.5.2** — Minimum corner distance for pair of HAC CRFoS U in a corner.

**Table 2.2.5.3** — Minimum substrate edge and corner distances for pair of HAC CRFoS U in corners in normal weight, sand-lightweight and all-lightweight concrete

**What drives the minimum corner distance?**

The minimum corner distance (Cca,2) is based on the minimum physical distance required to avoid clashing of the rebars of the two corner anchor channels, installed at the same elevation.

**HAC CRFoS U at non-90° corners**

HAC CRFoS U are suitable for non-90° corners. The use of two independent anchor channels simplifies the portfolio by no requiring custom made channels. See chapter 9 for design information.

**Table 2.2.4.5** — Minimum HAC CRFoS U member thickness, isometric view.

Minimum edge distance for anchor channels in composite slabs

The minimum edge and corner distances for HAC CRFoS U are consistent with the minimum requirements of its matching HAC profile size. Moreover, the AC232 test series 6 - splitting failure due to installation requires a 1/8 inch (3 mm) gap between channel lip and fixture to ensure introduction of a tension load into the anchor during torquing. This takes into considerations unfavorable anchor channel installation. However, this can be prevented in composite slabs where the anchor channel profile bears on the pour stop and the channel lips and fixture are flush with the pour stop.

For composite slabs where the anchor channel is fixed to the pour stop and the channel cannot be recessed in the slab, smaller edge distances may be allowed. Additional measurement may be required if the rebar is embedded in the metal deck zone. See section 9 for additional information.

**Figure 2.2.4.6** — HAC CRFoS U in composite slab.

**Table 2.2.4.4** — Minimum distance from face of slab to metal deck, h_{nm,fp}

**Figure 2.2.4.5** — HAC CRFoS U at corners.

**Table 2.2.4.3** — Minimum edge and corner distances for pair of HAC CRFoS U

**Figure 2.2.4.4** — Minimum HAC CRFoS U edge and corner distances, elevation view.

Corner and edge distances are measured to the center of the anchor.

**Table 2.2.4.3** — Minimum edge and corner distances for pair of HAC CRFoS U

**Table 2.2.4.4** — Minimum HAC CRFoS U edge and corner distances, elevation view.

*Minimum slab thickness, h_{min,fp} may be reduced.

---

**Figure 2.2.4.5** — Minimum HAC CRFoS U member thickness, isometric view.

Minimum edge distance for anchor channels in composite slabs

The minimum edge and corner distances for HAC CRFoS U are consistent with the minimum requirements of its matching HAC profile size. Moreover, the AC232 test series 6 - splitting failure due to installation requires a 1/8 inch (3 mm) gap between channel lip and fixture to ensure introduction of a tension load into the anchor during torquing. This takes into considerations unfavorable anchor channel installation. However, this can be prevented in composite slabs where the anchor channel profile bears on the pour stop and the channel lips and fixture are flush with the pour stop.

For composite slabs where the anchor channel is fixed to the pour stop and the channel cannot be recessed in the slab, smaller edge distances may be allowed. Additional measurement may be required if the rebar is embedded in the metal deck zone. See section 9 for additional information.

**Figure 2.2.4.6** — HAC CRFoS U in composite slab.

**Table 2.2.4.4** — Minimum distance from face of slab to metal deck, h_{nm,fp}

**Figure 2.2.4.5** — HAC CRFoS U at corners.

**Table 2.2.4.3** — Minimum edge and corner distances for pair of HAC CRFoS U

**Figure 2.2.4.4** — Minimum HAC CRFoS U edge and corner distances, elevation view.

Corner and edge distances are measured to the center of the anchor.

**Figure 2.2.4.5** — Minimum HAC CRFoS U member thickness, isometric view.

Minimum edge distance for anchor channels in composite slabs

The minimum edge and corner distances for HAC CRFoS U are consistent with the minimum requirements of its matching HAC profile size. Moreover, the AC232 test series 6 - splitting failure due to installation requires a 1/8 inch (3 mm) gap between channel lip and fixture to ensure introduction of a tension load into the anchor during torquing. This takes into considerations unfavorable anchor channel installation. However, this can be prevented in composite slabs where the anchor channel profile bears on the pour stop and the channel lips and fixture are flush with the pour stop.

For composite slabs where the anchor channel is fixed to the pour stop and the channel cannot be recessed in the slab, smaller edge distances may be allowed. Additional measurement may be required if the rebar is embedded in the metal deck zone. See section 9 for additional information.

**Figure 2.2.4.6** — HAC CRFoS U in composite slab.

**Table 2.2.4.4** — Minimum distance from face of slab to metal deck, h_{nm,fp}

**Figure 2.2.4.5** — HAC CRFoS U at corners.

**Table 2.2.4.3** — Minimum edge and corner distances for pair of HAC CRFoS U

**Figure 2.2.4.4** — Minimum HAC CRFoS U edge and corner distances, elevation view.

Corner and edge distances are measured to the center of the anchor.
2.2.6 HAC CRFoS U in Top or Bottom of Slab Applications

HAC CRFoS U in intermediate applications

The use of HAC CRFoS U is not limited to face of slab applications. HAC CRFoS U is ideal for applications with high tension forces. In top of slab applications, HAC CRFoS U presents a great solution for applications (intermediate and corners) with high tension forces and HAC is not adequate. The minimum member thickness, corner and edge distances are provided in tables 2.2.5.1 and 2.2.5.2. The minimum rebar length should be established in accordance with applicable provisions of AC232 and ACI 318.

HAC CRFoS U in corner applications

The requirements for HAC CRFoS U in top of slab applications are similar to the HAC requirements discussed in section 2.2.3. See section 9 for additional design information.

HAC CRFoS U in top or bottom of slab applications

A good example for a top of “slab” applications where HAC CRFoS U may be the only solution is handrails in top of curb. Although the shear forces are typically low, the high tension forces on the t-bolts due to the cantilever effect of the rails tends to create unsatisfactory concrete breakout in tension utilizations. Figure 2.2.6.1 illustrates such scenario. The curb needs to be tall enough to meet the minimum member thickness. Standard hooks and headed rebars may be used if the minimum member thickness is not met.

Another example is a kicker in a spandrel beam (corner or intermediate) where the anchor is installed at a large edge distance but the bracket eccentricity generates overly high tension forces on the t-bolts.

HAC CRFoS U transfers higher tension forces than HAC. HAC CRFoS U does not increase the concrete breakout strength in shear. See section 9 for additional design information.

The concrete breakout strength in shear is not negatively impacted by the rebars. The concrete breakout strength in shear for HAC and its matching HAC CRFoS U is assumed to be equal and the same design standards are applied.

In bottom of slab applications, the concrete breakout strength in shear can be increased by increasing the edge distance. However, if the tension is too high as it can be the case with kicker, the interaction (or tension alone) of concrete in tension and shear can yield unsatisfactory utilizations. HAC CRFoS U can solve this limitation, if the member thickness is sufficient.

Hilti Anchor Channels with smooth channel lips and rebar edge confinement plate (HAC EDGE Lite and HAC EDGE) are offered in HAC-40 (HAC EDGE Lite only) and HAC-50 profiles. HAC EDGE with superior steel performance (HAC S EDGE) are offered in HAC-50 profiles. The anchor channel is identical to its matching HAC, except the rebar edge confinement plate (EDGE Lite or EDGE Plate) is incorporated for superior concrete performance in shear.

The standard portfolio consists of HAC-40 with a nominal anchor height of 3.70” (94.00 mm) and HAC-50 with two defined nominal anchor heights; 4.31” (109.50 mm) and 3.84” (97.50 mm). Moreover, defined channel length, EDGE Lite and EDGE Plate geometry, rebar lengths, anchor and rebar diameter, and number of rebar are also defined. The number of anchors per channels is pre-defined and may be modified and ordered upon request. Refer to section 2.4 and 2.5 for additional information about standard items and lead times. For custom solutions, refer to section 2.6.

The concrete edge shear confinement plate (EDGE Plate) is fixed to the form work or pour stop. The EDGE Plate comes with installation holes. As an added value, the product comes with the specified edge distance (e*).

HAC EDGE Lite and HAC EDGE

These anchor channel systems consist of HAC and the new rebar edge confinement plate (EDGE plate). The EDGE plate is not structurally attached to the anchor channel. This allows to decouple the tension and shear forces. The HAC-50 EDGE C comes with an offset rebar and increased height of the front plate.

HAC S EDGE

This anchor channel is equal to its matching HAC EDGE, except the “S” bracket is added. The “S” bracket offers superior steel performance. The S bracket is structurally attached to the anchor channel. The S-bracket has a similar geometry to the connected channel profile to ensure direct bearing of the S bracket on the channel profile.
2.1 HAC Nomenclature

2.2 Geometric Parameters

2.3 Structural Performance

2.4 Ordering Information

2.5 Standard Portfolio

2.6 HAC Custom Solutions

Figure 2.2.7.2 — Section view of HAC-40 EDGE Lite and HAC-50 EDGE Lite.

Figure 2.2.7.3 — Section view of HAC-50 EDGE and HAC-50 EDGE C.

Figure 2.2.7.4 — Section view of HAC-50 S EDGE and HAC-50 S EDGE C.
HAC EDGE Lite, HAC EDGE, and HAC S EDGE utilize HAC-50 with rounded head anchors. HAC EDGE Lite is also offered in HAC-40. These are the same anchor channel covered by ICC-ESR-3520. The HAC-50 with reduced embedment depth ($h_e < 4.17$ in) is not covered by ESR-3520. Additional components are added to improve the concrete capacity in perpendicular shear and to provide superior steel performance in perpendicular shear.

Table 2.2.7.1 provides geometric parameters for the anchor channels that compose the HAC EDGE product line. Tables 2.2.7.2 and 2.2.7.3 provide geometric information about EDGE Lite and EDGE plate.

### Table 2.2.7.1 — Geometric parameters for HAC EDGE Lite, HAC EDGE, and HAC S EDGE

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. effective embedment depth</td>
<td>$h_{es}$</td>
<td>in (mm)</td>
<td>HAC-40 EDGE Lite</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HAC-50 S EDGE</td>
</tr>
<tr>
<td>Thickness of the anchor head</td>
<td>$t_a$</td>
<td>in (mm)</td>
<td>0.12 (3.10)</td>
</tr>
<tr>
<td>Nominal embedment depth</td>
<td>$h_{nb}$</td>
<td>in (mm)</td>
<td>3.70 (94.00)</td>
</tr>
<tr>
<td>Channel profile height</td>
<td>$h_{np}$</td>
<td>in (mm)</td>
<td>1.50 (38.1)</td>
</tr>
<tr>
<td>Channel profile width</td>
<td>$b_{np}$</td>
<td>in (mm)</td>
<td>1.61 (40.9)</td>
</tr>
<tr>
<td>Channel profile moment of inertia</td>
<td>$I_{ch}$</td>
<td>in² (mm²)</td>
<td>0.0375 (2146)</td>
</tr>
<tr>
<td>Channel profile opening</td>
<td>$d$</td>
<td>in (mm)</td>
<td>0.77 (19.5)</td>
</tr>
<tr>
<td>Channel tip flange thickness</td>
<td>$f$</td>
<td>in (mm)</td>
<td>0.18 (4.5)</td>
</tr>
<tr>
<td>Channel tip thickness (top)</td>
<td>$t_{tp}$</td>
<td>in (mm)</td>
<td>0.09 (2.25)</td>
</tr>
<tr>
<td>Channel tip thickness (bottom)</td>
<td>$t_{tb}$</td>
<td>in (mm)</td>
<td>0.09 (2.25)</td>
</tr>
<tr>
<td>Minimum and spacing</td>
<td>$s_{min}$</td>
<td>in (mm)</td>
<td>0.08 (2.0)</td>
</tr>
<tr>
<td>Anchor shaft diameter</td>
<td>$d_a$</td>
<td>in (mm)</td>
<td>0.28 (7.10)</td>
</tr>
<tr>
<td>Head diameter</td>
<td>$d_h$</td>
<td>in (mm)</td>
<td>0.89 (22.6)</td>
</tr>
<tr>
<td>Anchor length</td>
<td>$l_a$</td>
<td>in (mm)</td>
<td>3.00 (76.2)</td>
</tr>
<tr>
<td>Minimum anchor spacing</td>
<td>$s_{min}$</td>
<td>in (mm)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>Maximum anchor spacing</td>
<td>$s_{max}$</td>
<td>in (mm)</td>
<td>9.84 (250)</td>
</tr>
<tr>
<td>Net bearing area of the anchor head</td>
<td>$A_{ch}$</td>
<td>in² (mm²)</td>
<td>0.324 (8.28)</td>
</tr>
<tr>
<td>Matching channel bolt</td>
<td>$w_{bc}$</td>
<td>in (mm)</td>
<td>3.0 (76.2)</td>
</tr>
<tr>
<td>Minimum channel bolt spacing</td>
<td>$w_{bc}$</td>
<td>in (mm)</td>
<td>3.0 (76.2)</td>
</tr>
<tr>
<td>Nail hole location¹</td>
<td>$x_{nh}$</td>
<td>in (mm)</td>
<td>3.0 (76.2)</td>
</tr>
</tbody>
</table>

1. The head diameter is the inner diameter of the hexagonal shaped head, and does not fully reflect the cross sectional area of the anchor head.
2. HAC EDGE C and HAC S EDGE C are the matching corner channel and have the same anchor channel as the intermediate HAC EDGE and HAC S EDGE. Although the clear confinement plate has different geometry, the anchor channel is the same.
4. Nail hole diameter is 4 mm (0.16 in).
Table 2.2.7.3 — Geometric parameters for HAC S EDGE concrete edge shear confinement plate

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Unit</th>
<th>Anchor Channel</th>
<th>Substrate</th>
<th>EDGE</th>
<th>EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of the EDGE plate</td>
<td>t_1</td>
<td>mm</td>
<td>0.20</td>
<td>HAC-50 S</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td>Height of the EDGE plate</td>
<td>h</td>
<td>mm</td>
<td>2.36</td>
<td>HAC-50 S</td>
<td>3.94</td>
<td>0.60</td>
</tr>
<tr>
<td>Projection of the EDGE plate</td>
<td>x_1</td>
<td>mm</td>
<td>1.97</td>
<td>HAC-50 S</td>
<td>0.60</td>
<td>0.70</td>
</tr>
<tr>
<td>Length of the EDGE plate</td>
<td>l_1</td>
<td>mm</td>
<td>Channel length x L</td>
<td>HAC-50 S</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>Overall length of the EDGE plate rebar</td>
<td>l</td>
<td>mm</td>
<td>80</td>
<td>HAC-50 S</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Rebar nominal diameter</td>
<td>d</td>
<td>mm</td>
<td>0.47</td>
<td>HAC-50 S</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Bar effective cross-sectional area</td>
<td>A_1</td>
<td>mm²</td>
<td>0.18</td>
<td>HAC-50 S</td>
<td>(135.1)</td>
<td>(125.1)</td>
</tr>
<tr>
<td>Minimum rebar spacing</td>
<td>d_1</td>
<td>mm</td>
<td>3.74</td>
<td>HAC-50 S</td>
<td>(55)</td>
<td>(55)</td>
</tr>
<tr>
<td>Maximum rebar spacing</td>
<td>d_1</td>
<td>mm</td>
<td>5.71</td>
<td>HAC-50 S</td>
<td>(125)</td>
<td>(125)</td>
</tr>
<tr>
<td>C/C distance between the outer rebar and the outer anchor</td>
<td>r</td>
<td>mm</td>
<td>0.295</td>
<td>HAC-50 S</td>
<td>(7.50)</td>
<td>(7.50)</td>
</tr>
<tr>
<td>Distance from the end of the EDGE Lite or EDGE plate to the center of the installation hole</td>
<td>r_1</td>
<td>mm</td>
<td>0.40</td>
<td>HAC-50 S</td>
<td>(10)</td>
<td>(10)</td>
</tr>
<tr>
<td>Edge distance (from outside face of EDGE Lite or EDGE plate to center of HAC anchor)</td>
<td>r_2</td>
<td>mm</td>
<td>As specified</td>
<td>HAC-50 S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development length of rebar</td>
<td>l</td>
<td>mm</td>
<td>2(0.60)</td>
<td>HAC-50 S</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Nail hole diameter is equal to 6 mm (0.25 in.)

Table 2.2.7.4 — Minimum substrate dimensions for HAC EDGE Lite, HAC EDGE, and HAC S EDGE

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>t_1</th>
<th>h</th>
<th>c_a</th>
<th>c_u</th>
<th>c_a</th>
<th>c_u</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40 EDGE Lite</td>
<td>mm</td>
<td>3.58</td>
<td>(95)</td>
<td>3.94</td>
<td>(100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE Lite</td>
<td>mm</td>
<td>3.70</td>
<td>(95)</td>
<td>3.94</td>
<td>(100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE</td>
<td>mm</td>
<td>4.17</td>
<td>(115)</td>
<td>4.92</td>
<td>(125)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE C</td>
<td>mm</td>
<td>3.70</td>
<td>(95)</td>
<td>3.94</td>
<td>(100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE C</td>
<td>mm</td>
<td>4.17</td>
<td>(115)</td>
<td>4.92</td>
<td>(125)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.2.7.10 — Geometry of S bracket, section view.

Figure 2.2.7.12 — Isometric view of HAC-50 S EDGE.

Figure 2.2.7.11 — Isometric view of HAC-50 S Lite.

Minimum edge and corner distances for anchor channels in composite slabs

The minimum edge and corner distances for HAC EDGE are consistent with the minimum requirements of HAC. In response to the market trends such as composite slabs with pockets, Hilti has added HAC EDGE with shorter anchor lengths.

For composite slabs where there is a pour stop along the perimeter of the edge of slab preventing oxygen from reaching out to the bottom of the slab and concrete cover of the anchor is not required, the minimum member thickness can be reduced.

Chapters 8 and 9 provide design information for HAC EDGE in composite slabs and how to account for the potential negative influence of the metal deck.

Table 2.2.7.16 — Minimum member thickness for HAC EDGE Lite, HAC EDGE, and HAC S EDGE

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>h</th>
<th>c_a</th>
<th>c_u</th>
<th>c_a</th>
<th>c_u</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40 EDGE Lite</td>
<td>mm</td>
<td>3.58</td>
<td>(95)</td>
<td>3.94</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE Lite</td>
<td>mm</td>
<td>3.70</td>
<td>(95)</td>
<td>3.94</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE</td>
<td>mm</td>
<td>4.17</td>
<td>(115)</td>
<td>4.92</td>
<td>(125)</td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE C</td>
<td>mm</td>
<td>3.70</td>
<td>(95)</td>
<td>3.94</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE C</td>
<td>mm</td>
<td>4.17</td>
<td>(115)</td>
<td>4.92</td>
<td>(125)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.2.7.16 — Minimum member thickness for HAC EDGE Lite, HAC EDGE, and HAC S EDGE, isometric section view.

Minimum substrates requirements for HAC EDGE Lite, HAC EDGE, and HAC S EDGE

Similarly to HAC, the minimum edge distances for HAC EDGE are established via testing. Although the HAC EDGE product line are not implicitly covered in AC232, AC232 provides testing protocols for anchor channels to establish the minimum edge and corner distance for the minimum member thickness. The following substrate requirements have been established in accordance with testing protocols of AC232.

Figure 2.2.7.17 — HAC EDGE in a composite slab, section view.
**2.2.8 HAC EDGE AND HAC S EDGE IN TOP OR BOTTOM OF SLAB CORNERS**

Pair of HAC EDGE or HAC S EDGE in top of slab corner

HAC EDGE and HAC S EDGE are ideal for top of slab corner applications. Two independent anchor channels at the corner allows de-coupling the loads at both channels, preventing anchors and rebars from taking undesired loads. Furthermore, using two independent channels eases the installation in congested areas, preventing damage of the anchors during installation.

HAC EDGE C and HAC EDGE C steel strengths are provided in section 2.3. For design of channels at corners, refer to Chapter 9.

HAC EDGE and HAC S EDGE at non-90° corners

HAC EDGE C and HAC S EDGE C are suitable for non-90° corners. The use of two independent anchor channels simplifies the portfolio by no requiring custom made channels. See Chapter 9 for design information.

**2.2.9 HILTI CHANNEL BOLTS**

The Hilti Channel Bolts (HBC) are part of the anchor channel system. HBC are threaded fasteners commonly known as T-bolts. HBC are the link between the fixture and anchor channel. The HBC have a proprietary head geometry, therefore, and HBC are only compatible with Hilti Anchor Channels. The head of the HBC can be inserted along the channel cavity. The fixture is connected to the anchor channel by channel bolts with a nut and washer. Thus, allowing for the so desired jobsite tolerance.

The head of the t-bolt is first installed parallel to the channel profile. Once it is positioned in place, the bolt is turned 90° clockwise. The head of the bolt has been engineered in a way that the t-bolt cannot rotate more than 90° clockwise. This ensures the bolt is properly positioned before the required installation torque is applied.

HBC come with a special marking to ease the identification before and after installation takes place. All HBC are covered by ESR-3520.

**2.2.10 HILTI CHANNEL BOLTS: HBC-C**

Hilti Channel Bolts — C (HBC-C) are suitable for channel profiles HAC-40, HAC-50, HAC-60, & HAC-70. HBC-C come in bolt diameters M12, M16, and M20, steel grades 8.8 and 50, finishing and materials HDG and SS, respectively.

HBC-C can be used to transfer tensile loads, shear loads perpendicular to the longitudinal channel axis, or any combination of these loads. Transferring of the loads takes place via interlock between the HBC and the channel lips.

| Channel bolt Units Carbon steel Steel stainless steel |
|---------------------------------|------------------|------------------|
| Property class  | 8.8 A4-50  | 12.5  |
| lₙ (N/mm²)  | 116.0 (800)  | 92.92 (645) |
| lₚ (N/mm²)  | 30.4  | (210) |
| Coating  | 1  | 2  |
| Notes  | 1 | Hot-dip galvanized |

Special markings on the outer surface of the t-bolt aids the installer to ensure the t-bolt is properly positioned before the installation torque is applied. Moreover, it allows the installer and inspector to identify the type of bolt, after the fixture is installed. Once the fixture is installed, the head of the t-bolt is no longer visible and the only visible part of the t-bolt is its outer face.

**2.2.8 HAC EDGE AND HAC S EDGE IN TOP OR BOTTOM OF SLAB CORNERS**

Corner distance cₓ is measured to the center of the anchor.

![Figure 2.2.8.2 — Isometric view of HAC EDGE and HAC EDGE C.](image)

**Table 2.2.8.1 — Minimum substrate edge and corner distance for pair of HAC EDGE and HAC S EDGE at a corner**

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Normal weight concrete</th>
<th>Sand lightweight and all lightweight concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-50 EDGE</td>
<td>1.97 (50)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>HAC-50 EDGE C</td>
<td>3.94 (100)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>HAC-50 S EDGE</td>
<td>3.94 (100)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>HAC-50 S EDGE C</td>
<td>3.94 (100)</td>
<td>3.94 (100)</td>
</tr>
</tbody>
</table>

1. Mates according to Annex 3, Table 1
2. Hot-dip galvanized

![Figure 2.2.9.1 — HBC-C, washer, and nut (left). HBC-C outside face inspection marking and installation (right).](image)

![Figure 2.2.10.1 — T-bolt marking.](image)

![Figure 2.2.10.2 — Hot dip galvanized t-bolt (left) and stainless steel t-bolt (right).](image)
Hilti Channel Bolt Length (HBC-C)

**Table 2.2.10.2 — Hilti Channel Bolts dimensions**

<table>
<thead>
<tr>
<th>Channel Bolt</th>
<th>Anchor Channel Profile</th>
<th>Dimensions</th>
<th>Channel bolt length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diameter a, b, c, k</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>HAC-40</td>
<td>mm</td>
<td>in</td>
<td></td>
</tr>
<tr>
<td>M12 14 (0.55)</td>
<td>10.4 (0.41)</td>
<td>40-200 (1.57-7.37)</td>
<td></td>
</tr>
<tr>
<td>mm M16 15.3</td>
<td>11.4 (0.45)</td>
<td>40-200 (1.57-7.37)</td>
<td></td>
</tr>
<tr>
<td>mm M20 13.9</td>
<td>13.9 (0.55)</td>
<td>60-200 (2.36-7.87)</td>
<td></td>
</tr>
<tr>
<td>HAC-50</td>
<td>mm</td>
<td>in</td>
<td></td>
</tr>
<tr>
<td>M12 14 (0.55)</td>
<td>1/8 (0.10)</td>
<td>5/32 (1.57)</td>
<td></td>
</tr>
<tr>
<td>mm M16 15.3</td>
<td>5/32 (1.57)</td>
<td>5/32 (1.57)</td>
<td></td>
</tr>
<tr>
<td>mm M20 13.9</td>
<td>9/32 (2.89)</td>
<td>9/32 (2.89)</td>
<td></td>
</tr>
<tr>
<td>HAC-60</td>
<td>mm</td>
<td>in</td>
<td></td>
</tr>
<tr>
<td>1/8 (0.10)</td>
<td>1/8 (0.10)</td>
<td>1/8 (0.10)</td>
<td></td>
</tr>
<tr>
<td>HAC-70</td>
<td>mm</td>
<td>in</td>
<td></td>
</tr>
<tr>
<td>13/64 (0.53)</td>
<td>13/64 (0.53)</td>
<td>13/64 (0.53)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.2.10.3 — Channel lip thickness**

<table>
<thead>
<tr>
<th>Anchor Channel profile</th>
<th>Channel lip thickness, Lₜ</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td>7/64 in (0.25)</td>
</tr>
<tr>
<td>HAC-50</td>
<td>1/8 in (0.10)</td>
</tr>
<tr>
<td>HAC-60</td>
<td>9/32 in (0.29)</td>
</tr>
<tr>
<td>HAC-70</td>
<td>13/64 in (0.53)</td>
</tr>
</tbody>
</table>

**Minimum t-bolt overhang**

According to AISC Steel Construction Manual, 13th Edition, Section 14-10 “Adequate thread engagement for anchor rods is identical to the condition described in the RSCS Specification as adequate for steel to steel structural joints using high strength bolts: having the end of the (anchor rod) flush with or outside the face of the nut.”

There is no maximum thread protrusion limitation from the standpoint of the function of the bolt.

If needed, the excess at the end of the bolt can be cut-off. The nut shall be fully engaged. The outside face of the head of the t-bolt has special markings to identify the t-bolt type and proper head orientation of the t-bolt. If the t-bolt is to be cut or grind, inspect and ensure the orientation and t-bolt type is as specified prior to any work on the t-bolt. If the marking on the t-bolt are removed, proper inspection is not possible. Proper corrosion protection shall be required.

Although there is minimum t-bolt overhang (Lo) can be zero, for tolerance purposes it is recommended to have a minimum t-bolt overhang. Table 2.2.10.4 provides the minimum t-bolt overhang length.

**Installation torque of HBC-C**

**Table 2.2.10.5 — Installation torque for Hilti Channel Bolts (HBC-C)**

<table>
<thead>
<tr>
<th>Bolt type</th>
<th>Installation torque Tₘ (Installation type A)¹</th>
<th>Installation torque Tₘ (Installation type B)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2.2.10.3 — Overhang of Hilti Channel Bolts (HBC-C).**

**Figure 2.2.10.4 — Recommended t-bolt overhang, Lₒ.**

Hiltilockingchannel bolts (HBC-C-N) are suitable for channel profiles HAC-40, HAC-50, HAC-60, & HAC-70. HBC-C-N come in bolt diameters M12, M16, and M20, steel grade 8.8, and HDG finishing. All HBC-C-N are covered by ESR-3520.

HBC-C-N can be used to transfer tensile loads, shear loads perpendicular to the longitudinal channel axis, longitudinal shear forces, or any combination of these loads. Transferring the loads takes place via interlock between the head of the HBC-C-N and the channel lips.

**Longitudinal load transfer mechanism**

The inside head of the HBC-C-N has 4 hardened notches. After the required installation torque is applied, the head of the t-bolt “bites” into the channel lips, creating four (4) - 2 mm deep “notches” in the channel lip. Hence, a positive connection between channel lip and t-bolt head is created. The longitudinal shear resistance of the HBC-C-N and HAC is achieved via mechanical interlock between the channel lips and head of the notched bolt. The load transfer mechanism ensures full load capacity, even if the nut experiences up to 50 percent relaxation.

The notches created in the channel lips reduce the moment of inertia of the channel profile. Therefore, the flexural strength of the anchor channel in tension is reduced by 10-15 percent, due to the reduction of the moment of inertia of the channel profile. During the installation torque.

Can longitudinal shear loads be resisted via friction?

Although longitudinal shear forces may be justified via friction, AC322 requires a positive connection between t-bolt and channel lip. Due to different installation uncertainties, long-term relaxation, and performance variance, Hilti does not recommend the use of friction as a means of transferring longitudinal loads, especially seismic loads.

**Special channel bolt markings**

Special markings on the t-bolt aid the installer to ensure the bolt is properly positioned before the installation torque is applied. Moreover, it allows the installer and inspector to identify the type of bolt, after the fixture is installed.
Mechanical interlock between channel lip and locking channel bolts via channel lip notches

**Figure 2.2.11.4 – Notches in channel lips due to HBC-C-N.**

Notch in channel lip created by HBC-C-N after installation torque, 4 total.

**Table 2.2.11.1 — Depth of notches created by Hilti Locking Channel Bolts (HBC-C-N)**

<table>
<thead>
<tr>
<th>Channel Bolt</th>
<th>Diameter (mm)</th>
<th>(N_h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBC-C-N</td>
<td>12</td>
<td>2 mm</td>
</tr>
<tr>
<td>HBC-C-N</td>
<td>16</td>
<td>2 mm</td>
</tr>
<tr>
<td>HBC-C-N</td>
<td>20</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

The extra 2 mm shall be considered when determining the protruding length of HBC-C-N t-bolt and the depth of notches.

**Hilti Locking Channel bolt grade**

**Table 2.2.11.2 — Hilti Locking Channel Bolts (HBC-C-N) material information**

<table>
<thead>
<tr>
<th>Bolt type</th>
<th>Units</th>
<th>(f_y) (N/mm²)</th>
<th>(f_u) (N/mm²)</th>
<th>Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBC-C-N</td>
<td>M12</td>
<td>116.0</td>
<td>640</td>
<td>Hot-dip galvanized</td>
</tr>
</tbody>
</table>

**Table 2.2.11.3 — Hilti Locking Channel Bolts dimensions**

<table>
<thead>
<tr>
<th>Channel Bolt</th>
<th>Anchor Channel Profile</th>
<th>Dimensions</th>
<th>Channel bolt length</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBC-C-N</td>
<td>HAC-40</td>
<td>M12</td>
<td>16.5 mm (0.65&quot;)</td>
</tr>
<tr>
<td>HBC-C-N</td>
<td>HAC-50</td>
<td>M16</td>
<td>18.5 mm (0.73&quot;)</td>
</tr>
<tr>
<td>HBC-C-N</td>
<td>HAC-50 S</td>
<td>M16</td>
<td>18.5 mm (0.73&quot;)</td>
</tr>
<tr>
<td>HBC-C-N</td>
<td>HAC-60</td>
<td>M20</td>
<td>18.5 mm (0.73&quot;)</td>
</tr>
<tr>
<td>HBC-C-N</td>
<td>HAC-60 S</td>
<td>M20</td>
<td>18.5 mm (0.73&quot;)</td>
</tr>
</tbody>
</table>

**Table 2.2.11.4 — Channel lip thickness**

<table>
<thead>
<tr>
<th>Anchor Channel profile</th>
<th>Channel lip thickness, (L_{th})</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40</td>
<td>7/64 in (0.29 mm)</td>
</tr>
<tr>
<td>HAC-50</td>
<td>1/8 in (3.17 mm)</td>
</tr>
<tr>
<td>HAC-60</td>
<td>5/32 in (1.58 mm)</td>
</tr>
<tr>
<td>HAC-70</td>
<td>13/64 in (0.51 mm)</td>
</tr>
</tbody>
</table>

**Minimum bolt overhang**

According to AISC Steel Construction Manual, 13th Edition, Section 14.10: “Adequate thread engagement for anchor rods is identical to the condition described in the RCSC Specification as adequate for steel to steel structural joints using high strength bolts: having the end of the [anchor rod] flush with or outside the face of the nut.”

There is no maximum thread protrusion limit from the standpoint of the function of the bolt.

If needed, the excess at the end of the bolt can be cut-off. The nut shall be fully engaged. The outside face of the head of the t-bolt has special markings to identify the t-bolt type and proper head orientation of the t-bolt. If the t-bolt is to be cut or grind, inspect and ensure the orientation and t-bolt type is as specified.

**Figure 2.2.11.5 — Overhang of Hilti Locking Channel Bolt (HBC-C-N).**

**Table 2.2.11.5 — Recommended t-bolt overhang, \(L_o\)**

<table>
<thead>
<tr>
<th>Bolt type</th>
<th>Units</th>
<th>Minimum nominal overhang, (L_o)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12</td>
<td>1/8 in</td>
<td>0.73 mm</td>
</tr>
<tr>
<td>M16</td>
<td>13/64 in</td>
<td>1.58 mm</td>
</tr>
<tr>
<td>M20</td>
<td>9/32 in</td>
<td>1.58 mm</td>
</tr>
</tbody>
</table>

Although there is minimum t-bolt overhang \(L_o\) can be zero, for tolerance purposes it is recommended to have a minimum t-bolt overhang. **Table 2.2.11.5 provides the minimum t-bolt overhang length.**

**Installation Torque**

**Table 8-2 — Installation torque for Hilti Locking Channel Bolts (HBC-C-N)**

<table>
<thead>
<tr>
<th>Bolt type</th>
<th>Installation torque (T_{inst}) (Installation type A)**</th>
<th>Installation torque (T_{inst}) (Installation type B)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBC-C-N M12</td>
<td>8.8</td>
<td>R-18 (Nm)</td>
</tr>
<tr>
<td>HBC-C-N M16</td>
<td>8.8</td>
<td>R-18 (Nm)</td>
</tr>
<tr>
<td>HBC-C-N M20</td>
<td>8.8</td>
<td>R-18 (Nm)</td>
</tr>
</tbody>
</table>

**1** Installation type A: The fixture is in contact with the channel profile and the concrete surface; fixture is in contact with the channel profile only.

**2** Installation type B: The fixture is fastened to the anchor channel by suitable steel part (e.g. square plate washer), fixture is in contact with the channel profile only.
Hexagonal head nut
Anchor channel systems consist of a group of anchors, channel profile, and matching t-bolt. The t-bolt hardware consists of a hex head nut and a flat washer.

Table 2.2.12.1 — Material specifications of HBC-C and HBC-C-N Nuts

<table>
<thead>
<tr>
<th>Material specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>Finish</td>
</tr>
<tr>
<td>Thread</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2.2.12.2 — HBC-C and HBC-C-N nut dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
</tr>
<tr>
<td>p (pitch size)</td>
</tr>
<tr>
<td>d max.</td>
</tr>
<tr>
<td>d min.</td>
</tr>
<tr>
<td>d1 max.</td>
</tr>
<tr>
<td>d1 min.</td>
</tr>
<tr>
<td>d2 max.</td>
</tr>
<tr>
<td>a min.</td>
</tr>
<tr>
<td>m max.</td>
</tr>
<tr>
<td>m min.</td>
</tr>
<tr>
<td>m2 min.</td>
</tr>
<tr>
<td>s max.</td>
</tr>
<tr>
<td>s min.</td>
</tr>
</tbody>
</table>

Different surfaces and materials might have a significant influence on the ratio between torque moment and pre-tension. Therefore, it is important to use the washer as per product approval or recommended by Hilti.

Flat washers
Flat washers ensure compression forces (due to installation torque) from the nut are distributed over a larger surface, preventing localized damage of the base surface. Moreover, it ensures the nut presses against a smooth surface, reducing the probability of relaxation of the nut, as is the case when the nut bears against uneven surfaces.

Table 2.2.12.3 — Material specification of HBC-C and HBC-C-N washers

<table>
<thead>
<tr>
<th>Material specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Specifications</td>
</tr>
<tr>
<td>Finish</td>
</tr>
</tbody>
</table>

Figure 2.2.12.1 — Isometric view of HBC-C and HBC-C-N nut.

Figure 2.2.12.2 — HBC-C and HBC-C-N nut dimensions.

Figure 2.2.12.3 — HBC-C and HBC-C-N washer dimensions.
Hilti Anchor Channel with serrated channel lips (HAC-30 and HAC-T) is a cast-in solution for applications that require on-site adjustability and slip resistances along the long axis of the anchor channel resulting from loads such as seismic wind, live, gravity or other.

HAC-30 profile is cold formed and although its name does not include ‘-T’, the profile comes with serrated lips, HAC-30 is for low range loads. The innovative manufacturing technology allows HAC-T to offer slip resistances that require up to 58 percent lower installation torques than existing technologies without compromising the price point or performance of the anchorage. Because of the lower installation torque, the installation time per connection can be reduced and muscle fatigue may be avoided. HAC-30 and HAC-T are fully covered by the International Council Code Evaluation Service Report 3520 (ESR-3520).

Hilti Anchor Channels with serrated channel lips (HAC-T) are offered in two channel profile sizes; HAC-T50 and HAC-T70. Hilti Serrated Channel Bolts (HBC-T) are suitable for all HAC-T profiles. HAC-T50 and HAC-T70 profiles are utilized in all different types of anchor channels.

Hilti Anchor Channel (HAC-T) come with a serrated channel profile and rounded head anchors. Pre-formed serrations allows the channel to resist longitudinal shear loads via a positive connection with lower installation torque.

The standard portfolio consists of HAC30, HAC-T50, and HAC-T70 channels profiles with pre-defined channel length, rebar lengths, number of anchors, and defined rebar diameter. Non-standard anchor channels (i.e. custom channel length, rebar length, number of rebars etc.) can be provided upon request. Refer to section 2.4, 2.5, and 2.6 for additional information about standard items lead times, and custom anchor channels.

### 2.2.13 SERRATED ANCHOR CHANNELS: HAC-T AND HAC-30

#### Table 2.2.13.1 — Geometric parameters of serrated anchor channels

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor channel size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel profile height</td>
<td>( h_n )</td>
<td>mm</td>
<td>HAC-30 HAC-T50 HAC-T70</td>
</tr>
<tr>
<td>Channel profile width</td>
<td>( b_n )</td>
<td>mm</td>
<td>HAC-30 HAC-T50 HAC-T70</td>
</tr>
<tr>
<td>Channel profile moment of inertia</td>
<td>( I_n )</td>
<td>mm(^2)</td>
<td>(15,349) (32,049) (92,192)</td>
</tr>
<tr>
<td>Channel profile opening</td>
<td>( d )</td>
<td>mm</td>
<td>(22.38) (19.50) (19.50)</td>
</tr>
<tr>
<td>Channel lip flange thickness</td>
<td>( t )</td>
<td>mm</td>
<td>(7.50) (3.50) (7.40)</td>
</tr>
<tr>
<td>Channel lip thickness</td>
<td>( t_m )</td>
<td>mm</td>
<td>(0.079) (0.11) (0.18)</td>
</tr>
<tr>
<td>Channel lip thickness (bottom)</td>
<td>( t_m )</td>
<td>mm</td>
<td>(0.079) (0.11) (0.18)</td>
</tr>
<tr>
<td>Serration height</td>
<td>( S_n )</td>
<td>mm</td>
<td>(0.057) (0.057) (0.145)</td>
</tr>
<tr>
<td>Serration spacing</td>
<td>( S_n )</td>
<td>mm</td>
<td>(0.118) (0.118) (0.118)</td>
</tr>
<tr>
<td>Min. effective embedment depth(^1)</td>
<td>( h_{nem} )</td>
<td>mm</td>
<td>(2.68) (3.70) (4.17)</td>
</tr>
<tr>
<td>Thickness of the anchor head</td>
<td>( t_a )</td>
<td>mm</td>
<td>(0.08) (0.14) (0.20)</td>
</tr>
<tr>
<td>Nominal embedment depth(^2)</td>
<td>( h_{nem} )</td>
<td>mm</td>
<td>(2.76) (3.84) (4.31)</td>
</tr>
<tr>
<td>Minimum end spacing</td>
<td>( h_{se} )</td>
<td>mm</td>
<td>(0.098) (0.098) (0.098)</td>
</tr>
<tr>
<td>Anchor shaft diameter</td>
<td>( d_2 )</td>
<td>mm</td>
<td>(0.21) (0.21) (0.21)</td>
</tr>
<tr>
<td>Head diameter(^3)</td>
<td>( d_2 )</td>
<td>mm</td>
<td>(0.45) (0.77) (0.91)</td>
</tr>
<tr>
<td>Anchor length</td>
<td>( l_a )</td>
<td>mm</td>
<td>(1.75) (2.82) (3.19)</td>
</tr>
<tr>
<td>Minimum anchor spacing</td>
<td>( h_{ms} )</td>
<td>mm</td>
<td>(1.97) (3.94) (3.94)</td>
</tr>
<tr>
<td>Maximum anchor spacing</td>
<td>( h_{ms} )</td>
<td>mm</td>
<td>(1.84) (5.84) (9.84)</td>
</tr>
<tr>
<td>Net bearing area of the anchor head(^4)</td>
<td>( A_{nem} )</td>
<td>mm(^2)</td>
<td>(0.138) (0.4) (0.552)</td>
</tr>
<tr>
<td>Matching channel bolt</td>
<td></td>
<td></td>
<td>HBC-B HBC-T</td>
</tr>
<tr>
<td>Minimum channel bolt spacing</td>
<td>( h_{mb} )</td>
<td>mm</td>
<td>(3 x bolt diameter)</td>
</tr>
</tbody>
</table>

---

\(^1\) Manufacturing tolerance is ±0.06 in (1.58 mm).

\(^2\) The head diameter is the inner diameter of the hexagonal shaped head, and does not fully reflect the cross sectional area of the anchor head.

\(^3\) Net hole diameter is 4 in (10.16 mm).

---

Figure 2.2.13.1 — Hilti Serrated Anchor Channel (HAC-T)

Figure 2.2.13.3 — Section view of HAC-T50 and HAC-T70
Minimum substrate requirements for HAC-T and HAC-30

The minimum edge distance and member thickness for anchor channels are established via testing. It is the interaction between minimum member thickness and minimum edge distance that determines the minimum edge distance. If the anchor channel is installed closer than the minimum edge distance, cracking of the concrete may occur while applying the required installation torque to the t-bolts. Testing to determine the minimum edge distance considers unfavorable site conditions. The test is based on having the anchor channel recessed 1/8" in unreinforced concrete. Splitting/cracking may occur. Therefore, minimum substrate requirements vary depending on the anchor channel size. HAC-T substrate requirements are provided in Table 2.2.13.2 and 2.2.13.3.

Table 2.2.13.2 — Minimum substrate dimensions for HAC-T and HAC-30 in normal weight and sand-lightweight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>h_eff</th>
<th>Minimum c_a1</th>
<th>Minimum c_a2</th>
<th>h_min</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-30</td>
<td>mm</td>
<td>2.68</td>
<td>1.97</td>
<td>1.97</td>
<td>3.15</td>
</tr>
<tr>
<td>HAC-T50</td>
<td>mm</td>
<td>3.70</td>
<td>3.94</td>
<td>3.94</td>
<td>3.94</td>
</tr>
<tr>
<td>HAC-T70</td>
<td>mm</td>
<td>4.17</td>
<td>1.97</td>
<td>1.97</td>
<td>4.92</td>
</tr>
</tbody>
</table>

Corner distance facts:
- Any edge parallel to the long axis of the anchor channels is considered a corner.
- For determination of the minimum corner distance, c_cca1 = min of c_a1 and c_a2.
- Corner distances are always measured from the center of the anchor under consideration.

Corner and edge distances are measured to the center of the anchor. Figure 2.2.13.6 — Minimum HAC-T and HAC-30 edge and corner distances, plan view.

Corner distance c_cca1 is measured to the center of the anchor. Figure 2.2.13.7 — Minimum HAC-T and HAC-30 member thickness, isometric view.

Corner distance c_cca2 is measured to the center of the anchor. Figure 2.2.14.2 — Minimum corner distances for pair of HAC-T, plan view.

Table 2.2.13.3 — Minimum substrate dimensions for HAC-T and HAC-30 in all lightweight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>h_eff</th>
<th>Minimum c_a1</th>
<th>Minimum c_a2</th>
<th>h_min</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-30</td>
<td>mm</td>
<td>2.68</td>
<td>2.95</td>
<td>2.95</td>
<td>3.15</td>
</tr>
<tr>
<td>HAC-T50</td>
<td>mm</td>
<td>3.70</td>
<td>3.94</td>
<td>3.94</td>
<td>3.94</td>
</tr>
<tr>
<td>HAC-T70</td>
<td>mm</td>
<td>4.17</td>
<td>2.95</td>
<td>2.95</td>
<td>4.92</td>
</tr>
</tbody>
</table>

Edge distance facts:
- Any edge perpendicular to the long axis of the anchor channels is considered an edge.
- For determination of the minimum edge distance, c_e = min of c_a1 and c_a2.
- For analysis purposes, c_e is always measured in the direction of the applied shear load.
- Edge distances are always measured from the center of the anchor under consideration.

Single HAC-T or HAC-30 in face of slab corners

AC232 provides design guidelines to account for the influence of corners where only one anchor channel is present. The design of this type of applications is covered in ESR-3520. Table 2.2.13.1 provides the minimum edge and corner distances for HAC-T and HAC-30.

Table 2.2.14.2 — Minimum substrate edge and corner distances for pair of HAC-T or HAC-30 in corners in normal weight, sand-lightweight and all-lightweight concrete

For face of slab applications, it is not recommended to install HAC-T or HAC-30 in both sides of the corner if there is no overlapping of the anchors. Additional measurements shall be taken in consideration to account for the negative influence of the adjacent anchor channel, if both channels are to be loaded simultaneously. See chapter 9, Anchor Channel Design for additional design information. Although this solution is technically feasible, installing anchor channels at 4 to 7 inches away from the corner typically results in unpractical bracket sizes, large eccentricities, large forces, and consequently, inadequate concrete strengths.

Table 2.2.14.2 and figure 2.2.14.2 provide information about the minimum corner distance for pair of HAC-T. See chapter 9, Anchor Channel Design for additional design information.

Pair of HAC-T or HAC-30 in a corner

AC232 does not include provisions to account for the influence of an adjacent channel in a face of slab corner. Technically, HAC-T or HAC-30 can be used in both sides of the corner if there is no overlapping of the anchors. The overlapping of the two anchor channels creates a weakened failure plane, making the corner susceptible to undesired cracking and therefore, reduced concrete strengths.

For all lightweight concrete, c_e = 2.95" (75 mm).
2.2.15 HAC-T AND HAC-30 IN TOP OR BOTTOM OF SLAB CORNERS

Single HAC-T or HAC-30 in top of slab corner

HAC-T and HAC-30 in top or bottom of slab corners are equal.

Table 2.2.15.1 — Minimum substrate edge and corner distances for single HAC-T in a corner in normal weight, sand-lightweight, and All light-weight concrete

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>Minimum ( c_{a1} )</th>
<th>Minimum ( c_{a2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-30</td>
<td>in (mm)</td>
<td>2.68 (68)</td>
<td>1.97 (50)</td>
</tr>
<tr>
<td>HAC-T50</td>
<td>in (mm)</td>
<td>3.70 (94)</td>
<td>3.94 (100)</td>
</tr>
<tr>
<td>HAC-T70</td>
<td>in (mm)</td>
<td>4.17 (106)</td>
<td>1.97 (50)</td>
</tr>
<tr>
<td>HAC-T75</td>
<td>in (mm)</td>
<td>6.89 (175)</td>
<td>2.95 (75)</td>
</tr>
</tbody>
</table>

*For all-lightweight concrete, \( c_{a1} = c_{a2} = 2.95" \) (75 mm)

Figure 2.2.15.1 — Minimum corner distance for single HAC-T and HAC-30 in top of slab, plan view.

Corner distance \( c_{a2} \) is measured to the center of the anchor.

Figure 2.2.15.2 — Minimum corner distance for pair of HAC-T or HAC-30 in top of slab, plan view.

Corner distance \( c_{a2} \) is measured to the center of the anchor.

Figure 2.2.15.3 — Corner configuration of pair of HAC-T or HAC-30 in top of slab.

Pair of HAC-T or HAC-30 in top of slab corners

AC232 does not include provisions to account for the influence of an adjacent anchor channel. Technically, HAC-T can be used in both sides of the corner.

Additional measurements shall be taken into consideration to account for the negative influence of the adjacent anchor channel, if both channels are to be loaded simultaneously. See chapter 9, Special Anchor Channel Design for additional design information.

The minimum corner distances for pair of HAC-T in top of slab corners \( (c_{a2}) \) are consistent with table 2.2.15.1. These minimum distances are based on installation requirements. Both HAC-T at corners cannot be installed at the minimum corner distance due to physical constraints (clashing of HAC-T will occur).

However, two HAC can be installed next to each other in a corner configuration where the anchor channels are installed perpendicular to each other.

Figure 2.2.15.2 illustrates a pair of HAC-T in a corner. Corner distances greater than the minimum corner distance may be required based on the structural adequacy of the concrete at the corner.

Design of top of slab corners

Hilti has developed a model to account for the influence of adjacent and corner channels. The model follows the fundamentals of AC232 and allows analysis of more complex but typical applications encountered in a project such as the conditions shown in Figure 2.2.15.3. See chapter 9, Special Anchor Channel Design for additional design information.

2.2.16 HAC-T EDGE LITE, HAC-T EDGE, AND HAC-T S EDGE

Hilti Anchor Channels with serrated channel lips and rebar edge confinement plate (HAC-T EDGE Lite and HAC EDGE) and HAC-T EDGE with superior steel performance (HAC-T S EDGE) are offered in HAC-T50 profiles. The anchor channel is identical to its matching HAC-T, except the rebar edge confinement plate (EDGE Lite or EDGE plate) is incorporated for superior concrete performance in shear.

The standard portfolio consists of HAC-T50 with two defined nominal anchor heights: 4.31" (109.50 mm) and 3.84" (97.50 mm). Moreover, defined channel length, EDGE Plate geometry, rebar lengths, anchor and rebar diameter, and number of rebar are also defined. The number of anchors per channel is pre-defined and can be modified and ordered upon request. Refer to section 2.4 for additional information about standard items and lead times.

The concrete edge shear confinement plate (EDGE plate) is fixed to the form work or pour stop. The EDGE plate comes with installation holes. As an added value, the product comes with the specified edge distance \( c_{a2} \).

HAC-T EDGE Lite and HAC EDGE

These anchor channel systems consist of HAC-T and the new rebar edge confinement plate (EDGE plate). The EDGE plate is not structurally attached to the anchor channel. This allows decoupling of the tension and shear forces. HAC-T50 EDGE C comes with an offset rebar and increased height of the front plate.

HAC-T S EDGE

This anchor channel is equal to its matching HAC-T EDGE, except the "S" bracket is added. The "S" bracket offers superior steel performance. The S bracket is structurally attached to the anchor channel. The S-bracket has a similar geometry to the connected channel profile to ensure direct bearing of the S bracket on the channel profile.
2.1 HAC Nomenclature

2.2 Geometric Parameters

2.3 Structural Performance

2.4 Ordering Information

2.5 Standard Portfolio

2.6 HAC Custom Solutions

Figure 2.2.16.2 - Section view of HAC-T50 EDGE Lite.

Figure 2.2.16.3 - Section view of HAC-T50 EDGE Lite (h_g = 94 mm) and HAC-T50 EDGE C.

Figure 2.2.16.4 - Section view of HAC-T50 S EDGE and HAC-T50 S EDGE C.

Figure 2.2.16.5 - Section view of HAC-T50 S EDGE (h_g = 94 mm) and HAC-T50 S EDGE C.
HAC-T50 EDGE Lite, HAC-T50 EDGE, and HAC-T50 S EDGE utilize HAC-T50 with rounded head anchors. HAC-T50 is covered by ICC ESR-3520. HAC-T50 with reduced embedment depth \( h_{e, m} = 3.70 \) (94 mm) is not covered by ESR-3520.

Table 2.2.16.1 provides geometric parameters for the anchor channels that compose the HAC-T EDGE product line. Tables 2.2.16.2 and 2.2.16.3 provide geometric information about the EDGE Lite, EDGE, and S EDGE Plate. These components increase the perpendicular concrete edge breakout strength.

The S brackets improve the shear steel performance (perpendicular shear) of HAC. Dimensions of the S bracket are given in Figures 2.2.16.8 and 2.2.16.9.

### Table 2.2.16.1 — Geometric parameters for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T S EDGE

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. effective embedment depth</td>
<td>( h_{e, m} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Thickness of the anchor head</td>
<td>( t_h )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Nominal embedment depth</td>
<td>( \Delta h_{n} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel profile height</td>
<td>( h_0 )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel profile width</td>
<td>( b_0 )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel profile moment of inertia</td>
<td>( I_{y} )</td>
<td>mm²</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel profile opening</td>
<td>( d_0 )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel tip flange thickness</td>
<td>( t )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel tip thickness (top)</td>
<td>( t_{top} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Channel tip thickness (bottom)</td>
<td>( t_{bot} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Minimum end spacing</td>
<td>( x_{min} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Anchor shaft diameter</td>
<td>( d_0 )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Head diameter</td>
<td>( d_t )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Anchor length</td>
<td>( l_a )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Minimum anchor spacing</td>
<td>( s_{min} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Maximum anchor spacing</td>
<td>( s_{max} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Net bearing area of the anchor head</td>
<td>( A_n )</td>
<td>mm²</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Matching channel bolt</td>
<td>( HBC-T )</td>
<td></td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Minimum channel bolt spacing</td>
<td>( x_{min,b} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
<tr>
<td>Nail hole location</td>
<td>( x_{nail} )</td>
<td>mm</td>
<td>HAC-T50 EDGE Lite</td>
</tr>
</tbody>
</table>

---

1. Head diameter is the inner diameter of the hexagonal shaped head, and does not fully reflect the cross-sectional area of the anchor head.
2. HAC-T EDGE C is the matching corner channel and has the same anchor channel as the intermediate HAC EDGE. The shear confinement plate has different geometry.
3. Effective embedment depth not covered by ICC ESR-3520.
4. Anchor head diameter is equal to \( 4.16 \) (0.16 in.)
Table 2.2.16.3 — Geometric parameters for HAC-T S EDGE rebar edge confinement plate (EDGE Plate)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of the EDGE plate</td>
<td>t_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Height of the EDGE plate</td>
<td>h_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Projection of the EDGE plate</td>
<td>x_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Length of the EDGE plate</td>
<td>l_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Overall length of the EDGE plate rebar</td>
<td>l_{\text{t}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Bar effective cross-sectional area</td>
<td>a_{\text{f}}</td>
<td>mm² (in²)</td>
</tr>
<tr>
<td>Minimum rebar spacing</td>
<td>s_{\text{min,R}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Maximum rebar spacing</td>
<td>s_{\text{max,R}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Reinforcement diameter</td>
<td>d_{\text{b}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Edge distance (ca1) from the face of the slab (outer face of the EDGE plate)</td>
<td>ca1</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Edge distance (ca2) from the face of the edge of slab (outer face of the EDGE plate) to the center of the anchor</td>
<td>ca2</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Distance from the end of the EDGE plate to the center of the installation hole</td>
<td>d_{\text{i}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Minimum substrate dimension</td>
<td>h_{\text{min}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Thickness of the EDGE plate</td>
<td>t_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Height of the EDGE plate</td>
<td>h_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Projection of the EDGE plate</td>
<td>x_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Length of the EDGE plate</td>
<td>l_{\text{p}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Overall length of the EDGE plate rebar</td>
<td>l_{\text{t}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Bar effective cross-sectional area</td>
<td>a_{\text{f}}</td>
<td>mm² (in²)</td>
</tr>
<tr>
<td>Minimum rebar spacing</td>
<td>s_{\text{min,R}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Maximum rebar spacing</td>
<td>s_{\text{max,R}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Reinforcement diameter</td>
<td>d_{\text{b}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Edge distance (ca1) from the face of the slab (outer face of the EDGE plate)</td>
<td>ca1</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Edge distance (ca2) from the face of the edge of slab (outer face of the EDGE plate) to the center of the anchor</td>
<td>ca2</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Distance from the end of the EDGE plate to the center of the installation hole</td>
<td>d_{\text{i}}</td>
<td>in (mm)</td>
</tr>
<tr>
<td>Minimum substrate dimension</td>
<td>h_{\text{min}}</td>
<td>in (mm)</td>
</tr>
</tbody>
</table>

Table 2.2.16.4 — Minimum substrate dimensions for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T S EDGE

<table>
<thead>
<tr>
<th>Anchor Channel</th>
<th>h_{\text{p}}</th>
<th>t_{\text{p}}</th>
<th>h_{\text{min}}</th>
<th>ca1</th>
<th>ca2</th>
<th>(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-T50 S EDGE Lite</td>
<td>3.70</td>
<td>3.94</td>
<td>1.97</td>
<td>1.97</td>
<td>1.97</td>
<td>(100)</td>
</tr>
<tr>
<td>HAC-T50 EDGE C</td>
<td>4.17</td>
<td>4.92</td>
<td>2.36</td>
<td>2.36</td>
<td>2.36</td>
<td>(125)</td>
</tr>
<tr>
<td>HAC-T50 S EDGE C</td>
<td>4.17</td>
<td>4.92</td>
<td>2.36</td>
<td>2.36</td>
<td>2.36</td>
<td>(125)</td>
</tr>
<tr>
<td>HAC-T50 EDGE (C)</td>
<td>4.17</td>
<td>4.92</td>
<td>2.36</td>
<td>2.36</td>
<td>2.36</td>
<td>(125)</td>
</tr>
<tr>
<td>HAC-T50 S EDGE (C)</td>
<td>4.17</td>
<td>4.92</td>
<td>2.36</td>
<td>2.36</td>
<td>2.36</td>
<td>(125)</td>
</tr>
</tbody>
</table>

Min. substrate requirements for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T S EDGE

Similarly, to HAC, the minimum edge distances for HAC EDGE are established via testing. Although the HAC EDGE product line are not implicitly covered in AC232, AC232 provides testing protocols for anchor channels to establish the minimum edge and corner distance for the minimum member thickness. The following substrate requirements have been established in accordance with testing protocols of AC232.

Minimum edge distance for anchor channels in composite slabs

The minimum edge and corner distances for HAC-T EDGE are consistent with the minimum requirements of HAC. However, as a response to the market trends, composite slabs with pockets, Hilti has added HAC EDGE-T with shorter anchor lengths.

For composite slabs where there is a pour stop along the perimeter of the edge of slab prevent, prevent oxygen from reaching out to the bottom of the slab, the minimum member thickness can be reduced.

Chapters 8 and 9 provide design information for HAC-T EDGE in composite slabs and how to account for the potential negative influence of the metal deck.
2.2.17 HAC-T EDGE AND HAC-T S EDGE IN TOP OR BOTTOM OF SLAB CORNERS

Pair of HAC-T EDGE and HAC-T S EDGE in top of slab corners

HAC-T EDGE and HAC-T S EDGE are ideal for top of slab corner applications. Two independent anchor channels at the corner allows de-coupling the loads at both channels, preventing anchors and rebars from taking undesired loads. Furthermore, using two independent channels eases the installation in congested areas, preventing damage of the anchors during installation.

New Hilti design method for corners follows the principles of AC232 and allows the anchor channels to be installed as close as physically possible to the corner, as long as the minimum corner and edge distances are not exceeded. The use of HAC-T EDGE allows the concrete to take higher shear forces, making it the perfect solution for corner applications.

HAC-T EDGE at corner requires the use of HAC-T EDGE and HAC-T EDGE C. The EDGE C plate of HAC-T EDGE C comes with rebars that are located 1 rebar diameter below the bottom of the channel profile to prevent clashing of the rebars with the HAC-T EDGE.

Table 2.2.17.1 — Minimum substrate edge and corner for pair of HAC-T EDGE and HAC-T S EDGE at a corner.

<table>
<thead>
<tr>
<th>Anchor channel</th>
<th>Units</th>
<th>$h_a$</th>
<th>$h_{min}$</th>
<th>$C_a$</th>
<th>$C_{a1}$</th>
<th>$C_{a2}$</th>
<th>$C_{a}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 EDGE</td>
<td>in</td>
<td>3.70</td>
<td>(94)</td>
<td>3.94</td>
<td>(100)</td>
<td>3.94</td>
<td>(100)</td>
</tr>
<tr>
<td>HAC-50 EDGE C</td>
<td>in</td>
<td>4.17</td>
<td>(105)</td>
<td>4.92</td>
<td>(125)</td>
<td>3.94</td>
<td>(100)</td>
</tr>
<tr>
<td>Sand lightweight concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAC-50 S EDGE</td>
<td>in</td>
<td>3.70</td>
<td>(94)</td>
<td>3.94</td>
<td>(100)</td>
<td>3.94</td>
<td>(100)</td>
</tr>
<tr>
<td>HAC-50 S EDGE C</td>
<td>in</td>
<td>4.17</td>
<td>(105)</td>
<td>4.92</td>
<td>(125)</td>
<td>3.94</td>
<td>(100)</td>
</tr>
</tbody>
</table>

2.2.18 HILTI SERRATED CHANNEL BOLTS

The Hilti Serrated Channel Bolts (HBC-T and HBC-B) are part of the anchor channel system. HBC are threaded fasteners commonly known as T-bolts. HBC are the link between the fixture and anchor channel. The HBC have a proprietary head geometry and are compatible with Hilti channels only. The head of the HBC-T or HBC-B can be inserted along the channel cavity. The fixture is connected to the anchor channel by channel bolts with a nut and washer. Thus, allowing for the so needed jobsite tolerance.

The head of the t-bolt is first installed parallel to the channel profile. Once it is positioned in place, the bolt is turned 90° clockwise. The head of the bolt has been engineered in a way that the t-bolt cannot rotate more than 90° clockwise. This ensures that the bolt is properly positioned before the installation torque is applied.

HBC-T and HBC-B come with a special marking to ease the identification before and after installation. All Hilti serrated channel bolts are covered by ESR-3520.

2.2.19 HILTI SERRATED CHANNEL BOLTS: HBC-T AND HBC-B

Hilti serrated channel bolts (HBC-T) are only suitable for channel profiles HAC-T50 & HAC-T70. HBC-T come in bolt diameters M12, M16, and M20, steel grades 8.8 and HDG finishing. Hilti serrated channel bolts (HBC-B) are only suitable for channel profiles HAC-T30.

HBC-T and HBC-B can be used to transfer tensile loads, shear loads perpendicular to the longitudinal channel axis, longitudinal shear forces, or any combination of these loads. Transferring of the loads takes place via interlock of the serrations of the HBC-T and serrated lips of HAC-T or HBC-B and serrated lips of HAC-30.

Table 2.2.19.1 — Hilti Serrated Channel Bolts (HBC-T) material information

<table>
<thead>
<tr>
<th>Channel bolt</th>
<th>Carbon steel¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material class</td>
<td>8.8</td>
</tr>
<tr>
<td>fy</td>
<td>(N/mm²)</td>
</tr>
<tr>
<td>fy</td>
<td>(N/mm²)</td>
</tr>
<tr>
<td>Coating F</td>
<td></td>
</tr>
</tbody>
</table>

1. Material according to Annex 3, Table 1
2. Hot-dip galvanized

Special markings on the t-bolt aid the installer to ensure the bolt is properly positioned before the installation torque is applied. Moreover, it allows the installer and inspector to identify the type of bolt after the fixture is installed.
Minimum t-bolt overhang

According to AISC Steel Construction Manual, 13th Edition, Section 14-10: “Adequate thread engagement for anchor rods is identical to the condition described in the RCSC Specification as adequate for steel to steel structural joints using high strength bolts: having the end of the [anchor rod] flush with or outside the face of the nut”.

There is no maximum thread protrusion limitation from the standpoint of the function of the bolt.

If needed, the excess at the end of the bolt can be cut-off. The nut shall be fully engaged. The outside face of the head of the t-bolt has special markings to identify the t-bolt type and proper protection shall be required.

Onsite adjustability

Serrations of channel lip allow incremental longitudinal displacement of 1/8” (3 mm). If the bracket needs to be slightly adjusted, while a force is applied (i.e. hung panel), the HBC-T will not slide. The HBC-T need not to be loaded in order to reposition the bracket. Therefore, it is not acceptable to adjust the location of the t-bolts via hammering of the bracket, if the weight of the panel is applied on the bracket.

Installation Torque

Table 2.2.19.5 — Installation torque for Hilti serrated channel bolts (HBC-T and HBC-B)

<table>
<thead>
<tr>
<th>Bolt type</th>
<th>Units</th>
<th>Installation torque Tinst (Installation type A)</th>
<th>Installation torque Tinst (Installation type B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBC-T M10</td>
<td>11/16 in</td>
<td>15 (15)</td>
<td>11 (15)</td>
</tr>
<tr>
<td>HBC-T M12</td>
<td>3/8 in</td>
<td>19 (25)</td>
<td>19 (25)</td>
</tr>
<tr>
<td>HBC-T M16</td>
<td>5/8 in</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>HBC-T M20</td>
<td>N/A</td>
<td>55 (75)</td>
<td>N/A</td>
</tr>
<tr>
<td>HBC-T M24</td>
<td>N/A</td>
<td>74 (105)</td>
<td>N/A</td>
</tr>
<tr>
<td>HBC-B M12</td>
<td>N/A</td>
<td>89 (125)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1 Installation type A: The fixture is in contact with the channel profile and the concrete surface.

2 Installation type B: The fixture is fastened to the anchor channel by suitable steel part (e.g. square plate washer). Fixture is in contact with the channel profile only.

Hexagonal head nut

Anchor channel systems consist of a group of anchors, channel profile, and matching t-bolt. The t-bolt hardware consists of a hex head nut and a flat washer.

Table 2.2.20.1 — Material specifications of HBC-T nuts

<table>
<thead>
<tr>
<th>Material specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>ASTM A 563 Grade A; Stainless Steel 316</td>
</tr>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>ASME/BANS16.2-2.2-1996</td>
</tr>
<tr>
<td>Finish</td>
</tr>
<tr>
<td>ASTM B 633-96, SC 1 Type I</td>
</tr>
<tr>
<td>Thread</td>
</tr>
<tr>
<td>Class 2A; Class 2B; Hrcd; ASME B1.1</td>
</tr>
</tbody>
</table>

Different surfaces and materials might have a significant influence on the ratio between torque moment and pre-tension. Therefore, it is important to use the washer as per product approval or recommended by Hilti.
Flat washers

Ensures compression forces (due to installation torque) from the nut are distributed over a larger surface, preventing localized damage of the base surface. Moreover, it ensures the nut presses against a smooth surface, reducing the probability of relaxation of the nut, as is the case when the nut bears against uneven surfaces.

Table 2.2.20.3 — Material specification of HBC-T washers

<table>
<thead>
<tr>
<th>Material specifications</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel, Hardness A, 200 HV</td>
<td>ISO 7089 and ISO 7093-1</td>
</tr>
</tbody>
</table>

| Finish | Iso 10684 |

Table 2.2.20.4 — HBC-T washer dimensions

<table>
<thead>
<tr>
<th>Order Designation</th>
<th>Suitable for channel bolt</th>
<th>Inner diameter, D1</th>
<th>Outer, diameter D</th>
<th>Thickness, T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat washer A 13/24-F</td>
<td>M12</td>
<td>13 (0.51)</td>
<td>24 (0.94)</td>
<td>2.5 (0.10)</td>
</tr>
<tr>
<td>Flat washer A 17/30-F</td>
<td>M16</td>
<td>17 (0.67)</td>
<td>30 (1.18)</td>
<td>3 (0.12)</td>
</tr>
<tr>
<td>Flat washer A 21/37-F</td>
<td>M20</td>
<td>22 (0.87)</td>
<td>37 (1.46)</td>
<td>3 (0.12)</td>
</tr>
</tbody>
</table>

2.3 STRUCTURAL STEEL PERFORMANCE OF HILTI ANCHOR CHANNEL SYSTEMS

The design of cast-in anchor channels requires the verification of up to 25 different failure modes. As is the case with any other type of anchor, its design requires the verification of the adequacy of the steel, concrete at the anchorage zone, and/or anchor reinforcement. In addition, up to 5 interaction equations are required to complete the design of the anchor channel. Figure 2.3.1.1 illustrates the possible failure modes of a cast-in anchor channel system with rounded head anchors (HAC and HAC-T). Some of the failure modes illustrated on Figure 2.3.1.1 are not applicable to HAC CRFoS U while there are additional failure modes to HAC EDGE. For instance, pry-out is not applicable to HAC CRFoS U.

This chapter provides information about the structural performance of the Hilti cast-in anchor channel system. Therefore, information about the steel strengths of the anchor channels for all possible steel failure modes are covered in this section.

Table 2.3.1.1 — Possible failure modes of an anchor channel.

Acceptance Criteria 232 (AC232) is a comprehensive document of technical guidelines and testing protocols for cast-in anchor channels systems. AC232 was established through public hearings with industry experts and building officials’ committee approval. The published steel strength values in this brochure are based on the International Code Council — Evaluation Service Report 3520 (ICC ESR-3520) when applicable. Steel strengths of anchor channels outside the scope of AC232 and ESR-3520 (i.e. HAC CRFoS U) have been derived in accordance with applicable testing protocols of AC232.

For additional design information such as interaction equations, impact of bolt spacing to anchor channel lip strength, etc., see anchor channel theory, see chapter 7. The provided steel strengths shall be applied in conjunction with the design guidelines provided in chapter 7. Moreover, refer to chapter 5 for information about the evaluation of the concrete at the anchorage zone and anchor reinforcement. Due of the number of factors that can influence the concrete performance, design guidelines are provided for its verification.

Possible failure modes of anchor channel per AC232

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Possible failure modes of anchor channel per AC232

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Possible failure modes of anchor channel per AC232
2.3.1 HAC STRUCTURAL STEEL PERFORMANCE — TENSION

Table 2.3.1.1 — Tension steel strength design information for Hilti Anchor Channels (HAC) with Hilti Channel Bolts (HBC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 F</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile strength for local failure of channel lip1</td>
<td>N_u</td>
<td>lb (kN)</td>
<td>5,620 (25.0)</td>
<td>7,685 (35.0)</td>
<td>11,240 (50.0)</td>
<td>15,960 (71.0)</td>
</tr>
<tr>
<td>Nominal tensile strength for local failure of channel lip for seismic design</td>
<td>N_u,seis</td>
<td>lb (kN)</td>
<td>5,620 (25.0)</td>
<td>7,685 (35.0)</td>
<td>7,855 (35.0)</td>
<td>15,960 (71.0)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lip1</td>
<td>ϕ</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal tensile strength of a single anchor</td>
<td>N_L</td>
<td>lb (kN)</td>
<td>7,080 (31.5)</td>
<td>11,240 (50.0)</td>
<td>11,240 (50.0)</td>
<td>16,320 (72.8)</td>
</tr>
<tr>
<td>Nominal tensile strength of a single anchor for seismic design</td>
<td>N_L,seis</td>
<td>lb (kN)</td>
<td>7,080 (31.5)</td>
<td>11,240 (50.0)</td>
<td>11,240 (50.0)</td>
<td>16,320 (72.8)</td>
</tr>
<tr>
<td>Strength reduction factor for anchor failure1</td>
<td>ϕ</td>
<td>-</td>
<td>0.65</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal tensile strength of connection between anchor and channel</td>
<td>N_L</td>
<td>lb (kN)</td>
<td>5,620 (25.0)</td>
<td>7,685 (35.0)</td>
<td>7,855 (35.0)</td>
<td>15,960 (71.0)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel1</td>
<td>ϕ</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C</td>
<td>M_u</td>
<td>kN·m (lb·ft)</td>
<td>10,050 (1,136)</td>
<td>14,125 (1,659)</td>
<td>16,355 (1,817)</td>
<td>28,000 (3,154)</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C-N</td>
<td>M_u,seis</td>
<td>kN·m (lb·ft)</td>
<td>10,050 (1,136)</td>
<td>14,125 (1,659)</td>
<td>16,355 (1,817)</td>
<td>28,000 (3,154)</td>
</tr>
</tbody>
</table>

1 The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

2.3.2 HAC STRUCTURAL STEEL PERFORMANCE — SHEAR

Table 2.3.2.1 — Shear steel strength design information for Hilti Anchor Channels (HAC) with Hilti Channel Bolts (HBC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 F</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength for local failure of channel lip</td>
<td>V_u</td>
<td>lb (kN)</td>
<td>7,833 (34.8)</td>
<td>10,675 (47.4)</td>
<td>16,205 (72.5)</td>
<td>21,590 (95.8)</td>
</tr>
<tr>
<td>Nominal shear strength for local failure of channel lip for seismic design</td>
<td>V_u,seis</td>
<td>lb (kN)</td>
<td>7,833 (34.8)</td>
<td>10,675 (47.4)</td>
<td>16,205 (72.5)</td>
<td>21,590 (95.8)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lip1</td>
<td>ϕ</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor</td>
<td>V_L</td>
<td>lb (kN)</td>
<td>8,903 (39.6)</td>
<td>12,050 (53.0)</td>
<td>17,378 (77.3)</td>
<td>25,790 (114.2)</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor for seismic design</td>
<td>V_L,seis</td>
<td>lb (kN)</td>
<td>8,903 (39.6)</td>
<td>12,050 (53.0)</td>
<td>17,378 (77.3)</td>
<td>25,790 (114.2)</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure1</td>
<td>ϕ</td>
<td>-</td>
<td>0.65</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel</td>
<td>V_L</td>
<td>lb (kN)</td>
<td>5,552 (25.1)</td>
<td>5,920 (26.3)</td>
<td>5,920 (26.3)</td>
<td>6,722 (29.9)</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel for seismic design</td>
<td>V_L,seis</td>
<td>lb (kN)</td>
<td>5,552 (25.1)</td>
<td>5,920 (26.3)</td>
<td>5,920 (26.3)</td>
<td>6,722 (29.9)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel1</td>
<td>ϕ</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel</td>
<td>V_L</td>
<td>lb (kN)</td>
<td>3,552 (15.8)</td>
<td>5,920 (26.3)</td>
<td>5,920 (26.3)</td>
<td>5,920 (26.3)</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel for seismic design</td>
<td>V_L,seis</td>
<td>lb (kN)</td>
<td>3,552 (15.8)</td>
<td>5,920 (26.3)</td>
<td>5,920 (26.3)</td>
<td>5,920 (26.3)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel1</td>
<td>ϕ</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

1 The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are allowed.

2.3.1 HAC STRUCTURAL STEEL PERFORMANCE — TENSION

Table 2.3.1.2 — Tension concrete strength design information for Hilti Anchor Channels (HAC)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 F</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge distance required to develop full concrete capacity in absence of anchor reinforcement</td>
<td>e_c</td>
<td>in (mm)</td>
<td>10.75 (273)</td>
<td>12.52 (318)</td>
<td>17.48 (444)</td>
<td>25.67 (657)</td>
</tr>
<tr>
<td>Strength reduction factor for tendon, concrete failure models1</td>
<td>ϕ</td>
<td>-</td>
<td>Condition A - 0.75</td>
<td>Condition B - 0.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.
Table 2.3.2.2 — Shear concrete strength design information for Hilti Anchor Channels (HAC) with Hilti Channel Bolts (HBC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 F</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td><strong>d</strong>&lt;sub&gt;shear&lt;/sub&gt;</td>
<td>lb/in&lt;sup&gt;2&lt;/sup&gt; (N/mm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>10.55</td>
<td>(75.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient for pryout strength</td>
<td><strong>k</strong>&lt;sub&gt;vp&lt;/sub&gt;</td>
<td>-</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Strength reduction factor for shear, concrete failure modes:

- **ϕ** = 0.75

1. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.3 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are met.

2. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

Table 2.3.2.3 — Steel strength design information for shear acting in longitudinal direction of the channel axis for Hilti Anchor Channels (HAC) with Hilti Locking Channel Bolts (HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Channel bolt type</th>
<th>HBC-C-N</th>
<th>HAC-40 F</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts</td>
<td><strong>V</strong>&lt;sub&gt;cr&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>M12&lt;sup&gt;1&lt;/sup&gt;</td>
<td>HBC-C-N</td>
<td>1,920</td>
<td>(8.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M16</td>
<td>4,420</td>
<td>(19.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M20</td>
<td>5,425</td>
<td>(24.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts for seismic design</td>
<td><strong>V</strong>&lt;sub&gt;cr,seis&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>M12&lt;sup&gt;1&lt;/sup&gt;</td>
<td>HBC-C-N</td>
<td>1,920</td>
<td>(8.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M16</td>
<td>4,420</td>
<td>(19.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M20</td>
<td>5,425</td>
<td>(24.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts (periodic inspection)</td>
<td><strong>ϕ</strong></td>
<td>-</td>
<td>M12</td>
<td>0.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M16</td>
<td>-</td>
<td>0.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M20</td>
<td>-</td>
<td>0.65</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are met.

2. In case of continuous inspection the value for **V**<sub>cr</sub> for the size M12 can be taken for all channel sizes HAC-40 F through HAC-70 F as **V**<sub>cr</sub> = 2,021 lb (9.0 kN).

Table 3.2.1.2 — Tension concrete strength design information for Hilti CRFoSU Hilti Anchor Channels (HAC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile steel strength for local failure of channel lips</td>
<td><strong>N</strong>&lt;sub&gt;sl&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>7,531</td>
<td>(33.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10,723</td>
<td>(47.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14,275</td>
<td>(63.5)</td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td><strong>ϕ</strong></td>
<td>-</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.3.3.1 — Tension steel strength design information for Hilti CRFoSU with Hilti Channel Bolts (HBC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile strength for local failure of channel lips</td>
<td><strong>N</strong>&lt;sub&gt;sl&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>7,531</td>
<td>(33.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10,723</td>
<td>(47.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14,275</td>
<td>(63.5)</td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for bending failure</td>
<td><strong>ϕ</strong></td>
<td>-</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2.1.2 — Tension concrete strength design information for Hilti Anchor Channels CRFoSU Hilti Anchor Channels (HAC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 F</th>
<th>HAC-60 F</th>
<th>HAC-70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile steel strength for local failure of channel lips</td>
<td><strong>N</strong>&lt;sub&gt;sl&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>14,125</td>
<td>(63.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>26,594</td>
<td>(118.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28,000</td>
<td>(127.6)</td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for bending failure</td>
<td><strong>ϕ</strong></td>
<td>-</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are allowed.

2. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are allowed.

3. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are allowed.
supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

### Table 2.3.4.1 — Shear strength design information for HAC CRFoS U with Hilti Channel Bolts (HBC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 F CRFoS U</th>
<th>HAC-60 F CRFoS U</th>
<th>HAC-70 F CRFoS U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength for local failure of channel lips</td>
<td>$V_{s,a}$</td>
<td>lb</td>
<td>10,675</td>
<td>16,205</td>
<td>21,550</td>
</tr>
<tr>
<td>Nominal shear strength for local failure of the channel lips for seismic design</td>
<td>$V_{s,a,seis}$</td>
<td>lb</td>
<td>10,675</td>
<td>16,205</td>
<td>21,550</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td>$\phi$</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor</td>
<td>$V_{a}$</td>
<td>lb</td>
<td>12,050</td>
<td>17,378</td>
<td>24,474</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor for seismic design</td>
<td>$V_{a,seis}$</td>
<td>lb</td>
<td>12,050</td>
<td>17,378</td>
<td>24,474</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure</td>
<td>$\phi$</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel</td>
<td>$V_{c,CH}$</td>
<td>lb</td>
<td>12,050</td>
<td>17,378</td>
<td>24,474</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel</td>
<td>$\phi$</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel lips</td>
<td>$V_{c,CHL}$</td>
<td>lb</td>
<td>4,519</td>
<td>6,430</td>
<td>8,565</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel for seismic design</td>
<td>$V_{c,CHL,seis}$</td>
<td>lb</td>
<td>4,519</td>
<td>6,430</td>
<td>8,565</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel lips</td>
<td>$\phi$</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor</td>
<td>$V_{a}$</td>
<td>lb</td>
<td>12,050</td>
<td>17,378</td>
<td>24,474</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor for seismic design</td>
<td>$V_{a,seis}$</td>
<td>lb</td>
<td>12,050</td>
<td>17,378</td>
<td>24,474</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure</td>
<td>$\phi$</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
</tbody>
</table>

1 The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

### Table 2.3.4.2 — Shear concrete strength design information for HAC CRFoS U with Hilti Channel Bolts (HBC-C and HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td>$a_{s,c}$</td>
<td>lb/in ($N/mm$)</td>
</tr>
<tr>
<td>Coefficient for pullout strength</td>
<td>$k_{cp}$</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes</td>
<td>$\phi$</td>
<td>-</td>
</tr>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td>$a_{s,c}$</td>
<td>lb/in ($N/mm$)</td>
</tr>
<tr>
<td>Coefficient for pullout strength</td>
<td>$k_{cp}$</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes</td>
<td>$\phi$</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 2.3.4.3 — Steel strength design information for shear acting in longitudinal direction of the channel axis for HAC CRFoS U with Hilti Locking Channel Bolts (HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 F CRFoS U</th>
<th>HAC-60 F CRFoS U</th>
<th>HAC-70 F CRFoS U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts</td>
<td>$V_{c,CH}$</td>
<td>lb</td>
<td>1,920</td>
<td>4,420</td>
<td>5,425</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts (periodic inspection)</td>
<td>$\phi$</td>
<td>-</td>
<td>0.55</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts</td>
<td>$V_{c,CH}$</td>
<td>lb</td>
<td>1,920</td>
<td>4,420</td>
<td>5,425</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts (continuous inspection)</td>
<td>$\phi$</td>
<td>-</td>
<td>0.55</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

1 The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.
### 2.3.5 HAC EDGE LITE, HAC EDGE, AND HAC EDGE C

**Table 2.3.5.1 — Tension steel strength design information for HAC EDGE Lite, HAC EDGE, and HAC EDGE C with Hilti Channel Bolts (HBC-C and HBC-C-N)**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 EDGE Lite</th>
<th>HAC-50 EDGE Lite</th>
<th>HAC-50 EDGE Lite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile steel strength for local failure of channel lips</td>
<td>$N_a$</td>
<td>[N]</td>
<td>5,620 (25.3)</td>
<td>7,665</td>
<td>7,665</td>
</tr>
<tr>
<td>Nominal tensile steel strength for local failure of channel lips for seismic design</td>
<td>$N_{a,seis}$</td>
<td>[N]</td>
<td>5,620 (25.3)</td>
<td>7,665</td>
<td>7,665</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal tensile steel strength of a single anchor</td>
<td>$N_b$</td>
<td>[N]</td>
<td>7,080 (31.5)</td>
<td>11,240</td>
<td>11,240</td>
</tr>
<tr>
<td>Nominal tensile steel strength of a single anchor for seismic design</td>
<td>$N_{b,seis}$</td>
<td>[N]</td>
<td>7,080 (31.5)</td>
<td>11,240</td>
<td>11,240</td>
</tr>
<tr>
<td>Strength reduction factor for anchor failure</td>
<td>$\phi$</td>
<td></td>
<td>0.65</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal tensile steel strength of connection between anchor and channel</td>
<td>$N_c$</td>
<td>[N]</td>
<td>5,620 (25.3)</td>
<td>7,665</td>
<td>7,665</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C</td>
<td>$M_{bc}$</td>
<td>[N·m]</td>
<td>10,050 (1,196)</td>
<td>14,125</td>
<td>14,125</td>
</tr>
<tr>
<td>Strength reduction factor for bending failure</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C-N</td>
<td>$M_{bc}$</td>
<td>[N·m]</td>
<td>8,673 (985)</td>
<td>11,903</td>
<td>11,903</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C-N for seismic design</td>
<td>$M_{bc,seis}$</td>
<td>[N·m]</td>
<td>8,673 (985)</td>
<td>11,903</td>
<td>11,903</td>
</tr>
<tr>
<td>Strength reduction factor for bending failure</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

1. The tabulated value of $\phi$ applies when both the load combinations of Section 9.2.2 of the BC-ACI 318-14 Section 5.3.3 or ACI 318-11 Section 5.3.3 are used and when the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are not met.

### 2.3.6 HAC EDGE LITE, HAC EDGE, AND HAC EDGE C

**Table 2.3.6.1 — Shear steel strength design information for HAC EDGE Lite, HAC EDGE, and HAC EDGE C with Hilti Channel Bolts (HBC-C and HBC-C-N)**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 EDGE Lite</th>
<th>HAC-50 EDGE Lite</th>
<th>HAC-50 EDGE Lite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength for local failure of channel lips</td>
<td>$V_{sa,x}$</td>
<td>[kN]</td>
<td>7,835 (31.5)</td>
<td>10,675</td>
<td>10,675</td>
</tr>
<tr>
<td>Nominal shear strength for local failure of the channel lips for seismic design</td>
<td>$V_{sa,x,seis}$</td>
<td>[kN]</td>
<td>7,835 (31.5)</td>
<td>10,675</td>
<td>10,675</td>
</tr>
<tr>
<td>Strength reduction factor for failure of channel lips</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor</td>
<td>$V_{sa,x}$</td>
<td>[kN]</td>
<td>8,903 (35.0)</td>
<td>12,050</td>
<td>12,050</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor for seismic design</td>
<td>$V_{sa,x,seis}$</td>
<td>[kN]</td>
<td>8,903 (35.0)</td>
<td>12,050</td>
<td>12,050</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure</td>
<td>$\phi$</td>
<td></td>
<td>0.65</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel</td>
<td>$V_{sa,y}$</td>
<td>[kN]</td>
<td>8,903 (35.0)</td>
<td>12,050</td>
<td>12,050</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel for seismic design</td>
<td>$V_{sa,y,seis}$</td>
<td>[kN]</td>
<td>8,903 (35.0)</td>
<td>12,050</td>
<td>12,050</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel with HBC-C</td>
<td>$V_{sa,y}$</td>
<td>[kN]</td>
<td>3,552 (15.0)</td>
<td>5,240</td>
<td>5,240</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel with HBC-C-N for seismic design</td>
<td>$V_{sa,y,seis}$</td>
<td>[kN]</td>
<td>3,552 (15.0)</td>
<td>5,240</td>
<td>5,240</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel with HBC-C</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor</td>
<td>$V_{sa,y}$</td>
<td>[kN]</td>
<td>4,249 (18.3)</td>
<td>6,790</td>
<td>6,790</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor for seismic design</td>
<td>$V_{sa,y,seis}$</td>
<td>[kN]</td>
<td>4,249 (18.3)</td>
<td>6,790</td>
<td>6,790</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure</td>
<td>$\phi$</td>
<td></td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

1. The tabulated value of $\phi$ applies when both the load combinations of Section 9.2.2 of the BC-ACI 318-14 Section 5.3.3 or ACI 318-11 Section 5.3.3 are used and when the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are not met.

**Table 2.3.6.2 — Shear concrete strength design information for HAC EDGE Lite and HAC EDGE C with Hilti Channel Bolts (HBC-C and HBC-C-N) when shear load acts away from the EDGE Plate.**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 F</th>
<th>HAC-50 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td>$a_{seis}$</td>
<td>[$^2$/in$^{1/2}$/in$^{1/3}$]</td>
<td>10.50</td>
<td>7.50</td>
</tr>
<tr>
<td>Coefficient for pryout strength</td>
<td>$h_p$</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure model</td>
<td>$\phi$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.3.6.3 — Steel strength design information for shear acting in longitudinal direction of the channel axis for HAC EDGE Lite, HAC EDGE, and HAC EDGE C with Hilti Locking Channel Bolts (HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 EDGE Lite</th>
<th>HAC-50 EDGE Lite</th>
<th>HAC-50 EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts</td>
<td>$V_{sl,x}$</td>
<td>lb (kN)</td>
<td>1,000 (4.47)</td>
<td>4,400 (19.7)</td>
<td>5,425 (24.1)</td>
</tr>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts for seismic design</td>
<td>$V_{sl,x,seis}$</td>
<td>lb (kN)</td>
<td>1,000 (4.47)</td>
<td>4,400 (19.7)</td>
<td>5,425 (24.1)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts</td>
<td>$\phi$</td>
<td></td>
<td>M12</td>
<td>-</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M16</td>
<td>-</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M20</td>
<td>-</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Table 2.3.6.4 — Steel strength design information for rebar edge confinement plate (EDGE Lite, EDGE, and EDGE C plate)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 EDGE Lite</th>
<th>HAC-50 EDGE Lite</th>
<th>HAC-50 EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module of elasticity of the EDGE Lite and EDGE plate</td>
<td>$E$</td>
<td>ksi (MPa)</td>
<td>30,458 (210,500)</td>
<td>75,750 (520)</td>
<td>72,500 (500)</td>
</tr>
<tr>
<td>Minimum specified ultimate strength</td>
<td>$f_y$</td>
<td>psi (MPa)</td>
<td>5,650 (39.27)</td>
<td>8,828 (59.55)</td>
<td>12,713 (86.87)</td>
</tr>
<tr>
<td>Minimum specified yield strength</td>
<td>$f_{pu}$</td>
<td>psi (MPa)</td>
<td>5,650 (39.27)</td>
<td>8,828 (59.55)</td>
<td>12,713 (86.87)</td>
</tr>
<tr>
<td>Nominal rebar steel strength</td>
<td>$N_{ru}$</td>
<td>lb (kN)</td>
<td>5,650 (25.13)</td>
<td>8,828 (59.27)</td>
<td>12,713 (86.55)</td>
</tr>
<tr>
<td>Strength reduction factor for rebar</td>
<td>$\phi$</td>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
</tr>
</tbody>
</table>

Table 2.3.7.1 — Steel strength design information for HAC EDGE Lite, HAC EDGE, and HAC EDGE C rebar edge confinement plate (EDGE Lite, EDGE, and EDGE C plate)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
<th>HAC-40</th>
<th>HAC-50</th>
<th>HAC-50</th>
<th>HAC-50</th>
<th>HAC-50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of plate size and rebar diameter on concrete edge breakout strength in shear for the EDGE Lite and EDGE plate</td>
<td>$N_{b,max}$</td>
<td>lb (kN)</td>
<td>Imperial units</td>
<td>575 (2.59)</td>
<td>700 (3.16)</td>
<td>720 (3.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor to account for the influence of plate size and rebar diameter on concrete edge breakout strength in shear for anchors channels loaded in shear</td>
<td>$N_{b,max}$</td>
<td>lb (kN)</td>
<td>Imperial units</td>
<td>575 (2.59)</td>
<td>700 (3.16)</td>
<td>720 (3.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exponent for the modification factor to account for the influence of member thickness on concrete edge breakout strength for anchors channels loaded in shear</td>
<td>$x_3$</td>
<td></td>
<td></td>
<td>0.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exponent for the concrete distance in the basic value of the concrete edge breakout strength</td>
<td>$x_1$</td>
<td></td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exponent for the modification factor to account for the influence of reinforcement on concrete edge breakout strength for anchors channels loaded in shear</td>
<td>$x_2$</td>
<td></td>
<td></td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exponent for the modification factor to account for the influence of rebar diameter on concrete edge breakout strength for anchors channels loaded in shear</td>
<td>$x_3$</td>
<td></td>
<td></td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification factor for the critical anchor spacing in combination with the EDGE Lite and EDGE plate</td>
<td>$\phi$</td>
<td></td>
<td></td>
<td>0.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient for pry out strength</td>
<td>$k_{Vc}$</td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification factor for HAC EDGE Lite and HAC EDGE to control splitting</td>
<td>$\phi_U$</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification factor to account for influence of cracked or uncracked concrete for concrete edge breakout strength</td>
<td>$\phi_f$</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes1</td>
<td>$\phi$</td>
<td></td>
<td></td>
<td>0.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 3.3 or ACI 318-11 Section 9.3 are used and the requirements of ACI 318-14 D.4.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. See chapter 9 for additional design information for HAC EDGE Lite, HAC EDGE, and HAC EDGE C.
### Table 2.3.9.1 — Tension steel strength design information for HAC S EDGE and HAC S EDGE C with Hilti Channel Bolts (HBC-C and HBC-C-N).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 S EDGE</th>
<th>HAC-50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile steel strength for local failure of channel tips</td>
<td>N_y</td>
<td>(kN)</td>
<td>7,865 (35.5)</td>
<td>10,675 (47.4)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel tips</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal tensile steel strength for a single anchor</td>
<td>N_As</td>
<td>(kN)</td>
<td>11,240 (50.5)</td>
<td>15,875 (70.1)</td>
</tr>
<tr>
<td>Strength reduction factor for anchor failure</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal tensile steel strength of connection between anchor and channel for seismic design</td>
<td>N_sc,seis</td>
<td>(kN)</td>
<td>13,865 (61.7)</td>
<td>18,707 (84.1)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel for seismic design</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C</td>
<td>M_y</td>
<td>(kN-m)</td>
<td>14,125 (61.6)</td>
<td>19,320 (85.7)</td>
</tr>
<tr>
<td>Nominal bending strength of the anchor channel with HBC-C-N</td>
<td>M_y</td>
<td>(kN-m)</td>
<td>11,903 (51.4)</td>
<td>15,875 (70.1)</td>
</tr>
<tr>
<td>Strength reduction factor for bending failure</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.85</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 2.3.10.1 — Shear concrete strength design information for HAC S EDGE and HAC S EDGE C with Hilti Channel Bolts (HBC-C and HBC-C-N).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 S EDGE</th>
<th>HAC-50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength for local failure of channel lips in opposite direction of the S bracket</td>
<td>V_y</td>
<td>(kN)</td>
<td>10,879 (47.4)</td>
<td>17,707 (78.7)</td>
</tr>
<tr>
<td>Nominal shear strength for local failure of the channel lips in direction of the S bracket</td>
<td>V_y</td>
<td>(kN)</td>
<td>10,675 (47.4)</td>
<td>17,707 (78.7)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor in opposite direction of the S bracket</td>
<td>V_As,clip</td>
<td>(kN)</td>
<td>13,865 (61.7)</td>
<td>18,707 (84.1)</td>
</tr>
<tr>
<td>Strength reduction factor for anchor failure</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
<tr>
<td>Nominal shear strength of connection between anchor and channel in opposite direction of the S bracket</td>
<td>V_sc,clip</td>
<td>(kN)</td>
<td>18,707 (84.1)</td>
<td>25,240 (109.3)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between anchor and channel</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>0.75</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 2.3.10.2 — Shear concrete strength design information for HAC S EDGE and HAC S EDGE C with Hilti Channel Bolts (HBC-C and HBC-C-N) when shear load acts away from the EDGE Plate.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-50 S EDGE</th>
<th>HAC-50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td>n_F</td>
<td>(N/mm²)</td>
<td>10.50 (7.50)</td>
<td>14.50 (10.0)</td>
</tr>
<tr>
<td>Coefficient for prusiy strength</td>
<td>_k_e</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes</td>
<td><em>ϕ</em></td>
<td>-</td>
<td>Condition: A, N/A</td>
<td>Condition: B, 0.70</td>
</tr>
</tbody>
</table>

1. The tabulated value of _ϕ_ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.3 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 17.3.3(b), as applicable, for Condition B are not met. For installations where complying supplementary reinforcement is not provided, for installations where complying supplementary reinforcement can be verified, the _ϕ_ factors described in ACI 318-14 17.3.3(b) or ACI 318-11 17.3.3(b), as applicable, for Condition A are allowed.

2. The tabulated value of _ϕ_ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.3 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 17.3.3(b), as applicable, for Condition B are not met. For installations where complying supplementary reinforcement is not provided, for installations where complying supplementary reinforcement can be verified, the _ϕ_ factors described in ACI 318-14 17.3.3(b) or ACI 318-11 17.3.3(b), as applicable, for Condition A are allowed.
Table 2.3.10.3 — Steel strength design information for shear acting in longitudinal direction of the channel axis for HAC S EDGE and HAC S EDGE C with Hilti Locking Channel Bolts (HBC-C-N)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-40 EDGE lite</th>
<th>HAC-50 S EDGE HAC-50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear steel strength of connection between channel lips and channel bolts</td>
<td>V&lt;sub&gt;ult&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>1,920 (8.5)</td>
<td>4,420 (19.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5,425 (24.1)</td>
<td></td>
</tr>
<tr>
<td>Nominal shear steel strength of connection between channel lips and channel bolts for seismic design</td>
<td>V&lt;sub&gt;ult,seis&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>1,920 (8.5)</td>
<td>4,420 (19.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5,425 (24.1)</td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts' (periodic inspection)</td>
<td>φ</td>
<td>-</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.65</td>
<td></td>
</tr>
</tbody>
</table>

1. The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used, and the requirements of ACI 318-14 3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided.

2.3.11 HAC S EDGE AND HAC S EDGE C PLATE STEEL STRENGTH INFORMATION

Table 2.3.11.1 — Steel strength design information for HAC S EDGE and HAC S EDGE C rebar edge confinement plate (EDGE and EDGE C plate)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of elasticity of the EDGE plate</td>
<td>E</td>
<td>ksi (MPa)</td>
<td>30,458 (210,020)</td>
</tr>
<tr>
<td>Minimum specified ultimate strength</td>
<td>f&lt;sub&gt;u&lt;/sub&gt;</td>
<td>psi (MPa)</td>
<td>79,750 (550)</td>
</tr>
<tr>
<td>Minimum specified yield strength</td>
<td>f&lt;sub&gt;y&lt;/sub&gt;</td>
<td>psi (MPa)</td>
<td>72,500 (505)</td>
</tr>
<tr>
<td>Nominal rebar steel strength</td>
<td>N&lt;sub&gt;s&lt;/sub&gt;</td>
<td>lb (kN)</td>
<td>12,713 (55.55)</td>
</tr>
<tr>
<td>Strength reduction factor for rebar steel tensile strength</td>
<td>ϕ</td>
<td>-</td>
<td>0.75</td>
</tr>
</tbody>
</table>

2.3.12 DESIGN INFORMATION FOR HAC S EDGE AND HAC S EDGE C CONCRETE BREAKOUT IN PERPENDICULAR SHEAR

Table 2.3.12.1 — Shear concrete strength design information for HAC S EDGE and HAC S EDGE C when shear load acts towards the EDGE Plate.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of plate size and rebar diameter on concrete edge breakout strength in shear for the EDGE plate</td>
<td>k&lt;sub&gt;EDGE&lt;/sub&gt;, k&lt;sub&gt;EDGE C&lt;/sub&gt;</td>
<td>Imperial units</td>
<td>880 (415)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SI units</td>
<td>720 (340)</td>
</tr>
<tr>
<td>Exponent for the edge distance in the basic value of the concrete edge breakout</td>
<td>α&lt;sub&gt;xe&lt;/sub&gt;</td>
<td>-</td>
<td>0.97</td>
</tr>
<tr>
<td>Exponent for the concrete strength in the basic value of the concrete edge breakout</td>
<td>α&lt;sub&gt;xc&lt;/sub&gt;</td>
<td>-</td>
<td>0.18</td>
</tr>
<tr>
<td>Exponent for the modification factor to account for influence of member thickness on concrete edge breakout strength for anchors channels loaded in shear</td>
<td>α&lt;sub&gt;x&lt;/sub&gt;</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>Exponent for the modification factor for corner effects on concrete edge breakout strength for anchor channels loaded in shear</td>
<td>α&lt;sub&gt;xx&lt;/sub&gt;</td>
<td>-</td>
<td>0.11</td>
</tr>
<tr>
<td>Modification factor for the critical anchor spacing in combination with the EDGE plate</td>
<td>α&lt;sub&gt;e&lt;/sub&gt;</td>
<td>-</td>
<td>0.60</td>
</tr>
<tr>
<td>Coefficient for pry out strength</td>
<td>k&lt;sub&gt;xe&lt;/sub&gt;</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Modification factor for HAC EDGE to control splitting</td>
<td>ψ&lt;sub&gt;xe&lt;/sub&gt;</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Modification factor to account for influence of cracked or uncracked concrete for concrete edge breakout strength</td>
<td>ψ&lt;sub&gt;e&lt;/sub&gt;</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes’</td>
<td>ϕ</td>
<td>-</td>
<td>0.70</td>
</tr>
</tbody>
</table>

1. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 5.4.3(b), as applicable, for Condition B are met. Condition B applies when supplementary reinforcement is not provided.

See chapter 9 for additional design information for HAC S EDGE and HAC S EDGE C.
### 2.3.13 HBC-C AND HBC-C-N STEEL PERFORMANCE — TENSION

Table 2.3.13.1 — Tension steel strengths design information for Hilti Channel Bolts (HBC-C and HBC-C-N).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Unit</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile strength of a channel bolt</td>
<td>( N_{t} )</td>
<td>lb (kN)</td>
<td>14,080 (62.6)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HBC-C 8.8</td>
<td>lb (kN)</td>
<td>16,940 (75.3)</td>
<td>27,427 (122.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HBC-C-N 8.8</td>
<td>lb (kN)</td>
<td>16,940 (75.3)</td>
<td>27,427 (122.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for tension, steel failure modes</td>
<td>( \phi )</td>
<td>-</td>
<td>-</td>
<td>0.65</td>
<td></td>
</tr>
</tbody>
</table>

1. The tabulated value of \( \phi \) applies when the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used.

### 2.3.14 HBC-C AND HBC-C-N STEEL PERFORMANCE — SHEAR

Table 2.3.14.1 — Shear strength design information for Hilti Channel Bolts (HBC-C and HBC-C-N).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Unit</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength of a channel bolt</td>
<td>( V_{n} )</td>
<td>lb (kN)</td>
<td>16,940 (75.3)</td>
<td>27,427 (122.0)</td>
<td></td>
</tr>
<tr>
<td>HBC-C 8.8</td>
<td>lb (kN)</td>
<td>16,940 (75.3)</td>
<td>27,427 (122.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HBC-C-N 8.8</td>
<td>lb (kN)</td>
<td>16,940 (75.3)</td>
<td>27,427 (122.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength reduction factor for shear, steel failure modes</td>
<td>( \phi )</td>
<td>-</td>
<td>-</td>
<td>0.65</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3.15 HAC-30 AND HAC-T STRUCTURAL STEEL PERFORMANCE — TENSION

Table 2.3.15.1 — Tension steel strengths design information for HAC-T with Hilti Serrated Channel Bolts (HBC-T).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Unit</th>
<th>HAC-30 (compatible with HBC-T)</th>
<th>HAC-T50 (compatible with HBC-T)</th>
<th>HAC-T70 (compatible with HBC-T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile strength for local failure of channel tips</td>
<td>( N_{ts} )</td>
<td>lb</td>
<td>3,935 (17.5)</td>
<td>7,865 (35.0)</td>
<td>15,960 (71.0)</td>
</tr>
<tr>
<td>Nominal tensile strength for local failure of channel tips for seismic design</td>
<td>( N_{ts,seis} )</td>
<td>lb</td>
<td>3,935 (17.5)</td>
<td>7,865 (35.0)</td>
<td>15,960 (71.0)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel tips</td>
<td>( \phi )</td>
<td>-</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.3.16 HAC-30 AND HAC-T STRUCTURAL STEEL PERFORMANCE — SHEAR

Table 2.3.16.2 — Tension concrete strength design information for HAC-T and HAC-30.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Unit</th>
<th>HAC-30</th>
<th>HAC-T50</th>
<th>HAC-T70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge distance required to develop full concrete capacity in absence of anchor reinforcement</td>
<td>( t_{sw} )</td>
<td>in (mm)</td>
<td>8.03 (204)</td>
<td>12.52 (318)</td>
<td>20.67 (527)</td>
</tr>
<tr>
<td>Strength reduction factor for tension, concrete failure modes</td>
<td>( \phi )</td>
<td>-</td>
<td>Condition A: 0.75</td>
<td>Condition B: 0.70</td>
<td>Condition C: 0.70</td>
</tr>
</tbody>
</table>

1. The tabulated value of \( \phi \) applies when both the load combinations of Section 1605.3 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 17.3.3(b), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the \( \phi \) factors described in ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are allowed.

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2.3.16 HAC-30 AND HAC-T STRUCTURAL STEEL PERFORMANCE — SHEAR

Table 2.3.16.2 — Shear concrete strength design information for HAC-T with Hilti Serrated Channel Bolts (HBC-T) and HAC-30 with Hilti Channel Bolts (HBC-B).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td>$\phi_{\text{shear}}$</td>
<td>lb/in (N/mm)</td>
</tr>
<tr>
<td>Coefficient for pryout strength</td>
<td>$\phi_{\text{ Pryout}}$</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes</td>
<td>$\phi$</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td>$\phi_{\text{ local}}$</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure</td>
<td>$\phi_{\text{ anchor}}$</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2.3.16.3 — Steel strength design information for shear acting in longitudinal direction of the channel axis for HAC-T with Hilti Serrated Channel Bolts (HBC-T) and HAC-30 with Hilti Channel Bolts (HBC-B).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts</td>
<td>$V_{\text{shear}}$</td>
<td>HBC-B (compatible with HAC-B), HBC-T (compatible with HAC-T)</td>
</tr>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts for seismic design</td>
<td>$V_{\text{shear}}$</td>
<td>HBC-B (compatible with HAC-B), HBC-T (compatible with HAC-T)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts</td>
<td>$\phi$</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2.3.16.4 — Steel strength design information for shear acting in longitudinal direction of the channel axis for HAC-T with Hilti Serrated Channel Bolts (HBC-T) and HAC-30 with Hilti Channel Bolts (HBC-B).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts</td>
<td>$V_{\text{shear}}$</td>
<td>HBC-B (compatible with HAC-B), HBC-T (compatible with HAC-T)</td>
</tr>
<tr>
<td>Nominal shear strength of connection between channel lips and channel bolts for seismic design</td>
<td>$V_{\text{shear}}$</td>
<td>HBC-B (compatible with HAC-B), HBC-T (compatible with HAC-T)</td>
</tr>
<tr>
<td>Strength reduction factor for failure of connection between channel lips and channel bolts</td>
<td>$\phi$</td>
<td>-</td>
</tr>
</tbody>
</table>

1. The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the BC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.3 are used and the requirements of ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b) as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(b) or ACI 318-11 D.4.3(b), as applicable, for Condition A are allowed.
2. *Note: HBC-T are only compatible with HAC-T. HBC-B are only compatible with HAC-30.

Cast-In Anchor Channel Product Guide, Edition 1 • 02/2019
2.1 HAC Nomenclature
2.2 Geometric Parameters
2.3 Structural Performance
2.4 Ordering Information
2.6 HAC Custom Portfolio
2.7 Field Fixing
2.8 Reinforcing Bar Anchorages
### Table 2.3.17.1 — Tension steel strength design information for HAC-T EDGE Lite, HAC-T EDGE and HAC-T EDGE C

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 EDGE Lite</th>
<th>HAC-T50 EDGE</th>
<th>HAC-T50 EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tensile steel strength for local failure of channel lips</td>
<td>( N_{tp} )</td>
<td>lb (kN)</td>
<td>7,865 (35.0)</td>
<td>7,865 (35.0)</td>
<td>7,865 (35.0)</td>
</tr>
<tr>
<td>Normal tensile steel strength for local failure of channel lips for seismic design</td>
<td>( N_{tp,seis} )</td>
<td>lb (kN)</td>
<td>11,240 (50.0)</td>
<td>11,240 (50.0)</td>
<td>11,240 (50.0)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td>( \phi )</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal tensile steel strength of a single anchor</td>
<td>( N_{ta} )</td>
<td>lb (kN)</td>
<td>7,865 (35.0)</td>
<td>7,865 (35.0)</td>
<td>7,865 (35.0)</td>
</tr>
<tr>
<td>Normal tensile steel strength of a single anchor for seismic design</td>
<td>( N_{ta,seis} )</td>
<td>lb (kN)</td>
<td>11,240 (50.0)</td>
<td>11,240 (50.0)</td>
<td>11,240 (50.0)</td>
</tr>
<tr>
<td>Strength reduction factor for anchor failure</td>
<td>( \phi )</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

### Table 2.3.17.2 — Tension concrete strength design information for HAC-T EDGE Lite, HAC-T EDGE and HAC-T EDGE C

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 EDGE Lite</th>
<th>HAC-T50 EDGE</th>
<th>HAC-T50 EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal bending strength of the anchor channel with HBC-T</td>
<td>( M_{b} )</td>
<td>lb-in (N-mm)</td>
<td>14,125 (1,598)</td>
<td>14,125 (1,598)</td>
<td>14,125 (1,598)</td>
</tr>
<tr>
<td>Normal bending strength of the anchor channel with HBC-T</td>
<td>( M_{b,seis} )</td>
<td>lb-in (N-mm)</td>
<td>14,125 (1,598)</td>
<td>14,125 (1,598)</td>
<td>14,125 (1,598)</td>
</tr>
<tr>
<td>Strength reduction factor for bending failure</td>
<td>( \phi )</td>
<td>-</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
</tr>
</tbody>
</table>

### Table 2.3.18.1 — Shear steel strength design information for HAC-T EDGE Lite, HAC-T EDGE and HAC-T EDGE C

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 EDGE Lite</th>
<th>HAC-T50 EDGE</th>
<th>HAC-T50 EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal shear strength for local failure of channel lips</td>
<td>( V_{sa} )</td>
<td>lb (kN)</td>
<td>10,675 (47.4)</td>
<td>10,675 (47.4)</td>
<td>10,675 (47.4)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel lips</td>
<td>( \phi )</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Nominal shear strength of a single anchor</td>
<td>( V_{sa} )</td>
<td>lb (kN)</td>
<td>12,050 (53.5)</td>
<td>12,050 (53.5)</td>
<td>12,050 (53.5)</td>
</tr>
<tr>
<td>Strength reduction factor for anchor failure</td>
<td>( \phi )</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

### Table 2.3.18.2 — Shear concrete strength design information for HAC-T EDGE Lite and HAC-T EDGE C with Hilti Serrated Channel Bolts (HBC-T)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T70 F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear</td>
<td>( \alpha )</td>
<td>kN/(m²-mm)</td>
<td>10.50 (47.5)</td>
</tr>
<tr>
<td>Coefficient for pryout strength</td>
<td>( \lambda_{p} )</td>
<td>-</td>
<td>7.50 (33.0)</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure modes</td>
<td>( \phi )</td>
<td>-</td>
<td>Condition A: 0.70, Condition B: 0.70</td>
</tr>
</tbody>
</table>

---

1. The tabulated value of \( \phi \) applies when both the load combinations of Section 1805.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the \( \phi \) factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

---

1. The tabulated value of \( \phi \) applies when both the load combinations of Section 1805.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the \( \phi \) factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.
Table 2.3.18.3 — Steel strength design information for shear acting in longitudinal direction of the channel axis for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T EDGE C with Hilti Serrated Channel Bolts (HBC-T)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Channel bolt type HBC-T</th>
<th>Units</th>
<th>HAC-T50 EDGE Lite</th>
<th>HAC-T50 EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal shear steel strength of connection between channel lips and channel bolts</td>
<td>$\phi_{\beta}$</td>
<td>M12</td>
<td>lb (kN)</td>
<td>3,395</td>
<td>(15.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M16</td>
<td>lb (kN)</td>
<td>4,519</td>
<td>(20.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M20</td>
<td>lb (kN)</td>
<td>4,519</td>
<td>(20.1)</td>
</tr>
<tr>
<td>Normal shear steel strength of connection between channel lips and channel bolts for seismic design</td>
<td>$\phi_{\beta_{seis}}$</td>
<td>M12</td>
<td>lb (kN)</td>
<td>3,395</td>
<td>(15.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M16</td>
<td>lb (kN)</td>
<td>4,519</td>
<td>(20.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M20</td>
<td>lb (kN)</td>
<td>4,519</td>
<td>(20.1)</td>
</tr>
</tbody>
</table>

2.3.19 HAC-T EDGE LITE, HAC-T EDGE, AND HAC-T EDGE C PLATE STEEL STRENGTH INFORMATION

Table 2.3.19.1 — Steel strength design information for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T EDGE C rebar edge confinement plate (EDGE Lite, EDGE, and EDGE C plate)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of elasticity of the EDGE lite and EDGE plate</td>
<td>$E$</td>
<td>ksi (MPa)</td>
<td>30,458 (210,000)</td>
</tr>
<tr>
<td>Minimum specified ultimate strength</td>
<td>$f_{u}$</td>
<td>psi (MPa)</td>
<td>79,750 (550)</td>
</tr>
<tr>
<td>Minimum specified yield strength</td>
<td>$f_{y}$</td>
<td>psi (MPa)</td>
<td>72,500 (505)</td>
</tr>
</tbody>
</table>

2.3.20 DESIGN INFORMATION FOR HAC-T EDGE LITE, HAC-T EDGE, AND HAC-T EDGE C CONCRETE BREAKOUT IN PERPENDICULAR SHEAR

Table 2.3.20.1 — Shear concrete strength design information for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T EDGE C with Hilti Serrated Channel Bolts (HBC-T) when shear load acts towards the EDGE Plate.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of plate size and rebar diameter on concrete edge breakout strength in shear for the EDGE Lite and EDGE plate</td>
<td>$k_{HAC-EDGE}$ / $k_{HAC-EDGE C}$</td>
<td>Imperial units</td>
</tr>
<tr>
<td>SI units</td>
<td>(330)</td>
<td>(410)</td>
</tr>
<tr>
<td>Exponent for the edge distance in the basic value of the concrete edge breakout</td>
<td>$x_{3}$</td>
<td>-</td>
</tr>
<tr>
<td>Exponent for the concrete strength in the basic value of the concrete edge breakout</td>
<td>$x_{4}$</td>
<td>-</td>
</tr>
<tr>
<td>Exponent for the modification factor to account for influence of member thickness on concrete edge breakout strength for anchors channels loaded in shear</td>
<td>$x_{5}$</td>
<td>-</td>
</tr>
<tr>
<td>Exponent for the modification factor for corner effects on concrete edge breakout strength for anchors channel loaded in shear</td>
<td>$x_{6}$</td>
<td>-</td>
</tr>
<tr>
<td>Modification factor for the critical anchor spacing in combination with the EDGE Lite and EDGE plate</td>
<td>$\alpha_{3}$</td>
<td>-</td>
</tr>
<tr>
<td>Coefficient for pry out strength</td>
<td>$k_{p}$</td>
<td>-</td>
</tr>
<tr>
<td>Modification factor for HAC-T EDGE Lite and HAC-T EDGE C to control splitting</td>
<td>$\psi_{d}$</td>
<td>-</td>
</tr>
<tr>
<td>Modification factor to account for influence of cracked or uncracked concrete for concrete edge breakout strength</td>
<td>$\psi_{c}$</td>
<td>-</td>
</tr>
<tr>
<td>Strength reduction factor for shear concrete failure mode</td>
<td>$\phi_{c}$</td>
<td>-</td>
</tr>
</tbody>
</table>

1. The tabulated value of $\phi$ applies when the load combinations of Section 1605.3 of the BC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.3 are used.

See chapter 9 for additional design information for HAC-T EDGE Lite, HAC-T EDGE, and HAC-T EDGE C.
Table 2.3.21.1 — Tension strength design information for HAC-T S EDGE and HAC-T S EDGE C with Hilti Serrated Channel Bolts (HBC-T)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 S EDGE HAC-T50 S EDGE C</th>
<th>HAC-T50 S EDGE HAC-T50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal tensile steel strength for local failure of channel tips</td>
<td>$N_{\text{ty}}$</td>
<td>kN</td>
<td>7,865 (25.0)</td>
<td>7,865 (25.0)</td>
</tr>
<tr>
<td>Normal tensile steel strength for local failure of channel tips for seismic design</td>
<td>$N_{\text{ty,seis}}$</td>
<td>kN</td>
<td>7,865 (25.0)</td>
<td>7,865 (25.0)</td>
</tr>
<tr>
<td>Strength reduction factor for local failure of channel tips</td>
<td>$\phi$</td>
<td>-</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

| Normal tensile steel strength of a single anchor | $N_{\text{ty,avg}}$ | kN | 11,240 (39.0) | 11,240 (39.0) |
| Normal tensile steel strength of a single anchor for seismic design | $N_{\text{ty,avg,seis}}$ | kN | 11,240 (39.0) | 11,240 (39.0) |
| Strength reduction factor for anchor failure | $\phi$ | - | 0.75 | 0.75 |

| Normal tensile steel strength of connection between anchor and channel | $N_{\text{ty,con}}$ | kN | 7,865 (25.0) | 7,865 (25.0) |
| Normal tensile steel strength of connection between anchor and channel for seismic design | $N_{\text{ty,con,seis}}$ | kN | 7,865 (25.0) | 7,865 (25.0) |
| Strength reduction factor for failure of connection between anchor and channel | $\phi$ | - | 0.75 | 0.75 |

| Normal bending strength of the anchor channel with HBC-C | $M_{\text{by}}$ | kN·mm | 14,125 (1,192) | 14,125 (1,192) |
| Normal bending strength of the anchor channel with HBC-C-N | $M_{\text{by,N}}$ | kN·mm | 11,033 (931) | 11,033 (931) |
| Normal bending strength of the anchor channel for seismic design with HBC-C | $M_{\text{by,seis}}$ | kN·mm | 14,125 (1,192) | 14,125 (1,192) |
| Normal bending strength of the anchor channel for seismic design with HBC-C-N | $M_{\text{by,N,seis}}$ | kN·mm | 11,033 (931) | 11,033 (931) |
| Strength reduction factor for bending failure | $\phi$ | - | 0.85 | 0.85 |

Table 2.3.21.2 — Tension concrete strength design information for HAC-T S EDGE and HAC-T S EDGE C

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 S EDGE HAC-T50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge distance required to develop full concrete capacity in absence of anchor reinforcement</td>
<td>$h_{\text{cr}}$</td>
<td>mm</td>
<td>TRD TRD 12.52 [158]</td>
</tr>
</tbody>
</table>

Strength reduction factor for tension, concrete failure mode | $\phi$ | - | Condition A: 0.75 Condition B: 0.70 |

1 The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are not met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.

Table 2.3.22.1 — Shear steel strength design information for HAC-T S EDGE and HAC-T S EDGE C with Hilti Serrated Channel Bolts (HBC-T)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 S EDGE HAC-T50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal shear strength for local failure of channel lips in opposite direction of the S bracket</td>
<td>$V_{\text{s,x,y}}$</td>
<td>kN</td>
<td>10,675 (23.3)</td>
</tr>
<tr>
<td>Nominal shear strength for local failure of the channel lips in direction of the S bracket</td>
<td>$V_{\text{s,x,y,seis}}$</td>
<td>kN</td>
<td>10,675 (23.3)</td>
</tr>
<tr>
<td>Nominal shear strength for local failure of channel lips in seismic design in both directions</td>
<td>$V_{\text{s,x,y,seis}}$</td>
<td>kN</td>
<td>10,675 (23.3)</td>
</tr>
<tr>
<td>Strength reduction factor anchor failure</td>
<td>$\phi$</td>
<td>-</td>
<td>0.75</td>
</tr>
</tbody>
</table>

| Nominal shear strength of connection between anchor and channel in opposite direction of the S bracket | $V_{\text{c,x,y}}$ | kN | 10,675 (23.3) | 10,675 (23.3) |
| Nominal shear strength of connection between anchor and channel in direction of the S bracket | $V_{\text{c,x,y}}$ | kN | 10,675 (23.3) | 10,675 (23.3) |
| Nominal shear strength of connection between anchor and channel for seismic design in both directions | $V_{\text{c,x,y,seis}}$ | kN | 10,675 (23.3) | 10,675 (23.3) |
| Strength reduction factor for failure of connection between anchor and channel | $\phi$ | - | 0.75 | 0.75 |

| Nominal shear strength of connection between anchor and channel | $V_{\text{c,x,y}}$ | kN | 5,240 (11.7) | 5,240 (11.7) |
| Nominal shear strength of connection between anchor and channel for seismic design | $V_{\text{c,x,y,seis}}$ | kN | 5,240 (11.7) | 5,240 (11.7) |
| Strength reduction factor anchor failure | $\phi$ | - | 0.75 | 0.75 |
| Nominal shear strength of a single anchor | $V_{\text{s,x,y}}$ | kN | 6,740 (15.0) | 6,740 (15.0) |
| Nominal shear strength of a single anchor for seismic design | $V_{\text{s,x,y,seis}}$ | kN | 6,740 (15.0) | 6,740 (15.0) |

Table 2.3.22.2 — Shear concrete strength design information for HAC-T S EDGE and HAC-T S EDGE C with Hilti Serrated Channel Bolts (HBC-T) when shear load acts away from the EDGE Plate.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>HAC-T50 S EDGE HAC-T50 S EDGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor to account for the influence of channel size and anchor diameter on concrete edge breakout shear strength</td>
<td>$a_{\text{by,N}}$</td>
<td></td>
<td>10.50 (2.34)</td>
</tr>
<tr>
<td>Coefficient for prusyl strength</td>
<td>$k_{\text{by,N}}$</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Strength reduction factor for shear, concrete failure mode</td>
<td>$\phi$</td>
<td>-</td>
<td>Condition A: N/A Condition B: 0.70</td>
</tr>
</tbody>
</table>

1 The tabulated value of $\phi$ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the $\phi$ factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed.
### 2.3.23 HAC-T S EDGE AND HAC-T S EDGE C PLATE STEEL STRENGTH INFORMATION

#### Table 2.3.23.1 — Steel strength design information for HAC-T S EDGE and HAC-T EDGE C rebar edge confinement plate (EDGE and EDGE C plate)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HAC-T S EDGE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HAC-T S EDGE C</td>
</tr>
</tbody>
</table>

| Modulus of elasticity of the EDGE plate | E | kN/mm² | 30,458 (210,000) |
| Minimum specified ultimate strength | fₚₜₚₑ | psi (MPa) | 79,750 (550) |
| Minimum specified yield strength | fₚₚₑ | psi (MPa) | 72,500 (505) |
| Nominal rebar steel strength | Nₛₑₚₑ | lb (kN) | 12,713 (55.55) |
| Nominal connection strength of rebar-EDGE Lite or EDGE plate | Nₛₑₑₚₑ | lb (kN) | - |
| Strength reduction factor for rebar tensile steel strength | ϕ | - | 0.75 |

### 2.3.24 DESIGN INFORMATION FOR HAC-T S EDGE AND HAC-T S EDGE C CONCRETE BREAKOUT IN PERPENDICULAR SHEAR

#### Table 2.3.24.1 — Shear concrete strength design information for HAC-T S EDGE and HAC-T S EDGE C with Hilti Serrated Channel Bolts (HBC-T) when shear load acts towards the EDGE Plate.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Units</th>
<th>Anchor Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HAC-T S EDGE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HAC-T S EDGE C</td>
</tr>
</tbody>
</table>

| Factor to account for the influence of plate size and rebar diameter on concrete edge breakout strength in shear for the EDGE plate | nₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑئة | Imperial units | 880 (415) |
| Exponent for the edge distance in the basic value of the concrete edge breakout strength | xₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑئة | - | 0.97 |
| Exponent for the concrete strength in the basic value of the concrete edge breakout strength | xₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑ廨ede | - | 0.18 |
| Exponent for the modification factor to account for influence of member thickness on concrete edge breakout strength for anchors channels loaded in shear | xₑₑₑₑₑₑₑₑₑₑₑ廨ede | - | 0.25 |
| Exponent for the modification factor for corner effects on concrete edge breakout strength for anchor channels loaded in shear | xₑₑₑₑₑ廨ede | - | 0.11 |
| Modification factor for the critical anchor spacing in combination with the EDGE plate | Mₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑ廨ede | - | 0.80 |
| Coefficient for pry out strength | kₑₑₑ廨ede | - | 2.0 |
| Modification factor for HAC-T EDGE to control splitting | ψₑₑₑ廨ede | - | 1.0 |
| Modification factor to account for influence of cracked or uncracked concrete for concrete edge breakout strength | ψₑₑₑ廨ede | - | 1.0 |
| Strength reduction factor for shear, concrete failure model | ϕ | - | 0.70 |

1. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided.

2. The tabulated value of ϕ applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used.
### 2.3.25 HBC-B AND HBC-T STEEL PERFORMANCE — SHEAR

**Table 2.3.26.1 — Shear steel strengths design information for Hilti Serrated Channel Bolts (HBC-B and HBC-T).**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Bolt type</th>
<th>Units</th>
<th>M10</th>
<th>M12</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear strength of a channel bolt</td>
<td>N_{cc, HBC-T}</td>
<td>HBC-T 8.8</td>
<td>lb</td>
<td>5,215 (23.2)</td>
<td>7,575 (33.7)</td>
<td>15,160 (67.6)</td>
<td>28,235 (123.6)</td>
<td>39,239 (174.5)</td>
</tr>
<tr>
<td>Shear strength of a channel bolt for seismic design</td>
<td>N_{cc, seis HBC-T}</td>
<td>HBC-T 8.8</td>
<td>lb</td>
<td>-</td>
<td>7,575 (33.7)</td>
<td>15,160 (67.6)</td>
<td>28,235 (123.6)</td>
<td>39,239 (174.5)</td>
</tr>
</tbody>
</table>

| Strength reduction factor for shear, steel failure model | $\phi$ | - | - | - | 0.65 |

1. The tabulated value of $\phi$ applies when the load combinations of Section 1605.2 of the IBC, ACI 318-11 Section 5.3 or ACI 318-14 Section 9.2 are used.

### 2.3.26 HBC-B AND HBC-T STEEL PERFORMANCE — TENSION

**Table 2.3.25.1 — Tension steel strengths design information for Hilti Serrated Channel Bolts (HBC-B and HBC-T).**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Bolt type</th>
<th>Units</th>
<th>M10</th>
<th>M12</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension strength of a channel bolt</td>
<td>V_{cc, HBC-T}</td>
<td>HBC-T 8.8</td>
<td>lb/in.</td>
<td>3,125 (13.9)</td>
<td>4,540 (20.1)</td>
<td>9,095 (40.4)</td>
<td>16,940 (75.5)</td>
<td>27,427 (122.0)</td>
</tr>
<tr>
<td>Tension strength of a channel bolt for seismic design</td>
<td>V_{cc, seis HBC-T}</td>
<td>HBC-T 8.8</td>
<td>lb/in.</td>
<td>-</td>
<td>4,540 (20.1)</td>
<td>9,095 (40.4)</td>
<td>16,940 (75.5)</td>
<td>27,427 (122.0)</td>
</tr>
</tbody>
</table>

| Nominal tensile strength of a channel bolt | M_{ss, HBC-T} | HBC-T 8.8 | kN | 265 (23.2) | 469 (52.4) | 930 (104.8) | 2,355 (269.3) | 4,768 (538.7) |
| Nominal tensile strength of a channel bolt for seismic design | M_{ss, seis HBC-T} | HBC-T 8.8 | kN | 469 (52.4) | 930 (104.8) | 2,355 (269.3) | 4,768 (538.7) |

| Strength reduction factor for tension, steel failure model | $\phi$ | - | - | - | 0.60 |

1. The tabulated value of $\phi$ applies when the load combinations of Section 1605.2 of the IBC, ACI 318-11 Section 5.3 or ACI 318-14 Section 9.2 are used.

### 2.4 ORDERING INFORMATION

**HAC**

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Anchor Channel Length (in mm)</th>
<th>Nominal Channel Length (in mm)</th>
<th>No. of Anchors</th>
<th>Anchor Spacing (in mm)</th>
<th>Weight (lbf/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-40 9/150 F</td>
<td>B</td>
<td>9.81 (150)</td>
<td>3.7 (94.0)</td>
<td>2</td>
<td>3.94 (100)</td>
<td>0.79</td>
</tr>
<tr>
<td>HAC-40 9/200 F</td>
<td>B</td>
<td>7.87 (150)</td>
<td>3.7 (94.0)</td>
<td>2</td>
<td>5.91 (150)</td>
<td>1.01</td>
</tr>
<tr>
<td>HAC-40 9/250 F</td>
<td>A</td>
<td>6.84 (250)</td>
<td>3.7 (94.0)</td>
<td>2</td>
<td>7.87 (250)</td>
<td>1.21</td>
</tr>
<tr>
<td>HAC-40 9/300 F</td>
<td>A</td>
<td>4.81 (300)</td>
<td>3.7 (94.0)</td>
<td>2</td>
<td>8.84 (300)</td>
<td>1.41</td>
</tr>
<tr>
<td>HAC-30 9/150 F</td>
<td>A</td>
<td>3.78 (150)</td>
<td>3.7 (94.0)</td>
<td>3</td>
<td>5.91 (150)</td>
<td>1.72</td>
</tr>
<tr>
<td>HAC-30 9/200 F</td>
<td>A</td>
<td>2.74 (200)</td>
<td>3.7 (94.0)</td>
<td>3</td>
<td>7.87 (200)</td>
<td>2.14</td>
</tr>
<tr>
<td>HAC-30 9/250 F</td>
<td>A</td>
<td>1.70 (250)</td>
<td>3.7 (94.0)</td>
<td>3</td>
<td>1.94 (250)</td>
<td>2.58</td>
</tr>
<tr>
<td>HAC-30 9/300 F</td>
<td>A</td>
<td>0.66 (300)</td>
<td>3.7 (94.0)</td>
<td>4</td>
<td>8.84 (250)</td>
<td>28.68</td>
</tr>
</tbody>
</table>

### 2.4 ORDERING INFORMATION

- **HAC**
  - **Item Number**: HAC-40 9/150 F
  - **Lead Time Category**: B
  - **Anchor Channel Length (in mm)**: 9.81 (150)
  - **Nominal Channel Length (in mm)**: 3.7 (94.0)
  - **No. of Anchors**: 2
  - **Anchor Spacing (in mm)**: 3.94 (100)
  - **Weight (lbf/unit)**: 0.79

- **HAC**
  - **Item Number**: HAC-40 9/200 F
  - **Lead Time Category**: B
  - **Anchor Channel Length (in mm)**: 7.87 (150)
  - **Nominal Channel Length (in mm)**: 3.7 (94.0)
  - **No. of Anchors**: 2
  - **Anchor Spacing (in mm)**: 5.91 (150)
  - **Weight (lbf/unit)**: 1.01

- **HAC**
  - **Item Number**: HAC-40 9/250 F
  - **Lead Time Category**: A
  - **Anchor Channel Length (in mm)**: 6.84 (250)
  - **Nominal Channel Length (in mm)**: 3.7 (94.0)
  - **No. of Anchors**: 2
  - **Anchor Spacing (in mm)**: 7.87 (250)
  - **Weight (lbf/unit)**: 1.21

- **HAC**
  - **Item Number**: HAC-40 9/300 F
  - **Lead Time Category**: A
  - **Anchor Channel Length (in mm)**: 4.81 (300)
  - **Nominal Channel Length (in mm)**: 3.7 (94.0)
  - **No. of Anchors**: 2
  - **Anchor Spacing (in mm)**: 8.84 (300)
  - **Weight (lbf/unit)**: 1.41
### HAC Edge C

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Anchor Channel Length in. (mm)</th>
<th>Nominal Anchor Depth in. (mm)</th>
<th>No. of Anchors</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Weight (lb/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-50 4/50 F EDGE C</td>
<td>1</td>
<td>11.81 (305)</td>
<td>3.84 (97.5)</td>
<td>2</td>
<td>3.94 (100)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>3.74 (95)</td>
</tr>
<tr>
<td>HAC-50 4/50 F EDGE C</td>
<td>1</td>
<td>13.78 (350)</td>
<td>3.84 (97.5)</td>
<td>3</td>
<td>3.91 (100)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>3.74 (95)</td>
</tr>
<tr>
<td>HAC-50 4/50 F EDGE C</td>
<td>1</td>
<td>17.72 (450)</td>
<td>3.84 (97.5)</td>
<td>3</td>
<td>7.87 (200)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>3.74 (95)</td>
</tr>
</tbody>
</table>

### HAC Edge Lite

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Anchor Channel Length in. (mm)</th>
<th>Nominal Anchor Depth in. (mm)</th>
<th>No. of Anchors</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Weight (lb/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC-50 S 106/450 F EDGE C</td>
<td>1</td>
<td>11.81 (305)</td>
<td>4.31 (109.5)</td>
<td>2</td>
<td>3.94 (100)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>3.74 (95)</td>
</tr>
<tr>
<td>HAC-50 S 106/450 F EDGE C</td>
<td>1</td>
<td>13.78 (350)</td>
<td>4.31 (109.5)</td>
<td>3</td>
<td>3.91 (100)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>3.74 (95)</td>
</tr>
<tr>
<td>HAC-50 S 106/450 F EDGE C</td>
<td>1</td>
<td>17.72 (450)</td>
<td>4.31 (109.5)</td>
<td>3</td>
<td>7.87 (200)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>3.74 (95)</td>
</tr>
</tbody>
</table>

### HAC S Edge (for superior perpendicular shear steel performance)

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Anchor Channel Length in. (mm)</th>
<th>Nominal Anchor Depth in. (mm)</th>
<th>No. of Anchors</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Weight (lb/unit)</th>
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<tr>
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<td>1</td>
<td>11.81 (305)</td>
<td>3.7 (94.0)</td>
<td>3</td>
<td>7.87 (200)</td>
<td>23.6 (600)</td>
<td>4</td>
<td>5.71 (145)</td>
</tr>
<tr>
<td>HAC-50 S 94/450 F EDGE C</td>
<td>1</td>
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<td>3.7 (94.0)</td>
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<td>7.87 (200)</td>
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### HAC S Edge C (for superior perpendicular shear steel performance)

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<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Rebar Spacing in. (mm)</th>
<th>Weight (lb/unit)</th>
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<td>7.35 (187)</td>
<td>23.6 (600)</td>
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<td>4.68 (119)</td>
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### HBC-C

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<th>Rebar Spacing in. (mm)</th>
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### HAC Crench U

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<tr>
<td>HAC-50 356/450 F CRFoSU 2157399 A</td>
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### General note:
It’s recommended to always check availability with Hilti for all items.
Flat Washers

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<th>Material</th>
<th>Thread size</th>
<th>Channel Bolt Length (mm)</th>
<th>Pieces per sales unit</th>
<th>Weight (lb/unit)</th>
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<td>HBC-C N M16x50 8.8F</td>
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<td>M16</td>
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HBC-C Stainless Steel (flate bolts with nut)

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Flat washer A 13/44-F

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<th>Weight (lb/unit)</th>
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HAC-T EDGE Lite

Rebar HAC-T EDGE 94/350 F Edge Lite

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<th>Item Number</th>
<th>Lead Time Category</th>
<th>Anchor Channel Length in. (mm)</th>
<th>Nominal Channel Depth in. (mm)</th>
<th>No. of Anchors</th>
<th>Anchor Spacing in. (mm)</th>
<th>Nominal Rebar Length in. (mm)</th>
<th>No. of Rebar Spacing in. (mm)</th>
<th>Weight (lb/unit)</th>
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<td>3.71 (94)</td>
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<td>9.84 (250)</td>
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<td>4</td>
<td>7.34 (177)</td>
</tr>
<tr>
<td>2317539</td>
<td>B</td>
<td>11.81 (305)</td>
<td>3.71 (94)</td>
<td>0.80</td>
<td>9.84 (250)</td>
<td>19.68 (500)</td>
<td>4</td>
<td>7.34 (177)</td>
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HAC-T EDGE

Rebar HAC-T 94/350 F Edge Lite

<table>
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<th>Nominal Channel Depth in. (mm)</th>
<th>No. of Anchors</th>
<th>Anchor Spacing in. (mm)</th>
<th>Nominal Rebar Length in. (mm)</th>
<th>No. of Rebar Spacing in. (mm)</th>
<th>Weight (lb/unit)</th>
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<tr>
<td>2020871</td>
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<td>13.78 (350)</td>
<td>3.71 (94)</td>
<td>0.80</td>
<td>9.84 (250)</td>
<td>19.68 (500)</td>
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<tr>
<td>2020872</td>
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<td>3.71 (94)</td>
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<td>9.84 (250)</td>
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<tr>
<td>2020873</td>
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<td>3.71 (94)</td>
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<td>9.84 (250)</td>
<td>19.68 (500)</td>
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<td>7.34 (177)</td>
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<tr>
<td>2020874</td>
<td>A</td>
<td>2.94 (100)</td>
<td>3.71 (94)</td>
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<tr>
<td>2020875</td>
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<td>3.71 (94)</td>
<td>0.80</td>
<td>9.84 (250)</td>
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<td>7.34 (177)</td>
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<tr>
<td>2020876</td>
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<td>3.71 (94)</td>
<td>0.80</td>
<td>9.84 (250)</td>
<td>19.68 (500)</td>
<td>4</td>
<td>7.34 (177)</td>
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</table>

© HAC EDGE product line comes with the specified edge distance. Therefore, the edge distance is part of the product. The provide item number is for HAC EDGE products with 4.00” edge distance. This item number can be used for pricing purposes. A different edge distance does not impact the price. Please contact Brian Chauvin@chauvin.com for the correct item number.
HAC-T EDGE C

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Anchor Channel Length in (mm)</th>
<th>Nominal Channel Depth in (mm)</th>
<th>No. of Anchors</th>
<th>Anchor Spacing in (in.)</th>
<th>Nominal Rebar Spacing in (in.)</th>
<th>No. of Rebar tails</th>
<th>Rebar Spacing in (in.)</th>
<th>Weight (lb/unit)</th>
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<td>3.94 (100)</td>
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<td>7.87 (200)</td>
<td>23.5 (600)</td>
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<td>7.35 (187)</td>
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HAC-T EDGE C

(For superior perpendicular shear steel performance)

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<th>No. of Anchors</th>
<th>Anchor Spacing in (in.)</th>
<th>Nominal Rebar Spacing in (in.)</th>
<th>No. of Rebar tails</th>
<th>Rebar Spacing in (in.)</th>
<th>Weight (lb/unit)</th>
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HBC-T

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<th>Thread size</th>
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<th>Pieces per sales unit</th>
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<td>HBC-T M16 x 60 8.8F</td>
<td>215276</td>
<td>D</td>
<td>M16</td>
<td>3.94 (105)</td>
<td>50</td>
<td>22.47</td>
</tr>
<tr>
<td>HBC-T M20 x 40 8.8F</td>
<td>215276</td>
<td>A</td>
<td>M20</td>
<td>2.36 (50)</td>
<td>50</td>
<td>20.21</td>
</tr>
<tr>
<td>HBC-T M20 x 50 8.8F</td>
<td>215276</td>
<td>A</td>
<td>M20</td>
<td>3.15 (50)</td>
<td>50</td>
<td>29.76</td>
</tr>
<tr>
<td>HBC-T M20 x 60 8.8F</td>
<td>215276</td>
<td>D</td>
<td>M20</td>
<td>3.94 (105)</td>
<td>50</td>
<td>34.44</td>
</tr>
</tbody>
</table>

HBC-B

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Material</th>
<th>Thread size</th>
<th>Channel Bolt Length in (mm)</th>
<th>Pieces per sales unit</th>
<th>Weight (lb/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBC-B M10 x 40 4.6G</td>
<td>433527</td>
<td>D</td>
<td>M10</td>
<td>1.57 (40)</td>
<td>100</td>
<td>16.56</td>
</tr>
<tr>
<td>HBC-B M10 x 50 4.6G</td>
<td>433527</td>
<td>A</td>
<td>M10</td>
<td>2.36 (50)</td>
<td>100</td>
<td>19.47</td>
</tr>
<tr>
<td>HBC-B M12 x 40 4.6G</td>
<td>433527</td>
<td>A</td>
<td>M12</td>
<td>3.04 (105)</td>
<td>100</td>
<td>19.83</td>
</tr>
<tr>
<td>HBC-B M12 x 50 4.6G</td>
<td>433527</td>
<td>D</td>
<td>M12</td>
<td>3.15 (40)</td>
<td>100</td>
<td>16.42</td>
</tr>
<tr>
<td>HBC-B M16 x 40 4.6G</td>
<td>433527</td>
<td>A</td>
<td>M16</td>
<td>2.36 (50)</td>
<td>100</td>
<td>19.65</td>
</tr>
</tbody>
</table>

Flat Washers

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Lead Time Category</th>
<th>Material</th>
<th>Thread size</th>
<th>Channel Bolt Length in (mm)</th>
<th>Pieces per sales unit</th>
<th>Weight (lb/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat washer A 1/2 x 3/4 F</td>
<td>30477</td>
<td>A</td>
<td>steel, hot dip galvanized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat washer A 1/2 x 1 F</td>
<td>30477</td>
<td>A</td>
<td>steel, hot dip galvanized</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Custom lengths are available upon request in increments of 5 mm. Min. length 150 mm, max. length 5600 mm. See section for custom made anchor channels.

3) HAC EDGE product line comes with the specified edge distance. Therefore, the edge distance is a part of the product. The precise item number is for HAC EDGE products with 4.00” edge distance. This item number can be used for pricing purposes. A different edge distance does not impact the price. Please contact Hilti Channel Systems for the correct item number for a HAC EDGE product with an edge distance different to 4.00”.

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### 2.5.1 HAC STANDARD ANCHOR CONFIGURATION

**HAC and HAC-T**

<table>
<thead>
<tr>
<th>Units</th>
<th>Channel Length</th>
<th>Anchor Spacing</th>
<th>Number of Anchors</th>
</tr>
</thead>
<tbody>
<tr>
<td>in [mm]</td>
<td>5.91</td>
<td>3.94</td>
<td>2</td>
</tr>
<tr>
<td>in [mm]</td>
<td>11.81</td>
<td>9.84</td>
<td>2</td>
</tr>
<tr>
<td>in [mm]</td>
<td>13.78</td>
<td>9.84</td>
<td>3</td>
</tr>
<tr>
<td>in [mm]</td>
<td>21.65</td>
<td>9.84</td>
<td>3</td>
</tr>
<tr>
<td>in [mm]</td>
<td>31.50</td>
<td>9.84</td>
<td>4</td>
</tr>
<tr>
<td>in [mm]</td>
<td>41.34</td>
<td>9.84</td>
<td>5</td>
</tr>
<tr>
<td>in [mm]</td>
<td>228.35</td>
<td>9.84</td>
<td>24</td>
</tr>
</tbody>
</table>

Custom anchor channel lengths with custom anchor configurations are available upon request. The minimum anchor spacing is equal to 4.00" (102 mm).

**2.5.2 HAC EDGE LITE, HAC EDGE, AND HAC S EDGE ANCHOR AND EDGE PLATE CONFIGURATION**

#### HAC Edge Lite, HAC Edge, HAC S Edge

<table>
<thead>
<tr>
<th>Units</th>
<th>Channel Length</th>
<th>Anchor Spacing</th>
<th>Number of Anchors</th>
<th>Rebar Spacing</th>
<th>Number of Rebars</th>
</tr>
</thead>
<tbody>
<tr>
<td>in [mm]</td>
<td>11.81</td>
<td>9.84</td>
<td>2</td>
<td>3.74</td>
<td>4</td>
</tr>
<tr>
<td>in [mm]</td>
<td>13.78</td>
<td>9.84</td>
<td>3</td>
<td>4.41</td>
<td>4</td>
</tr>
<tr>
<td>in [mm]</td>
<td>17.72</td>
<td>7.87</td>
<td>3</td>
<td>5.71</td>
<td>4</td>
</tr>
<tr>
<td>in [mm]</td>
<td>24.00</td>
<td>9.84</td>
<td>3</td>
<td>4.68</td>
<td>6</td>
</tr>
</tbody>
</table>

**HAC EDGE Lite and HAC-T EDGE Lite are only available in 11.81" (300 mm) lengths.**

#### 2.5.3 HAC CRFoS U STANDARD ANCHOR CONFIGURATION

<table>
<thead>
<tr>
<th>Units</th>
<th>Channel Length</th>
<th>Anchor Spacing</th>
<th>Number of Anchors</th>
</tr>
</thead>
<tbody>
<tr>
<td>in [mm]</td>
<td>7.87</td>
<td>5.91</td>
<td>2</td>
</tr>
<tr>
<td>in [mm]</td>
<td>9.84</td>
<td>7.87</td>
<td>2</td>
</tr>
<tr>
<td>in [mm]</td>
<td>11.81</td>
<td>9.84</td>
<td>2</td>
</tr>
<tr>
<td>in [mm]</td>
<td>13.78</td>
<td>5.91</td>
<td>3</td>
</tr>
</tbody>
</table>

Custom anchor channel lengths with custom anchor configurations are available upon request. The minimum anchor spacing is equal to 3.94" (100 mm).
2.6 CUSTOM SOLUTIONS

Hilti keeps in stock anchor channel that are commonly used in North America. Non-standard and custom anchor channel can be provided upon request. A non-stock item is not necessarily a custom item. See section 2.4 for standard non-stock items. Depending on the level of customization, longer lead times and minimum order may be required.

Custom or non-stock channel may be required due to performance or geometric constraints. It is recommended to always specify products that are kept in stock in North America. However, there are cases where custom conditions cannot be avoided. The information in this section provides guidelines of the level of customization of the HAC product line. For questions, please reach out to Hilti.

2.6.1 CUSTOM ANCHOR CHANNEL LENGTHS (HAC, HAC CRFoS U, HAC EDGE)

Anchor channel with custom lengths (non-standard anchor spacing) can be provided upon request. AC232 and ICC ESR-3520 have minimum spacing requirements that shall be met. The lead time for anchor channels with non-standard anchor spacing is 10-12 weeks.

This information is applicable to HAC and HAC CRFoS U.

The minimum anchor spacing (S) for anchor channels is as follows: HAC-40, HAC-50, HAC-60, and HAC-70 is 3.94” (100 mm)

The maximum anchor spacing (S) for anchor channels is 9.84” (250 mm).

Anchor channels outside the lead time category “A” provided in section 2.4 are not necessarily custom channels. What defines a custom anchor channel is whether a custom component is required. A component is referred to any member of an anchor channel (i.e. anchor, channel profile, rivet, rebar, or EDGE Plate). For instance, an anchor channel with a non-standard anchor spacing (i.e. 2 anchors at 6.75 in. O.C.) or number of anchors (i.e. 11.80 in. (300 mm) long with 3 anchors) do not require custom components. However, an anchor channel with a custom anchor length (i.e. HAC-50 with 7” long anchors) requires the use of a new component.

The level of customization of an anchor channel may be limited by code requirements, structural performance, and design constraints.
2.6.2 CUSTOM ANCHOR LENGTH (HAC, HAC EDGE, HAC EDGE LITE)

Anchor channels with custom anchor lengths can be provided upon request. For such applications, the standard lead time (shipping via sea-freight) is 6 months. A minimum order of 4000 channels is required. The only exception is HAC-50 and HAC-60. These two channels utilize the same anchor diameter and therefore, they are interchangeable.

Minimum Anchor Spacing

See chapter 7 for the AC232 minimum requirements and design provisions for anchor channels with reduced anchor lengths.

For rounded head anchors, the maximum anchor length is 25 in.

2.6.3 CUSTOM REBAR LENGTHS (HAC CRFOS U)

Anchor channels with custom anchor lengths can be provided upon request. For longer rebars, the lead time is 6 months and the minimum order is 1000 channels. Anchor channels with shorter rebars than the standard rebar length require two additional weeks than the standard lead time and no minimum order is required.

Rebar Length, \( l_b \)

2.6.4 CUSTOM NUMBER OF ANCHORS/REBARS

The Hilti Anchor Channel portfolio comes with predetermined configurations. Some conditions may require anchor channel with different anchor configurations. The minimum anchor spacing is 3.84 in (100 mm). The maximum anchor spacing is 9.84 in (250 mm). The standard lead time (shipping via sea-freight) is 10-12 weeks.
3. APPLICATIONS

This chapter provides a general overview of some of the most common applications. The applications of cast-in anchor channels are not limited to the ones mentioned in the chapter. Generally speaking, Hilti Anchor Channel Systems can be used in any application where a cast-in solution is needed, site tolerance is required, and/or high performing anchors are demanded based on the applied loads.

3.1 HILTI CAST-IN ANCHOR CHANNEL APPLICATIONS

- Curtain wall façade
- Handrail
- Elevator guide rail
- Window wall (precast members)
- Brick façade
- Network rack
- Pipe Support
- Stadium seat
- Precast concrete member
- Pipe support
- Lateral restrain for masonry wall
- Man-Lifts
4. DESIGN INTRODUCTION

The design of an anchor channel system depends on two different aspects; substrate type and applied loads. They are both equally important and therefore they are both essential for an accurate anchor channel analysis. The design introduction opens up the sections that cover the design of an anchor channel.

INTRODUCTION

4.1 PUBLISHED LOAD VALUES

Technical data presented herein was current as of the date of publication (see back cover). Anchor channel strength (capacity) published in this technical manual are based on International Council Code Evaluation Research Report 3520 (ICC ESR-3520) when applicable. Likewise, analytical calculations are based on ICC ESR-3520 and ACI 318 when applicable.

Capacity (strength) of anchor channels outside the scope of ICC ESR-3520 are based on applicable testing protocols of Acceptance Criteria 232 (AC232). Load values obtained from testing represent the average results of multiple identical samples. Analytical calculations are based on applicable design provisions of AC232 and ACI 318.

Variations in base materials such as concrete and local site conditions require on-site testing to determine actual performance at any specific site.

The tables and diagrams in this guide are intended purely as an aid to the user and no guarantee can be given regarding their correctness or accuracy when used for design calculations for a specific application. Should you, despite the care we have taken, discover an error in the information given here, please notify us accordingly. In any event, the static system or, respectively, the specific application must always be checked for plausibility by the user.

For information regarding updates and changes, please contact Hilti, Inc. (U.S.) Technical Support at 1-877-749-6337 or Hilti (Canada) Corporation at 1-800-363-4458.

4.2 UNITS

Technical data is provided in Imperial units. Metric values, when provided, use the International System of units (SI) in observance with the Metric Conversion Act of 1975 as amended by the Omnibus Trade and Competitiveness Act of 1988. MI and MQ connector and base dimensions are converted from SI units, shown in parentheses, to Imperial units.

4.3 ANCHOR CHANNEL DESIGN

Acceptance Criteria for Anchor Channels in Concrete Elements (AC232) establishes the requirements for anchor channels in normal weight or lightweight concrete elements comply with International Building Code Evaluation Service, LLC (ICC-ES), evaluation report under the 2018, 2015, 2012, 2009, and 2006 International Building Code (IBC) and the 2018, 2015, 2012, 2009, and 2006 International Residential Code (IRC). The bases of compliance are IBC Section 104.11, and IRC Section R104.11. AC232 requires the verification of up to 20 different anchor channel failure modes, in addition to 6 additional anchor reinforcement failure modes if anchor reinforcement is used. Moreover, a total of up to 5 different interaction equations are required.

The design process of an anchor channel requires the verification of its structural adequacy to resist specific loads. Nowadays, design software such as PROFIS Anchor Channel facilitates and helps to speed up the design process. However, in order to utilize the software at its maximum potential and ensure the design is correct, a thorough understanding of several requirements is needed. For instance, PROFIS Anchor Channel does not allow the input of a cold join in the substrate element. On the other hand, even when a specific condition is fully covered by the software, one must still understand these elements for a proper design.

Such elements are as follows:
- Base material (chapter 5)
- Applied loads (chapter 6)
- Anchor strength (chapter 2)
- Anchoring to concrete theory and design guidelines (chapter 7)
- Reinforcing bar theory (chapter 8)

Figure 4.3.1 — Overview of anchor channel design elements.
The first Acceptance Criteria for Anchor Channels in Concrete Elements (AC232) was first approved by the ICC-ES Evaluation Committee in October 2010. Since then, several improvements and additions to the original AC232 provisions such as seismic provisions have been performed.

AC232 provisions are in a continuous state of development. AC232 is still a work-in-progress document. The design provisions and testing protocols are limited to specific type of anchor channels, anchor channel configurations, base materials, and type of loads. Design information for anchor channels and configurations not implicitly covered by AC232 such as HAC EDGE and corners with pair of channels load simultaneously, are covered in Chapter 9 of this technical manual.

Chapter 10 provides a general overview of PROFIS Anchor Channel.

Chapter 11 covers a wide range of best practices for an optimal anchor channel design and ensure designers can offer value engineered anchor channel designs as well as to help contractors to minimize field fixes.

Chapter 12 provides Instructions for use.

Chapter 13 provides general recommendations for typical field fixes encountered in jobsites.

5. BASE MATERIAL

Base materials or substrate information is fundamental in determining the anchor channel strength. Oftentimes, the design of an anchor channel is limited by the substrate’s strength. Therefore, the design of an anchor channel is contingent to the adequacy of the base material at the anchor zone.

Having the right substrate properties and a solid understanding of how different base materials properties impacts the design of an anchor channel design is essential. Therefore, the base material shall be carefully examined prior to the design of an anchor channel, in order to assess how the anchor channel design may be impacted.
5.1 BASE MATERIALS

5.1.1 BASE MATERIALS FOR FASTENING

The wide variety of building materials used today provides different anchoring conditions for anchors. There is hardly a base material in or to which a fastening cannot be made with a Hilti product. However, the properties of the base material play a decisive role when selecting a suitable fastener/anchor and determining the load it is capable of carrying. It is the responsibility of the designer to carefully match the type of fastener with the base material to obtain the desired results.

5.1.2 CONCRETE

Concrete is a synthetic stone consisting of a mixture of cement, aggregates, and water. In many cases, special additives are used to influence or change certain properties. Concrete has a relatively high compressive strength compared to its tensile strength. Thus, steel reinforcing bars are frequently cast in concrete to carry tensile forces, and this combination is referred to as reinforced concrete. Cement is a binding agent which combines with water and aggregates and hardens through the process of hydration to form concrete. Portland cement is the most commonly used cement and is available in several different types to meet specific design requirements (ASTM C150).

Table:

<table>
<thead>
<tr>
<th>Aggregate grading</th>
<th>Concrete unit weight</th>
<th>ASTM concrete type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate grading</td>
<td>145-155</td>
<td>Normal-weight</td>
</tr>
<tr>
<td>Fine</td>
<td>Coarse</td>
<td>ASTM C33</td>
</tr>
<tr>
<td>Sand-lightweight</td>
<td>105-115</td>
<td>Coarse</td>
</tr>
<tr>
<td>Fine</td>
<td>Coarse</td>
<td>All-lightweight</td>
</tr>
</tbody>
</table>

The effect of aggregate mechanical properties on anchor performance is less well understood. In general, harder/denser aggregates (i.e. granite) tend to result in higher concrete cone breakout loads, whereas lightweight aggregates produce lower tensile stress and shear capacities. Concrete is typically assumed to crack under normal service load conditions or, more specifically, when tensile stresses imposed by loads or restraint conditions exceed its tensile strength. Crack width and distribution are generally controlled through the use of reinforcement. With consideration for the protection of the reinforcing steel, crack widths, per ACI 318, are assumed to be less than approximately 0.012 in (0.3 mm). Under seismic loading, flexural crack widths corresponding to the onset of reinforcing yield are assumed to be approximately 1-1/2 x static crack width = 0.02” (0.5 mm). Both ACI 318 and the International Building Code conservatively assume cracked concrete as the baseline condition for the design of cast-in-place and post-installed anchors since the existence of cracks in the vicinity of the anchor can result in a reduced ultimate load capacity and increased displacement at ultimate load compared to uncracked concrete conditions.

Conditions where anchor channels are installed near tendon(s) shall be designed accordingly. Additional coordination with the Engineer of Records (EOR), design engineer, and/or pre-stressed concrete engineer is required.

5.1.3 PRE-TENSIONED / PRE-STRESSED CONCRETE

Pretensioned concrete refers to concrete cast around pretensioned steel tendons. Cast-in anchor channel systems can be a solution for pretensioned concrete, as it does not require drilling into the concrete. AC232 does not provide provisions to account for the influence of pre-tensioned cables on the anchor channel concrete capacity.

Anchor channels installed near tendon(s) may induce additional stresses in the concrete. Likewise, tendon(s) near anchor channel(s) may impact the performance of the channel. Anchor channels installed near tendon(s) shall be designed accordingly. Additional coordination with the Engineer of Records (EOR), design engineer, and/or pre-stressed concrete engineer is required.

5.1.4 BONDED POST-TENSIONED CONCRETE

Post-tensioned concrete refers to a concrete member containing steel tendons that are tensioned after casting the concrete. As with the prestressed concrete case, anchor channels close to post-tensioning should be designed accordingly and additional coordination with the Engineer of Records (EOR), design engineer, and/or post-tensioned concrete engineer is required. AC232 does not provide provisions to account for the influence of post-tensioned cables on the anchor channel concrete capacity.

5.1.5 ADMIXTURES

Chemical admixtures are ingredients added to the basic components of concrete or mortar (cement, water, and aggregates) immediately before or during mixing. Chemical admixtures are used to enhance the properties of concrete and mortar in the plastic and hardened state. These properties may be modified to increase compressive and flexural strength, decrease permeability and improve durability, inhibit corrosion, reduce shrinkage, accelerate or retard initial set, increase slump, and working properties, increase cement efficiency, improve the economy of the mixture, etc.

Testing of post-installed anchors is performed in concrete without admixtures. Designers should take into consideration the effects produced by admixtures on concrete when considering the use of post-installed anchors.

5.2 EVALUATION OF TEST DATA

5.2.1 DEVELOPING FASTENER PERFORMANCE DATA

State-of-the-art anchor design uses what is known as the Strength Design Method. By using the Strength Design Method, nominal strengths are first calculated for all the possible anchor failure modes. Subsequently, strength reduction factors are applied to each nominal strength to obtain a design strength. The controlling design strength is finally compared to a factored load. The provisions of ACI 318-14 Chapter 17 are the basis used for Strength Design.

Strength Design data for Hilti anchor channels in concrete elements is derived from testing as per the provisions of ICCES AC232.

Beginning with IBC 2003, the IBC Building Codes have adopted the Strength Design Method for anchorage into concrete of both cast-in-place and post-installed anchors.

Another anchor design method known as “Allowable Stress Design” can be used as an alternative to the Strength Design provisions. Section 2.2.2 provides detailed explanations to analyze cast-in anchor channels via Allowable Stress Design. Allowable Stress Design data for Hilti cast-in anchor channels is derived from testing based on ICC-ES AC232.

Allowable loads are developed applying a statistical method to the test data which relates the allowable working load to the performance variability of the fastening.

5.3 CORROSION

5.4 SPECIAL APPLICATIONS

5.5 SEISMIC CONSIDERATIONS
5.2.2 ALLOWABLE LOADS

Historically, allowable loads for anchors have been derived by applying a global safety factor to the average ultimate value of test results as shown in Eq. (5.2.1).

\[ F_a = \frac{F}{k} \quad (5.2.1) \]

Where:
- \( F_a \) = mean ultimate value of test data (population sample)
- \( k \) = global safety factor

Global safety factors of 3 for cast-in anchor channels have been industry practice for nearly three decades. The global safety factor is assumed to cover expected variations in field installation conditions and in anchor performance from laboratory tests.

Note that global safety factors applied to the mean do not explicitly account for the coefficient of variation, i.e., all anchors are considered equal with respect to variability in the test data.

5.2.3 STATISTICAL EVALUATION OF DATA

Experience from a large number of tests on anchors shows that ultimate loads generally approximate a normal Gaussian probability density function as shown in Fig. 5.2.1. This allows for the use of statistical evaluation techniques that relate the resistance to the system performance variability associated with a particular anchor.

The 5% fractile characteristic value has been adopted by the IBC as the basis for determining published design loads based on anchor testing results for Strength Design. There is a 95% probability that 95% of the test loads will exceed a 5% fractile value. The 5% fractile value is calculated by subtracting a certain number of standard deviations of the test results from the mean based on the number of trials. See Eq. (5.2.2) and the referenced statistical table by D. B. Owen. For a series of 5 trials, the 5% fractile value is calculated by multiplying the standard deviations by \( k = 3.401 \) and subtracting from the mean.


5.3 CORROSION

5.3.1 THE CORROSION PROCESS

Corrosion is defined as the chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties (ASTM G15). The corrosion process can be very complex and have many contributing factors that lead to immediate or gradual destructive results. In anchorage and fastener design, the most common types of corrosion are direct chemical attack and electro-chemical contact.

5.3.2 TYPES OF CORROSION

5.3.2.1 DIRECT CHEMICAL ATTACK

Corrosion by direct chemical attack occurs when the base material is soluble in the corroding medium. One method of mitigating these effects is to select a fastener that is not susceptible to attack by the corroding chemical. Compatibility tables of various chemical compounds with Hilti adhesives and epoxy fastening systems are provided in this technical guide.

When selection of a base metal compatible with the corroding medium is not possible or economical, another solution is to provide a coating that is resistant to the corroding medium. This might include metallic coatings such as zinc or organic coatings such as epoxies or fluorocarbons.

5.3.2.2 ELECTROCHEMICAL CONTACT CORROSION

All metals have an electrical potential relative to each other and are classified accordingly in the galvanic series of metals and alloys. When metals of different potential come into contact in the presence of an electrolyte (moisture), the metal with more negative potential becomes the anode and corrodes, while the other becomes the cathode and is galvanically protected.

The severity and rate of attack are influenced by:
- a. Relative position of the contacting metals in the galvanic series
- b. Relative surface areas of the contacting materials
- c. Conductivity of the electrolyte

The effects of electro-chemical contact corrosion may be mitigated by:
- a. Using similar metals close together in the electromotive force series.
- b. Separating dissimilar metals with gaskets, plastic washers or paint with low electrical conductivity. Materials typically used in these applications include:
  1. High Density Polyethylene (HDPE)
  2. Polytetrafluoroethylene (PTFE)
  3. Polycarbonates
  4. Neoprene/chloroprene
  5. Cold galvanizing compound
  6. Bituminous coatings or paint

Note: Specifiers must ensure that these materials are compatible with other anchorage components in the service environment.

- c. Selecting materials so that the fastener is the cathode, the most noble or protected component
- d. Providing drainage or weep holes to prevent entrapment of the electrolyte

<table>
<thead>
<tr>
<th>Galvanic Series of Metals and Alloys</th>
<th>Corroded End (anodic, or least noble)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>Magnesium alloys</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Zinc</td>
</tr>
<tr>
<td>Copper</td>
<td>Aluminum 1100</td>
</tr>
<tr>
<td>Galvanized</td>
<td>Aluminum 2024-T4</td>
</tr>
<tr>
<td>Steel or Iron</td>
<td>Cast Iron</td>
</tr>
<tr>
<td>Chromium</td>
<td>Chromium-iron (active)</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni-Resist cast iron</td>
</tr>
<tr>
<td>Monel nickel-copper alloy</td>
<td>Hastelloy Alloy C (active)</td>
</tr>
<tr>
<td>Stainless</td>
<td>Stainless</td>
</tr>
<tr>
<td>Hastelloy Alloy C</td>
<td>Stainless</td>
</tr>
<tr>
<td>Hastelloy Alloy C</td>
<td>Stainless</td>
</tr>
<tr>
<td>Inconel nickel-chromium alloy</td>
<td>Inconel nickel-chromium alloy</td>
</tr>
<tr>
<td>Monel nickel-copper alloy</td>
<td>Hastelloy Alloy C</td>
</tr>
<tr>
<td>Nickel (active)</td>
<td>Nickel (active)</td>
</tr>
<tr>
<td>Inconel nickel-chromium alloy</td>
<td>Type 304 Stainless (active)</td>
</tr>
<tr>
<td>Monel nickel-copper alloy</td>
<td>Type 316 Stainless (active)</td>
</tr>
<tr>
<td>Lead</td>
<td>Lead</td>
</tr>
<tr>
<td>Tin</td>
<td>Silver</td>
</tr>
<tr>
<td>Copper</td>
<td>Silver</td>
</tr>
<tr>
<td>Stainless</td>
<td>Stainless</td>
</tr>
<tr>
<td>Galvanized</td>
<td>Stainless</td>
</tr>
<tr>
<td>Monel nickel-copper alloy</td>
<td>Stainless</td>
</tr>
<tr>
<td>Nickel (passive)</td>
<td>Stainless</td>
</tr>
<tr>
<td>Monel nickel-copper alloy</td>
<td>Stainless</td>
</tr>
<tr>
<td>Stainless</td>
<td>Stainless</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Stainless</td>
</tr>
<tr>
<td>Titanium</td>
<td>Titanium</td>
</tr>
<tr>
<td>Graphite</td>
<td>Graphite</td>
</tr>
<tr>
<td>Gold</td>
<td>Gold</td>
</tr>
<tr>
<td>Silver</td>
<td>Silver</td>
</tr>
<tr>
<td>Platinum</td>
<td>Platinum</td>
</tr>
<tr>
<td>Protected End (cathodic, or most noble)</td>
<td>Hastelloy Alloy C (passive)</td>
</tr>
</tbody>
</table>

Source: RTI Fastener Standards, 5th Edition
5.3.2.3 HYDROGEN ASSISTED STRESS CORROSION CRACKING

Often incorrectly referred to as hydrogen embrittlement, hydrogen assisted stress corrosion cracking (HASSC) is an environmentally induced failure mechanism that is sometimes delayed and most times occurs without warning. HASSC occurs when a hardened steel fastener is stressed (loaded) in a service environment which chemically generates hydrogen (such as when zinc and iron combine in the presence of moisture). The potential for HASSC is directly related to steel hardness. The higher the fasterener hardness, the greater the susceptibility to stress corrosion cracking failures. Eliminating or reducing any one of these contributing factors (high steel hardness, corrosion or stress) reduces the overall potential for this type of failure. Hydrogen embrittlement, on the other hand, refers to a potential damaging side effect of the steel fastener manufacturing process, and is unrelated to project site corrosion. Hydrogen embrittlement is neutralized by proper processing during fastener pickling, cleaning and plating operations (specifically, "baking" the fasteners after the application of the galvanic coating).

5.3.3 CORROSION PROTECTION

The most common material used for corrosion protection of carbon steel fasteners is zinc. Zinc coatings can be uniformly applied by a variety of methods to achieve a wide range of coating thicknesses depending on the application. All things being equal, thicker coatings typically provide higher levels of protection.

An estimating table for the mean corrosion rate and service life of zinc coatings in various atmospheres is provided to the right. These values are for reference only, due to the large variance in the research findings and specific project site conditions, but they can provide the specifier with a better understanding of the expected service life of zinc coatings. In controlled environments where the relative humidity is low and no corrosive elements are present, the rate of corrosion of zinc coatings is approximately 0.15 microns per year.

Zinc coatings can be applied to anchors and fasteners by different methods. These include (in order of increasing coating thickness and corrosion protection):

b. ASTM B695 – Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
c. ASTM A153 – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
d. Sherardizing Process – Proprietary Diffusion Coated Zinc Coating Process

5.3.4 HILTI FASTENING SYSTEMS

5.3.4.1 HILTI CHANNELS

Most Hilti metal anchors are available in carbon steel with an electroplated zinc coating of at least 5 μm with chromate passivation. Chromate passivation reduces the rate of corrosion for zinc coatings, maintains color, abrasion resistance and, when damaged, exhibits a unique “self healing” property. This means that the chromium within the film on the anchor surface will repassivate any exposed areas and lower the corrosion rate.

5.3.5 APPLICATIONS

5.3.5.1 GENERAL APPLICATION

These application charts are offered as general guidelines. Site specific conditions may influence the decision.

<table>
<thead>
<tr>
<th>Application</th>
<th>Conditions</th>
<th>Fastener recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural steel components to concrete and masonry (interior connections within the building envelope not subjected to free weathering)</td>
<td>Interior applications without condensation</td>
<td>Galvanic zinc electroplating</td>
</tr>
<tr>
<td>Structural steel components to concrete and masonry (interior connections subjected to free weathering)</td>
<td>Interior applications with occasional condensation</td>
<td>HDG or Sherardized</td>
</tr>
<tr>
<td>Temporary framework, erection bracing and short-term scaffolding</td>
<td>Slightly corrosive environments</td>
<td>HDG or Sherardized</td>
</tr>
<tr>
<td>Parking garages / parking decks subject to periodic application of de-ice-cards including chloride solutions</td>
<td>Safety critical</td>
<td>Stainless steel1</td>
</tr>
<tr>
<td>Road / bridge decks subject to periodic application of de-ice-cards including chloride solutions</td>
<td>Non-safety critical</td>
<td>HDG or Sherardized</td>
</tr>
</tbody>
</table>

1 Refer to ACI 318-19 Chapter 14 – Durability
2 Refer to ACI 318-19 Section 6.6 – Coatings for Corrosion Protection
3 Refer to PCI Parking Structures: Recommended Practice for Design and Construction – Chapters 3, 5 and Appendix
4 Current guidelines address environmental corrosion (direct chemical attack). Additional considerations should be taken into account when using hardened steel fasteners susceptible to HASSC.
5.4 SPECIAL APPLICATIONS

This application chart offers a general guideline addressing environmental corrosion (direct chemical attack). Site specific conditions may influence the decision.

<table>
<thead>
<tr>
<th>Application</th>
<th>Conditions</th>
<th>Fastener Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum fastenings (flashing / roofing accessories, hand rails, grating panels, sign posts and miscellaneous fixtures)</td>
<td>Interior applications without condensation</td>
<td>Galvanic zinc plating</td>
</tr>
<tr>
<td></td>
<td>Exterior applications with condensation</td>
<td>stainless steel, X-CR</td>
</tr>
<tr>
<td>Water treatment</td>
<td>Not submerged</td>
<td>HDG, Sherardized or Stainless steel</td>
</tr>
<tr>
<td></td>
<td>Submerged</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Waste water treatment</td>
<td>Not submerged</td>
<td>HDG or Stainless steel</td>
</tr>
<tr>
<td></td>
<td>Submerged</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Marine (salt water environments, shipyards, docks, off-shore platforms)</td>
<td>Non-safety critical or temporary connections</td>
<td>HDG</td>
</tr>
<tr>
<td></td>
<td>High humidity with the presence of chlorides — splash zone</td>
<td>stainless steel¹</td>
</tr>
<tr>
<td></td>
<td>On the off-shore platform or rig</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Indoor swimming pools</td>
<td>Non-safety critical</td>
<td>HDG</td>
</tr>
<tr>
<td></td>
<td>Safety critical or subjected to high concentrations of soluble chlorides</td>
<td>Stainless steel¹</td>
</tr>
<tr>
<td>Pressure / chemically treated wood</td>
<td>Above grade</td>
<td>HDG</td>
</tr>
<tr>
<td></td>
<td>Below grade</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Power plant stacks / chimneys</td>
<td>Non-safety critical</td>
<td>HDG or Stainless steel</td>
</tr>
<tr>
<td></td>
<td>Safety critical or subjected to high concentration of soluble chlorides</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Tunnels (lighting fixtures, rails, guard posts)</td>
<td>Non-safety critical</td>
<td>HDG, Stainless steel</td>
</tr>
<tr>
<td></td>
<td>Safety critical</td>
<td>Stainless steel¹</td>
</tr>
</tbody>
</table>

¹ Steel selection depends on safety relevance

5.5 SEISMIC CONSIDERATIONS

5.5.1 SEISMIC CONSIDERATIONS

Rapid ground movement during an earthquake leads to relative displacement of a building’s foundation. Owing to the inertia of its mass, the building cannot follow this movement without experiencing deformations in the building frame. In addition, accelerations are induced in the structure. Due to the stiffness of the structure, restoring forces result and cyclic strains are induced in the structure. These strains are also experienced by anchors used for attachment of nonstructural components, such as cladding, to the structural frame. The loads acting on these anchors can be calculated directly on the basis of the dynamic characteristics of the building, local site seismicity, soil characteristics, and the dynamic characteristics of the components fastened to the building.

In general terms, the main difference between static loading and seismic loading of attachments is the multi-directional cyclic loading induced by the seismic event as shown in Figure 5.5.1.1.

A seismic hazard is the probability that an earthquake will occur in a given geographic area, within a given window of time, and with ground motion intensity exceeding a given threshold.

The U.S Geological Survey (USGS) has produced a one-year 2017 seismic hazard forecast for the central and eastern United States from induced and natural earthquakes that updates the 2016 one-year forecast; this map is intended to provide information to the public and to facilitate the development of induced seismicity forecasting models, methods, and data. The 2017 hazard model applies the same methodology and input logic tree as the 2016 forecast, but with an updated earthquake catalog.

In order to ensure the adequacy of the anchor to resist seismic loads, the seismic analysis needs to be performed, even when at first glance, the seismic loads seem to be significant lower than the static loads.

Figure 5.5.1.2 illustrates the different seismic design categories in different states of the United States. Although regulations in some states are more stringent than others, in order to provide IBC-compliant solutions and ensure the general welfare of citizens, seismic design verification for anchor channels is performed for anchor channels located in structures assigned to Seismic Design Categories C, D, E, or F.

Figure 5.5.1.2 — U.S. seismic hazard map.

In summary:

- Seismic conditions can significantly change the behavior of anchors, compared to static conditions.
- It’s important to include seismic design for both structural and non-structural elements of a build, as research shows that non-structural systems suffer the largest damage in commercial buildings during an earthquake.
- Adequate seismic construction design and specification reduces the probability of a failure of the anchorage during a seismic event.
- Seismic events have a big impact on the loading and behavior of anchors in the supporting material, resulting in the possibility of some anchors being unsuitable for seismic conditions or having a lower capacity under seismic conditions than under static conditions.
5.5.2 BEHAVIOR OF THE MATERIALS IN WHICH ANCHORS ARE SET

Due to the multiple responses of seismic action, the assumed compression zone under static action may suddenly become the tension zone. The possibility of cracks intersecting the anchor location can therefore be assumed to be highly probable, even if the original anchoring location was assumed to be uncracked, as indicated.

Static loading: cracks may occur in defined tension zones

Seismic loading: cracks may occur almost everywhere in concrete members.

The nature of seismic loads is very different than the static loads, hence there is a different testing criteria for the anchor channel used in seismic zones replicating the seismic activity and also the design methodology is more stringent.

Acceptance Criteria 232 (AC232) provides design guidelines for cast-in anchor channels. Anchor channels are now easier to show compliance with the International Building Code via an Evaluation Service Report. The lack of explicit provisions for anchor channels in the anchor provisions of ACI 318 are addressed by the design guidelines provided in AC232, which are written as amendments to ACI 318.

Historically, anchor channels have been designed using ASD (allowable stress design) concepts. With the introduction of AC232, the use of LRFD (strength design) for the design of anchor channels was made possible. Whereas ASD assigns global safety factors to cover all aspects of the design problem (variability, consequences of failure, etc.), strength design permits explicit consideration of the variability in resistance and loads. In many cases, strength design may result in more efficient design solutions. The ACI 318 model code has used strength design since 1971, and its use for anchorage problems is now accepted practice throughout the U.S.
6.1 STRENGTH DESIGN VS ALLOWABLE STRESS DESIGN

Allowable Stress Design (ASD)
Design philosophy based on ensuring the service loads do not exceed the elastic limit. This is accomplished by ensuring that stresses remain within the limits through the use of safety factors. The safety factor accounts for all of the uncertainties in loads and strength (material).

\[
\frac{R}{FS} = \sum_{i=1}^{n} \gamma L_i
\]

Where:
- \( R_i \) = nominal or design strength (stress, moment, force, etc.)
- \( FS \) = Safety factor (3-4 typically)
- \( \gamma \) = load factor for the ith load component out of n components

Strength Design
Also known as Load and Resistance Factor Design (LRFD). Design philosophy considers uncertainties in material properties, construction tolerances, and loads. It incorporates state-of-the-art analysis and load and resistance factors are statistically calibrated to ensure a uniform level of safety.

\[
\frac{\phi R_i}{FS} = \sum_{i=1}^{n} \gamma L_i
\]

Where:
- \( \phi \) = strength reduction factor
- \( \gamma \) = load factor for the ith load component out of n components
- \( L_i \) = nominal or service value for the ith load component out of m components

6.2 ANCHOR CHANNEL LOADING

6.2.1 ANCHOR CHANNEL LOADING
The design of anchor channels is now based on Strength Design philosophy. Applied loads shall be factored according to the applicable building code.

Symbols and Notation
- \( D \) = dead load
- \( D_i \) = weight of ice
- \( E \) = earthquake load
- \( F \) = load due to fluids with well-defined pressures and maximum heights
- \( F_i \) = Flood load
- \( H \) = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials.
- \( L \) = live load
- \( R \) = roof live load
- \( S \) = snow load
- \( T \) = self-straining force
- \( W \) = wind load
- \( Wi \) = wind-on-ice determined in accordance with Chapter 10.

Terminology
Load Factors:
Strength Design philosophy uses load factors to amplify the magnitude of the calculated loads to account for the uncertainties involved in estimating the magnitude of different loads.

Load Combinations:
Different types of loads can be combined since it can be applied simultaneously, however they may not be with the same magnitudes and factors.

6.2.2 LOAD COMBINATIONS
Anchor channels shall be designed using the applicable load combination. When selecting the required load combination, it is important to ensure the load combinations are consistent with the International Building Code used to derive the loads. If load combinations and derive loads use different IBC versions, the anchor channel design may result in very unconservative or conservative results.

IBC refers to ASCE Standards for the determination of loads and selection of the required load combinations. Although some of the load combinations do not change in different ASCE year, ASCE 7-10 has undergone some important changes. Special attention shall be paid to the ASCE version used for the determination of forces and load combinations.

Introduction
Wind design in ASCE 7-10 underwent several major changes. Wind provisions in ASCE 7-10 follow the form introduced for the seismic provisions in the 2005 edition. New wind speed maps that vary by risk category have been introduced. The wind speeds provided in such maps are applicable for determining wind pressures for strength design. Therefore, wind pressures are strength level and the wind load factor was changed to 1.0.

Load Combinations ASCE 7-10 — Allowable Stress Design

1. \( D \)
2. \( D + L \)
3. \( D + \beta L \) or \( S \) or \( R \)
4. \( D + 0.75L + 0.75S \) or \( S \) or \( R \)
5. \( D + 0.6W \) or \( 0.7E \)
6a. \( D + 0.75L + 0.75W + 0.75R \) or \( S \) or \( R \)
6b. \( D + 0.75L + 0.75W + 0.75S + 0.75E \) or \( R \)
7. \( 0.6D + W + H \)
8. \( 0.6D + 0.7E + H \)

Load Combinations ASCE 7-10 — Strength Design

1. \( 1.2D \)
2. \( 1.2D + 1.6L \) or \( 0.5L \) or \( S \) or \( R \)
3. \( 1.2D + 1.6L \) or \( S \) or \( R \) + \( 0.5L or 0.3L or 0.15L or 0.05L \)
4. \( 1.2D + 1.4L + 0.5L \) or \( S \) or \( R \)
5. \( 1.2D + 1.0L + S \) or \( R \)
6. \( 1.0D + 1.0L \)
7. \( 0.9D + 0.7E \)

6.3.0 SEISMIC LOADING

6.3.1 SEISMIC LOAD BEHAVIOR

Cyclic loads are a characteristic feature of actions acting on structures and anchorages during earthquakes. During seismic events, anchors used to connect structural and non-structural elements to concrete are subjected to cyclic tension and cyclic shear loads. Cycling loads may induce additional cracking that can ultimately reduce the concrete capacity of the anchor. This effect is reflected in Figure 6.3.1. Incorrectly designed or inadequately qualified anchors have caused severe damage and failure of the connection.

6.3.1 SEISMIC LOAD DERIVATION FOR NONSTRUCTURAL COMPONENTS — ASCE 7-10, CHAPTER 13

ASCE 7-10 §12.14.3.1 Seismic Load Effect The seismic load effect, E, shall be determined in accordance with the following:

1. For use in load combination 5 in ASCE 7-10 Section §2.3.2 or load combinations 5 and 6 in ASCE 7-10 Section §2.4.1, E shall be determined in accordance with ASCE 7-10 Eq. 12.14-3 as follows:

\[ E = E_v + E_h \] (ASCE 7-10 Eq. §12.14-3)

2. For use in load combinations 7 in ASCE 7-10 Section §2.3.2 or load combination 8 in ASCE 7-10 Section §2.4.1, E shall be determined in accordance with ASCE 7-10 Eq. §12.14-4 as follows:

\[ E = E_v + E_h + E_p \] (ASCE 7-10 Eq. §12.14-4)

where

- E = seismic load effect
- \( E_v \) = effect of horizontal seismic forces as defined in ASCE 7-10 Section §12.14.3.1.2
- \( E_h \) = effect of vertical seismic forces as defined in ASCE 7-10 Section §12.14.3.1.2
- \( E_p \) = component operating weight

ASCE 7-10 §12.14.3.1.1 Horizontal Seismic Load Effect

The horizontal seismic load effect, \( E_h \), shall be determined in accordance with Eq. 12.14-5 as follows:

\[ E_h = 0.2SDS\left(W_p\sin\theta\right) \] (ASCE 7-10 Eq. §12.14-5)

where

- \( S_{DS} \) = design spectral response acceleration parameter at short periods obtained from ASCE 7-10 §11.4.4
- \( D \) = effect of dead load
- \( W_p \) = component operating weight
- \( \theta \) = angle between the component's center of gravity and the gravity vector

EXCEPTION: The seismic load effect, \( E_h \), is permitted to be taken equal to 1 and the overstrength factor, \( \Omega \), does not apply.

ASCE 7-10 §12.14.3.1.2 Vertical Seismic Load Effect The vertical seismic load effect, \( E_v \), shall be determined in accordance with Eq. 12.14-6 as follows:

\[ E_v = 0.2SDS\left(W_p\sin\theta\right) \] (ASCE 7-10 Eq. §12.14-6)

where

- \( S_{DS} \) = design spectral response acceleration parameter at short periods obtained from ASCE 7-10 §11.4.4
- \( D \) = effect of dead load
- \( W_p \) = component operating weight
- \( \theta \) = angle between the component's center of gravity and the gravity vector

6.3.2 OVERSTRENGTH FACTORS PER ASCE 7-10

Overstrength factor is used to satisfy seismic detailing requirement of ACI 318. Structures in Seismic Design Category (SDC) C, D, E or F are designed to yield which induces additional cracking in concrete. The objective of the overstrength factor is to cope with the unpredictability of the seismic forces and to avoid brittle failure (concrete failure) of the anchorage in a seismic event. This can be achieved by increasing the concrete capacity of the anchorage by increasing the seismic load by the overstrength factor.

6.4.0 LOADS ON HANDRAIL AND GUARDRAIL SYSTEMS — ASCE 7-10

ASCE 7-10 §4.5.1

All handrail and guardrail systems shall be designed to resist a single concentrated load of 200 lb (0.89 kN) applied in any direction at any point on the handrail or top rail to transfer this load through the supports to the structure to produce the maximum load effect on the element being considered.

Further, all handrail and guardrail systems shall be designed to resist a load of 50 lb/ft (pound-force per linear foot) (0.73 kN/m) applied in any direction along the handrail or top rail.
7. ANCHOR CHANNEL DESIGN CODE

Base material or substrate information is fundamental in determining the anchor channel strength. Although Chapter 2 provides nominal steel strengths of the anchor channel, the adequacy of an anchor in general is contingent on the adequacy of the base material.

Having the right substrate properties and a good understanding of how different base materials’ properties or requirements may impact the anchor channel design. Therefore, the base material shall be carefully examined prior to the design of an anchor channel system.

This chapter contains testing, theory and design methodology of anchor channel described in AC232. The AC232 acceptance criteria describes the principles and requirements for safety, serviceability and durability of anchor channels for use in uncracked or cracked concrete.

The AC232 applies to anchor channels used to resist loads in cracked and uncracked normal weight and lightweight concrete and included assessments of strength capacity, design procedures and quality control. This chapter will cover testing procedure based on AC232 for evaluation of the steel strengths of anchor channel as well as the design methodology described in AC232 in order to evaluate the various concrete breakout failure modes for standard anchor channel with headed studs and anchor channels with deformed bars.

7.1 — OVERVIEW OF ANCHOR CHANNEL THEORY

Before the publication of Acceptance Criteria 232 (AC232), it was difficult to show cast-in anchor channels compliant with the International Building Code (IBC) since ACI 318 Anchoring-to-Concrete provisions exclude the design of specialty inserts. The publication of (AC232) brought significant benefits to the cast-in anchor channel industry and design community. The use of optimized anchor channel solutions and simplification of the design and approval processes for anchor channels ultimately can avoid construction shutdowns.

Cast-in anchor channels can now more easily be shown compliant with the IBC, as AC232 3.0 Design Requirements provides suggested additions to ACI 318 Anchoring-to-Concrete provisions that permit the design of anchor channel systems as if they were included in ACI 318 Anchoring-to-Concrete provisions. In addition, AC232 allows the design community to have a clear understanding of cast-in anchor channel systems.

Prior to AC232, designers had to design anchor channels via engineering judgment, which may require applying design provisions not applicable to anchor channels, research papers, and/or using manufacturers’ technical data. The non-model code design methodology used to approve the anchor channel design had to be backed-up by the P.E. stamp of a licensed engineer of the state of the project’s location. In some extreme cases, this was not accepted by local jurisdictions and additional testing was required. Additional testing added an extra problem since testing protocol for anchor channels did not exist. Providing model code compliant designs increases the probability of acceptance by local jurisdictions and reduce the probability of additional testing.

Relying on technical data is adequate only if the tests are performed correctly. Tests results can be positively or negatively impacted if the system is not tested properly. Technical data via testing created an additional problem since prior to AC232, there were no testing protocols for cast-in anchor channel systems neither. AC232 provides testing protocols and design guidelines for anchor channels.

Since its inception, AC232 has been an ever-evolving document. In its infancy stage, AC232 did not include provisions for anchor channels systems in structures assigned to Seismic Design Category C, D, E, or F. In 2015, AC232 incorporated seismic provisions for anchor channels in Seismic Design Category C, D, E, or F. Later provisions permitting the use of anchor channels in all-weight concrete and sand-lightweight concrete were adopted by AC232.

Important design provisions have been added to AC232 over the last years. The ultimate goal is to have a complete framework that covers all typical and non-typical applications encountered in a building such as corners with a pair of anchor channels loaded simultaneously or parallel channels.

The scope of AC232 was limited to anchor channels with rounded head anchors or I-anchors. The latest AC232 approved in June 2018 also includes anchor channels replacing rounded head anchors with deformed reinforcing bars. AC232 also includes provisions for anchor reinforcement, where the concrete breakout in shear and/or tension can be precluded.

This chapter provides design and testing information for anchor channels covered by AC232 (HAC and HAC-T). Chapter 2 provides design steel strengths for the anchor channel system. However, additional calculations are needed to complete the steel verification of anchor channels. Moreover, this chapter provides design provisions for the verification of the concrete at the anchorage zone. Due to the number of variables that can impact the performance of the concrete, AC232 has provided additional design guidelines.
7.2 ANCHOR CHANNEL THEORY

7.2.1 ANCHOR PRINCIPLES AND DESIGN

Definitions

5 percent Praxtle Value corresponding to a 5 percent probability of non-exceedance

Adhesive anchor is a post-installed anchor that is inserted into a drilled hole in hardened concrete, masonry or stone. Loads are transferred to the base material by the bond between the anchor and the adhesive and the adhesive and the base material.

Anchor category is an assigned rating that corresponds to a specific strength reduction factor for concrete failure modes associated with anchors in tension. The anchor category is established based on the performance of the anchor in reliability tests.

Anchor Channel is steel profile with rigidly connected anchors installed prior to concrete placement.

Anchor Channel Assemblies anchor channel consist of a product produced from hot rolled or cold-formed steel and at least two metal anchors on the channel web as illustrated in figure 7.2.2.1 & 7.2.2.2. The anchor channel shall be flushed with the concrete surface. A fixture shall be connected to the anchor channel by channel bolts (hammer head or hooked channel bolts) with nut and washer in accordance with figure 7.2.2.2.

Anchor Channel Installation instructions for placement of subject anchor channel.

Anchor Channel loading: Axial Tension is load applied perpendicular to the surface of the base material and in direction of the anchor axis.

Anchor Channel loading: Bending Bending effect induced by a tension load applied in direction of the anchor axis at any location between anchors.

Anchor Channel loading: Longitudinal shear Loads acting parallel to the concrete surface and co-linear with the longitudinal axis of the anchor channel.

Anchor Channel loading: Perpendicular shear Loads acting parallel to the concrete surface and perpendicular to the longitudinal axis of the anchor channel.

Anchor Channel System Specific combination of anchor channel and channel bolt under consideration.

Anchor Diameter Nominal diameter of the anchor channel.

Anchor group is a group of anchors of approximately equal effective embedment and stiffness where the maximum anchor spacing is less than the critical spacing.

Anchor reinforcement is reinforcement used to transfer the full design load from the anchors into the structural member.

Anchor spacing is centerline-to-centerline distance between loaded anchors.

Attachment Structural assembly, external to the surface of the concrete, that transfers loads to or receives loads from the anchor channel.

Attachment is the structural assembly, external to the surface of the concrete, that transmits loads to or receives loads from the anchor.

Base Material Material, such as concrete, in which the anchor channel is installed.

Cast-in-place anchor is traditionally a headed bolt, headed stud or hooked bolt installed before placing concrete. Additionally, cast-in-place internally threaded inserts are a form of cast-in-place anchors.

Channel Bolt Threaded fastener that connects the element to be attached to the anchor channel.

Characteristic capacity is a statistical term indicating 90 percent confidence that there is 95 percent probability of the actual strength exceeding the nominal strength. This is also called the 5% fractile capacity.

Characteristic spacing Spacing for ensuring the characteristic resistance of a single anchor.

Clamping Force Prestressing force resulting from tightening of the channel bolt against the fixture.

Concrete breakout is a concrete failure mode that develops along the concrete and results in the movement of the anchor body away from the fixture. Concrete breakout is the spacing from the centerline of the concrete member to the center of the anchor channel and the anchors fixed to the channel profile. To allow adequate placement and compaction of concrete and to avoid damage to the concrete during torquing of the channel bolt, to be reported in the ICC-ES evaluation Service Report.

Concrete splitting failure is a concrete failure mode in which the concrete fractures along a plane passing through the axis of the anchor or an anchor component. Concrete splitting failure is the spacing from the centerline of the concrete member to the center of the anchor channel and the anchors fixed to the channel profile, to allow adequate placement and compaction of concrete and to avoid damage to the concrete during torquing of the channel bolt, to be reported in the ICC-ES evaluation Service Report.

Minimum edge distance is the spacing from the centerline of the anchor to the edge of the base material required to minimize the likelihood of splitting of the base material during anchor installation.

Minimum member thickness is minimum required thickness of member where the anchor channels can be installed, to be reported in the ICC-ES Report.

Minimum spacing Minimum distance between anchors of anchor channels, measured in the direction of the longitudinal channel axis to allow adequate placing and compaction of the concrete, measured centerline to centerline, to be reported in the ICC-ES Evaluation Service Report.

Minimum spacing is distance between the centerlines of adjacent loaded anchors to minimize the likelihood of splitting of the base material during anchor installation.

Post-installed anchor is an anchor installed in hardened concrete or masonry. Expansion, undercut, and adhesive anchors are examples of post-installed anchors.

Projected area is the area on the free surface of the concrete member that is used to represent the larger base of the assumed rectangular failure surface.

Pryout failure is a failure mode where anchors having limited embedment depth and loaded in shear exhibit sufficient rotation to produce a pryout fracture whereby the primary fracture surface develops behind the point of load application. This failure mode does not depend on the presence of free edges.

Pullout failure is a failure mode in which the anchor pulls out of the concrete without development of the full steel or concrete capacity.

Pull-through failure is a failure mode in which the anchor body pulls through the expansion mechanism without development of the full steel or concrete capacity.

Splitting failure A failure in which the concrete fractures along a plane passing through the axis of the tensioned anchor or anchors.

Statistically Equivalent Two groups of test results shall be considered as statistically equivalent if there are no significant differences between the means and between the standard deviations of the two groups. Such statistical equivalence shall be demonstrated using a one-sided Student’s T-test at a confidence level of 90 percent.

Steel failure is a failure mode in which the steel anchor parts fracture.

Supplementary reinforcement is reinforcement that acts to restrain the potential concrete breakout area but is not designed to transfer the full design load from the anchors into the structural member.

Torsion controlled expansion anchor is a post-installed expansion anchor that is set by the expansion of one or more sleeves or other elements against the sides of the drilled hole through the application of torque, which pulls the cone into the expansion sleeve(s). After setting, tensile loading can cause additional expansion (follow-up expansion).

Undercut anchor is a post-installed anchor that derives tensile holding strength by the mechanical interlock provided by undercut (or other elements) rather than by a special tool or by the anchor itself during installation.
7.2.2 REQUIREMENTS OF ANCHOR CHANNEL WITHIN AC232.

What is an anchor channel system

Anchor channels consist of a channel produced from hot-rolled or cold-formed steel and at least two metal anchors on the channel web as illustrated in Figure 7.2.2.1.

An anchor channel system consists of:

- The fixture being attached
- T-bolts attaching the fixture to the channel
- Steel channel cast into a concrete element
- Anchor elements attached to the channel and embedded into the concrete

The anchor channels shall be placed flush with the concrete surface as illustrated in Figure 7.2.2.2. A fixture shall be connected to the anchor channel by channel bolts (also known as T-bolts) with nut and washer in accordance with Figure 7.2.2.1 and Figure 7.2.2.2.

What is the minimum channel bolt (t-bolt) spacing, $d_{cmin}$?

3 x $d_{c}$Where $d_{c}$ is the diameter of channel bolt refer figure 7.2.2.2

What are the anchor channel requirements according to AC232?

Channel height, $hch$ 0.60 in. (15 mm) ≤ $hch$ ≤ 2 in. (51 mm)

Channel depth, $bh$ 1 in. (25.4 mm) ≤ $bh$ ≤ 3 in. (76 mm).

Minimum channel length: 4 in. (102 mm).

Maximum channel length: unlimited.

The maximum effective embedment according to AC 318-14 section 17.4.2.2, $hef$ = 25 in.

Geometry requirements: $hch/hef ≤ 0.5$ $bh/hef ≤ 0.70$

What is the minimum channel bolt (t-bolt) spacing, $d_{cmin}$?

Minimum number of anchors: 2

Maximum number of anchors: unlimited.

Minimum round headed anchor spacing: 2.00 in. (50 mm)

Minimum deformed reinforcing bars anchor spacing: 4.00 in. (100 mm).

Maximum anchor spacing: $c_{a}$ shall not be larger than 5 times minimum edge distance or 16 in (400 mm).

Spacing between the anchors or deformed reinforcing bars should be constant.

Minimum allowable slab thickness shall be $h_{min} = hef + th + cnom$

$tch$ = anchor head thickness

$c_{con}$ = required concrete cover

The anchors may be welded, forged or bolted to the channel.

All anchors attached to the anchor channel shall be of the same type, size and embedment.

What are the requirements for round anchors and deforming rebars under AC232?

Round headed anchors shall comply with the following dimensions: length $l_{a}$ ≥ 19/16 in. (30 mm), shaft diameter $d_{a}$ ≥ 1/8 in. (5 mm), and head diameter $d_{h}$ ≥ 1/2 in. (12 mm). The head is forged to the anchor or may consist of a nut.

The anchors shall be placed into prefabricated holes in the back of the channel and connected rigidly with the channel back.

Deformed reinforcing bars as defined in section 2.3 of ACI 318-14 may be attached to the channel in lieu of anchors as described above. Deformed reinforcement is defined as that meeting the reinforcement specifications in the model Code. No other reinforcement qualifies. This definition permits accurate statement of development lengths. Where deformed reinforcing bars are welded, they shall be of a weldable grade.

Deformed bars shall conform with ACI 20.2.1.3, 20.2.1.5 or 20.2.1.7, 20.2.1.3.

Deformed bars shall conform a b, c, d or e.

a) ASTM A615 — carbon steel

b) ASTM A706 — low-alloy steel

c) ASTM A996 — axle steel and rail steel; bars from rail steel shall be Type R

d) ASTM A955 — stainless steel

(e) ASTM A1035 — low-carbon chromium steel

The axial distance between the end of the channel and the nearest anchor, $x$, shall be ≥ 1 in. (25.4 mm).
7.2.3 ANCHOR CHANNEL WORKING PRINCIPLES

Loading of Anchor Channels

The anchor channel may be used to transmit tensile loads, shear loads perpendicular to the longitudinal channel axis, and loads acting in the direction of the longitudinal channel axis (optional), or any combination of these loads applied at any location between the outermost anchors of the anchor channel in accordance with Figure 7.2.3.1 as shown. Transfer of tension loads takes place via interlock between the channel bolt and the channel lips, bending of the channel, tension in the anchors, and mechanical interlock with the concrete. Shear loads acting in the direction of the longitudinal channel axis are transferred by the anchors and by compression stresses between the side of the channel and the concrete. However, for reasons of simplicity, it is assumed that the shear loads are transferred by the anchors only (see D.3.1.1.3 (ACI 318-05, ACI 318-08), D.3.1.2.3 (ACI 318-11), Section 17.2.1.2.3 (ACI 318-14)). Shear loads acting in the direction of the longitudinal channel axis are assumed to be transferred from the channel bolt via the channel and the anchors into the concrete without consideration of friction and/or adhesion (see D.3.1.1.5 (ACI 318-05, ACI 318-08), D.3.1.2.5 (ACI 318-11), Section 17.2.1.1.5 (ACI 318-14)).

Where compliance is sought for seismic loading in Seismic Design Categories C, D, E and F compliance for shear loads in the direction of the longitudinal channel axis is required. Where compliance is sought for static shear loading along the longitudinal axis of the anchor channel, the longitudinal loads shall be transferred by a positive load transfer mechanism (e.g. mechanical interlock between the channel bolt and the channel profile by notches in the smooth channel lips created by notching channel bolts (example see Fig. 7.2.3.2a) or by matching serrations between the channel lips and channel bolt (example see Fig. 7.2.3.2b)).

Transfer of shear load in the direction of the longitudinal channel axis from the channel bolt and anchors into the concrete shall use a positive load transfer mechanism that shall be capable of ensuring safe and effective behavior under normal and adverse conditions, both during installation and in service. Factors included are installation conditions in concrete and torqueing of the channel bolt.

Where compliance is sought for seismic loading in Seismic Design Categories C, D, E and F compliance for shear loads in the direction of the longitudinal channel axis is required.

Figure 7.2.3.1 — Anchor channel loaded in three directions.

7.2.4 ANCHOR CHANNEL BEHAVIOR UNDER LOAD

When loaded to failure, anchor channels may exhibit one or more identifiable failure modes.

These include:

Possible failure modes of anchor channel per AC232

- IMPORTANT! Failure analysis modes evaluated follow ACI 318-14, chapter 17. This DOES NOT include evaluating the base material (e.g. edge-of-slab) capacity to resist compressive forces generated by the fixture. The engineer must ALWAYS verify the base material (e.g. edge-of-slab) design is capable of resisting the applied loading.

For additional information, please contact Hilti at US-CA.HAC@Hilti.com

Superposition of tension and shear loads (up to 5 interaction equations)
### 7.2.5 ACI 318 CHAPTER 17 STRENGTH DESIGN — SD (LRFD)

The design strength of anchor channels under the 2015 IBC as well as Section R301.1.3 of the 2015 IRC must be determined in accordance with ACI 318-14 Chapter 17 and ESR-3520.

The design strength of anchor channels under the 2012 IRC as well as Section R301.1.3 of the 2012 IRC must be determined in accordance with ACI 318-11 Appendix D and ESR-3520.

The design strength of anchor channels under the 2009 IRC as well as Section R301.1.3 of the 2009 IRC must be determined in accordance with ACI 318-08 Appendix D and ESR-3520.

The design strength of anchor channels under the 2006 IRC as well as Section R301.1.3 of the 2006 IRC must be determined in accordance with ACI 318-05 Appendix D and ESR-3520.

### 7.2.6 STRENGTH DESIGN TERMINOLOGY

Equations are provided in units of inches and pounds. For convenience, SI (metric) units are provided in parentheses where appropriate. Unless otherwise noted, values in SI units shall not be used in equations without conversion to units of inches and pounds.

- **b**
  - Width of channel, as shown in Figure 7.2.2.2, inch (mm)

- **C**
  - Edge distance of anchor channel, measured from edge of concrete member to axis of the nearest anchor, in. (mm)

- **C**
  - Edge distance of anchor channel in direction 1, in. (mm)

- **C**
  - Net distance between edge of the concrete member and the anchor channel: C** = C** - b/2 (in. (mm))

- **C**
  - Reduced edge distance of the anchor channel (in. (mm))

- **C**
  - Edge distance of anchor channel in direction 2, in. (mm)

- **C**
  - Minimum edge distance of anchor channel, in. (mm)

- **C**
  - Minimum edge distance of anchor channel, in. (mm)

- **C**
  - Edge distance required to develop full concrete capacity in absence of reinforcement to control splitting, in. (mm)

- **C**
  - Edge distance required to develop full concrete capacity in absence of anchor reinforcement, in. (mm)

- **C**
  - Critical edge distance for anchor channel for tension loading for concrete breakout, in. (mm)

- **C**
  - Critical edge distance for anchor channel for tension loading, concrete blow out, in. (mm)

- **C**
  - Critical edge distance for anchor channel for shear loading, concrete edge breakout, in. (mm)

- **d**
  - Width of head of I-anchors or diameter of head of round anchor, in. (mm) as shown in Figure 7.2.2.2

- **d**
  - Shaft diameter of round anchor, in. (mm) as shown in Figure 7.2.2.2

- **d**
  - Diameter of anchor reinforcement, in. (mm) as shown in Figure 7.2.2.2

- **d**
  - Diameter of channel bolt, in. (mm)

- **d**
  - Distance between shear load and concrete surface, in. (mm)

- **d**
  - Distance between axis of the shaft load and the axis of the anchor reinforcement resisting the shear load, in. (mm)

- **d**
  - Distance between anchor head and surface of the concrete, in. (mm)

- **f**
  - Specified concrete compressive strength, psi (MPa)

- **f**
  - Height of channel, as shown in Figure 7.2.2.2, in. (mm)

- **f**
  - Critical member thickness, in. (mm)

- **f**
  - Effective depth of member, as shown in Figure 7.2.2.2, in. (mm)

- **f**
  - Reduced effective depth of member, in. (mm)

- **f**
  - Load distribution factor (17.2.1.2.1a, ACI 318-14)

- **f**
  - Projector factor

- **f**
  - Lever arm of the shear force acting on the channel bolt, in. (mm)

- **f**
  - Development length in tension of deformed bar or deformed wire with a standard hook, measured from critical section to outside end of hook, in. (mm)

- **f**
  - Influence length of an external load Naa along an anchor channel, in. (mm)

- **f**
  - Spacing of anchors in direction of longitudinal axis of channel, in. (mm)

- **f**
  - Clear distance between channel bolts in direction of longitudinal axis of channel, in. (mm)

- **f**
  - Anchor spacing required to develop full concrete capacity in absence of anchor reinforcement, in. (mm)

- **f**
  - Critical anchor spacing for tensile loading, concrete breakout, in. (mm)

- **f**
  - Maximum spacing between anchor elements in anchor channels, in. (mm)

- **f**
  - Minimum spacing between anchor elements in anchor channels, in. (mm)

- **f**
  - Critical anchor spacing for tension loading, concrete blow-out, in. (mm)
shear loads) or \( V_{cs} \) (anchor channels with anchor reinforcement to take up shear loads) and \( V_{seis} \) (nominal steel strength of anchor channel loaded in shear)

\[ V_{sc} = \text{factor to account for the influence of channel size and anchor diameter on concrete edge breakout strength in shear} \]

\[ V_{seis} = \text{adjustment factor for seismic loading (y-direction, perpendicular to the channel axis)} \]

\[ V_{sa} = \text{adjustment factor for seismic loading (x-direction, in longitudinal channel axis)} \]

\[ V_{ns} = \text{factor to account for influence of cracked or uncracked concrete on concrete breakure strength} \]

\[ V_{sa,x} = \text{nominal seismic shear steel strength in longitudinal channel axis of a single anchor, lbf (N)} \]

\[ V_{sa,y} = \text{nominal seismic shear steel strength perpendicular to the channel axis of a single anchor, lbf (N)} \]

\[ V_{ns,a} = \text{nominal strength of anchor channel loaded in shear, lbf (N)} \]

\[ V_{ns} = \text{nominal steel strength of anchor channel loaded in shear, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength in longitudinal axis of connection between one anchor bolt and the anchor channel, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength in longitudinal axis of connection between one anchor bolt and the anchor channel, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength perpendicular to the channel axis of connection between one anchor bolt and the anchor channel, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength in longitudinal channel axis of connection between one anchor bolt and the anchor channel, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength perpendicular to the channel axis of the local bending of the channel lip, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength in longitudinal channel axis of connection between channel bolt and channel lips, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength perpendicular to the channel axis of the local bending of the channel lip, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength in longitudinal channel axis of connection between channel bolt and channel lips, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength perpendicular to the channel axis of the local bending of the channel lip, lbf (N)} \]

\[ V_{sa} = \text{nominal shear strength in longitudinal channel axis of connection between channel bolt and channel lips, lbf (N)} \]

\[ V_{sa} = \text{exponent of interaction equation} \]

\[ V_{sa} = \text{conversion factor for allowable stress design} \]

\[ V_{sa} = \text{factor to account for the influence of channel size on concrete breakout strength in tension} \]

\[ V_{sa} = \text{factor to account for the influence of restraint of fixture on the flexural strength of the channel bolt} \]

### 7.2.7 LOAD DISTRIBUTION

**Determination of t-bolt forces acting on anchor channels**

The forces on a t-bolt can generally be determined using general principles of structural mechanics. In doing so, the displacement of the t-bolt is usually assumed to be small (i.e., negligible). The distribution of forces acting on a fixture of a t-bolt group to the individual t-bolt of the group can be calculated with elastic theory.

**Tension Loads:**

Calculation of t-bolt loads induced by tension loads and bending moments acting on the fixture per elastic theory involves the following assumptions (Fig. 7.2.7.1): a) The fixture remains plane (flat) under the influence of internal forces. In order to warrant this supposition, the fixture must be sufficiently stiff and must be in contact with the base material. A stiff fixture may be assumed if under the design actions, the stresses in the fixture are smaller than the design resistance of the fixture material. The stiff fixture assumption corresponds to the Bernoulli hypothesis in reinforced concrete design, wherein plane cross-sections are assumed to remain plane. b) In the part of the fixture subjected to compression, t-bolts do not act in either tension or compression. c) The stiffness of all t-bolt in a group are identical. The t-bolt stiffness is directly proportional to the area of the stressed cross-section and the modulus of elasticity of the steel. The stiffness of the concrete is characterized by its elastic modulus and the stressed area.

Consequently, the calculation of the tension forces in the t-bolts corresponds to how one determines the tension resultant in the reinforcing bars of a reinforced concrete member. However, in contrast to strength design of reinforced concrete members, we assume here that the response of the concrete and steel elements remains linear elastic.

In most cases, elastic analysis yields satisfactory results and is recommended. It should be noted, however, that the assumption of anchor load linearly proportional to the magnitude of the applied load and the distance from the neutral axis of the group is valid only if the attachment (e.g., baseplate) is sufficiently stiff in comparison to the axial stiffness of the t-bolts. Note: Assuming a rigid base plate condition, Hilti’s PROFIS Anchor channel analysis and design software performs a simplified finite element analysis to establish anchor load distribution on an elastic basis.

![Figure 7.2.7.1 — Distribution of forces predicted by elastic theory in an t-bolt group subjected to tension force and bending moment.](image-url)
7.2.8 CALCULATION OF LOADS ON ANCHORS OF THE ANCHOR CHANNEL

Anchor channels are designed for critical effects of factored loads as determined by elastic analysis taking into account the elastic support by anchors and the partial restraint of the channel ends by concrete compression stresses. An alternative, the triangular load distribution method in accordance with 17.2.2.1.2 (ACI 318-14) to calculate the tension and shear loads on anchors is permitted.

Tension Loads:
The stiffness of an anchor channel is less than that of a stiff fixture. The distribution of tension loads acting on the channel to the anchors is calculated using a beam on elastic supports with partial restraint of the channel ends. The stiffness of the elastic supports corresponds to the displacement of the anchors which includes the displacements of the channel lips, anchors and concrete. The distribution of anchor forces can be approximated by a triangle load distribution with a peak at the applied load and an influence length $L$.

The influence length depends mainly on the anchor spacing, the moment of inertia of the channel and on the head size. Further minor influencing factors are the concrete compression strength, the type of steel (galvanized or stainless steel) and the state of concrete (cracked or non-cracked). For sufficiently large head sizes (head pressure $p$, effective $p_e$) the influence length can be taken as:

$$L = 4.93(2.5A_{go} s^2 s \pm 5) \text{ in}$$

$$L = 13(2.5A_{go} s^2 s \pm 5) \text{ mm}$$

where:

$A_{go}$ = anchor spacing, in. (mm)
$s$ = the moment of inertia of the channel shall be taken from Table 2.2.2.1.1

For an arbitrary position of the load $N$ the forces on the anchors can be calculated in accordance with equation:

$$N_{aux} = k \cdot A_i \cdot A_{go}$$

where:

$k = \frac{1}{\sum_i A_i}$

$$A_{aux} = \frac{N_{aux}}{\sum_i A_i}$$

and $N_{aux}$ the moment of inertia of the channel shall be taken from Table 2.2.2.1.1

The tension loads, $N_{aux}$, on an anchor due to a tension load $N_{aux}$ acting on the channel shall be computed in accordance with Eq. (1). An example for the calculation of the tension loads acting on the anchors is given in Figure 7.2.8.1.

Perpendicular Shear Loads:
Shear loads acting on the channel are mainly transferred by compression stresses between channel profile and concrete and to a smaller extent by the anchors. However, the anchors are stressed by tension forces due to the eccentricity between the acting shear load and the resultant of the stresses in the concrete. A model to calculate the concrete edge capacity of channel anchors under shear loading towards the edge is described in section 7.4.2. It assumes that shear forces acting on the channel are transferred by bending of the channel to the anchors and by the anchors into the concrete. This approach simplifies the real behavior. It has been chosen to allow for a simple interaction between tension and shear forces acting on the channel. For reasons of simplicity it is proposed to calculate the (fictional) shear forces on anchors using the same approach and the same influence length as for tension loads. The shear load, $V_{aux}$, on an anchor due to a shear load $V_{aux}$ acting on the channel perpendicular to its longitudinal axis should be computed in accordance with the previous Section of tension replacing $N_{aux}$ in Eq. (5) by $V_{aux}$.

Longitudinal Shear Loads:

- The shear load acting in the direction of the longitudinal channel axis are transferred from the channel bolt to the channel and by the anchors into the concrete without considering friction and/or adhesion between channel and concrete.
- Longitudinal shear loads shall be transferred by a positive load transfer mechanism (e.g. mechanical interlock between the channel bolt and the channel). In the design model it is assumed that longitudinal shear loads are solely transferred by the anchors into the concrete. A positive load transfer mechanism from the channel bolt via the channel and anchors into the concrete is required.
- Load transfer in the longitudinal direction shall not rely on friction.

If more than one t-bolt are transferring the tension loads on to the channel then the linear superposition of the anchor forces for all loads should be assumed as shown in the figure 7.2.8.2.

If in the design the exact position of the load on the channel is unknown the most unfavorable loading position should be assumed for each failure mode (e.g. load acting over an anchor for the case of failure of an anchor by steel rupture or concrete break-out and load acting between anchor’s in case of bending failure of the channel).

For the bending moment, $M_{aux}$, on the channel due to tension loads acting on the channel shall be computed assuming a simply supported single span beam with a span length equal to the anchor spacing.

Figure 7.2.8.1 — Example for the calculation of anchor forces in accordance with the triangular load distribution method for an anchor channel with five anchors. The influence length is assumed as $L = 1.5s$.

$$d_1 = \sqrt{(L_0 - 0.25s) / L} = 0.25s / (L_0 - 1.5s)$$

$$N_{aux} = N_{aux} = 0$$

$$N_{aux} = 0.5 \times (L_0 - 1.5s)$$

$$N_{aux} = 0.75 \times (L_0 - 1.5s)$$

$$N_{aux} = 1 \times (L_0 - 1.5s)$$

$$N_{aux} = 1.5 \times (L_0 - 1.5s)$$

If $L = 1.5s$.

Figure 7.2.8.2 — Triangular load distribution for different anchor channel system configurations.

The shear load, $V_{aux}$, on an anchor due to a shear load, $V_{aux}$ acting on the channel in direction of the longitudinal channel axis shall be computed in accordance with 7.2.2.1.2 (ACI 318-14) to calculate the tension and shear loads on anchors is permitted.

$$V_{aux} = V_{aux} / 3$$

$$V_{aux} = V_{aux} / 3$$

$$N_{aux} = N_{aux} = V_{aux}$$

$$N_{aux} = N_{aux} = V_{aux} / 3$$

Figure 7.2.8.4 — Example for the calculation of anchor forces in case of anchor channels with 5 anchors loaded in shear longitudinal to the channel axis for steel and pryout failure.
In principle, the method follows the strength design concept with the application of different strength reduction factors. The limit states design method generally results in a more accurate estimate of anchor resistance as compared to the ASD approach.

Allowable loads: Under the Allowable Stress Design Method, the allowable load, or resistance, is based on the application of a safety factor to the result of laboratory testing to failure, regardless of the controlling failure mode observed in the tests. The safety factor is intended to account for reasonably expected variations in loading. Adjustments for anchor spacing and edge distance are developed as individual factors based on testing of two- and four-anchor groups and single anchors near free edges. These factors are multiplied together for specific anchor layouts.

For anchors designed using load combinations in accordance with IBC Section 1605.3 (Allowable Stress Design) allowable loads shall be established using following equations.

\[
\begin{align*}
\gamma_f \cdot N_{,\text{allowable, ASD}} & = f_{,\text{allowable, ASD}} \\
\gamma_f \cdot V_{,\text{allowable, ASD}} & = V_{,\text{allowable, ASD}} \\
\gamma_f \cdot M_{,\text{allowable, ASD}} & = M_{,\text{allowable, ASD}}
\end{align*}
\]

where:

- \( N_{,\text{allowable, ASD}} \) = Allowable tension load, lb (N)
- \( V_{,\text{allowable, ASD}} \) = Allowable shear load in longitudinal channel axis, lb (N)
- \( M_{,\text{allowable, ASD}} \) = Allowable bending moment due to tension loads, lb-in (Nm)

\( \gamma_f \) = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, \( \gamma_f \) shall include all applicable factors to account for non-ductile failure modes and required overstrength.

7.3.9 ANCHOR CHANNEL DESIGN

The design of anchors channel is based on an assessment of the loading conditions and anchor capacity. Strength design (SD), limit state design (LSD), and allowable stress design (ASD) methods are currently in use in North America for the design of anchors.

Strength Design: The Strength Design Method for anchor design has been incorporated into several codes such as IBC and ACI 318. The method assigns specific strength reduction factors to each of several possible failure modes, provides predictions for the strength associated with each failure mode, and compares the controlling strength with factored loads. The Strength Design Method is a more accurate estimate of anchor resistance as compared to the ASD approach. The Strength Design Method, as incorporated in ACI 318-14 Chapter 17. Strength Design is state-of-the-art and Hilti recommends its use where applicable.

Limit State Design: The limit state design method for anchor design is described and included in the CSA A23.3 Annex D.

7.3 ANCHOR CHANNEL DESIGN IN TENSION

Tension Analysis

The ultimate load associated with tension failure of the steel bolt or anchor may be determined with equation \( \frac{N_{,\text{total}}}{A_{,\text{f}}} = f_{,\text{tensile steel strength}} \cdot \frac{A_{,\text{f}}}{A_{,\text{f}}} \).

Where:

- \( N_{,\text{total}} \) = Tensile load, lb (N)
- \( A_{,\text{f}} \) = Area of the anchor, in² (mm²)
- \( f_{,\text{tensile steel strength}} \) = Tensile steel strength, ksi (N/mm²)
- \( A_{,\text{f}} \) = Tensile cross-sectional area, in² (mm²)

The ultimate load corresponding to rupture of the connection between the anchor and the channel web may be assessed using ordinary structural steel design principles. In contrast, the ultimate load associated with distortion of the channel flanges is quite difficult to establish without testing. The flanges are to some degree supported by the surrounding concrete and therefore exhibit a different load-bearing behavior compared to a free-standing channel. Similarity, the failure load corresponding to the separation of an anchor element that is swaged onto or pressed into the back of the channel can only be determined through testing.

Table 7.3.1.1 (AC232 Table 4.1) — Test program for anchor channels for use in uncracked and cracked concrete

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Test Ref</th>
<th>Test description</th>
<th>( f )</th>
<th>( \Delta w )</th>
<th>Minimum No. of tests</th>
<th>Channel</th>
<th>Anchor</th>
<th>Material</th>
<th>Channel bolt strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.3</td>
<td>Channel/anchor</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>Steel failure under tension load</td>
</tr>
<tr>
<td>2</td>
<td>7.3</td>
<td>Bending of channel lips, pull-out of channel bolt</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>See AC232 section 7.3.2</td>
</tr>
<tr>
<td>3</td>
<td>7.3</td>
<td>Channel bolt head</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>See AC232 section 7.4.2</td>
</tr>
<tr>
<td>4</td>
<td>7.4</td>
<td>Bending strength of the channel</td>
<td>Low</td>
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<td>5</td>
<td></td>
<td></td>
<td></td>
<td>See AC232 section 7.4.2</td>
</tr>
<tr>
<td>5</td>
<td>7.5</td>
<td>Torque tests*</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>See AC232 section 7.4.2</td>
</tr>
<tr>
<td>6</td>
<td>7.6</td>
<td>Splitting failure due to installation</td>
<td>Low</td>
<td>0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>See AC232 section 7.7.2</td>
</tr>
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<td>7.7</td>
<td>Concrete breakout strength</td>
<td>Low</td>
<td>0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>See AC232 section 7.7.2</td>
</tr>
</tbody>
</table>

1. The coefficient of variation on the failure loads is 5 percent; the number of tests can be reduced to \( n = 3 \).
2. Tests are only necessary if restraint of channels embedded in concrete shall be taken into account (\( n > 6 \); see Section 8.8).
3. The tests shall only be performed if the conditions in Section 7.3.2 of this annex apply.
4. The prestressing force is determined in accordance with Section 8.9.2 of this annex, only the smallest, medium and large channel bolts need to be tested in the corresponding medium sized channel. The next unfavorable combination of material and covering for the channel bolt and the channel shall be tested. No torque tests are required with channel bolts without lubrication or friction-reducing coatings if the prestressing force is calculated according to AC 232 Eq. (8.11) of this AC 232 annex with \( k = 0.15 \). See also Section 7.3.2.1 of AC 232 annex.
5. Only the small, medium and large channel axes need to be tested if the conditions of Section 7.6.2.1 are fulfilled.
6. See AC232 section 7.4.2

* Friction-reducing coatings if the prestressing force is calculated according to AC 232 Eq. (8.11) of this AC 232 annex with \( k = 0.15 \). See also Section 7.5.2.1 of AC 232 annex.
7.3.1 STEEL TENSILE STRENGTHS

**Anchor Strength of Connection Between Anchor and Channel**

The connection between anchor and channel shall be tested in a tension test rig without being cast into concrete. Insert the channel bolt over one anchor and apply the load directly to channel bolt without a fixture.

**Channel Lip Strength**

Channel lip strength $N_{sl}$, and $\phi$ is tabulated in Table ESR-3520 Table 8-3 for HAC and HAC-T with Hilti channel bolts (HBC-C, HBC-T and HBC-C-N).

$\phi N_{sl} \geq N_{ua}$

The Test No. 2 of AC232 is performed to determine the strength of the channel lip. The test rig without being cast into concrete (See Figure 7.3.1.2). Insert the channel bolt over one anchor and apply the load directly to channel bolt without a fixture.

**Exception:** In Test No. 2 determination of the channel lip strength tests shall be performed with anchor channels with two anchors cast into low-strength concrete with anchor spacing $s > s_{min}$, which shall be taken as the value which will be published in the ICC-ES Evaluation Service Report but shall not be taken less than 4 inches (100 mm). The distance between the end of the channel and the anchor axis shall correspond to the minimum value specified for the tested channel size. Insert the channel bolt over one anchor and apply the load directly to the channel bolt. A fixture with the following dimensions shall be used: width $= b$, length $= 3b$, thickness $= d$. The fixture shall be shimmed with steel strips having a thickness $= 1/8$ inch (3.2 mm) located on each side of the anchor channel as shown in Figure 7.3.1.3 below. The diameter of the hole in the fixture shall be approximately 10 percent larger than the diameter of the shaft of the channel bolt. The channel bolt shall be pre-tensioned. However, the support spacing may be reduced to 1.0 $P_{min}$ in every direction as shown in Figure 7.3.1.4. Direct contact between the test stand and the channel profile is not permitted.

The failure load, the corresponding displacement, and the failure mode shall be recorded.

Figure 7.3.1.2 — Tension test setup for testing anchor channels in a universal testing machine. (Figure taken from AC232, Figure 5.5).

Figure 7.3.1.3 — Test setup for tests in accordance with table 4.1 of AC232, test No. 5. (Figure taken from AC232, Figure 7.1)

Figure 7.3.1.4 — Example of an unconfined tension test setup for testing anchor channels (Figure taken from AC232, Figure 5.4).
The nominal strength of the channel lips to take up tension loads transmitted by a channel bolt, $N_{ss}$, must be taken from ESR 3520 Table 8-3. This value is valid only if the center-to-center distance between the channel bolt under consideration and adjacent channel bolts, $s_{adj}$, is at least 2$b$ (see fig 7.3.1.5). If this requirement is not met then the value $N_{ss}$ given in table 8-3 must be reduced by the factor

$$I = \frac{1}{1 + \sum_{i=1}^{n} \left(1 - \frac{s_{adj,i}}{2b}\right) N_{ss,i}}$$

Where the center-to-center spacing between channel bolts shall not be less than 3-times the bolt diameter $d_b$.

Channel Bolt Strength $\phi N_{aua}$

Channel bolt strength $N_{aua}$ and $\phi$ are tabulated in ESR-3520 Table 8-11 for HAC and HAC-T with Hilti channel bolts (HBC-C, HBC-T and HBC-C-N).

$\phi N_{aua} \geq N_{suse}$

The nominal strength of the channel bolt, $N_{suse}$, shall not exceed the value determined in accordance with the following equation:

$$N_{suse} = A_{use} f_{y}$$

where $A_{use}$ is the effective cross-sectional area in tension, in² (mm²); and $f_{y}$ shall be taken as the smaller of 19500 and 125,000 psi (860 MPa).

Test No. 3 is performed to evaluate the strength of the head of the channel bolt under consideration. ESR-3520 Table 8-3 for HAC and HAC-T with Hilti channel bolts (HBC-C, HBC-T and HBC-C-N). $\phi M_{auu} \geq M_{suse}$ and $\phi$ are tabulated in accordance to Test No. 4 of AC232. The purpose of this test is to measure the bending strength of the channel taking account of the restraint of the deformation of the outer ends of the channel by the concrete. The tests shall be performed with all sizes and materials of anchor channels. Anchor channels with two anchors with a maximum spacing and the minimum distance between the end of the channel and the anchor axes as specified by the manufacturer and with an anchor type that provides the lowest anchor strength shall be tested. The channel bolt with the smallest head size and maximum steel strength that, when tested, still results in steel failure of a part of the channel other than the channel bolt shall be used. If the largest channel bolt size still results in bolt failure, the bolt failure load shall be taken as the load corresponding to bending failure. In case of locking channel bolts in combination with non-serrated channels, test has been performed with all channel bolt sizes.

In Test No. 4, concrete failure shall be avoided. This may be achieved by testing anchor channels with anchors that have an increased embedment depth.

Channel Flexural Strength $\phi M_{auu}$

The flexural strength of an anchor channel shall be established in accordance to Test No. 4 of AC232. The purpose of this test is to measure the bending strength of the channel taking account of the restraint of the deformation of the outer ends of the channel by the concrete. The tests shall be performed with all sizes and materials of anchor channels. Anchor channels with two anchors with a maximum spacing and the minimum distance between the end of the channel and the anchor axes as specified by the manufacturer and with an anchor type that provides the lowest anchor strength shall be tested. The channel bolt with the smallest head size and maximum steel strength that, when tested, still results in steel failure of a part of the channel other than the channel bolt shall be used. If the largest channel bolt size still results in bolt failure, the bolt failure load shall be taken as the load corresponding to bending failure. In case of locking channel bolts in combination with non-serrated channels, test has been performed with all channel bolt sizes.

In Test No. 4, concrete failure shall be avoided. This may be achieved by testing anchor channels with anchors that have an increased embedment depth.

In tension Test No. 4 the distance between the support reaction and any loaded anchor may be smaller than 2$h_{ef}$ to avoid concrete failure.

Channel Flexural Strength $\phi M_{auu}$

Channel Flexural Strength $\phi M_{auu}$

Channel Bolt Strength $\phi N_{aua}$

7.3.2 CONCRETE TENSILE STRENGTHS

Pull Out Strength $\phi N_{p}$

Pull-out and pull-through failure is characterized by the anchor being pulled out, whereby the concrete in the immediate vicinity of the anchor may not be damaged. Per ESR-3520 Section 4.1.3.2.4, nominal pullout strength ($N_{p}$) is calculated using ACI 318 anchoring to concrete provisions. ACI 318-11 Appendix D and ACI 318-14 Chapter 17 provisions.

$$\phi N_{p} \geq N_{p}$$

where

- $N_{p}$ is the nominal pullout strength
- $A_{c}$ is the cross-sectional area of the concrete
- $f'_{c}$ is the characteristic compressive strength of the concrete

Concrete

Pull-out failure is characterized by the anchor being pulled out, whereby the concrete in the immediate vicinity of the anchor may not be damaged.

Concrete

Pull-out and pull-through failure is characterized by the anchor being pulled out, whereby the concrete in the immediate vicinity of the anchor may not be damaged. Per ESR-3520 Section 4.1.3.2.4, nominal pullout strength ($N_{p}$) is calculated using ACI 318 anchoring to concrete provisions. ACI 318-11 Appendix D and ACI 318-14 Chapter 17 provisions.

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$$\phi N_{p} \geq N_{p}$$

where

- $N_{p}$ is the nominal pullout strength
- $A_{c}$ is the cross-sectional area of the concrete
- $f'_{c}$ is the characteristic compressive strength of the concrete

Concrete
Condition A (ϕ = 0.75) is considered when:

- Supplementary reinforcement is present
- Reinforcement does not need to be explicitly designed for the anchor channel
- Arrangement should generally conform to anchor reinforcement
- Development is not required

Condition B (ϕ = 0.70) is considered when:

- No Supplementary reinforcement is present

Concrete breakout strength $N_{cb}$

Concrete breakout strength, also known as concrete cone failure, is characterized by the formation of a cone-shaped fracture surface in the concrete. The full tensile capacity of the concrete is utilized. Anchor channels with an adequately large bearing surface will generate concrete cone breakout failures if the steel capacity is not exceeded. Headed studs transfer the tensile force into the base material through bearing (mechanical interlock). Consequently, for the same load, the amount of displacement depends on the bearing contact area.

Figure 7.3.2.3 — Arrangement of anchor reinforcement for anchor channels loaded by tension load at an edge.

Figure 7.3.2.4 — Arrangement of anchor reinforcement for anchor channels loaded by tension load in a narrow member.

Concrete breakout strength $N_{cb}$ is not dependent on the anchor element being considered. The basic concrete breakout strength in tension ($N_{cb}$) is calculated using ESR 3520 Equation (6).

$$N_{cb} = N_b \cdot \frac{N_{cb,N}}{N_{cb}}$$

ESR-3520 Equation (6)

Per ESR-3520 Section 4.1.3.2.3, nominal concrete breakout strength ($N_{cb,N}$) is calculated using ESR 3520 Equation (6). The value calculated for concrete breakout strength in tension (Ncb) is based on the location of the anchor element being considered. The basic concrete breakout strength in tension ($N_{cb}$) is not dependent on the anchor element being considered or the concrete geometry. Therefore, the calculated value for $N_{cb}$ will be the same for each anchor element.

If the anchors are short, or if they are closely spaced or positioned near a free edge, a cone-shaped concrete breakout may limit the tensile capacity of the anchor. This type of failure the load-bearing behavior of channels with two anchors or of channels with more than two anchors and equal load on each anchor mimics that of headed studs. The presence of the channel profile in the breakout cone may influence the load-carrying capacity depending on the ratio of the height of the channel to embedment depth.

According to ACI 318-14 of section 17.4.2.2 the basic concrete breakout strength of a single anchor in tension in cracked concrete, $N_s$, shall be determined in accordance with Eq. (7).

$$N_s = 24 - \alpha \cdot N_{cb}$$

ACI 318-14: Equation17.4.2.2a

The basic concrete breakout strength of a single anchor in tension in cracked concrete, $N_s$, shall be determined in accordance with Eq. (7).

$$N_s = 10 - \alpha \cdot N_{cb}$$

ESR-3520 Equation (8)

$\alpha = 0.75$ for All Light weight concrete

$\lambda = 0.75$ for All Light weight concrete

$\psi_{ef}$ modification factor for anchor splice

$\psi_{c,N}$ modification factor for edge effects

$\psi_{s,N}$ modification factor crack/uncracked concrete

$\alpha$ factor to account for the influence of channel size on concrete breakout strength in tension. It decreases the concrete breakout capacity for the anchor channels with embedment depth less than 7.1 in.

If the embedment depth is less than 7.1 in., the reduction in this capacity is negligible. This observation has been included in the reduction of ESR-3520 Equation (8).

$N_{cr}$ basic concrete breakout strength of a single anchor in tension in cracked concrete

Concrete element $N_{cb}$ shall not exceed ACI 318-14 Equation17.4.2.2b. Hence in case of an anchor with an adequately large bearing surface will generate concrete cone breakout failure the load-bearing behavior of channels with two anchors positioned near a free edge, a cone-shaped concrete breakout surface in the concrete.

$N_{cb} = 16.2 \cdot \sqrt[3]{h_{ef} / \lambda_{ef}}$

ACI 318-14: Equation17.4.2.2b

A practical solution to assess the failure loads of anchors is via empirically derived equations that encompass theoretical models. This approach has led to the development of the CCD (Concrete Capacity Design) Method. Concrete cone failure loads subjected to concentric tension as a function of embedment depth.

$\alpha_{ce}$ factor to account for the influence of channel size on concrete breakout strength in tension. It decreases the concrete breakout capacity for the anchor channels with embedment depth less than 7.1 in.

$\psi_{ef}$ modification factor for anchor splice

$\psi_{c,N}$ modification factor for edge effects

$\psi_{s,N}$ modification factor crack/uncracked concrete

$\lambda_{ef}$ factor to account for the influence of channel size on concrete breakout strength in tension. It decreases the concrete breakout capacity for the anchor channels with embedment depth less than 7.1 in.

According to ACI 318-14 of section 17.4.2.2 the basic concrete breakout strength of a single anchor in tension in cracked concrete, $N_s$, shall not exceed ESR-3520 Equation 7 or ACI 318-14: 17.4.2.2. Additionally, in case of an anchor with channel $N_s$ shall not exceed ACI 318-14 Equation 17.4.2.2b. In case of an anchor with channel $N_s$ shall not exceed ACI 318-14 Equation 17.4.2.2b. The values of 24 in Eq. (17.4.2.2a) were determined from a large database of test results in uncracked concrete (Fuchs et al., 1995) at the 5 percent fractile. The values were adjusted to correspond to 24 value for cracked concrete (Elaghan and Balogh 1995; Goto 1971). For anchors with a deeper embedment ($h_{cb} > 11$ in.), test evidence indicates the use of $h_{cb}$ as also be conservative for some cases. An alternative expression (Eq. (17.4.2.2b)) is provided using $h_{cb}$ for evaluation of cast-in headed studs and headed bolts with 11 in. $h_{cb} < 25$ in.

Figure 7.3.2.5 — Concrete cone breakout of a group of anchors. (Picture from Anchorage in Concrete Construction, R. Eligehausen).

$N_{cb} = $ basic concrete breakout strength in tension

$N_{cb}$ modification factor for anchor spacing

$N_{cb}$ modification factor for edge effects

$N_{cb}$ modification factor for corner effects

$N_{cb}$ modification factor crack/uncracked concrete

$\alpha$ factor to account for the influence of channel size on concrete breakout strength in tension. It decreases the concrete breakout capacity for the anchor channels with embedment depth less than 7.1 in.

The presence of the channel profile in the breakout cone may influence the load-carrying capacity depending on the ratio of the height of the channel to embedment depth. As shown in Fig. 7.3.2.7, it has been observed in testing that having less concrete because of profile occupying the volume of concrete reduces the concrete breakout capacity in tension by the reduction factor $\alpha_{ce}$. Another observation that has been seen is that the anchor channels with effective embedment greater than 7.1 in. The reduction in this capacity is negligible. This observation has been included in the reduction of ESR-3520 Equation (8).

$\alpha_{ce}$ factor to account for the influence of channel size on concrete breakout strength in tension. It decreases the concrete breakout capacity for the anchor channels with embedment depth less than 7.1 in.

According to ACI 318-14 of section 17.4.2.2 the basic concrete breakout strength of a single anchor in tension in cracked concrete, $N_s$, shall not exceed ESR-3520 Equation 7 or ACI 318-14: 17.4.2.2. Alternatively in accordance with Eq. (14) from the anchor under consideration, the values of $h_{cb}$ used in Eq. (7), (8), and (11) may be reduced to $h_{cb}$ in accordance with Eq. (9).

$$h_{cb} = \max \left\{ \frac{c_{ef}}{c_{ef}} \cdot \frac{c_{cb}}{c_{cb}} \cdot h_{cb} \right\}$$

ESR-3520 Equation (9)

Where:

- $c_{ef}$ maximum value of edge or corner distance, in. (mm)
- $h_{cb}$ values of $c_{cb}$ and $h_{cb}$ in Eq. (9) shall be computed with $h_{cb}$
Figure 7.3.2.8 — Anchor channel with influence of one edge and two corners.

Figure 7.3.2.10 — Example of anchor channel with non-uniform tension forces.

The modification factor for corner effect of anchors loaded in tension near a corner (a and b), two corners and one edge (c), and two edges and one corner (d).

ψ_{c,N} = modification factor for cracked/uncracked concrete

A cracked tension zone is assumed because concrete possesses relatively low tensile strength, which may be fully or partly used by internal or restraint tensile stresses not taken into account in the design. The load-bearing behavior of an anchor can be significantly influenced by the presence of a crack passing through the anchor location. For anchor channels located in a region of a concrete member where analysis indicates cracking at service load levels, the following modification factor shall be permitted

ψ_{c,N} = 1.25

Where analysis indicates cracking at service load levels ψ_{c,N} shall be taken as 1.0. The cracking in the concrete shall be controlled by flexural reinforcement distributed in accordance with ACI 318-14 Section 24.3.2 and 24.3.3, or equivalent crack control shall be provided by confining reinforcement.

Concrete 
Cracked: 1
Uncracked: 1.25
The basic concrete breakout strength can be achieved if the minimum edge distance $c_{a,min}$ equals $c_{cu}$. Test results, however, indicate that it requires minimum edge distances exceeding $c_{cu}$ to achieve the basic concrete breakout strength when tested in uncracked concrete without supplementary reinforcement to control splitting. When a tension load is applied, the resulting tensile stresses at the embedded end of the anchor are added to the tensile stresses induced due to anchor installation, and splitting failure may occur before reaching the concrete breakout strength. To account for this potential splitting mode of failure, the basic concrete breakout strength is reduced by a factor $\psi$ if $c_{min}$ is less than the critical edge distance $c_{cu}$. If supplementary reinforcement to control splitting is present or if the anchors are located in a region where analysis indicates cracking of the concrete at service loads, then the reduction factor $\psi_{cu}$ is taken as 1.0. The presence of supplementary reinforcement to control splitting does not affect the selection of Condition A or B.

$\psi_{cu} = \text{modification factor for splitting}$

The modification factor for anchor channels designed for uncracked concrete without supplementary reinforcement to control splitting, $\psi_{cu}$, shall be computed in accordance with Eq. (17) or (18). The critical edge distance, $c_{cu}$, shall be taken from Table 8-4 of ESR-3520.

$C_{ac}$ = critical edge distance for splitting

$C_{ac}$ = critical anchor edge distance

$C_{min}$ = minimum edge distance

<table>
<thead>
<tr>
<th>Condition</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.75</td>
</tr>
<tr>
<td>B</td>
<td>0.70</td>
</tr>
</tbody>
</table>

If $c_{min} < C_{ac}$, ESR 3520 Eq. (18)

If $c_{min} \geq C_{ac}$, ESR 3520 Eq. (17)

$\psi_{cu} = \frac{\max\{C_{ac}, C_{cu}\}}{c_{min}}$

The basic concrete breakout strength can be achieved if the minimum edge distance $c_{a,min}$ equals $c_{cu}$. Test results, however, indicate that it requires minimum edge distances exceeding $c_{cu}$ to achieve the basic concrete breakout strength when tested in uncracked concrete without supplementary reinforcement to control splitting. When a tension load is applied, the resulting tensile stresses at the embedded end of the anchor are added to the tensile stresses induced due to anchor installation, and splitting failure may occur before reaching the concrete breakout strength. To account for this potential splitting mode of failure, the basic concrete breakout strength is reduced by a factor $\psi$ if $c_{min}$ is less than the critical edge distance $c_{cu}$. If supplementary reinforcement to control splitting is present or if the anchors are located in a region where analysis indicates cracking of the concrete at service loads, then the reduction factor $\psi_{cu}$ is taken as 1.0. The presence of supplementary reinforcement to control splitting does not affect the selection of Condition A or B.

$\phi$ = factor for concrete breakout strength in tension

Condition A ($\phi = 0.75$) is considered when

- Supplementary reinforcement is present
- Reinforcement does not need to be explicitly designed for the anchor channel
- Arrangement should generally conform to anchor reinforcement
- Development is not required

Condition B ($\phi = 0.70$) is considered when

- No Supplementary reinforcement is present

Where anchor reinforcement is developed in accordance with ACI 318-11 Chapter 12 or ACI 318-14 Chapter 25 on both sides of the breakout surface for an anchor of an anchor channel, the design strength of the anchor reinforcement shall be permitted to be used instead of the concrete breakout strength in determining $\Phi N_b$ or $\Phi V_n$, dependent upon the if the load is tension or shear. A strength reduction factor of 0.75 shall be used in the design of the anchor reinforcement. Anchor reinforcement can be utilized in tension, longitudinal shear, and perpendicular shear. An explicit design and full development are required for anchor reinforcement.

Tension (AC232 D5.2.10.9)

In accordance with the provisions of AC232 D5.2.10.9, the tension anchor reinforcement shall consist of stirrups made from deformed reinforcing bars with a maximum diameter of 5/8 in. (No. 5 bar)

![Figure 7.3.2.14 — Cracked and uncracked concrete.](image)

![Figure 7.3.2.15 — Arrangement of anchor reinforcement for anchor channels loaded in tension load in a narrow member.](image)

![Figure 7.3.2.16 — Arrangement of anchor reinforcement for anchor channels loaded by tension load at an edge.](image)

![Figure 7.3.2.17 — Arrangement of anchor reinforcement for anchor channels loaded in tension, plan view.](image)

![Figure 7.3.2.17 — Arrangement of anchor reinforcement for anchor channels loaded in tension, section view.](image)
Concrete side-face blowout strength $\Phi_{N_{sb}}$

Tension-loaded headed studs provided with small edge distances can generate local blowout failures in the vicinity of the head. Side blow-out failure will govern the concrete capacity of studs having small edge distance (concrete cover) in combination with large embedment depth. Local concrete side blow-out failure is caused by the quasi-hydrostatic pressure in the region of the head of the stud which gives rise to a lateral bursting force. The failure load will increase in proportion to the edge distance $c_{sb}$. For anchor channels located perpendicular to the edge and loaded uniformly, verification is only required for the anchor closest to the edge. For anchor channels with deep embedment close to an edge ($h_{eb} > 2c_{co}$) the nominal side-face blowout strength, $N_{sb}$, of a single anchor shall be computed in accordance with Eq. (19).

$$N_{sb} = N_{sb}^0 \cdot \psi_{sb} \cdot \psi_{s,Nb} \cdot \psi_{a,Nb} \cdot \psi_{c,Nb} \cdot \psi_{co,Nb}$$ ESR-3520 Equation (19)

- $N_{sb}$: Basic concrete side-face blowout strength in tension
- $\psi_{sb}$: Modification factor for effect of distance to neighboring anchors
- $\psi_{s,Nb}$: Modification factor for effect of influence of the bearing area of neighboring anchors
- $\psi_{a,Nb}$: Modification factor for effect of distance to and loading of neighboring anchors, $\psi_{s,Nb}$ shall be computed in accordance with Eq. (16), however $s_{sb,a1}$ shall be replaced by $s_{sb,cr}$, which shall be computed in accordance with Eq. (21).

$$s_{sb,cr} = 4c_{sb}, \text{ in. (mm)}$$ ESR-3520 Equation (21)

- $\psi_{c,Nb}$: Modification factor to account for influence of uncracked concrete
- $\psi_{co,Nb}$: Modification factor for effect of corner effects

The following modification factor to account for influence of uncracked concrete, $\psi_{co,Nb}$, shall be permitted:

$$\psi_{co,Nb} = 1.25$$

$\psi_{s,Nb}$ = modification factor for effect of distance to neighboring anchors

$\psi_{a,Nb}$ = modification factor for effect of influence of the bearing area of neighboring anchors

$\psi_{c,Nb}$ = modification factor to account for influence of corner effects

$\psi_{co,Nb}$ = modification factor to account for influence of the member thickness

$\psi_{n}$ = number of tensioned anchors in a row parallel to the edge

$\phi_{n}$ = modification factor for concrete side-face blowout strength

$\phi_{n}$ is considered when:

- Supplementary reinforcement is present
- Reinforcement does not need to be explicitly designed for the anchor channel
- Arrangement should generally conform to anchor reinforcement
- Development is not required

Condition $\phi$ is considered when:

- No Supplementary reinforcement is present

$$\phi_{n} = \begin{cases} A & \text{if } n > 3 \\ B & \text{if } n \leq 3 \end{cases}$$

Where anchors consist of deformed reinforcing bars, verification for concrete breakout is not required provided that the deformed reinforcing bars are lap spliced with reinforcing bars in the member according to the requirements of ACI 318-14 Section 25.5. Refer Section 8.6 of Chapter 8 regarding splice length.
7.4 ANCHOR CHANNEL DESIGN IN SHEAR

Shear Load Acting Perpendicular to Channel

7.4.1 STEEL STRENGTHS IN PERPENDICULAR SHEAR

Steel failure Anchors loaded in shear exhibit steel failure when the edge distance and the embedment depth are sufficiently large, whereby conical spalling of the surface concrete precedes steel failure Figure 7.4.1.1. For a given anchor, steel failure represents a limit on the maximum shear capacity. Anchors made of ductile steels can develop relatively large displacements at failure.

Table 7.4.1.1 — Test program for anchor channels for use in uncracked and cracked concrete (Table 4.1 of AC232).

<table>
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<tr>
<th>Test no.</th>
<th>Test Ref</th>
<th>Test description</th>
<th>fc</th>
<th>psi</th>
<th>ft</th>
<th>in (mm)</th>
<th>Minimum</th>
<th>Channel</th>
<th>Anchor</th>
<th>Material</th>
<th>dₘ</th>
<th>strength</th>
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<td>Failure of anchor channel connection</td>
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<td>0</td>
<td>5</td>
<td>85</td>
<td>See AC 232 section 7.8.2</td>
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<tr>
<td>10</td>
<td>T7-10</td>
<td>Concrete edge failure factor nₑₐₜₐ</td>
<td>Low</td>
<td>0</td>
<td>5</td>
<td>85</td>
<td>See AC 232 section 7.10.2</td>
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</table>

Steel failure under Shear load

Concrete failure under shear load

Tests 8 can be omitted if the nominal shear strength of the channel, Vₛₐₐ, is taken as ≤ Nₐₐ Vₛₐₛₐ and Vₛₐₛₐ is the nominal steel strength of the anchor channel loaded in tension (lowest value of Nₐₐ, Nₛₐₛₐ and Nₛₐₛₐ). Vₛₐₐ: Nominal steel strength of anchor channel loaded in shear (lowest value of Vₛₐₛₐ and Vₛₐₛₐ).

The nominal strength of the channel lips to take up shear loads perpendicular to the channel transmitted by a channel bolt, Vₛₜₛₜₜ, must be taken from Table 8-5 for HAC and HAC-T with Hilti channel bolts (HBC-B, HBC-C, HBC-T and HBC-C-N).

Anchor strength is determined from Test 8. The test is performed on anchor channels cast into concrete.

The nominal strength of one anchor, Vₐₐ, and anchor and channel connection Vₛₐₐₐ is determined from Test 8. The test is performed on anchor channels cast into concrete.

The nominal strength of a channel bolt in shear, Vₛₐₛₐ, must be taken from Table 8-12. The maximum value shall be computed in accordance with Eq. (28).

Vₛₐₛₐ = \( \alpha_a M_{a} \) \( \text{lb} \cdot \text{in} \) (N mm)

ESR-3520 Equation (28)

\( \alpha_a \) = factor to take into account the restraint condition of the fixture

= 1.0 if the fixture can rotate freely (no restraint)

= 2.0 if the fixture cannot rotate (full restraint)

Mₐ = Mₐ \( \text{in} \cdot \text{lb} \) (N mm)

ESR-3520 Equation (29)

fₑₐₐ = minimum [1.9 f_y and 125,000 psi (860 MPa)]

(Combined Loading)
corner (Fig. b3) by the limited depth of the member Fig. b4) or by proximate edges parallel with the load direction (Fig. b5). In these cases the failure load associated with the anchor or one anchor of the group is reduced compared to the application shown in Fig. b1.

The behavior of anchor channels loaded towards the free edge is based on numerical and experimental investigations. The shear load is initially transferred into the concrete via the channel and the anchors. Owing to the edge distance from the front face of the channel closer to the edge, which is smaller than the edge distance of the anchor, a local concrete failure starting at the front edge of the channel frequently occurs before the ultimate load is reached. Thereafter, the entire load is transferred to the concrete via the anchors.

Figure 7.4.2.2 — Failure of concrete breakout in shear b 1, b2 and b3) close to an edge, b4 close to an edge, b5 close to an edge, b6 close to an edge and corner, away from the edge b 4 close to an edge, b 5 close to an edge.

The ultimate load of a channel segment with one anchor depends on the size of the channel and anchor and is given by:

$$ V_a = \text{Basic concrete breakout strength in shear} $$

$$ V_{cb,y} = \lambda \cdot \phi \cdot \psi_{b,\lambda} \cdot \sqrt{\frac{\psi_V}{\omega}} $$

ESR-3520 Equation (31)

$\lambda$ = the lesser of the specified concrete compressive strength and 8,500 psi (59 MPa)

$\phi$ = Basic concrete breakout strength in shear

$\psi_{b,\lambda}$ = Modification factor for channel size (channel factor depending on dimensions of profile and anchor) (10.50, max ACI32 test 10 has been used to determine $\alpha_{\psi_{b,\lambda}}$ for various anchor channel. Tests may be omitted if the nominal strength, $V_a$ is computed in accordance with (17.5.2 10.2, ACI 318-14) with $\alpha_{\psi_{b,\lambda}} = 5.6 \times 10^{-6} \psi_{s,V}$ (Normal weight concrete)

The value calculated for concrete breakout strength in shear $V_{cb,y}$ is based on the location of the anchoring elements being considered. The basic concrete breakout strength in shear $V_a$ is not dependent on the anchoring element being considered, but it is dependent on the concrete geometry via the parameter $\psi_{b,\lambda}$. However, the calculated value for $V_a$ will be the same for each anchoring element if the $c_b$ value is the same for each element.

$$ V_{cb,y} = \psi_s \cdot V_a $$

ESR-3520 Equation (32)

The value calculated for concrete breakout strength in shear $V_{cb,y}$ is based on the location of the anchoring element being considered. The basic concrete breakout strength in shear $V_a$ is not dependent on the anchoring element being considered, but it is dependent on the concrete geometry via the parameter $c_b$. However, the calculated value for $V_a$ will be the same for each anchoring element if the $c_b$ value is the same for each element. The parameter $c_b$ will be dependent on the anchoring element being considered and the concrete geometry. Reference ESR-3520 Equation (32) for more information on how to calculate $c_b$. 

Figure 7.4.2.4— Anchor channel arranged perpendicular to the edge and loaded parallel to the edge.
The parameter \( s_{v,c} \) corresponds to the maximum distance that is assumed with respect to the influence of an anchor element on the anchor element being considered. Any anchor elements that are within \( s_{v,c} \) from the anchor element being considered are assumed to have an influence on that anchor element. The calculated value for \( s_{v,c} \) will be the same for each anchor element if the \( s_{v,c} \) value is the same for each element; however, the number of anchor elements within the distance \( s_{v,c} \) from the anchor element being considered may not always be the same. Reference ESR-3520 Equation (33) for more information on how to calculate \( s_{v,c} \). Example for finding \( s_{v,c} \): 

Example: Find \( s_{v,c} \) for anchor element A.

\[
\psi_{c,v} = (ca_2/ccr,V)^{0.5} \quad \text{ESR-3520 Equation (35)}
\]

where:

- \( ca_2 \) is the edge distance perpendicular to the channel.

If \( c_{cr} \) is specified in Table 4.1.3.3.3 of ESR-3520, then \( \psi_{c,v} = 1.2 \) or \( \psi_{c,v} = 1.4 \) as specified.

If cracked concrete conditions are assumed, an increase in \( V_{cb,y} \) is permitted via the modification factor \( \psi_{c,v} \). Reference ESR-3520 Section 4.1.3.3.3 for more information.

Uncracked Concrete \( \psi_{c,v} = 1.0 \)

Anchor channels located in a region of a concrete member where analysis indicates no cracking at service load levels.

Note: in order to activate the reinforcement, concrete has to crack. Therefore, if uncracked concrete is assumed, supplementary reinforcement does not impact this factor.

Concrete is typically assumed to be cracked under normal service load conditions. If cracked concrete conditions are assumed, an increase in \( V_{cb,y} \) is permitted via the modification factor \( \psi_{c,v} \). If supplementary edge reinforcement is used. If uncracked concrete conditions are assumed, an increase in \( V_{cb,y} \) is likewise permitted via the modification factor \( \psi_{c,v} \). Reference ESR-3520 Section 4.1.3.3.3 for more information.

Cracked concrete \( \psi_{c,v} = 1.0 \)

No supplementary reinforcement

With supplementary reinforcement

- Cracked concrete with edge reinforcement (4# min.) and stirrups (4# min.) spaced at 4" O.C.

Cracked concrete \( \psi_{c,v} = 1.2 \)

No supplementary reinforcement

- Cracked concrete with edge reinforcement (4# min.) and stirrups (4# min.) spaced at 4" O.C.

Anchor channel influenced by two corners and member thickness \( c_{cr}\) 

Where an anchor channel is located in a narrow member \( c_{cr} \) with a thickness \( h < h_{cr} \), the edge distance \( c_{cr} \) in Eq. (31), (33), (36) and (38) shall not exceed the value \( c_{cr} \) determined in accordance with Eq. (39).

\[
c_{cr} = \max\left(\frac{c_{cr,max} - h_{cr}}{2}, \frac{h_{cr}}{2}\right), \quad \text{in. (mm)}
\]

ESR-3520 Equation (39)

where \( c_{cr,max} \) is the largest of the edge distances perpendicular to the longitudinal axis of the channel. For this example, the value of \( c_{cr,max} \) is obtained by moving the failure surface forward until it intersects the corner as shown.
Anchor reinforcement in perpendicular shear, ACI 318-14 17.5.2.10.1

For condition where reinforcement is anchored as illustrated in figure 7.4.2.9, the concrete breakout strength in perpendicular shear can be that of the reinforcement strength.

The anchor reinforcement of an anchor channel shall be designed for the maximum perpendicular shear load acting at the anchor channel anchors and channel bolts. Such anchor reinforcement shall be arranged at all anchors of an anchor channel. The maximum strength of the anchor reinforcement (Vcby, max) of a single anchor of an anchor channel shall be computed in accordance with ACI 318-14, 

\[ V_{cby, \text{max}} = \frac{2.5}{c_{b,y}} \left( \frac{V_{cby}}{V_{y}} \right) \cdot lbf \]

where:
- \( c_{b,y} \) = edge distance (in)
- \( V_{cby, \text{max}} \) = nominal concrete breakout strength in shear parallel to the channel axis of an anchor channel

In accordance with the provisions of ACI 318-14, 17.5.2.10.8.2, perpendicular shear anchor reinforcement shall consist of stirrups made from deformed reinforcing bars with a maximum diameter of 5/8 in (No. 5 bar) and straight edge reinforcement with a diameter not smaller than the diameter of the stirrups. Only one bar at both sides of each anchor shall be assumed as effective. The distance of this bar from the anchor shall not exceed 0.5(hef) and the anchorage length in the breakout body shall not be less than 4 times the bar diameter. The distance between stirrups shall not exceed the smaller of anchor spacing or 6 inches.

Because the anchor reinforcement is placed below where the shear is applied, the force in the anchor reinforcement will be larger than the shear force acting on the anchor channel bolts. If the shear load (Vcby) is acting on the anchor channel, the resulting factored tension force of the anchor reinforcement (Na, re) shall be computed by the following equation

\[ N_{a, \text{re}} = N_{a, \text{e}} \left( \frac{z + 1}{z} \right) \cdot lbf \]

where:
- \( N_{a, \text{e}} \) = distance between reinforcement and shear force acting on the anchor channel (in)
- \( z \) = internal lever arm of the concrete member (in) = 0.85(h - r, Vcby = 0.54d) ≤ (2n, cr, 2c1)

\( c_{b,y} \) = edge distance of anchor channel in direction 1
s = spacing on anchors in direction of longitudinal axis of channel
\( s_{cr} \) = critical anchor spacing for shear loading, concrete edge breakout
\( d_{a} \) = diameter of anchor reinforcement
\( f_{t} \) = development length
\( f_{c} \) = development length in tension of a deformed or deformed bar with a standard hook, measured from critical section to outside end of hook

The anchor reinforcement of an anchor channel shall be designed for the highest anchor load, \( V_{cby} \), of all anchors but at least for the highest individual shear load, \( V_{cby} \), acting on the channel. This anchor reinforcement shall be arranged at all anchors of an anchor channel.

Also with increasing load and stud elongation, the baseplate rotates and loses contact with the concrete on the loaded side. These two mechanisms act to further increase the eccentricity between the applied shear load \( V \) and the stress resultant \( V \) in the concrete. The moment resulting from this eccentricity generates a compressive force \( C \) between baseplate and concrete, and a tensile force \( N \) in the stud. If the tensile force in the stud exceeds the tensile capacity associated with the maximum fracture surface that can be activated by the stud, a fracture surface originating at the head of the stud and projecting in conical fashion behind the stud forms Figure 7.4.2.11. This is defined as a pry-out failure. V_{cby} is in shear of a single anchor of an anchor channel without anchor reinforcement shall be computed in accordance with Eq. (41).

\[ V_{cby} = V_{cby} = k_{c}N_{a, \text{re}} \cdot lbf \]

where:
- \( k_{c} \) shall be taken from ESR-3520 Table 8-10

\( N_{a, \text{re}} \) = nominal concrete breakout strength of the anchor under breakout in tension; however in the determination of the failure load associated with pry-out, the load-bearing mechanism of a single headed stud anchorage subjected to a shear load is illustrated schematically in Fig 7.4.2.10. The applied shear load gives rise to bearing stresses in the concrete. With increasing load the surface concrete is crushed or spalled, shifting the centroid of resistance \( V_{c} \) to a location deeper in the concrete.

Tests indicates that the pryout shear resistance can be approximated as one to two times the anchor tensile resistance with the lower value appropriate for height less than 2.5 in.

- \( k_{c} \) = 1.0 for \( h_{a} < 2.5 \) in.
- \( k_{c} = 2.0 \) for \( h_{a} > 2.5 \) in.

The nominal pryout strength, \( V_{cby} \), in shear of a single anchor of an anchor channel with anchor reinforcement shall not exceed:

\[ V_{cby} = V_{cby} = 0.75k_{c}N_{a, \text{re}} \cdot lbf \]

The ICC-ES Acceptance Criteria AC232 includes amendments to the ACI 318 anchoring to concrete provisions. These amendments are given in Section 3.1 Strength Design — Amendments to ACI 318, Part D.6.3.2 (ACI 318-11) and Section 3.7.6.3.2 (ACI 318-14) of these amendments require the factor \( k_{c} \) be modified when calculating concrete pryout strength in shear. All of the parameters used to calculate \( \psi \), in tension are used except the parameter \( N_{c} \). The shear loads acting on the anchor elements are substituted for the tension loads such that \( V_{cby} / N_{a, \text{re}} \) is used instead of \( N_{a, \text{re}} / N_{a, \text{re}} \).
7.4.3 STEEL STRENGTHS IN LONGITUDINAL SHEAR

The nominal strength of one anchor, \( V_{sl,x} \), and anchor and channel connection strength \( V_{sc,x} \), to take up shear loads acting in longitudinal channel axis must be taken from Table 8-5 for HAC and HAC-T with Hilti channel bolts (HBC-C, HBC-T and HBC-C-N).

Table 7.4.3.1 — Test program for anchor channels for use in uncracked and cracked concrete (Table 4.2 of AC232)

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Test Ref</th>
<th>Test description</th>
<th>( f_c ) (ksi)</th>
<th>( \Delta w ) (in.)</th>
<th>Channel</th>
<th>Anchor</th>
<th>Material</th>
<th>Channel bolt strength (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>7.14</td>
<td>Failure of connection between channel lips and channel bolt</td>
<td>Low</td>
<td>0</td>
<td>see AC232 Section 7.14.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>7.15</td>
<td>Failure of connection between channel lips and channel bolt — influence of level of prestressing force</td>
<td>Low</td>
<td>0</td>
<td>see AC232 Section 7.16.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>7.17</td>
<td>Failure of connection between channel lips and channel bolt — influence of channel below concrete surface</td>
<td>Low</td>
<td>0</td>
<td>see AC232 Section 7.17.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Steel failure under shear load acting in longitudinal channel axis

Table 8-8 gives steel strength information for shear acting in longitudinal direction of the channel axis for anchor channel HAC and channel bolts HBC-C-N. Please note the following:

- The \( \phi \) value is 0.65 for which periodical inspection is provided for M16 to M20 t-bolts.
- The \( \phi \) value is 0.75 for in which continuous inspection is provided for M12 to M20 t-bolts.

Table 8-9 gives steel strength information for shear acting in longitudinal direction of the channel axis for anchor channel HAC-T and channel bolts HBC-T. Please note the following:

- The \( \phi \) value is 0.65 for which periodical inspection is provided for M12 to M20 t-bolts.
- The \( \phi \) value is 0.75 for in which continuous inspection is provided for M12 to M20 t-bolts.

The \( \phi \) value is 0.55 for which continuous inspection is provided for all t-bolts.

Table 8-12 gives nominal flexural strength of channel bolt according to ESR-3520 Equation (29)

- \( \phi \) = factor to take into account the restraint condition of the fixture
  - \( \phi \) = 1.0 if the fixture can rotate freely (no restraint)
  - \( \phi \) = 2.0 if the fixture cannot rotate (full restraint)

The coefficient \( \alpha \) depends on the degree of rotational fixity of the anchor where it joins the baseplate.

The coefficient \( \alpha \) is computed in accordance with Eq. (28).

\[
V_{sl,x} = \alpha \frac{M_s}{l} \text{ lb(N)}
\]

Example

If the fixture is not clamped against the concrete but secured to the channel bolt at a distance from the concrete surface (e.g. by double nuts), the nominal strength of a channel bolt in shear, \( V_{ss,x} \), shall be computed in accordance with Eq. (28).

\[
V_{ss,x} = \frac{\phi V_{sl,x}}{\phi V_{sc,x}} \geq V_{ss,x}
\]
The nominal concrete breakout strength, \( V_{cb,x} \), in shear acting in the longitudinal direction of an anchor channel in cracked concrete shall be computed as follows:

a) For a shear force perpendicular to the edge, by Eq. (17.5.2.1a), Section 17.5.2.1 (ACI 318-14). The basic concrete breakout strength in shear, \( V_{cb,x} \), in cracked concrete shall be computed in 17.5.2.2 (ACI 318-14).

\[
V_{cb,x} = \left( \frac{V_{u,x}}{f_{c}'v_{c}} \right) \sqrt{A_{vco} \Psi_{cr} \Psi_{c,v} \Psi_{p,v}}
\]

Equation (43)

For a shear force parallel to an edge, \( V_{cb,x} \), shall be permitted to be twice the value of the shear force determined from Eq. (17.5.2.1a), Section 17.5.2.1 (ACI 318-14) with the shear forces assumed to act perpendicular to the edge.

The shear strength equations were developed from the CCD method. They assume a breakout cone angle of approximately 35 degrees (refer to Fig. 7.4.4.1) and consider fracture mechanics theory. The effects of multiple anchors, spacing of anchors, edge distance, and thickness of the concrete member on nominal concrete breakout strength in shear are included by applying the reduction factor of \( A_{vco} \Psi_{cr} \Psi_{c,v} \Psi_{p,v} \) in Equation (43).

b) For a shear force parallel to an edge, \( V_{cb,x} \), shall be permitted to be computed in 17.5.2.2 (ACI 318-14).

The anchor close to the edge is anchor 1. Full shear forces acting on the 3rd anchor away from the edge.

Case I-b: Shear forces are distributed amongst the three anchors closer to the edge. The leading/front anchor is the controlling one.

\[
V_{cb,x} = \left( \frac{V_{u,x}}{f_{c}'v_{c}} \right) \sqrt{A_{vco} \Psi_{cr} \Psi_{c,v} \Psi_{p,v}}
\]

Equation (44)

For a shear force perpendicular to an edge, \( V_{cb,x} \), shall be considered of the two cases for corner anchors.

\[
V_{cb,x} = \left( \frac{V_{u,x}}{f_{c}'v_{c}} \right) \sqrt{A_{vco} \Psi_{cr} \Psi_{c,v} \Psi_{p,v}}
\]

Equation (43-b)

\[
V_{cb,x} = \frac{7(V_{u,x})^{0.5}}{f_{c}'v_{c}}
\]

Equation (43-a)

\[
V_{cb,x} = \frac{9(V_{u,x})^{0.5}}{f_{c}'v_{c}}
\]

Equation (45)

\[A_{vco} = 4.5 \psi_{c,v} \psi_{p,v} \]

Equation (45)

\[\psi_{c,v} = \psi_{c,v} = \psi_{p,v} = 1.0\]

\[\psi_{c,v} = \psi_{c,v} = \psi_{p,v} = 2.0\]
Case II: Shear force parallel, $\Psi_{parallel}=2.0$

Concrete edge breakout may be limited by the side concrete edge breakout, even if the load acts in a different direction. The side concrete edge breakout is equal to twice the perpendicular concrete edge breakout strength.

- $C_v$ is measured from the corner to the center of the anchor channel.
- The analysis shall consider a maximum of three anchors.
- Projected areas are in accordance with ACI 318-14.

Calculation of projected area for a single anchor in a deep member, $A_{proj}$:

$$A_{proj} = (1.5c_a) \times ([2(1.5c_a) \times (1.5c_a)] + [N_1 - 1] \times s) + (1.5c_a)[2]$$

Calculation of projected area of the failure surface, $A_{vc}$:

$$A_{vc} = \left(\min\left(h, 1.5c_a\right) \times \left[\min\left[c_{a,mw} \times 1.5c_a\right], N_1 - 1 + c_{a,mw} \times 1.5c_a\right]\right)$$

where

- $N_1$ = number of anchors

$\Psi_{c,v}$: Modification factor for cracked/uncracked concrete

For anchors located in a region of a concrete member where analysis indicates cracking at service load levels, the following modification factor shall be permitted $\Psi_{c,v} = 1.4$

$\Psi_{c,v} = 1.4$ For anchors located in a region of a concrete member where analysis indicates cracking at service load levels, the following modification factors shall be permitted:

$\Psi_{c,v} = 1.0$ For anchors in cracked concrete without supplementary reinforcement or with edge reinforcement smaller than a No. 4 bar

$\Psi_{c,v} = 1.2$ For anchors in cracked concrete with straight reinforcement of a No. 4 bar or greater between the anchor and the edge

$\Psi_{c,v} = 1.4$ For anchors in cracked concrete with reinforcement of a No. 4 bar or greater between the anchor and the edge, and with the reinforcement enclosed within stirrups spaced at not more than 4 in.

$\Psi_{s,v}$: Modification factor for concrete thickness

The modification factor for edge effect in shear

The modification factor for edge effect for a single anchor or group of anchors loaded in shear, $\Psi_{s,v}$, shall be calculated as follows using the smaller value of $c_{a,mw}$:

- If $c_{a,mw} < 1.5c_a$, then $\Psi_{s,v} = 1.0$
- If $c_{a,mw} > 1.5c_a$, then

$$\Psi_{s,v} = 0.7 + 0.3 \left(\frac{c_{a,mw}}{1.5c_a}\right) \leq 1.0$$

$C_{a,mw}$: Distance from the edge to axis (in.)

$C_a$: Edge distance (in.) of anchor channel in direction 2

If anchors are located close to an edge so that there is not enough space for a complete breakout prism to develop, the strength of the anchor is further reduced beyond that reflected in $A_{proj}$. If the smallest side cover distance is greater than or equal to 1.5 times the bar diameter, a complete prism can form and there is no reduction in $\Psi_{s,v} = 1$. If the side cover is less than 1.5 times the factor $\Psi_{s,v}$ is required to adjust for the edge effect

Anchor reinforcement in longitudinal shear (ACI 318-11 D6.2.9)

For conditions where anchor reinforcement is provided as illustrated in figure 7.4.4.5, the concrete breakout strength in longitudinal shear can be that of the reinforcement strength.

The anchor reinforcement of an anchor channel shall be designed for the total longitudinal shear load acting on the anchor channel anchors and channel bolts. Such anchor reinforcement shall be arranged at all anchors of an anchor channel.

Anchor reinforcement shall consist of stirrups made from deformed reinforcing bars with a maximum diameter of 5/8 in (No. 5 bar). The enclosing anchor reinforcement should be in contact with the anchor and as close to the concrete surface as possible, while still observing minimum cover requirements.

In case of yielding of the anchor reinforcement, the anchoring reinforcement shall be designed for the total longitudinal shear load acting at the longitudinal axis of the anchor channel.

Because the anchor reinforcement is placed below where the anchor is applied, the force in the anchor reinforcement will be larger than the shear force acting on the anchor channel bolts. If a shear load ($N_{s,y}$) is acting on the anchor channel, the resultant factored tension force of the anchor reinforcement, $N_{s,y}$, shall be computed by the following equation:

$$N_{s,y} = V_{a,y} = \frac{C_v}{A_{vc}} \left(\frac{c_{a,mw} + 1}{2}\right) b h' d'$$

where

- $b$: Distance between reinforcement and shear force acting on the anchor channel (in.)
- $z$: Internal lever arm of the concrete member, (in.)

In accordance with the provisions of ACI 318-14, 7.5.2.10.8.2, longitudinal shear anchor reinforcement shall consist of stirrups made from deformed reinforcing bars with a maximum diameter of 5/8 in (No. 5 bar) and straight edge reinforcement with a diameter not smaller than the diameter of the stirrups. Only one bar at both sides of each anchor shall be assumed as effective. The distance of this bar from the anchor shall not exceed 0.5c_a and the anchorage length in the breakout body shall not be less than 4 times the bar diameter. The distance between stirrups shall not exceed the smaller of anchor spacing or 6 inches.
Concrete Pryout Strength of Anchor Channels in Shear Longitudinal to the Channel Axis $\phi_{Va}$

Failure load associated with pry-out: The load bearing mechanism of a single headed stud anchorage subjected to a shear load is illustrated schematically in Figure 7.4.47. The applied shear load gives rise to bearing stresses in the concrete. With increasing load, the surface concrete is crushed or spalled, shifting the centroid of resistance $V_o$ to a location deeper in the concrete.

The nominal pryout strength, $V_{pa}$, in shear of a single anchor of an anchor channel without anchor reinforcement shall be computed in accordance with ESR 3520 Eq. (41).

$$N_{pa} = N_c \cdot \bar{V}_{a,c} \cdot \bar{V}_{a,c} \cdot \bar{V}_{a,c}$$

where:

- $N_c$ shall be taken from Table 8-10
- $V_{a,c}$ is nominal concrete breakout strength of the anchor under consideration, $lb$ (N), determined in accordance with ESR 3520 Eq. (10) and shall be replaced by $V_{a,c}$ and $V_{a,vu}$ respectively.

The nominal pryout strength, $V_{pa}$, in shear of a single anchor of an anchor channel with anchor reinforcement shall not exceed:

$$V_o = V_{pa} = 0.75 \cdot k_o \cdot N_{pa}, \text{lb} (N)$$

ESR-3520 Equation (42)

The ICC-ES Acceptance Criteria AC232 includes amendments to the ACI 318 anchoring to concrete provisions. These amendments are given in Section 3.1 Strength Design — Amendments to ACI 318. Part D.6.3.2 (ACI 318-11) and Section 17.5.3.2 (ACI 318-14) of these amendments require the factor $V_o$ to be modified when calculating concrete pryout strength in shear. All of the parameters used to calculate $V_o$ in tension are used except the parameter $V_{a,c}$ in tension loads such that $V_{a,c}$ is used instead of $V_{a,c}$.

Minimum Member Thickness, Anchor Spacing, and Edge Distance:
Anchor channels shall satisfy the requirements for edge distance, spacing, and member thickness. The minimum edge distance, minimum and maximum anchor spacing and minimum member thickness shall be taken from Table 8-1 ESR-3520. The critical edge distance, $c_{ed}$, shall be taken from Table 8-4 ESR-3520.

$V_{pa,x} = 5.02 \cdot k_o \cdot N_{pa}$

ESR-3520 Equation (41)

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7.6 SEISMIC DESIGN

7.6.1 SEISMIC CONSIDERATIONS

The anchors in structures assigned to Seismic Design Category (SDC) C, D, E, or F shall satisfy the additional requirements of 17.2.3.2 through 17.2.3.7 of ACI 318-14. Unless 17.2.3.4.1 or 17.2.3.5.1 apply, all anchors in structures assigned to Seismic Design Categories (SDC) C, D, E, or F are required to satisfy the additional requirements of 17.2.3.7. Regardless of whether earthquake loads are included in the controlling load combination for the anchor design.

- The most recent development of structural classification has been the establishment of seismic design categories to determine seismic detailing requirements. Recognizing that building performance during a seismic event depends not only on the severity of subsurface rock motion, but also on the type of soil upon which a structure is founded, the Seismic Design Category (SDC) is a function of location, building occupancy, and soil type.
- Seismic provisions are applicable for all the load combinations if the condition is in a project located in SDC C, D, E or F.
- The behavior of concrete under static and seismic loading is different. Concrete member statically loaded have defined tensile and compression zones. Cracking of the concrete due to static loads is predictable, well understood, and the crack width is limited to 0.3 mm.
- Concrete members that undergo seismic loads deal with more unpredictable loads. Additional safety factors are built into the seismic design to deal with such variances. Due to the cycling nature of seismic loads, tension and compression zones can be inverted and cracking of the concrete can occur through the structure. Moreover, according to extensive research results, the crack width can be up to 0.5 mm during seismic events. Crack open and closes dramatically, concrete tends to crack open and close with changing of live load, crack close naturally.
- The wind analysis should also have the seismic design provision of reduced tensile strengths associated with concrete failure modes. This is applicable to account for increased cracking and spalling in the concrete resulting from seismic actions.
- Non-structural systems (housed ceilings, conduit attachments, mechanical, plumbing, electrical and communications equipment, doors, windows, wood sill plates, cold-formed steel track attachments, and architectural components) suffer the largest damage in commercial buildings during an earthquake. Since nonstructural elements of a building are not a part of the main load resisting system, they are often neglected from the structural design point of view. It’s important to include seismic design for both structural and non-structural elements as Seismic conditions significantly change the behavior of anchors, compared to static conditions. Research is compelling! The percentage of damage caused by non-structural elements is significantly higher than structural elements.

According to ACI 318-14 Section 17.2.3.2: The provisions of the chapter 17 do not apply to the design of anchors in plastic hinge zones of concrete structures under earthquake forces.

- The possible high or low levels of cracking and spalling in plastic hinge zones are beyond the conditions for which the nominal concrete governed strength values are applicable.
- Plastic hinge zones are considered to extend a distance equal to twice the member depth from any column or beam face, and also include any other sections in walls, frames, and slabs where yielding of reinforcement is likely to occur as a result of lateral displacements.
- Where anchors must be located in plastic hinge regions, they should be detailed so that the anchor forces are transferred directly to anchor reinforcement that is designed to carry the anchor forces into the body of the member beyond the anchorage region. Configurations that rely on concrete tensile strength should not be used.

7.6.2 SEISMIC CONSIDERATIONS TENSION

The Requirements for tensile loading is stated in section 17.2.3.4 of ACI 318-14

- 17.2.3.4.1 Where the tensile component of the strength level earthquake force applied to a single anchor or group of anchors is equal to or less than 20 percent of the total factored anchor tensile force associated with the same load combination, it shall be permitted to design a single anchor or group of anchors.

7.6.2.2 How the tensile component of the strength level earthquake force applied to anchors exceeds 20 percent of the total factored anchor tensile force associated with the same load combination, anchors and their attachments shall be designed in accordance with 17.2.3.4.4 as described in Figure 7.6.2.1 and 7.6.2.2.

- The anchor design tensile strength shall be determined in accordance with 17.2.3.4.4, which states that an additional seismic reduction factor of 0.75 is applied to the concrete or non steel tensile design strengths.

Refer to Figure 7.6.2.1 and 7.6.2.2 explaining the requirements of ACI 318-14 Section 17.2.3.4.3 and in a flow chart.

- Option a: For tension loadings, anchor strength should be governed by yielding of the ductile steel element of the anchor. For single anchors, the concrete-governed strength shall be greater than the steel strength of the anchor. For anchor groups, the ratio of the tensile load on the most highly stressed anchor to the steel strength of that anchor shall be equal to or greater than the ratio of the tensile load on tension loaded anchors to the concrete-governed strength of those anchors. In each case:
  i) The steel strength shall be taken as 1.2 times the nominal steel strength of the anchor.
  ii) The concrete-governed strength shall be taken as the nominal strength considering pullout, side-face breakout, concrete, and bond strength as applicable. For consideration of pullout in groups, the ratio shall be calculated for the most highly stressed anchor. In addition, the following shall be satisfied:
    a) Anchors shall transmit tensile loads via a ductile steel element with a stretch length of at least eight anchor diameters unless otherwise determined by analysis.

(iv) Where anchors are subject to load reversals, the anchor shall be designed against buckling.
(v) Where connections are threaded and the ductile steel elements are not threaded over their entire length, the ratio of \( t_{fa} \) shall be not less than 1.3 unless the threaded portions are upset. The upset portions shall not be included in the stretch length.
(vi) Deformed reinforcing bars used as ductile steel elements to transfer earthquake effects shall be limited to ASTM A615 Grades 40 and 60 satisfying the requirements of ACI 318-14 20.4.2.1.5(b) or ASTM A706 Grade 60.

The design of anchors in accordance with option (a) should be used only where the anchor yield behavior is well defined and where the interaction of the yielding anchor with other elements in the load path has been adequately addressed.

Please note that when it comes to anchor channel none of the manufacturers satisfy ductility requirements. We are now left with satisfying one of the other three seismic requirement options.
Option b) The anchor or group of anchors shall be designed for the maximum tension that can be transmitted to the anchor or group of anchors based on the development of a ductile yield mechanism in the attachment in tension, flexure, shear, or bearing, or a combination of those conditions, and considering both material overstrength and strain hardening effects for the attachment. The anchor design tensile strength shall be calculated from 17.2.3.4.4, which states that an additional seismic reduction factor of 0.75 is applied to the concrete or non steel tensile design strengths. For the design of anchors, the force associated with yield of a steel attachment, such as an angle, baseplate, or web tab, should be the expected strength, rather than the specified yield strength of the steel.

Option c) The anchor or group of anchors shall be designed for the maximum tension that can be transmitted to the anchors by a non-yielding attachment. The anchor design tensile strength shall be calculated from 17.2.3.4.4, which states that an additional seismic reduction factor of 0.75 is applied to the concrete or non steel tensile design strengths. This option may apply to a variety of special cases, such as the design of sill bolts where the crushing of the wood limits the force that can be transferred to the bolt, or where the provisions of the American National Standards Institute/American Institute of Steel Construction (AISC) Code Seismic Provisions for Structural Steel Buildings (AISC 341) specify loads based on member strengths.

Option d) The anchor or group of anchors shall be designed for the maximum tension obtained from design load combinations that include E, with E increased by Q. The anchor design tensile strength shall satisfy the tensile strength requirements of 17.2.3.4.4, which states that an additional seismic reduction factor of 0.75 is applied to the concrete or non steel tensile design strengths. This seismic provisions intend to ensure anchors resisting significant seismic forces do not undergo sudden brittle failure. One way to achieve this is to add sufficient extra strength to the anchor by design, so that the failure must occur elsewhere in the system. Increasing the earthquake inertial load with an overstrength factor D has been included in the ACI 318-14 standard as one of four possible options for preventing premature anchor failure. Here ACI refers us back to ASCE 7-10 load combination 5 and 7 of chapter 12.

5. (1.2 + 0.2SDS) D + QE + L + 0.25
6. (0.9 - 0.2SDS) D + QO + 1.6H

QO overstrength factor for architectural component can be obtained from Table 13.5.1 of ASCE 7-10 and for structural components from Table 12.2.1.

7.6.3 SEISMIC CONSIDERATIONS SHEAR

Requirements for shear loading is stated in ACI 318-14 Section 17.2.3.5

According to ACI 318-14 section 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the non steel tensile failure modes assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked:

(a) 0.7ϕNc for a single anchor, or for the most highly stressed individual anchor in a group of anchors.
(b) 0.75ϕNc or 0.75ϕNc, except that Nc, or Nce need not be calculated where anchor reinforcement is provided.
(c) 0.75ϕNc for a single anchor, or for the most highly stressed individual anchor in a group of anchors.
(d) 0.75ϕNc or 0.75ϕNce
(e) 0.75ϕNc or 0.75ϕNce

where ϕ is in accordance with ACI 318-14 section 17.3.3.

Where anchor reinforcement is provided in accordance with 17.4.2.9, no reduction in design tensile strength beyond that specified in 17.4.2.9 shall be required. The reduced anchor nominal tensile strengths associated with concrete failure modes is to be calculated seismic force 17.2.3.5.3(c)

Seismic Design for E

Seismic Design for E

Seismic Design for E

Option a (Ductile yield mechanism in attachment)

Option b (Non-yielding attachment)

Option c (Design for Eo)

Finish

Figure 7.6.3.2 — Flow chart - Seismic provisions for tension; ACI 318-14 Section 17.2.3.5.
7.6.4 TRANSFER OF LONGITUDINAL FORCES

- Historically, longitudinal loads in anchor channels have been transferred by means of friction. AC232 requires a positive connection for transferring of the forces.
- Traditionally, the longitudinal loads are transferred by means of friction.
- The loads are assumed to be transferred larger than the frictional resistance caused by tightening the bolts.
- The bolts are fully pretensioned to cause a clamping force between the connected components, which allows frictional resistance to develop between them.
- The frictional resistance prevents the connected components from slipping into bearing against the body of the bolt.
- To ensure successful performance, the faying surfaces require special preparation.
- The longitudinal load transfer depends on installation and special inspection on site.
- There were no measures that would include into the design for reduction of capacity.

In order to validate the global level of safety or conservatism for a product application, AC232 section 1.3.2 states that the load transfer in the longitudinal direction shall not rely on friction.

Where compliance is sought for seismic loading or for static shear loading along the longitudinal axis of the anchor channel, the longitudinal loads shall be transferred by a positive load transfer mechanism.

The anchor channel must be flush with the substrate surface and installed with specified installation torque to ensure proper interlock between channel lip and t-bolt.

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Transfer of shear load in the direction of the longitudinal channel axis from the channel bolt via anchor and anchors into the concrete shall use a positive load transfer mechanism that shall be capable to ensure safe and effective behavior under normal and adverse conditions, both during installation and in service.

Factors included are installation conditions in concrete and adverse conditions, both during installation and in service.

The transferring of longitudinal forces shall not rely on friction.

The cycling nature of seismic loading combined with the long-term relaxation of the nut and the high sensitivity to installation error are some of the major reasons why a positive load transfer mechanism (a connection that does not rely on friction) is required.

Anchor channels provide two options to positively transfer longitudinal forces; using locking channel bolts with smooth channel profiles or serrated channels with serrated bolts. AC232 covers both systems. The load transfer mechanism is mechanical interlock.
7.6.5 ANALYSIS IN SCD A OR AND SDC C, D, E OR F

Seismic tension Seismic Loading (SDC C, D, E and F)

All anchor channels systems in a test series shall complete the simulated seismic-tension load history. Subject the anchor channel to the sinusoidal tension loads with a cycling frequency between 0.1 and 2 Hz. All anchor channels systems in a test series shall complete the simulated seismic-tension load history specified. Failure of an anchor channel system to develop the required tension resistance in any cycle before completing the loading history shall be recorded as a failure of an anchor channel system to develop the sinusoidal tension loads with a cycling frequency connected by a reduced-speed, ramped load as shown in figure 7.6.4.1. The edge distance shall be large enough to avoid an edge influenced failure. The reduced anchor nominal tensile strengths associated with concrete failure modes is to account for increased cracking and spalling in the concrete resulting from seismic actions. Because seismic design generally assumes that all or portions of the structure are loaded beyond yield, it is likely that the concrete is cracked throughout for the purpose of determining the anchor strength. In locations where it can be demonstrated that the concrete does not crack, uncracked concrete may be assumed for determining the anchor strength as governed by concrete failure modes.

Nominal bending strength of the anchor channel for seismic design HBC-C-N and HBC-T

\[ \phi M_{hk,seis} \geq M_{hk} \]

\[ N_{hk,seis} \text{ and } \phi \text{ are tabulated in Table ESR-3520 Table 8-3} \]

Nominal tensile strength of a channel bolt for seismic design

\[ \phi N_{hk,seis} \geq N'_{hk} \]

\[ N_{sa,seis} \text{ and } \phi \text{ are tabulated in Table ESR-3520 Table 8-10} \]

Nominal tensile strength for local failure of channel lips for seismic design

\[ \phi N_{hk,seis} \geq N'_{hk} \]

\[ N_{sa,seis} \text{ and } \phi \text{ are tabulated in Table ESR-3520 Table 8-3} \]

Nominal tensile strength of a single anchor for seismic design

\[ \phi N_{hk,seis} \geq N'_{hk} \]

\[ N_{sa,seis} \text{ and } \phi \text{ are tabulated in Table ESR-3520 Table 8-3} \]

Nominal tensile strength of connection between anchor and channel for seismic design

\[ \phi N_{hk,seis} \geq N'_{hk} \]

\[ N_{sa,seis} \text{ and } \phi \text{ are tabulated in Table ESR-3520 Table 8-3} \]

Seismic shear perpendicularly to the channel profile Seismic Loading (SDC C, D, E and F)

All anchor channels systems in a test series shall complete the simulated seismic shear loads. Test No. 13 is performed to extract seismic strength values for the various failures listed below. Perform the tests on anchor channels with two anchors embedded in concrete. The frequency of loading shall be between 0.1 and 2 Hz. To reduce the potential for uncontrolled slip during reversal, the alternating shear loading shall be permitted to be approximated by the application of two half-sinusoidal load cycles at the desired frequency connected by a reduced-speed, ramped load as shown in figure 7.8. The edge distance shall be large enough to avoid an edge influenced failure.

Table 7.1-a — Required load history for simulated seismic tension test

<table>
<thead>
<tr>
<th>Load level</th>
<th>( N_{eq} )</th>
<th>( N_l )</th>
<th>( N_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cycles</td>
<td>10</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

AC232 Table 4.2 — Optional test program for anchor channels for use in uncracked and cracked concrete for shear loading in longitudinal channel axis and for seismic loading (SDS C, D, E and F)

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Test Ref</th>
<th>Test description</th>
<th>( f_c )</th>
<th>( \Delta w )</th>
<th>Minimum No. of tests</th>
<th>Channel</th>
<th>Anchor</th>
<th>Material</th>
<th>Channel bolt embedment</th>
<th>Channel bolt strength</th>
<th>( a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>7.12</td>
<td>Seismic tension</td>
<td>Low</td>
<td>0.020</td>
<td>(0.5)</td>
<td>5</td>
<td>see Section 7.12.2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>7.13</td>
<td>Seismic shear perpendicular to the channel profile</td>
<td>Low</td>
<td>0</td>
<td>5</td>
<td>see Section 7.12.2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>7.14</td>
<td>Seismic shear in longitudinal channel axis</td>
<td>Low</td>
<td>0.020</td>
<td>(0.5)</td>
<td>5</td>
<td>see Section 7.15.2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of cycles</th>
<th>( V_{sa,seis} )</th>
<th>( V_{l,seis} )</th>
<th>( V_{sl,seis} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>30</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.5.4.2 — Required load history for simulated seismic shear test (Figure taken from AC232, Figure 7.7).

Nominal shear strength for local failure of the channel lips for seismic design

\[ \phi V_{sa,seis} \geq V_{sa,seis} \]

\[ V_{l,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5} \]

Nominal shear strength of a single anchor for seismic design

\[ \phi V_{sa,seis} \geq V_{sa,seis} \]

\[ V_{l,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5} \]

Nominal shear strength of connection between anchor and channel for seismic design

\[ \phi V_{sa,seis} \geq V_{sa,seis} \]

\[ V_{l,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5} \]

Nominal shear strength of a single anchor for seismic design

\[ \phi V_{sa,seis} \geq V_{sa,seis} \]

\[ V_{l,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5} \]

Nominal shear strength of a channel bolt for seismic design

\[ \phi V_{sa,seis} \geq V_{sa,seis} \]

\[ V_{l,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-11} \]
Seismic shear longitudinal to the channel profile

Seismic Loading (SDC C, D, E and F)

All anchor systems in a test series shall complete the simulated seismic shear loads. Test No. 14 is performed to extract seismic strength values for the various failures listed below.

Perform the tests on anchor channels to evaluate the nominal shear strength of the connection between the channel lips and channel bolt for shear acting in longitudinal axis without influence of concrete edges. Test No. 14 shall be permitted to be performed with anchor channels with two anchors outside of the concrete with the maximum anchor spacing and the minimum distance between the end of the channel and the anchor axis. The frequency of loading shall be between 0.1 and 2 Hz. To reduce the potential for uncontrolled slip during load reversal, the alternating shear loading shall be permitted to be approximated by the application of two half-sinusoidal load cycles at the desired frequency connected by a reduced-speed, ramped load as shown in Figure 7.8 of this annex.

Nominal shear steel strength in the longitudinal direction for local failure of the channel lips for seismic design anchor channel HAC-T with t-bolt HBC-T

The ϕ value is 0.65 for which periodical inspection is provided for M12 to M20 t-bolts

Nominal shear steel strength in longitudinal direction for local failure of the channel lips for seismic design anchor channel HAC-T with t-bolt HBC-CT

The ϕ value is 0.75 for which continuous inspection is provided for M12 to M20 t-bolts

Nominal shear steel strength in longitudinal direction for local failure of the channel lips for seismic design anchor channel located in SDC C, D, E or F. Please refer to section 7.4.5.

Interaction equation seismic loading (SDC C, D, E and F):

According to AC 232 June 2018 there is no distinction made in interaction equation, if project is in SDC A or B versus project located in SDC C, D, E or F. Please refer to section 7.4.5.

<table>
<thead>
<tr>
<th>SDC A or B</th>
<th>SDC C, D, E or F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing</td>
<td>The anchor channel is subjected to tests to determine the performance of anchor channel under service conditions in accordance with AC232</td>
</tr>
<tr>
<td></td>
<td>Simulated seismic tests are performed where an anchor channel is subjected to the sinusoidal loads. Refer to AC232 section 7.13 to 7.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concrete breakout in tension</th>
<th>The reduction factor of 0.75 is not required.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apply a seismic reduction factor of 0.75 to non-steel tension design strengths per ACI 318-14 Section 17.2.3.4.4.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concrete breakout in shear</th>
<th>An overstrength factor (Ω ) must not be applied.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load combination is based on ASCE 7-10 chapter 12 and ACI 318-14. When the anchorage design is controlled by a brittle anchor failure mode, an over strength factor (Ω ) must be applied to the earthquake component () of the factored load.</td>
</tr>
</tbody>
</table>

Nominal longitudinal shear steel strength of a single anchor for seismic design

V_{sa,x,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5 } \phi V_{sa,x,seis} \geq V_{sa}^{a}

Nominal longitudinal shear steel strength of connection between anchor and channel for seismic design

V_{sc,y,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5 } \phi V_{sc,y,seis} \geq N_{sa}^{a}

Nominal longitudinal shear steel strength of a single anchor for seismic design

V_{sa,x,seis} \text{ and } \phi \text{ are tabulated in ESR-3520 Table 8-5 } \phi V_{sa,x,seis} \geq V_{sa}^{a}

Interaction equation seismic loading (SDC C, D, E and F):

According to AC 232 June 2018 there is no distinction made in interaction equation, if project is in SDC A or B versus project located in SDC C, D, E or F. Please refer to section 7.4.5.

<table>
<thead>
<tr>
<th>Testing</th>
<th>The anchor channel is subjected to tests to determine the performance of anchor channel under service conditions in accordance with AC232</th>
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<td>Simulated seismic tests are performed where an anchor channel is subjected to the sinusoidal loads. Refer to AC232 section 7.13 to 7.19</td>
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</tr>
</tbody>
</table>

8. REINFORCING BAR ANCHORAGE

Anchor channels equipped with headed and T-shaped anchors are generally adequate for applications with thick concrete members, large edge and corner distances, normal weight concrete, high concrete compressive strengths, and medium load range, etc. However, the need for anchor channel solutions suitable for more stringent applications such as thin concrete members, lightweight concrete, high loads, corners, amongst others, led manufacturers, designers, and contractors to look beyond typical anchor channel geometries. For example concrete edge breakout typically governs the design of anchor channels used for near-edge applications such as curtain wall anchorage.

Anchor channels equipped with reinforcing bars that can engage the reinforcing in the slab directly are one way to extend anchor channel application range and efficiency. The use of anchor reinforcement and anchor channels with reinforcing bars requires a thorough understanding of development length theory as expressed in the ACI 318 model code. This chapter provides background on reinforcing bar development as it relates to the specific problem of anchor channel anchorage (see HAC CRFoS U and HAG EDGE).

Rebar theory presented in this chapter is based on ACI 318-14 and Reinforced Concrete Mechanics & Design, by James K. Wight and James G. MacGregor.
8.1 REINFORCING BAR THEORY

The information presented in this chapter is mainly based on Reinforced Concrete Mechanics & Design, by Jams K. Wight and James G. MacGregor, chapter 8 and ACI 318-14.

Introduction

In reinforced concrete structures, concrete resists flexural compressive forces, while the reinforcement resists the flexural tensile forces. Therefore, the bond between the two materials is necessary to ensure the transfer of forces. If no bond stresses are present, the bar will pull out of the concrete causing the reinforced concrete structure to fail.

Bond refers to the interaction between reinforcing steel and the surrounding concrete which allows for transferring of tensile stress from the steel into the concrete.

When reinforcing bars are loaded beyond the bond strength, the concrete will split parallel to the bar. The resulting crack will follow the path of least resistance, propagating out to the surface of the substrate. The splitting cracks follow the reinforcing bars along the bottom, top, and side surfaces. Splitting cracks along the reinforcing bar will generally occur in vertical and horizontal planes. The splitting crack may also occur between two rebars if the spacing is less than the distance between the reinforcing bar and an edge. Figure 8.1.1.3 illustrates different potential splitting cracks patterns.

The bond-transfer mechanism via mechanical interlock between reinforcing bar (transverse ribs on reinforcing bar) and concrete surrounding concrete which allows for transferring of tensile stress from the steel into the concrete.

Figure 8.1.1.1 — Bond stresses on a reinforcing bar.

The bond-transfer mechanism via mechanical interlock between reinforcing bar and concrete is shown in Figure 8.1.1.1. The reinforcing bar acts to transfer the forces into the concrete via bearing on the deformations of the reinforcing bar. While adhesion and friction are present initially, they are quickly lost as the rebar is loaded in tension. Figure 8.1.1.2 a, b, and c illustrate the equal and opposite bearing forces increase, leading to a splitting failure.

Figure 8.1.1.2 — Stresses and forces on a reinforcing bar and concrete. Source: Wight, James & MacGregor, James. Reinforced Concrete Mechanics & Design, 2012.

Splitting cracks occur mainly due to the wedging action of the reinforcing bar bearing against the concrete. Horizontal splitting cracks generally begin diagonally. The dowel action increases the tendency toward splitting.

After development of the cracks occurs, the bond transfer drops rapidly unless reinforcement is provided to restrain the opening of the splitting crack.

Figure 8.1.1.4 — Potential plane of splitting due to closely spaced reinforcing bars.

The load at which splitting failure develops is a function of 1. The minimum distance from the reinforcing bar to the surface of the concrete or to the next reinforcing bars — the smaller this distance, the smaller is the splitting load. 2. The tensile strength of the concrete. 3. The average bond stress—as this increases, the wedging forces increase, leading to a splitting failure.

If the cover and reinforcing bar spacing are large compared to the bar diameter, a pull-out failure can occur, where the bar and the annulus of concrete between successive deformations pull out along a cylindrical failure surface joining the tips of the deformations.

8.2 DEVELOPMENT LENGTH

Establishing the required reinforcing bar length

Although bond stress varies along the length of a bar anchored in a tension zone, ACI uses the concept of development length rather than bond stress. The development length concept is based on the attainable average bond stress over the length of embedment of the reinforcement.

Development length for straight deformed bars in tension given in §25.4.2.3 of ACI 318-14 as follows:

Deformed bars or deformed wires, development length \( (d_f) \) shall be calculated as follows:

\[
\frac{d_f}{b} = \frac{f_y}{(c + \psi e)}
\]

where:

- \( d_f \) = development length, in.
- \( b \) = development length, in.
- \( f_y \) = yield strength of bar
- \( \psi e \) = bar-location factor

Horizontal reinforcement so placed that more than 12 in. of fresh concrete is in the member below the development length or splice

Other reinforcement

\( \psi e \) = epoxy-coating factor

Epoxy coated bars or wires with cover less than 3db or clear spacing less than 6db

All other epoxy-coated bars or wires

Uncoated and galvanized reinforcement

The product \( \psi e \cdot \psi r \) need not exceed 1.7

Development length in accordance with the provisions of ACI 318-14

ACI 318-14 Chapter 25 contains provisions for reinforcing bar development lengths. Development lengths are assumed to preclude concrete splitting and reinforcing bar pullout failure prior to “development” (attainment) of bar yield stress.

In all cases, the development length of a reinforcing bar in tension should not be less than 12 in. Moreover, the values of \( \sqrt{f_y} \) used to calculate development length shall not exceed 100 psi.

Figure 8.2.1.2 — Development length of a reinforcing bar in a cantilever member. Source: Wight, James & MacGregor, James. Reinforced Concrete Mechanics & Design, 2012.

The development length concept incorporates two very important concepts — reinforcing bar stress and nominal yield strength. Bar stress is the force per unit area of the bar cross-section. The nominal yield strength is the minimum bar stress at which permanent (inelastic) deformation occurs.

Structural reinforced concrete design is based on the assumption that the reinforcing bar will develop its yield strength before premature failure occurs due to inadequate bond. Development length is intended to ensure that the nominal yield strength of the bar can be developed under structure loading.

Orangun, et al. [13] proposed an expression for determining the development length \( d_f \) of deformed reinforcing bars in tension. The ACI bond committee simplified the design expression.

Figure 8.2.1.1 — Stresses in concrete and rebar.
8.3 PULLOUT STRENGTH OF STRAIGHT REINFORCING BARS

Pullout strength of reinforcing bar per ACI 318-14, §25.4.2.3

The ACI concept of development length is based on the attainable average bond stress over the length of embedment of the reinforcement.

If a reinforcing bar provides the required development length, the reinforcing bar will yield before it is pulled-out of the concrete. In situations where the force at the reinforcing bar is less than its yield strength, ACI 318 allows reducing the excess development length in tension for a straight bar, shall be at least

\[ d \times d = \frac{40}{f_{y}} \]

ACI 318-14 Equation (25.4.2.3a) for deformed bars in tension can be recast in terms of an equivalent bond stress equation as follows:

\[ A_{y} = f_{y} \times d \times d \]

where

\[ f_{y} = \frac{f_{y}}{f_{y}} \]

Substituting \( A_{y} = d \times d \), the following expression for bond can be derived from the development length equation given in Section 12 2.3:

\[ f_{y} = f_{y} \times d \]

\[ d = \frac{40}{f_{y}} \]

Pullout strength reduction \( \phi \)-factor

ACI 318-14 development length equation does not require a \( \phi \) factor to be applied to the development length equation. An allowance for strength reduction is already included in the expression for determining development length. R25.4.1.3

When calculating the pull-out strength of the reinforcing bar, per ACI 318-14, §17.4.2.9 a reduction factor, \( \phi \) of 0.75 shall be applied to the nominal pull-out rebar strength.
8.4 PULLOUT STRENGTH OF HEADED BARS IN TENSION

Headed anchored bars in tension

When adequate space is not provided to reach full development length of a straight reinforcing bar, ACI 318 allows the use of headed reinforcing bars to reduce the development length. The development length for a headed reinforcing bar generally will be shorter than that for a straight or hooked rebar. Headed reinforcing bars are ideal for applications where there is limited space available to develop bars in tension.

The transfer of force from the bar to the concrete is assumed to be achieved by a combination of bond-transfer mechanism along the straight portion of the bar and bearing forces at the head.

Figure 8.4.1.1 — Stresses on headed anchored reinforcing bars.

Headed anchored bars in tension, \( \ell_{da} \) per ACI 318-14, 25.4.4

The provision for headed deformed bars were formulated with due consideration of the provisions for anchorage in ACI 318-14 Chapter 17 and the bearing strength provisions of ACI 318-14 Chapter 22.

The use of heads to develop deformed bars in tension shall be permitted if conditions (a) through (g) are satisfied:

(a) Bar shall conform to 20.2.1.3
(b) Bar \( f_y \) shall not exceed 60,000 psi
(c) Concrete shall be normal weight
(d) Net bearing area of head \( A_{brg} \) shall be at least 4\( A_b \)
(e) Concrete shall be normal weight
(f) Clear cover for bar shall be at least 2\( d_b \)
(g) Clear spacing between bars shall be at least 4\( d_b \)

The provisions for developing headed deformed bars give the length of bar, \( \ell_{da} \), measured from the critical section to the bearing face of the head, as shown in Fig.8.4.1.1.

Figure 8.4.1.2 — Development length of headed anchored reinforcing bar.

\[ \ell_{da} = \frac{0.0065}{e} \frac{f_y}{f_y} \ell_{dt} \]

25.4.4.2 Development length \( \ell_{da} \) for headed deformed bars in tension shall be the greatest of (a) through (c):

(a) \( \ell_{da} \) shall not exceed 6,000 psi
(b) 6\( d_b \)
(c) 6 in.

\( \ell_{da} \) = development length of headed anchored rebar, in.

\( f_y \) = yield strength of bar

\( e \) = epoxy-coating factor

For all other epoxy-coated bars or wires, 1.2

Uncoated and galvanized reinforcement, 1.0

\( f_y \) = concrete compressive strength

\( d_b \) = nominal diameter of the reinforcing bar

Transverse reinforcement, however, helps limit splitting cracks in the vicinity of the head and for that reason is recommended.

8.5 PULLOUT STRENGTH OF STANDARD HOOKS

Behavior of hooked rebar

When adequate space is not provided to reach full development length of a straight reinforcing bar, the reinforcing bar can be hooked or bent. The behavior of the hooked reinforcing bar changes as a result of the bend in the reinforcing bar. Hooked reinforcing bar resists bond failure by bond strength along the straight portion, anchorage provided by the hook, and by the bearing on the concrete inside the hook.

The forces that develop in a 90° hook are shown in Figure 8.5.1.1. The developed stresses cause the bar to move inwards, leaving a gap of concrete on the outside of the hook. The bar tends to straighten out due to the formation of the gap and directional change in force along the bend, causing compressive stresses on the outside of the tail. Because the compressive force inside the bend is not collinear with the applied tensile force, the bar tends to straighten out, producing compressive stresses on the outside of the tail. Therefore, the failure of the hook can most often be attributed to the crushing of concrete inside the hook. If the hook is close to a side face, the crushing may extend to the surface of the concrete, removing the side cover. If cracking in the vicinity of the tail occurs, the tail may straighten.

Figure 8.5.1.2 — Stresses in standard 90 and 180 degree hooks. Source: Wight, James & MacGregor, James. Reinforced Concrete Mechanics & Design, 2012.

Tension development length of hooked reinforcing bar: ACI 318-14, §25.4.3.1

A minimum value of hook development length (\( \ell_{dh} \)) is specified to prevent failure by direct pullout in cases where a hook may be located very near the critical section. The development length for deformed bars in tension terminating in a standard hook (90° and 180° between top and bottom bar hooks) shall be the greater of (a) through (c):

(a) \( \ell_{dh} \) = \( \frac{f_y}{f_y} \frac{A_{brg}}{A_b} \frac{\ell_{dt}}{50} \frac{1}{e} \)
(b) 6\( d_b \)
(c) 6 in.

The modification factors applicable to hooked reinforcing bar development length are as follows:

\( f_y \) = yield strength of bar

\( e \) = epoxy-coating factor

For all other epoxy-coated bars or wires, 1.2

Uncoated and galvanized reinforcement, 1.0

The modification factors apply when the hooked bar is not developing full tensile strength in the vicinity of the head, as shown in Figure 8.5.1.2. The slip of the rebar at point A is nearly twice as large in the 180° hook as compared to the 90° hook.

The main cause of failure of hooked reinforcing bars is splitting failure of the concrete cover in the plane of the hook. Splitting failure depends on hook cover and anchorage strength can be improved through confinement provided by stirrups.

Figure 8.5.1.3 — Stresses in 90 and 180 degree hooks. Source: Wight, James & MacGregor, James. Reinforced Concrete Mechanics & Design, 2012.
ψ = bar-cover factor
No. 11 bar and smaller hooks with side cover (normal to plane of hook) ≥ 2-1/2 in and for 90-degree hook with cover on bar extension beyond hook ≥ 2 in.

For 90-degree hooks of No. 11 and smaller bars enclosed along ℓ ∞ within ties or stirrups perpendicular to ℓ ∞ at s ≤ 3d, or
(2) enclosed along the bar extension beyond hook including the bend within ties or stirrups perpendicular to ℓ ∞ at s ≤ 4d

For 180-degree hooks of No. 11 and smaller bars enclosed along ℓ ∞ within ties or stirrups perpendicular to ℓ ∞ at s ≤ 3d, or
Other ................................................................. 1.0

ψ = confinement reinforcing factor
For 90-degree hooks of No. 11 and smaller bars
(1) enclosed along ℓ ∞ within ties or stirrups perpendicular to ℓ ∞ at s ≤ 3d, or
(2) enclosed along the bar extension beyond hook including the bend within ties or stirrups perpendicular to ℓ ∞ at s ≤ 4d

When the splitting tensile strength of the lightweight concrete is specified, shall be used to the development length equation. An allowance for strength reduction is already included in the expression for determining development length. R25.4.1.3

ψ ≤ 10,000 psi
db = nominal diameter of the reinforcing bar
Bar hooks are especially susceptible to a concrete splitting failure if both side cover (perpendicular to plane of hook) and top or bottom cover (in plane of hook) are small. For bars being developed by a standard hook at discontinuous ends of members with both side covers and top (or bottom) cover to hook less than 2-1/2 in., (a) through (c) shall be satisfied:
(a) The hook shall be enclosed along ℓ ∞ within ties or stirrups perpendicular to ℓ ∞ at s ≤ 3d,
(b) The first tie or stirrup shall enclose the bent portion of the hook within 2d or the outside of the bend
(c) ψ shall be taken as 1.0 in calculating ℓ ∞ in accordance with 25.4.3.1(α)

Reduction of development length for excess reinforcement
A reduction in development length is permitted in limited circumstances. If the flexural reinforcement provided exceeds the amount required to resist the factored moment, the bar stress that must be developed is less than In such a case, ACI 318-14, §25.4.10 allows to be multiplied by (Areq/Aconcrete).

A reduction of development length in accordance with 25.4.10.1 is not permitted for (a) through (e):
(a) At non-continuous supports
(b) At locations where anchorage or development for ℓ ∞ is required
(c) Where bars are required to be continuous
(d) For headed and mechanically anchored deformed reinforcement
(e) In seismic-force-resisting systems in structures assigned to Seismic Design Categories D, E, or F

ACI 318-14, §R25.4.2.4 The lightweight factor λ for calculating development length of deformed bars and deformed wires in tension is the same for all types of lightweight aggregate concrete. Research does not support the variations of this factor in Codes prior to 1989 for all-lightweight and sand-lightweight concrete. Section 25.4.2.4 allows a higher factor to be used when the splitting tensile strength of the lightweight concrete is specified. Refer to 19.2.4.

R17.4.3.5 Equation (17.4.3.5) for hooked bolts was developed by Lutz based on the results of Kuhn and Shaikh (1996). Reliance is placed on the bearing component only, neglecting any frictional component because crushing inside the hook will greatly reduce the stiffness of the connection and generally will be the beginning of pullout failure. The limits on db are based on the range of variables used in the three tests programs reported in Kuhn and Shaikh (1996).

Pull-out strength reduction factor, ϕ
ACI 318-14 development length equation does not require a ϕ factor to be applied to the development length equation. An allowance for strength reduction is already included in the expression for determining development length. R25.4.1.3

When calculating the pull-out strength of the reinforcing bar, per ACI 318-14, §17.4.2.9 a reduction factor, a, of 0.75 shall be applied to the nominal pull-out reinforcing bar strength.

Pull-out strength of L-bolts
If standard hook requirements of ACI are not met, the reinforcing bar may behave similar to the one of an L-bolt

The pullout strength in tension of a single hooked bolt (Np) per ACI 318-14, §17.4.3.5 shall not exceed

Np = 0.9futra db

where: 3d < b < 4.5db

Reduction of development length for excess reinforcement
The primary factors affecting the minimum bend diameter and extension length for a hooked reinforcing bar is as follows in the table:

<table>
<thead>
<tr>
<th>Type of standard hook</th>
<th>Bar size</th>
<th>Minimum inside band diameter(n)</th>
<th>Straight extension length, (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90-degree hook</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 3 through No. 8</td>
<td>8db</td>
<td>12db</td>
<td></td>
</tr>
<tr>
<td>No. 9 through No. 11</td>
<td>8db</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 14 through No. 18</td>
<td>10db</td>
<td></td>
<td></td>
</tr>
<tr>
<td>180-degree hook</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 3 through No. 8</td>
<td>8db</td>
<td>Greater of: 4db</td>
<td></td>
</tr>
<tr>
<td>No. 9 through No. 11</td>
<td>8db</td>
<td>2.5 in</td>
<td></td>
</tr>
<tr>
<td>No. 14 through No. 18</td>
<td>10db</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ψ = modification factor for lightweight concrete
When any lightweight-aggregate concrete is used

ψ = 0.75
When the splitting tensile strength f,∞ is specified, shall be permitted to be taken as t,∞/6.7T, but not more then 1.0
When normal-weight concrete is used ............................................. 1.0

ACI 318-14, §R25.4.2.4 The lightweight factor λ for calculating development length of deformed bars and deformed wires in tension is the same for all types of lightweight aggregate concrete.
8.6 REINFORCING BAR LAP SPLICES

Behavior of lap splice

Opposed to development length where the length of the reinforcing bar needed to transfer the stresses to the concrete is calculated, lap splice calculates the lap length of the reinforcing bar needed to transfer the stresses to another bar.

The mechanism of force-transfer in lap splicing is the force in one reinforcing bar is transferred into the concrete, which then is transferred to the adjacent reinforcing bar, or spliced reinforcing bar. This behavior is shown in Figure 8.6.1.1 and 8.6.1.2. Although the term “lap splice” implies direct transfer of stress from bar to bar, forces between bars are transferred via struts and hoop stresses in the concrete.

The transfer of forces out of the reinforcing bar into the concrete causes radially outward pressures on the concrete, as shown in figure 8.6.1.3. This force transfer may create pressures that result in splitting cracks on concrete between and along the two reinforcing bar. When such cracks occur, the splice fails. Therefore, transverse reinforcement can be supplemented to delay the openings of the splitting cracks and improve the splice capacity.

Table 8.6.1.1 (ACI 318-14 Table 25.5.2.1) — Lap splice lengths of deformed bars and deformed wires in tension

<table>
<thead>
<tr>
<th>As,required/As,provided</th>
<th>Maximum percent of As applied within required lap length</th>
<th>Splice type</th>
<th>ℓₘ</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2.0</td>
<td>50</td>
<td>Class A</td>
<td>1.0ℓ₀ and 12 in.</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>Class B</td>
<td>1.3ℓ₀ and 12 in.</td>
</tr>
<tr>
<td>&lt; 2.0</td>
<td>All cases</td>
<td>Class B</td>
<td>1.3ℓ₀ and 12 in.</td>
</tr>
</tbody>
</table>

§ 25.5.1.2 For contact lap splices, minimum clear spacing between the contact lap splice and adjacent splices or bars shall be in accordance with the requirements for individual bars in 25.2.1.

There is no difference in the performance of contact and noncontact lap splices. Forces are transferred from one bar to another via the concrete.

§ 25.5.1.4 Reduction of development length in accordance with § 25.4.10.1 is not permitted in calculating lap splice lengths. Because the splice classifications already reflect excess reinforcement, the development length, ℓ₀ used to determine the lap length should not include reduction factors for excess reinforcement.

§ 25.5.2.2 If bars of different size are lap spliced in tension, ℓ₀ shall be the greater of ℓ₀ of the larger bar and ℓ₀ of the smaller bar.
8.7 CONCRETE COVER

Minimum cover requirements: ACI 318-14 20.6.1.3
The specified concrete cover is measured as the distance between the outermost surface of embedded reinforcement and the closest outer surface of the concrete. The concrete cover can also be measured as the spacing from rebar to rebar. The tables below further explain the specified concrete cover requirements.

Table 8.7.1.1 (ACI 318-14 Table 20.6.1.3.1) — Specified concrete cover for cast-in-place nonprestressed concrete members

<table>
<thead>
<tr>
<th>Concrete exposure</th>
<th>Member</th>
<th>Reinforcement</th>
<th>Specified cover, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast against and permanently in contact with ground</td>
<td>All</td>
<td>All</td>
<td>3</td>
</tr>
<tr>
<td>Exposed to weather or in contact with ground</td>
<td>All</td>
<td>No. 8 through No. 18 bars</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. 5 bar, W31 or D31 wire, and smaller</td>
<td>1-1/2</td>
</tr>
<tr>
<td>Not exposed to weather or in contact with ground</td>
<td>Slabs, joists, and walls</td>
<td>No. 14 and No. 18 bars</td>
<td>1-1/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. 11 bar and smaller</td>
<td>3/4</td>
</tr>
<tr>
<td>Beans, columns, walls and tension ties</td>
<td>Primary reinforcement, stirrups, ties, spirals, and hoops</td>
<td>1-1/2</td>
<td></td>
</tr>
</tbody>
</table>

Table 8.7.1.2 (ACI 318-14 Table 20.6.1.3.2) — Specified concrete cover for cast-in-place prestressed concrete members

<table>
<thead>
<tr>
<th>Concrete exposure</th>
<th>Member</th>
<th>Reinforcement</th>
<th>Specified cover, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast against and permanently in contact with ground</td>
<td>All</td>
<td>All</td>
<td>3</td>
</tr>
<tr>
<td>Exposed to weather or in contact with ground</td>
<td>Slabs, joists, and walls</td>
<td>All</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>All</td>
<td>1-1/2</td>
</tr>
<tr>
<td>Not exposed to weather or in contact with ground</td>
<td>Slabs, joists, and walls</td>
<td>All</td>
<td>3/4</td>
</tr>
<tr>
<td>Beans, columns, and tension ties</td>
<td>Primary reinforcement, stirrups, ties, spirals, and hoops</td>
<td>1-1/2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stirrups, ties, spirals, and hoops</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

For corrosive environments, the concrete cover shall be increased as deemed necessary and specified by the licensed design professional per the exposure categories and classed in ACI 318-14 Section 19.3. The recommended cover for corrosive environments is not less than 2 in. For fire protection requirements, the general building code may require greater concrete cover than the required cover specified in ACI 318-11 7.7.1 through 7.7.7.

Chapter 7 (Anchor Channel Design Code) and chapter 8 (Reinforcing Bar Theory) provide the required information to have a deep understanding of the behavior of an anchor channel with rounded headed anchors and rebars. This chapter combines the information presented in chapter 7 and 8 and covers the design models for HAC, HAC CRFoS U, and HAC EDGE. The special conditions like anchor channels installed in metal deck, two anchor channels installed parallel to each other at an edge, anchor channels installed top and bottom of slab at the same elevation are the few examples. This chapter also introduces and explains the design methodology of the anchor channels used for high wind loads.

Design methods provided in chapter 9 are allowed for applications with known boundary conditions. The provisions described in this section are only valid for Hilti Anchor Channels. The design models presented in this chapter have not been evaluated with any other anchor channel type or anchoring technology. For applications that deviate from the design boundary conditions presented in this chapter, reach out to Hilti.
Introduction
Prior to the publication of the Acceptance Criteria 232 (AC232), cast-in anchor channels could not receive recognition under the International Building Code (IBC) as ACI 318 Anchor-to-Concrete provisions exclude specialty inserts. The publication of (AC232) brought major benefits to the cast-in anchor channel industry and design community. The use of optimized anchor channel solutions and simplification of the design and approval processes for anchor channels ultimately can avoid construction shutdowns.

Cast-in anchor channels can now receive recognition under the IBC, as AC232 3.0 Design Requirements provides amendments to ACI 318 Anchoring to Concrete provisions that permit the design of anchor channel systems as if they were included in ACI 318 Anchoring to Concrete provisions. In addition, AC232 allows the design community to have a clear understanding of the behavior of cast-in anchor channel systems.

In 2015, AC232 incorporated the so needed seismic provisions for anchor channels in Seismic Design Category C, D, E, or F. Later that year, provisions permitting the use of anchor channels in lightweight concrete and sand-lightweight concrete were adopted by AC232.

Important design provisions have been added to AC232 over the last years. The ultimate goal is to have a complete framework that covers all common applications encountered in a building such as corners with a pair of anchor channels loaded simultaneously, parallel channels, and wind corner zones with practical design requirements (i.e., typical edge distance). For these conditions, it is typically concrete that is limiting factor and having “fixed” design parameter such as member thickness, concrete type, concrete compressive strength, etc., brings the need of the so call anchor channels with rebars.

The scope of AC232 is limited to anchor channels with rounded headed anchors or channel anchors with rebars replacing rounded headed anchors or I-anchos. AC232 includes provisions for anchor reinforcement, where the concrete breakout in shear and/or tension can be precluded, but specifying additional reinforcement implies additional burdens and is typically an unpractical solution. The use of a complete anchor channel systems that allow the introduction of higher loads into the structure without specifying anchor reinforcement is the preferred solution.

All Hilti anchor channels covered by AC232 (HAC and HAC-T) are designed in accordance to ESR-3520. This is a future. That is why these so needed anchor channels with rebars are tested in accordance with AC232 and the design models are using AC232 principles and applicable provisions of AC232 and ACI 318. Table 9.1.1 provides a summary of the design method of the Hilti anchor channel systems. Our ultimate goal is to offer designers and contractors anchor channel system solutions that are 100 percent IBC compliant.

Table 9.1.1 — Overview of Hilti anchor channel systems design method

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Symbol</th>
<th>HAC HAC-T</th>
<th>HAC CRFs U HAC-T CRFs U</th>
<th>HAC EDGE HAC EDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Anchor and channel connection</td>
<td>$\Phi_{NC}$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Channel tip</td>
<td>$\Phi_V$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Pullout</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>ACI 3182</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Concrete breakdown</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>N/A</td>
<td>ESR-3520</td>
</tr>
</tbody>
</table>

Perpendicular shear design model

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Symbol</th>
<th>HAC HAC-T</th>
<th>HAC CRFs U HAC-T CRFs U</th>
<th>HAC EDGE HAC EDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel tip</td>
<td>$\Phi_V$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Anchor</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Anchor and channel connection</td>
<td>$\Phi_{NC}$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Channel bolt</td>
<td>$\Phi_V$</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Concrete edge breakout</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>N/A</td>
<td>ESR-3520</td>
</tr>
</tbody>
</table>

Longitudinal shear design model

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Symbol</th>
<th>HAC HAC-T</th>
<th>HAC CRFs U HAC-T CRFs U</th>
<th>HAC EDGE HAC EDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Anchor and channel connection</td>
<td>$\Phi_{NC}$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Channel bolt</td>
<td>$\Phi_V$</td>
<td>ESR-3520</td>
<td>AC232 based1</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Concrete edge breakout</td>
<td>$\Phi_N$</td>
<td>ESR-3520</td>
<td>N/A</td>
<td>ESR-3520</td>
</tr>
</tbody>
</table>

1 AC232 based indicates product has been tested in accordance to AC232 testing protocols for that specific failure mode and the design is based on applicable provisions and/or fundamentals of AC232 and/or ACI 316.  
2 ACI 318 indicates the implication of that specific failure mode is in accordance to the applicable ACI 318 provision.  
3 Hilti Method is derived based on testing according to AC232 testing protocols for that specific failure mode. However, the design is adjusted accordingly to account for the additional contribution of the added rebars.
9.2 — HAC AND HAC-T DESIGN

The general design of HAC and HAC-T is based on ICC ESR-3520. The design theory of rounded headed anchors is presented in chapter 7. This section provides additional design information for applications outside the scope of AC232 and therefore ESR-3520 such as corners and parallel channels.

The anchor channel design encompasses the verification of the steel and concrete at the anchorage zone. For conditions outside the scope of AC232, it is only the concrete failure mode that are excluded. The steel strengths of the anchor channel do not depend on the concrete and therefore, the steel strengths of HAC and HAC-T are based on ESR-3520.

This section provides guidelines to determine the concrete strengths of anchor channels for applications outside the scope of AC232. The design methodology of such applications is based on applicable provisions and principles of AC232. Table 9.2.1 summarizes the design methodology for each potential failure mode of HAC and HAC-T for intermediate, corners, and parallel anchor channels applications.

Table 9.2.1 — Design methodology for all potential failure modes of HAC and HAC-T for common applications

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Symbol</th>
<th>HAC &amp; HAC-T</th>
<th>Intermediate</th>
<th>Corners</th>
<th>Parallel channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor</td>
<td>$\phi_N$</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
</tr>
<tr>
<td>Anchor and channel connection</td>
<td>$\phi_N$</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
<td>ESR-3520</td>
</tr>
<tr>
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<td>ESR-3520</td>
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<td>Bending of channel</td>
<td>$\phi_N$</td>
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<tr>
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<tr>
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<td>$\phi_N$</td>
<td>ESR-3520</td>
<td>AC232 principles</td>
<td>AC232 principles</td>
<td></td>
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1. HAC232 based indicates product has been tested in accordance to AC232 testing protocols for that specific failure mode and the design is based on applicable provisions and/or fundamentals of AC232 and/or ACI 318.

2. AC232 and ACI 318 based indicates the analysis of that specific failure modes is in accordance to the applicable AC232 and ACI 318 principles.

IMPORTANT! Failure analysis modes evaluated follow ACI 318-14, chapter 17. This DOES NOT include evaluating the base material (e.g. edge-of-slab) capacity to resist compressive forces generated by the fixture. The engineer must ALWAYS verify the base material (e.g. edge-of-slab) design is capable of resisting the applied loading.

For additional information, please contact Hilti at US+CA.HAC@Hilti.com
9.2.1 — HAC AND HAC-T DESIGN: INTERMEDIATE APPLICATIONS

HAC and HAC-T at intermediate applications are designed in accordance with ESR-3520. Design methodology is fully in accordance with the anchor channel Design Code presented in chapter 7.

9.2.2 — HAC AND HAC-T DESIGN: FACE OF SLAB OUTSIDE CORNER WITH A SINGLE ANCHOR CHANNEL

90° corners

Outside corners where only one anchor channel is present are fully covered by ESR-3520. The design methodology is fully in accordance with the anchor channel Design Code presented in Chapter 7.

AC232 includes design provisions to account for the influence of a corner. The concrete strengths in tension and shear of the anchor channel may be reduced (depending on how far the anchor channel is away from the corner) since the concrete cones may not be fully developed. See chapter 7 for design provisions for corners.

In PROFIS Anchor Channel, these conditions can be simply modeled by reducing the corner distance. Although AC232 does not specifically address acute and obtuse corners, Hilti’s general recommendation is to not follow the idealized failure planes but the path of least resistance to assess the concrete volume available for the anchor channel. Upon determination of the corner distance, AC232 provisions can be used to analyze this type of corners.

In order to avoid calculating unconservative concrete strength, the path of least resistance for the crack should be always considered.

Obtuse corners: Tension analysis

Corner distance shall be considered assuming an imaginary edge at the joint of the corner. The following two options that has been illustrated and used for the analysis.
Acute corners: Tension analysis
Corner distance shall be considered as the shortest distance between the anchor and the edge. The straight line is drawn from the end of the headed stud of anchor channel. The line is extended until it intersects the edge of the acute angle corner. The point of intersection is extended back to the face of slab edge as shown in Figure 9.2.2.8. The side edge distance $C_{n2}$ is used for analyzing the tension breakout capacity of anchor channel which reduces the tension concrete breakout capacity by introducing the corner factor as seen in the equation below.

$$c_{n2} = b_A + 2c_{a2} \geq 1.5 b_{cr}$$

ESR-3520 Equation (14)

If $c_{a2} < c_{n2}$

then $\psi_{c,n} = \left(\frac{c_{n2}}{c_{n2}}\right)^{0.5} \leq 1.0$

ESR-3520 Equation (16)

Corner distance shall be considered as the shortest distance between the anchor and the edge as shown in the Figure 9.2.2.8. The side edge distance $C_{n2}$ is used for analyzing the tension breakout capacity of anchor channel which reduces the tension concrete breakout capacity by introducing the corner factor as seen in the equation below.

$$c_{n2} = b_A + 2c_{a2} \geq 1.5 b_{cr}$$

ESR-3520 Equation (14)

If $c_{a2} < c_{n2}$

then $\psi_{c,n} = \left(\frac{c_{n2}}{c_{n2}}\right)^{0.5} \leq 1.0$

ESR-3520 Equation (16)

Acute corners: Perpendicular Shear analysis
A path of least resistance line is drawn emitting from the headed stud of anchor channel. The line is extended until it intersects the edge of the acute angle corner. The point of intersection is extended back to the face of slab edge as shown in Figure 9.2.2.9, intersecting the edge 2 at 90°. A straight line is drawn limiting the height of the substrate by introducing stringent corner factor reflecting an acute angle corner effect. The substrate height is also measured and modelled in Profis anchor channel software. By limiting the height of the substrate we will introduce the height reduction factor, hence further reducing the overall capacity of perpendicular shear. Please refer to Figure 9.2.2.9 and Figure 9.2.2.10.

Acute corners: Longitudinal Shear analysis
The straight line is drawn limiting the height of the substrate. The line is extended until it intersects the edge of the acute angle corner. The point of intersection is extended back to the face of slab edge as shown in Figure 9.2.2.11 and Figure 9.2.2.12. By limiting the height of the substrate we will reduce the $A_{cr}$ in a basic longitudinal shear capacity which in turns reduces the longitudinal capacity.

$$V_{cha} = \left(\frac{A_{cr}}{A_{

ESR-3520 Equation (38)

$$h_{v,v} = \frac{h}{b_{h,v}} \leq 1.0$$

ESR-3520 Equation (37)

$$c_{v,v} = 0.5 \cdot s_{v,v} = 2c_{v,v} + b_{h,v} \cdot \text{mm}$$

ESR-3520 Equation (36)

$$\psi_{v,v} = \frac{c_{v,v}}{c_{v,v}} \leq 1.0$$

ESR-3520 Equation (35)

90° corners
Outside corners where two anchor channels are present and are loaded simultaneously are outside the scope of AC232. Most of the AC232 provisions can be applied to this type of application. However, the influence of the adjacent anchor channel shall be considered, as the concrete strength may be negatively impacted.

The concrete at the corner is shared by the two anchor channels and therefore, using the AC232 provisions with the actual corner distance for analysis purposes can yield very unconservative concrete strengths. The crack will propagate along the path of least resistance at the corner instead of following idealized failure plane. Figure 9.2.3.1 shows an example of a FOS corner, where anchor channels are installed at the distance away from the corner that the failure planes do not intersect, hence there will not be any reduction in concrete breakout capacity in tension. A side edge distance of $h_{cr}$ and $C_{r2}$ at the corner should be provided to make sure that the planes do not intersect.

Tension
For the concrete failure modes in tension, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner change the concrete behavior. The concrete crack instead of following the idealized failure plane ($C_{cr}$), it takes the path of least resistance at the corner. This concept is illustrated in figure 9.2.3.2.

Hilti uses applicable provisions of AC232 to analyze this type of anchor application. To account for the influence of the adjacent corner anchor channel, the corner distance is reduced by assuming the concrete crack follows the path of...
least resistance and considering the corner distance where the “crack” of each anchor channel overlaps. The shaded area for 90° angle outside corner with anchor channel with studs, the true side edge can be used once in an analysis of one of the two channels as shown in Figure 9.2.3.3. Concrete breakout in tension check for Channel a, the side edge distance is considered for analysis. Concrete breakout tension check for Channel b, the true side edge distance is considered in the analysis. This has been illustrated in Figure 9.2.3.3. The total distance of (a+b) can be divided between the two channels, while analyzing the individual channels. For example if channel a is loaded more than channel b than side edge distance of 3/4(a+b) can be assumed for channel a and side edge distance 1/4(a+b) can be assumed for channel b.

**Perpendicular shear analysis**

In simplified analysis concrete breakout perpendicular shear check at outside corner for Channel a or b, the side edge distance of true edge is considered for analysis with multiplying corner reduction factor of 0.8 to the perpendicular shear capacity. True side edge distance is the distance from the anchor to the edge at the corner.

On other hand detailed analysis can be performed which takes into account the effect of adjacent anchor channel with headed studs. This is incorporated in modification spacing factor ψ as described below. The diagonal distance from the second channel is taken into consideration along with the ratio of the shear load that each of the anchor has over anchor in consideration. Side edge used in the analysis will remain the true side edge distance. Determination of the critical spacing

\[
b = \max \left( \frac{(4c_{a1} + 2b_{a1})}{2} ; \frac{2c_{a1} + 2b_{a1}}{2} \right)
\]

Considering the linear distance between the anchors as

\[
x_i = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}
\]

is equivalent to use a circular idealized breakout body. Condition to ensure the same area as for the rectangles: 

\[
s_{cr,v} = 2 \times \sqrt{\frac{b}{\psi_{cr,v}/\psi_{cr,a}}} = 2 \times 1.13b
\]

\[
\psi_{cr,v} = \frac{1}{1 + \frac{n_{a1} + n_{a2}}{n_{b1} + n_{b2}}} \left( \frac{c_{a1} + c_{a2} + c_{b1} + c_{b2}}{c_{a1} + c_{a2} + c_{b1} + c_{b2}} \right)
\]

\[n_{a1} = \text{number of anchors of channel 1}
\]

\[n_{a2} = \text{number of anchors of channel 2}
\]

\[\psi_{cr,v}, \text{ modification factor for spacing influence for 90° angle corner: Example of spacing factor } \psi_{cr,v}, \text{ calculation for } a_i \text{. Please refer to Figure 9.2.3.7 for understanding the distance of anchor } a_i \text{ from anchor } b_i, b_j \text{ and } b_k \text{ as well as anchor } a_i \text{ and } a_k \text{. The shear force experienced by these anchors.}
\]

\[
b = \max(c_{a1}, h_{cr,v})
\]

\[
s_{cr,v} = 2 \times \sqrt{\frac{b}{\psi_{cr,v}}} = 2 \times 1.13b
\]

\[\psi_{cr,v}, \text{ modification factor for corner influence for 90° angle corner: The true edge distance is taken into consideration for determination of reduction factor for corner distance } C_{cr,v} \text{ or } C_{cr,b} \text{ as taken as distance in case of a 90° angle corner for corner anchors } a_i \text{ or } b_i \text{ respectively. }
\]

\[C_{cr,v} = \left( \frac{C_{cr,b} + c_{a1} + c_{b1}}{2} \right)
\]

\[\text{distance of the anchor } a_i \text{ under consideration to the corner (see Figure 9.2.3.7).}
\]
Longitudinal shear analysis

When Longitudinal shear is applied on both sides of the anchor channel towards the corner edge. The longitudinal shear capacity is determined with the edge distance of \( c_{cr} \) or with \( c_{cr} \) which ever controls. Please refer Figure 9.2.3.8 and Figure 9.2.3.9.

Interaction Equation

Interacting the concrete utilization in tension, perpendicular shear and longitudinal shear of both channels which will include the effect of all of these breakout cases as described below. 3D Load Interaction for Front of Slab solutions (verification for every shear and longitudinal shear of both channels which will include interacting the concrete utilization in tension, perpendicular shear and longitudinal shear of both channels). Interaction Equation

\[
\phi_{\psi} = \left( 1 + \frac{f_{y,c}}{f_{y,c}} \right) + \left( 1 + \frac{f_{y,c}}{f_{y,c}} \right)^{\frac{1}{m}} + \left( 1 + \frac{f_{y,c}}{f_{y,c}} \right) \leq 1.0
\]

with \( \alpha = 1.67 \)

Load Interaction for Front of Slab solutions (verification for every shear and longitudinal shear of both channels which will include interacting the concrete utilization in tension, perpendicular shear and longitudinal shear of both channels). Interaction Equation

\[
\phi_{\psi} = \left( 1 + \frac{f_{y,c}}{f_{y,c}} \right) + \left( 1 + \frac{f_{y,c}}{f_{y,c}} \right)^{\frac{1}{m}} + \left( 1 + \frac{f_{y,c}}{f_{y,c}} \right) \leq 1.0
\]

with \( \alpha = 1.67 \)

Perpendicular shear analysis:

The reduced side edge distance needed to be considered as shown in Figure 9.2.3.12. The ideal failure plane for perpendicular shear breakout is drawn propagating into the slab. The line is drawn parallel to edge 1 at a distance \( h_{cr} \) of \( h_{cr} \) from \( (h_{cr} + c_{a1}) \). The intersection point of this line with edge 2 is projected back to edge 1 in order to determine side edge distance \( c_{a2} \) for the analyses of channel b. Similar line can be drawn parallel to edge 2 at a distance \( h_{cr} \) of \( h_{cr} + c_{a1} \) to determine the side edge distance of channel a. This side edge is measured from that point to the anchor and is modelled in profis for analysis for analyses of individual channels. This will reduce the perpendicular shear capacity by taking into consideration the small edge introducing the more stringent corner modification factor. Please refer Figure 9.2.3.11 and Figure 9.2.3.12.

Moreover, the \( \psi_{cr} \) is calculated taking into consideration the respective distances of neighboring anchors with respect to the anchor that is in consideration. Refer to 90° corner section describing the method in detail. Please refer Figure 9.2.3.14

Example of spacing factor \( \psi_{cr} \) calculation for anchor a with respect to a anchor modification factor for spacing influence for acute angle corner: Example of spacing factor \( \psi_{cr} \) calculation for b of anchor channel “b” taking into consideration the presence of anchor channel a.

\[
b = \max \left( \frac{c_{a1} \cdot c_{b1}}{h_{cr} \cdot h_{cr}} \right)
\]

\[
\psi_{cr} = 2 \times \frac{b}{b + 2} = 2 \times 1.13b
\]

\[
\psi_{cr} = 2 \times \frac{b}{b + 2} = 2 \times 1.13b
\]

\[
\psi_{cr} = 2 \times \frac{b}{b + 2} = 2 \times 1.13b
\]

\[
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\]

\[
\psi_{cr} = 2 \times \frac{b}{b + 2} = 2 \times 1.13b
\]

\[
\psi_{cr} = 2 \times \frac{b}{b + 2} = 2 \times 1.13b
\]

Acute and obtuse corners

Acute Corner:

Acute angle corners with HAC (rounded headed anchors) loaded simultaneously in tension, perpendicular shear and longitudinal shear

Tension analysis:

The crack will propagate along the path of least resistance at the corner instead of following idealized failure plane. The side edge distance used in the analysis should be as shown in the Figure 9.2.3.10. This approach is followed in order to avoid utilizing the same concrete twice in the analysis, hence generating the results replicating the real condition. The shaded region of corner shown in the figure is not utilized. Please refer Figure 9.2.3.10. The total distance of (a+b) can be divided between the two channels, while analysing the individual channels. For example if channel a is loaded more than channel b than side edge distance of \( \frac{3}{4}(a+b) \) can be assumed for channel a and side edge distance \( \frac{1}{4}(a+b) \) can be assumed for channel b.

Perpendicular shear analysis:

The reduced side edge distance needed to be considered as shown in Figure 9.2.3.12. The ideal failure plane for perpendicular shear breakout is drawn propagating into the slab. The line is drawn parallel to edge 1 at a distance \( h_{cr} \). The intersection point of this line with edge 2 is projected back to edge 1 in order to determine side edge distance \( c_{cr} \) for the analyses of channel b. Similar line can be drawn parallel to edge 2 at a distance \( h_{cr} + c_{a1} \) to determine the side edge distance of channel a. This side edge is measured from that point to the anchor and is modelled in profis for analysis for analyses of individual channels. This will reduce the perpendicular shear capacity by taking into consideration the small edge introducing the more stringent corner modification factor. Please refer Figure 9.2.3.11 and Figure 9.2.3.12.

Moreover, the \( \psi_{cr} \) is calculated taking into consideration the respective distances of neighboring anchors with respect to the anchor that is in consideration. Refer to 90° corner section describing the method in detail. Please refer Figure 9.2.3.14

Example of spacing factor \( \psi_{cr} \) calculation for anchor a with respect to a anchor modification factor for spacing influence for acute angle corner: Example of spacing factor \( \psi_{cr} \) calculation for b of anchor channel “b” taking into consideration the presence of anchor channel a.

\[
b = \max \left( \frac{c_{a1} \cdot c_{b1}}{h_{cr} \cdot h_{cr}} \right)
\]

\[
\psi_{cr} = 2 \times \frac{b}{b + 2} = 2 \times 1.13b
\]
Longitudinal shear analysis:
The reduced side edge distance needed to be conservatively considered as shown in Figure 9.2.3.14 as done for perpendicular shear for determining the longitudinal shear capacity.

Interaction Equation:
Interacting the concrete utilization in tension, perpendicular shear and longitudinal shear of both channel will include the effect of all of these breakout cones as described below. Refer section for 90° corner describing the longitudinal shear check.

3D Load Interaction for Front of Slab solutions (verification for every anchor):

\[
\psi_{Lon} = \left( \frac{V_{Lon,a}}{\phi_{Lon,a}} + \frac{V_{Lon,b}}{\phi_{Lon,b}} \right) + \left( \frac{V_{Lon,a}}{\phi_{Lon,a}} + \frac{V_{Lon,b}}{\phi_{Lon,b}} \right) \leq 1.0
\]

with \( \alpha = 1.67 \)

Tension of anchor channel in consideration (channel b)

- Concrete breakout in tension utilization (anchor, including influence of the other channels)
- Pull Out Strength Utilization

\[
\psi_{Lon,b} = \frac{V_{Lon,b}}{\phi_{Lon,b}} \quad \text{: Longitudinal shear of anchor channel on acute edge (channel b)}
\]

- Anchor reinforcement for concrete edge failure utilization

\[
\psi_{Lon,a} = \frac{V_{Lon,a}}{\phi_{Lon,a}} \quad \text{: Perpendicular shear of anchor channel in consideration (channel b)}
\]

- Maximum Concrete edge breakout utilization for Perpendicular shear

\[
\psi_{Lon,b} = \frac{V_{Lon,b}}{\phi_{Lon,b}} \quad \text{: Longitudinal shear of anchor channel in consideration (channel a)}
\]

- Concrete edge (anchor)
- Anchor reinforcement for concrete edge failure

\[
\psi_{Lon,a} = \frac{V_{Lon,a}}{\phi_{Lon,a}} \quad \text{: Perpendicular shear of anchor channel in consideration (channel a)}
\]

Please note that using this interaction equation is a conservative method to incorporate longitudinal force utilization in the analysis. In order to optimize the design contact Hilti. We will optimize the design using the method that takes into consideration the longitudinal utilization of both the anchor channels.

Obtuse Corner

Tension:
Obtuse angle corners with headed studs HAC channel loaded only in tension: The crack will propagate along the path of least resistance at the corner instead of following idealized failure plane. The side edge distance used in the analysis should be as shown in Figure 9.2.3.15. This approach is followed in order to avoid utilizing the same concrete twice in the analysis, hence generating the results replicating the real condition. The shaded region of concrete shown in Figure 9.2.3.15 is not utilized.

The shaded area for obtuse angle corner with headed studs anchor channel the true side edge can be used once in an analysis as shown in Figure 9.2.3.16. Assigning true edge to one channel and assigning reduced edge to another channel. Concrete breakout in tension check for Channel a, the reduced side edge distance in case of Channel b can be used in the analysis. Concrete breakout tension check for Channel b, the true side edge is \( C_{Lon,b} \) can be used in the analysis. The total distance of \( (a+b) \) can be divided between the two channels, while analyzing the individual channels. For example if channel a is loaded more than channel b than side edge distance of \( 3/4(a+b) \) is used for channel b and side edge distance of \( 3/4(a+b) \) is used for channel a.

Perpendicular shear:
Concrete breakout perpendicular shear check at outside corner for Channel a or b, the side edge distance of true edge is considered for analysis in determining the perpendicular shear capacity. True side edge distance is the distance from the anchor to the corner edge at the corner. Moreover, the \( \psi_{Lon} \) is calculated taking into consideration the respective distances of neighboring anchors with respect to the anchor that is in consideration. Refer to 90° corner section describing the method in detail. Please refer to the Figure 9.2.3.17.

\[
\psi_{Lon} \quad \text{modification factor for spacing influence for acute angle corner:}
\]

Example of spacing factor \( \psi_{Lon} \) calculation for a\_a of channel a with respect to a\_b on the other side of obtuse angle corner. Please refer to the Figure 9.2.3.17.

\[
b = \max (c_{Lon, a, 1}, r_{Lon})
\]

\[
\psi_{Lon} = 2 + \frac{2}{\sqrt{b}} = 2 \times 1.33b
\]

\[
\psi_{Lon} \quad \text{modification factor for corner influence for an obtuse angle corner: A true side edge distance is taken into consideration for determination of reduction factor for corner distance } C_{Lon}, \text{ or}
\]
Longitudinal shear:
Concrete breakout longitudinal shear check for channel a and b, the true side edge is considered for analysis with no added corner reduction factor to the capacity.

Interaction Equation:
Interacting the concrete utilization in tension, perpendicular shear and longitudinal shear of both channel will include the effect of all of these breakout cones as described below.

3D Load Interaction for Front of Slab solutions (verification for every anchor):

\[ P_{T,a} = \left( \frac{V_{a}}{V_{a,max}} + \frac{V_{a}}{V_{a,max}} \phi_{a} \right) + \left( \frac{V_{b}}{V_{b,max}} + \frac{V_{b}}{V_{b,max}} \phi_{b} \right) \leq 1.0 \]

\[ N_{a,b} \phi_{a} : \text{Tension of anchor channel in consideration (channel a)} \]

- Concrete breakout in tension utilization (anchor, including influence of the other channels)
- Pull Out Strength Utilization

\[ \max \left( \frac{V_{a}}{V_{a,max}} + \frac{V_{a}}{V_{a,max}} \phi_{a} \right) : \text{Longitudinal shear of anchor channel on obtuse edge (channel b)} \]

- Longitudinal concrete edge failure Utilization

\[ V_{a,max} : \text{Perpendicular shear of anchor channel in consideration (channel a)} \]

- Maximum Concrete edge breakout utilization for Perpendicular shear

\[ V_{a,max} : \text{Longitudinal shear of anchor channel in consideration (channel a)} \]

- Concrete edge (anchor)
- Anchor reinforcement for concrete edge failure

9.2.4 — HAC AND HAC-T DESIGN: FACE OF SLAB INSIDE CORNER WITH PAIR OF ANCHOR CHANNEL

Inside corners where two anchor channels are present and are loaded simultaneously are outside the scope of AC232. Most of the AC232 provisions can be applied to this type of application. However, the influence of the adjacent anchor channel should be considered, as the concrete strength may be negatively impacted.

90° Inside Corner
An Imaginary edge is assumed while analyzing anchor channel b. The side edge distance of C_{b}, is taken as shown in figure 9.2.4.1 and figure 9.2.4.2.

The side edge distance with infinite amount of concrete to the right of the anchor channel a is assumed while analyzing as shown in the figure 9.2.4.1 and figure 9.2.4.2.

Tension: Refer Figure 9.2.4.1. This condition can be analyzed by fictitious edge between \( c_{a,b} + c_{a,a} \) assuming side edge concrete between channel a and b. The total distance of (a+b) can be divided between the two channels, while analyzing the individual channels. For example if channel a is loaded more than channel b than side edge distance of 3/4(a+b) can be assumed for channel a and side edge distance 1/4(a+b) can be assumed for channel b.

Acute and obtuse interior corners
Acute Interior Corner:
An Imaginary edge is assumed while analyzing anchor channel b. The side edge distance of C_{b} is taken as shown in the figure to the right figure 9.2.4.3 and figure 9.2.4.4. The concrete shaded in dark color in these Figures is not neglected, while analyzing anchor channel a or b.

The side edge distance with infinite amount of concrete to the right of the anchor channel a is assumed while analyzing as shown in the figure 9.2.4.3 and figure 9.2.4.4.

Tension: Refer Figure 9.2.4.3. This condition can be analyzed by fictitious edge between \( c_{a,b} + c_{a,a} \) assigning side edge concrete between channel a and b. The total distance of (a+b) can be divided between the two channels, while analyzing the individual channels. For example if channel a is loaded more than channel b than side edge distance of 3/4(a+b) can be assumed for channel a and side edge distance 1/4(a+b) can be assumed for channel b.

Perpendicular shear: Refer Figure 9.2.4.2. This condition can be analyzed by fictitious edge between \( c_{a,b} + c_{a,a} \) assigning side edge concrete between channel a and b. The total distance of (a+b) can be divided between the two channels, while analyzing the individual channels. For example if channel a is loaded more than channel b than side edge distance of 3/4(a+b) can be assumed for channel a and side edge distance 1/4(a+b) can be assumed for channel b.
9.2.5 — HAC AND HAC-T DESIGN: FACE OF SLAB THE MINIMUM DISTANCE THAT WILL assured that the CONCRETE CONE DOES NOT INTERSECT BOTH IN SHEAR AND TENSION

Tension: The amount of concrete that is needed to assure that the tension concrete breakout cones do not overlap should be as shown in Figure 9.2.5.1. The corner distance required should be sum of effective embedment (hₑₑ) and critical spacing (cₑₑ) for any one of the two channels. With that distance the channel perpendicular to the edge can be installed at critical distance cₑₑ away from the corner. In Figure 9.2.4.7 the channel b is installed at corner distance of (hₑₑ + cₑₑ) on edge 2, then the channel a can be installed at the corner distance of cₑₑ on edge 1.

Perpendicular shear: The amount of concrete that is needed to assure that the concrete breakout planes in perpendicular shear do not overlap should be as shown in Figure 9.2.5.2. The corner distance required should be sum of critical height (hₑₑ) and critical spacing (cₑₑ) for any one of the two channels. With that distance the channel perpendicular to the edge can be installed at critical distance cₑₑ away from the corner. In Figure 9.2.4.8 the channel b is installed at corner distance of (hₑₑ + cₑₑ) on edge 2, then the channel a can be installed at the corner distance of cₑₑ on edge 1.
9.2.6 — HAC AND HAC-T DESIGN: EXAMPLE OF DESIGN OF FACE OF SLAB OUTSIDE CORNER WHERE THE ANCHOR CHANNELS ARE LOCATED AT A CERTAIN DISTANCE

Quick conservative check can be done by using the method described in this section. For concrete breakout, in tension and concrete breakout, and pryout in shear, the imaginary concrete side edge of “(x/2)-1” is considered. This is done in order to take into account the overlapping of the failure planes.

The example is modeled as shown in the Figure 9.2.6.1 and Figure 9.2.6.2. Having the true edge distance yields unconservative results.

Alternatively the detailed method described section 9.2.3 can be applied in analyzing the anchor channels.

9.2.7 — HAC AND HAC-T DESIGN: TOP OR BOTTOM OF SLAB OUTSIDE CORNER SINGLE ANCHOR CHANNEL

90° corners

Outside corners where only one anchor channel is present are fully covered by ESR-3520. The design methodology is fully in accordance with the anchor channel Design Code presented in Chapter 7.

AC232 includes design provisions to account for the influence of a corner. The concrete strengths in tension and shear of the anchor channel may be reduced (depending on how far the anchor channel is away from the corner) since the concrete cones may not be fully developed. See chapter 7 for design provisions for corners. In PROFIS Anchor Channel, these conditions can be simply modeled by reducing the corner distance.

Obtuse corners

Although AC232 does not specifically address acute and obtuse corners, by not following the idealized failure planes but the path of least resistance, AC232 provisions can be used to analyze this type of corners.

In order to avoid calculating unconservative concrete strength, the path of least resistance for the crack should be always considered.

Obtuse corners

Perpendicular Shear: The line is drawn originating from the corner of the obtuse corner. The Ca1 is measured from the corner to the anchor. Not using the darkened shaded region of concrete in analysis as illustrated in Figure 9.2.7.2. This is done to make sure the concrete edge of Ca1 width is available through out for Ca2 side edge.

Tension: Similar to the perpendicular shear in tension analysis the line is drawn originating from the corner of the obtuse angle corner case with one channel. The Ca1 is measured from the anchor a3 to the line. The darkened shaded region of concrete is not used in analysis as illustrated in Figure 9.2.7.3.

Longitudinal Shear: Similar to the perpendicular shear again in longitudinal analysis the line is drawn originating from the corner of the obtuse corner. The Ca1 is measured from the corner to the anchor. The darkened shaded region of concrete is not used in analysis as illustrated in Figure 9.2.7.4. This is done to make sure the concrete edge of Ca1 width is available through out for Ca2.
Acute corners

Perpendicular Shear: Corner distance shall be considered as the shortest distance between the intersection of the formation of failure planes using $C_{cr,v}$ as shown in the Figure 9.2.4.5. The straight line is drawn (representing path of least resistance) extending out straight until it intersects the inclined slab edge. Which is then extended back on to the perpendicular edge. The $C_{cr}$ is measured from that point onwards to the closest anchor.

Tension: Corner distance shall be considered as the shortest distance between the intersection of the formation of failure cones $C_{cr,n}$ as shown in the Figure 9.2.4.6. The circle with radius of $C_{cr,n}$ and the shortest intersection of that circle with the edge is $C_{cr}$ distance.

Longitudinal Shear: Corner distance shall be considered as the shortest distance between the intersection of the formation of failure cones using $1.5C_{cr}$ as shown in the Figure 9.2.4.7. The $C_{cr}$ distance is assumed, where the 35° line intersects the inclined portion of the slab.

9.2.8 — HAC AND HAC-T DESIGN: TOP OR BOTTOM OF SLAB WITH PAIR OF ANCHOR CHANNEL ADJACENT TO EACH OTHER

Minimum distance that does not reduce the concrete capacity in tension and perpendicular shear: The capacity of anchor channel should be reduced because of the presence of the adjacent anchor channel. The anchor channels installed next to each other and subjected to perpendicular shear and tension as seen in Figure 9.2.8.1 does not require the reduction. The reason for this is that the breakout failure plane in shear and breakout failure cones in tension has been completely developed on the left side of channel a and right side of channel b. There is no overlapping of the breakout cones from the adjacent anchor channel. The shear breakout planes as represented by the red shaded area and breakout failure cone in tension as represented by brown circle are completely developed.

In order to make sure that there is no influence of the adjacent anchor channel on the concrete capacity, it is recommended to have them installed at least at a distance $2\max(C_{cr,v} ; C_{cr,n})$. Please refer to anchor channel theory for detailed instruction on the factor $C_{cr,v}$ and $C_{cr,n}$. Below are the equation defining these variables.

$$x_{cr,v} = \frac{2.8 - 1.3\frac{V}{h_1}}{7} h_2 \geq 3h_2$$

$$C_{cr,v} = 0.5x_{cr,v} \geq 1.5h_2$$

$$C_{cr,n} = 0.5x_{cr,n} = 2c + b_{max}$$
Design method for analyzing channels besides each other with concrete cones in tension and perpendicular shear intersecting each other: This method is based on ACI 318 principles. The capacity of anchor channel should be reduced because of the presence of the adjacent anchor channel. The anchor channels installed next to each other and subjected to perpendicular shear and tension as seen in Figure 9.2.8-b requires the reduction in the concrete capacities. The reason for this is that the breakout failure plane in shear has not been completely developed as represented by the red shaded area and breakout failure cone in tension is also not able to completely developed as represented by brown circle. These failure planes intersect as seen in the detail.

Having anchor channel “a” closer to anchor channel “b” has influence on the concrete breakout capacities. In order to incorporate the influence, the and modification factor influencing location of adjacent anchors should be modified following the concept in AC/232. Anchor channel a and b are modelled in profi anchor channel software individually with infinite edges to the sides and then incorporating the modification factor , using the equation as described below later by hand calculation. Please note that there will not be any imaginary corner influence taken into consideration when the method described below is used. The influence of the neighboring anchor channel is incorporated into the design by incorporating the influence in the spacing modification factor. 

In order to use this concept also for anchors and anchor channels. For 2 times the maximum of critical edge distance in tension controls the x dimension. The critical spacing for anchors is given as , as described in the following Figure 9.2.9.2. For anchor channels the equation 9.2.9.1 is used for . Figure 9.2.9.3 shows the comparison of for anchors and anchor channels. For effective embedment depth smaller than 180 mm the anchor channels have a larger than anchors.

Centralized method: An imaginary edge is assumed to be at y = 0.5 y for both anchor channel and b. This approach will lead to conservative results because concrete breakout capacity is reduced in tension and shear with modification factor and for corner influence respectively. Please refer equation 9.2.8-c and 9.2.9-d. This approach assumes a real edge which in turn leads to higher utilization by reducing the capacity tremendously.

If then Equation 9.2.9.8-c

If then Equation 9.2.9.8-d

9.2.9 — HAC AND HAC-T DESIGN: TOP OR BOTTOM OF SLAB MINIMUM DISTANCE THAT WILL ASSURE THAT THE CONCRETE CONE DOES NOT INTERSECT BOTH IN SHEAR AND TENSION

If we have 2 times the maximum of and distance between the two anchors closest to the edge of an anchor channel, we can say that there will not be any influence of the anchor channel at the other side of the outside corner as shown in the figure. Please refer to anchor channel theory for more information on this topic. A similar concept can be applied for inside corners as well.

In this case the real side distance can be used to analyze each anchor channel. The example illustrated in Figure 9.2.9.1, critical edge distance in tension controls the x dimension.

The proposed expression of s assumes a circular area of the influence areas of each anchor. In Figure 9.2.9.3 the circular area, for the proposed model for anchor channels is represented, together with the squared one used for anchors. For smaller than 6.10 in. (155 mm) the influence area of the anchor of an anchor channel is larger than those of a single anchor. Therefore, for embedded depth smaller than 6.10 in. (155 mm) the method can be applied without any modification. In order to use this concept also for embedded depth larger than 6.10 in. (155 mm) the following increase for per ACI 318-14

Figure 9.2.9.1 — TOS and BOS outside corner — Tension and perpendicular shear concrete cones does not intersect.

Figure 9.2.9.2 — Eqn 9.2.9.1

Figure 9.2.9.3 — Comparison of for anchors and for an anchor channel (left), Comparison of the idealized breakout area for anchors and for an anchor channel (right)
Outside corners where two anchor channels are present and are loaded simultaneously are outside the scope of AC232. Most of the AC232 provisions can be applied to this type of application. However, the influence of the adjacent anchor channel should be considered, as the concrete strength may be negatively impacted.

In this section an extension for the design AC232 to a group of channels and to channels close to a corner is presented. The method is valid for standard anchor channels.

The loads are distributed on each channel independently, according ESR3520 the steel verifications are not affected by the neighboring channels, some considerations should be done for the concrete failure modes.

According to ESR-3520 the minimum distance between the two anchors is 2" 100mm, hence Profis anchor channel software follows the rule stated in the Figure 9.2.10.1.a and Figure 9.2.10.1.b. The software has to be activated for corner in order to design the outside corner with two anchor channels.

When two HAC channels are placed close to each other or to a corner only the concrete verifications needed modifications. The calculation of the anchor loads and of the steel failure modes is calculated independently for the two different channels. The method applies in general to a group of channels with the same edge distance c_e in Profis anchor channel software.

When the second element is enabled the following condition must be fulfilled (Figure 9.2.10.1.a, Figure 9.2.10.1.b and Figure 9.2.10.1.c):

\[(d_1 + d_2) \geq 100\text{mm}\]

**Concrete breakout strength in tension**

The main difference in the calculation of the concrete cone capacity is the modification factor to account for influence of location and loading of neighboring anchors \(\psi_{c,N}\).

Verification: \(N_{c,N} \geq N_{c,N}\)

\[N_{c,N} = N_{c,1,N} \cdot \psi_{c,N} ; N_{c,2,N} \cdot \psi_{c,N} ; N_{c,3,N} \cdot \psi_{c,N}\]

The modification factor for spacing \(\psi_{c,N}\) is adjusted to take the loading of the adjacent anchors into account.

Given an anchor channel with only two anchors equally loaded \(\psi_{c,1}\) varies from 0.5 to 1, if the relative spacing varies from \(s_i = 0\) to \(s_i = s_{c,N}\) respectively. In practice, if \(s_i = 0\) the capacity of each anchor is the half, both together have the same capacity of 1 anchor. The equation of \(s_{c,N}\) limits the maximum capacity of the concrete for each anchor due to the presence of the other one.

Figure 9.2.10.3 shows \(\psi_{c,1}\) for two anchors symmetrically loaded increasing the spacing from 0 to \(s_i = s_{c,N}\).

The relative concrete utilization of each anchor is considered with the ratio \(N_{c,1} / N_{c,c,N}\). In this way if the load on the second anchor is much higher than that on the first, it results in a lower \(\psi_{c,1}\) for the first anchor. Figure 9.2.10.4 shows the variation of \(\psi_{c,1}\) for two anchors with a spacing of 0.5s_{c,N} varying the load ratio between the two anchors. The concrete capacity cone is almost proportional to \(A_{c,N} / A_0\) like in the CC Method (Concrete Capacity design method for anchors).

The same considerations are valid as well for more than two anchors and a linear superposition applies.

In Figure 9.2.10.3 standard anchor channel with 2 anchors is represented, where the red rectangle areas are the “influence areas” or idealized breakout surface of each anchor. Since the anchor spacing is smaller than the critical one there are several intersections represented by darker shaded area of cone projection. These intersections are considered with the \(\psi_{c,N}\) factor.

If second anchor channel is placed at a distance \(s_{c,N} < s_{c,N}\) (Figure 9.2.10.8), further intersections would be generated between the influence areas of the anchors of first and of the second channel. In the calculation of the concrete cone failure, these intersections can be considered with the factor \(\psi_{c,N}\) including in sum also for the anchors of the second channel. In this way, the capacity of each anchors is additionally reduced due to the presence and utilization of second channel and varies smoothly with the relative distance.

The same considerations are valid as well for more than two anchors and a linear superposition applies.

\[n = n_{r,1} + n_{r,2}\]

Moreover, considering the spacing of each single anchor in two dimensions, it is possible to consider even more anchor channels, and each relative position possible.

The critical spacing for anchors is 3h_{emb} based on idealized rectangular concrete cone area. For anchor channels the following equation is in accordance to AC232:

\[s_{c,N} = \frac{2.8}{1.16} h_{emb} \geq 3h_{emb}\]

Comparison of \(c_{emb}\) for anchors and for an anchor channels and comparison of the idealized breakout area for anchors and for an anchor channel of various embedment depths shows for effective embedment depth smaller than 7.1" (180 mm) the anchor channels have a larger \(c_{emb}\) than anchors. The proposed expression assumes a circular area of the influence areas of each anchor.

The influence area of the anchor of an anchor channel is larger than those of a single anchor, hence the following equation of \(s_{c,N}\) is proposed:

\[s_{c,N} = \frac{2.8}{1.16} h_{emb} \geq 3h_{emb}\]

Figure 9.2.10.5 — Influece on \(\psi_{c,1}\) of the relative load on the anchors.
The concrete cone verification remains the same:

Verification: \( \psi_{\text{co}} \cdot N \)  

The only parameter which is adjusted is the modification factor to take the loading of the adjacent anchors \( \psi_{\text{sa}} \) into account:  

\[
\psi_{\text{sa}} = \frac{1}{1 + \sum \left( \frac{s_i}{s_{\text{cr,N}}} \right)^2}
\]  

Equation 9.2.10.7

\( s_{\text{cr,N}} \) is the critical anchor spacing for tension and shear of \( a_i \). Please refer Figure 9.2.10.8.

90° Corner: Let's consider the anchor \( a_i \) of channel \( a \) with tension \( N_{a_i}^{\text{cr}} \) of channel \( a \). To find the modification factor \( \psi_{\text{sa}} \) used in determining concrete breakout capacity in tension of \( a_i \), please refer Figure 9.2.10.9.

\[
s_{\text{sa},a1} = \sqrt{(x_{a1} - x_{a2})^2 + (y_{a1} - y_{a2})^2}
\]  

Equation 9.2.10.7 a

\[
s_{\text{sa},a2} = \sqrt{(x_{a2} - x_{a1})^2 + (y_{a2} - y_{a1})^2}
\]  

Equation 9.2.10.7 b

\( r_{\text{ca}2} \) is the distance of the anchor under consideration to the corner refer Figure 9.2.10.8.

\( s_{\text{sa},a1} \) is evaluated using Equation 9.2.10.7 c.

\[
\psi_{\text{sa}} = \frac{1 - \left( \frac{s_{\text{sa},a1}}{s_{\text{cr,N}}} \right)^2}{1 - \left( \frac{s_{\text{sa},a1}}{s_{\text{cr,N}}} \right)^2} \leq 1
\]  

Equation 9.2.10.7 c

\( \psi_{\text{sa}} \) : (modification factor for corner influence) The true edge distance is taken into consideration as shown in the Figure 9.2.10.8 for 90° corner to determine reduction factor for corner distance \( c_{\text{co}} \). Please refer to Equation 9.2.10.7 d for \( \psi_{\text{sa},a1} \).

\[
c_{\text{sa},a1} = 0.5s_{\text{sa},a1} \geq 1.5h_{\text{a1}}
\]  

If \( s_{\text{sa},a1} \geq c_{\text{sa},a1} \) then \( \psi_{\text{sa},a1} = 1.0 \)  

Equation 9.2.10.7 d

\[
 \psi_{\text{sa},a1} = \left( \frac{s_{\text{sa},a1}}{c_{\text{sa},a1}} \right)^2 \leq 1.0
\]  

Equation 9.2.10.7 e

\( c_{\text{co}} \) is the distance of the anchor under consideration to the corner refer Figure 9.2.10.8.

Obtuse Angle Corner: Let's consider the anchor \( a_i \) of anchor channel \( a \) with tension \( N_{a_i}^{\text{cr}} \) of channel \( a \). To find the modification factor \( \psi_{\text{sa}} \) used in determining concrete breakout capacity in tension of \( a_i \), please refer Figure 9.2.10.9.

\[
s_{\text{sa},a1} = \sqrt{(x_{a1} - x_{a2})^2 + (y_{a1} - y_{a2})^2}
\]  

Equation 9.2.10.7 a

\[
s_{\text{sa},a2} = \sqrt{(x_{a2} - x_{a1})^2 + (y_{a2} - y_{a1})^2}
\]  

Equation 9.2.10.7 b

\( r_{\text{ca}2} \) is the distance of the anchor under consideration to the corner refer Figure 9.2.10.8.

\( s_{\text{sa},a1} \) is evaluated using Equation 9.2.10.7 c.

\[
\psi_{\text{sa}} = \frac{1 - \left( \frac{s_{\text{sa},a1}}{s_{\text{cr,N}}} \right)^2}{1 - \left( \frac{s_{\text{sa},a1}}{s_{\text{cr,N}}} \right)^2} \leq 1
\]  

Equation 9.2.10.7 c

\( \psi_{\text{sa}} \) : (modification factor for corner influence) The true edge distance is taken into consideration as shown in the Figure 9.2.10.8 for obtuse angle corner to determine reduction factor for corner distance \( c_{\text{co}} \). Please refer to Equation 9.2.10.7 e for \( \psi_{\text{sa},a1} \).

\[
c_{\text{sa},a1} = 0.5s_{\text{sa},a1} \geq 1.5h_{\text{a1}}
\]  

If \( s_{\text{sa},a1} \geq c_{\text{sa},a1} \) then \( \psi_{\text{sa},a1} = 1.0 \)  

Equation 9.2.10.7 d

\[
 \psi_{\text{sa},a1} = \left( \frac{s_{\text{sa},a1}}{c_{\text{sa},a1}} \right)^2 \leq 1.0
\]  

Equation 9.2.10.7 e

\( c_{\text{co}} \) is the distance of the anchor under consideration to the corner refer Figure 9.2.10.8.

Acute Angle Corner: Let's consider the anchor \( a_i \) of anchor channel \( a \) with tension \( N_{a_i}^{\text{cr}} \) of channel \( a \). To find the modification factor \( \psi_{\text{sa}} \) used in determining concrete breakout capacity in tension of \( a_i \), please refer Figure 9.2.10.9.

\[
s_{\text{sa},a1} = \sqrt{(x_{a1} - x_{a2})^2 + (y_{a1} - y_{a2})^2}
\]  

Equation 9.2.10.7 a

\[
s_{\text{sa},a2} = \sqrt{(x_{a2} - x_{a1})^2 + (y_{a2} - y_{a1})^2}
\]  

Equation 9.2.10.7 b

\( r_{\text{ca}2} \) is the distance of the anchor under consideration to the corner refer Figure 9.2.10.8.
Concrete Pryout for perpendicular and longitudinal load failure

The pryout failure is calculated based on the $N_{cb}$ as indicated above both for longitudinal and perpendicular shear. Test results show that two anchor channels that are located at the corner $k_{cp}$ for pryout check can be used as $3. k_{cp}=\frac{3}{4}$ is used for two corner anchors located at the corner edge.

Concrete breakout strength for perpendicular shear

A similar consideration on the modification factor for the anchor spacing can be done for the concrete edge failure for perpendicular shear. Figure 9.2.10.11 shows a similar approach to that proposed for the concrete cone for the concrete edge breakout for perpendicular shear. It two channels are located at a distance $d_{ab1}$ smaller than $C_{cr,V}$ (Figure 9.2.10.11 b) the concrete edge failure of the two channels would intersect and the capacity of the system will be reduced. In this case, all the anchors of both channels are considered for the calculation of the modification factor $\Psi_{s,V}$.

Figure 9.2.10.11a — Single anchor channel in shear.

Figure 9.2.10.11b — anchor channels adjacent to each other.

Placing two channels close to a corner (Figure 9.2.10.11 c), it is possible to calculate the channels with the method of “unfolding” the edge (Figure 9.2.10.11 d). Doing this operation, a fictitious distance between the two channels has to be defined and it is important to make sure that the corner area is used only once. In the case of Figure 9.2.10.11 c the area which can be considered only once is represented with black rectangle. If the channel a collapses under shear load, then the area in black would also collapse. The channel b would be left only with the area up to the black rectangle to resist shear loads. The same consideration is made for the channel b.

Therefore, it is proposed to calculate the factor $\Psi_{s,V}$ with the two anchor channels placed in a row with the edge of “fictitious” edge distance $d^*$: $d^* = c_{a1,a} + (c_{a1,b} - c_1)$

Where $c_1$ is the minimum edge distance of channel a and channel b. In case that $c_{a1,a}$ and $c_{a1,b}$ are different, the minimum will be assumed for the calculation of both channels. $s_i$ is calculated with $d^* = c_{a1,a} + (c_{a1,b} - c_1)$ fictitious distance between channel a and b.

If $c_{a1,a} \neq c_{a1,b}$ both channel will be considered as with $c_1 = \min(c_{a1,a}, c_{a1,b})$

Verification $\delta : V_{\delta b} \geq V_{\delta a}$

With:

$V_{\delta b} = V_{\delta a} \cdot \Psi_{s,V} \cdot \Psi_{s,V} \cdot \Psi_{s,V} \cdot \Psi_{s,V}$
Figure 9.2.10.10a — 90° Corner.

While unfolding the corner for this case the fictitious distance of (a+b) is taken into consideration while placing them (a+b) apart as shown in Figure 9.2.10.12b. Let's take into consideration anchor b1 of anchor channel b with shear Va ua,b1. Please refer Figure 9.2.10.12b. The following equation modification factor for spacing is used.

\[
P_{\text{co,V}} = \frac{1}{1 + \left( \frac{\left( \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} \right)^2}{\left( \frac{\left( \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} \right)^2}{\left( \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} \right)^2} \right)^2} \right)}
\]

For the condition illustrated below in Figure 9.2.10.12b the shear breakout plane emitting from anchor b1 overlaps shear plane emitting from anchor a1, b2, and a2. Therefore the spacing modification factor will be the equation above including the effects of anchors a1, b1, and a2 on anchor b1.

\[
\frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} = \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}}
\]

The true edge distance is taken into consideration for determination of reduction factor for corner distance c a2. The corner distance c a2,a1 or c a2,b1 is into consideration respectively depending on the anchor in consideration.

If \( c_{\text{a2,a1}} \geq c_{\text{a2,b1}} \)

then \( y_{\text{co,V}} = 1.0 \)

If \( c_{\text{a2,a1}} < c_{\text{a2,b1}} \)

then \( y_{\text{co,V}} = \left( \frac{c_{\text{a2,a1}}}{c_{\text{a2,b1}}} \right) \leq 1.0 \)

\[ s_{\text{ua,b1}} = 2a + 4c_{\text{a2,b1}} \]

\[ s_{\text{ua,b1}} = 0.5s_{\text{ua,b1}} - b_{\text{a2,b1}} + 2c_{\text{a2,b1}} \]

Acute angle Corner: Acute corner has been drawn in Figure 9.2.10.13a. The corner is unfolded in Figure 9.2.10.13b. Please refer to the distance marked on the detail for acute angle corner case. The variable a and b has been defined and marked up on figure representing acute angle corner condition. The line is drawn perpendicular to edge 2 emitting from anchor a1 of anchor channel. The intersection point of this line with edge 2 is extended perpendicular to edge 1. The distance between intersection point of this line with edge 1 and a1 of anchor channel a is c a1,b1. c a1,b1 is taken as \( \alpha \) in order to get the dimension b. c a1,b1 is calculated and is deducted from c a2. To get \( c_{\text{a2,b1}} \) is distance between anchor b1 and intersection of perpendicular line emitting from anchor a1, perpendicular to edge 2 and line emitting b1. b2 and edge 1. Refer Figure 9.2.10.13b. While unfolding the corner for this case the fictitious distance of (a+b) is taken into consideration while placing them (a+b) apart as shown in Figure 9.2.10.13b.

Let's take into consideration anchor b1 of anchor channel b with shear Va ua,b1. Please refer Figure 9.2.10.13b. The following equation modification factor for spacing is used.

\[
P_{\text{co,V}} = \frac{1}{1 + \left( \frac{\left( \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} \right)^2}{\left( \frac{\left( \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} \right)^2}{\left( \frac{s_{\text{ua,b1}}}{V_{\text{ua,b1}}} \right)^2} \right)^2} \right)}
\]

For the condition illustrated below in Figure 9.2.10.13b the shear breakout plane emitting from anchor b1 overlaps shear plane emitting from anchor a1, a2, and b2. Hence the spacing modification factor will be the equation above for the example in the Figure 9.2.10.13b.

\[ s_{\text{ua,b1}} = 2a + 4c_{\text{a2,b1}} \]

\[ c_{\text{a2,b1}} = 0.5s_{\text{ua,b1}} - b_{\text{a2,b1}} + 2c_{\text{a2,b1}} \]
Obtuse angle Corner: Obtuse corner has been drawn in Figure 9.2.10.14a. The corner is unfolded in Figure 9.2.10.14b. Please refer to the distance marked on the detail for obtuse angle corner case. The variable a and b has been defined and marked up on figure representing obtuse angle corner condition. The dimension b is evaluated by measuring a line emitting from anchor b and having it perpendicularly intersect edge 1, this distance is \( c_{a,b} \). The dimension b is evaluated by taking difference between \( c_{a,b} \) and \( c_{a} \). The side edge distance \( c_{a} \) or \( c_{b} \) is used as side edge distance. While unfolding the corner for this figure the fictitious distance of (a+b) is taken into consideration while placing them \((a+b)\) apart as shown in Figure 9.2.10.14b.

Let’s take into consideration anchor b1 of anchor channel b while placing them \((a+b)\) apart as shown in Figure 9.2.10.14b. The following equation modification factor for spacing is used.

\[
\nu_{(a+b)} = \frac{1}{1 - \left( \frac{c_{a,b}}{c_{a}} \right)^{0.5}}
\]

For the condition illustrated below in Figure 9.2.10.14b the shear breakout plane emitting from anchor b, overlaps shear plane emitting from anchor a, a and b, hence the spacing modification factor will be the equation above for the example in the Figure 9.2.10.14b.

\[
u_{a,b} \text{ modification factor for corner influence for obtuse angle corner:}
\]

The side edge distance is taken into consideration for determination of reduction factor for corner distance \( c_{a,b} \). The \( c_{a,b} \) or \( c_{a,b} \) is taken as side edge distance.

\[
\psi_{\text{co}} = \psi_{\text{co},a,b} \times \psi_{\text{co},a,b} = \psi_{\text{co},a,b} \leq 1.0
\]

With the only differences:

\[
\psi_{\text{co},a,b} = 1 \quad \text{Since the second corner is not available}
\]

\[
\psi_{\text{co},a,b} = 1 \leq 1.0
\]

\[
n = \nu_{(a+b)} - \nu_{(a+b)}
\]

is the number of all the anchors of the two channels

\[
\delta = \text{the relative distance of two anchors,}
\]

considering all the anchor on an imaginary “unfolded” channel, where the first anchor of the second channel, is located at a distance \( \delta \) from the last anchor of the first (Figure 9.2.10.11).

Concrete side-face blowout

The concrete side blowout is calculated with the same verification of ESR3520.

\[
\phi \space N_{b} \geq N_{a}
\]

\[
N_{a} = N_{a} \cdot \psi_{\text{co},a,b} \cdot \psi_{\text{co},a,b} \cdot \psi_{\text{co},a,b} \psi_{\text{co},a,b} \psi_{\text{co},a,b}
\]

With the only differences:

\[
\psi_{\text{co},a,b} = 1 \quad \text{Since the second corner is not available}
\]

\[
\psi_{\text{co},a,b} = 1 \leq 1.0
\]

\[
n = \nu_{(a+b)} - \nu_{(a+b)}
\]

is the number of all the anchors of the two channels

\[
\delta = \text{the relative distance of two anchors,}
\]

considering all the anchor on an imaginary “unfolded” channel, where the first anchor of the second channel, is located at a distance \( \delta \) from the last anchor of the first (Figure 9.2.10.11).

Concrete breakout strength for parallel shear

The concrete breakout strength for parallel shear is calculated according ESR for both channels are verified independently. The concrete utilization of both edges is then combined in conservative way as described in the next paragraph.

Concrete failure, load interaction

Every anchor already considers the second channel for tension and perpendicular shear. The governing failure modes in the three directions are combined according to the following method. Refer Figure 9.2.10.15.

A verification for each anchor of both anchor channel is needed.

\[
\chi, \alpha \text{ is the channel of the considered anchor}
\]

\[
\chi, \beta \text{ indicate the other channel}
\]

\[
\chi, \delta \text{ is the edge parallel to the channel of the considered anchor}
\]

\[
\chi, \delta \text{ indicate the edge parallel to the other channel}
\]

Considering the channel \( \beta \), tension and perpendicular shear of the channel \( \beta \) are considered “precisely” as described. Longitudinal shear of the channel itself is considered according to ESR3520. The effects of the channel due to longitudinal shear on the channel \( \beta \) is difficult to consider. Therefore, on the safe side, the highest utilization for longitudinal shear of channel \( \beta \) on the edge \( \delta \) is added linearly to the utilization of perpendicular shear of the considered anchor. Longitudinal shear on the channel \( \beta \) is calculated according to ESR3520.

Verification of the anchors of the channel \( \beta \).
\[ \beta_{\alpha,\text{in}} = \left( \frac{N_c}{\beta_{\alpha}} \right) \begin{cases} \frac{V_{c,x}}{\beta_{\alpha}} & \text{for channels without reinforcement} \\ \frac{V_{c,y}}{\beta_{\alpha}} & \text{with anchor reinforcement to take up tension and parallel shear loads} \end{cases} \leq 1.0 \]

\[ \beta_{\alpha,\text{in}} = \left( \frac{N_c}{\beta_{\alpha}} \right) \begin{cases} \frac{V_{c,x}}{\beta_{\alpha}} & \text{for tension loading between anchor b of anchor channel b} \\ \frac{V_{c,y}}{\beta_{\alpha}} & \text{for perpendicular shear loading (perpendicular) b of anchor channel b} \end{cases} \leq 1.0 \]

\[ \beta_{\alpha,\text{in}} = \left( \frac{N_c}{\beta_{\alpha}} \right) \begin{cases} \frac{V_{c,x}}{\beta_{\alpha}} & \text{for tension loading between anchor b of anchor channel b} \\ \frac{V_{c,y}}{\beta_{\alpha}} & \text{for perpendicular shear loading (perpendicular) b of anchor channel b} \end{cases} \leq 1.0 \]

On other hand, anchor channel can be analyzed using a simplified method as described below. Here anchor channel a and b is analyzed individually limiting the side edge distance as described below.

**Simplified method**

The concrete at the corner is shared by the two anchor channels and therefore, using the AC232 provisions with the actual corner distance for analysis purposes can yield very unconservative concrete strengths. Moreover, if the idealized failure plane is followed and the corner distance is taken to the point where the two idealized failure planes overlap, this may still create unconservative concrete strengths, as the concrete crack will follow the path of least resistance. Therefore, this model is only applicable for applications loaded in tension and/or perpendicular shear.

**90° Corner**

**Tension:** To account for the influence of the adjacent corner anchor channel, the corner distance is reduced by assuming the concrete crack follows the path of least resistance and considering the corner distance where the “crack” of each anchor channel overlaps. For the concrete failure modes in tension, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner generates a concrete cone with the radius of \( c_{cr,N} \). The distance between the closest anchor heads is defined as \( x \), as shown in the Figure 9.2.10.16-a. These channels should be analyzed using a fictitious \( c_{cr,N} \) of \( x/2 \). To evaluate channel a and b the anchor channel is modelled in Profis anchor channel software with \( c_{cr,N} \) of \( x/2 \). With limiting the edge the concrete breakout strength in tension is reduced by the modification factor for corner effect \( \psi_{co,N} \).

**Perpendicular shear:** For the concrete failure modes in shear, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner change the concrete behavior. The concrete crack does not follow the idealized failure plane \( (c_{cr}) \) but the path of least resistance. This concept is illustrated in Figure 9.2.10.16-b. The fictitious edge can be taken in between the distance \( (a+b) \) for analyzing the anchor channel a and b depending on whichever anchor channel needed more concrete. To evaluate channel a and b the anchor channel is modelled with \( c_{cr} \) distance of in between distance \( (a+b) \). With limiting the edge the concrete breakout strength in shear is reduced by the modification factor for corner effect \( \psi_{co,V} \).

Perpendicular outside corners with headed stud HAC channel loaded only in tension or in all three directions: The distance between the closest anchor heads is defined as \( x \), as shown in the Figure 9.2.10.16-a. These channels should be analyzed using a fictitious \( c_{cr} \) of \( x/2 \).
Acute and obtuse corners

**Acute Corner:**

**Tension:** To account for the influence of the adjacent corner anchor channel, the corner distance is reduced by assuming the concrete crack follows the path of least resistance and considering the corner distance where the “crack” of each anchor channel overlaps. For the concrete failure modes in tension, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner generates a concrete cone with the radius of \( c_{\text{cr},N} \). The distance between the closest anchor heads is defined as \( x \), as shown in the Figure 9.2.10.17-a. These channels should be analyzed using a fictitious \( c_{\text{cr}} \) of \( x/2 \). To evaluate channel a and b the anchor channel is modelled in Profis anchor channel software with \( c_{\text{cr}} \) of \( x/2 \). With limiting the edge the concrete breakout strength in tension is reduced by the modification factor for corner effect \( \psi_{\text{tcr}} \).

**Perpendicular shear:** For the concrete failure modes in shear, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner change the concrete behavior. The concrete crack does not follow the idealized failure plane \( (c_{\text{cr}}) \) but the path of least resistance. This concept is illustrated in Figure 9.2.10.17-b. The fictitious edge can be taken in between the distance \( (a+b) \) for analyzing the anchor channel a and b depending on whichever anchor channel needed more concrete. To evaluate channel a and b the anchor channel is modelled with \( c_{\text{cr}} \) distance of in between distance \( (a+b) \). With limiting the edge the concrete breakout strength in shear is reduced by the modification factor for corner effect \( \psi_{\text{scr}} \). Acute outside corners with headed stud HAC channel loaded only in tension or in all three directions: The distance between the closest anchor heads is defined as \( x \), as shown in the Figure 9.2.10.17-a. These channels should be analyzed using a fictitious \( c_{\text{cr}} \) of \( x/2 \).

**Obtuse Corner:**

**Tension:** To account for the influence of the adjacent corner anchor channel, the corner distance is reduced by assuming the concrete crack follows the path of least resistance and considering the corner distance where the “crack” of each anchor channel overlaps. For the concrete failure modes in tension, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner generates a concrete cone with the radius of \( c_{\text{cr},V} \). The distance between the closest anchor heads is defined as \( 25x \), as shown in the Figure 9.2.10.18-a. These channels should be analyzed using a fictitious \( c_{\text{cr}} \) of \( x/2 \). To evaluate channel a and b the anchor channel is modelled in Profis anchor channel software with \( c_{\text{cr}} \) of \( x/2 \). With limiting the edge the concrete breakout strength in tension is reduced by the modification factor for corner effect \( \psi_{\text{tcr}} \).

**Perpendicular shear:** For the concrete failure modes in shear, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner change the concrete behavior. The concrete crack does not follow the idealized failure plane \( (c_{\text{cr}}) \) but the path of least resistance. This concept is illustrated in Figure 9.2.10.18-b. The fictitious edge can be taken in between the distance \( (a+b) \) for analyzing the anchor channel a and b depending on whichever anchor channel needed more concrete. To evaluate channel a and b the anchor channel is modelled with \( c_{\text{cr}} \) distance of in between distance \( (a+b) \). With limiting the edge the concrete breakout strength in shear is reduced by the modification factor for corner effect \( \psi_{\text{scr}} \). Channel a is evaluated using \( c_{\text{cr},A} \) and channel b can be evaluated using \( c_{\text{cr},B} \).

Obtuse angle corners with headed stud HAC channel loaded only in tension or forces in all three directions: The distance between the closest anchor heads is defined as \( x \), as shown in Figure 9.2.10.18-a. These channels should be analyzed using a fictitious \( c_{\text{cr}} \) of \( x/2 \).
9.2.11 — HAC AND HAC-T DESIGN: EXAMPLE OF DESIGN OF TOP OF SLAB OUTSIDE CORNER

The distance between the closest anchor heads is defined as x, as shown in the Figure 9.2.11.1. For concrete breakout in tension, concrete breakout and pryout in shear the imaginary concrete side edge distance of (x/2) is considered. The side edge distance of (x/2) (1") can be used while modeling in Hilti PROFIS Anchor Channel software as shown in Figure 9.2.11.2. 1" is anchor channel's overhang that is needed to be deducted from side edge when modeling it in profis.

Figure 9.2.11.1 — Example of simplified method of HAC in a top of curb corner.

Figure 9.2.11.2 — Analysis of channel 1 using the simplified method in PROFIS Anchor Channel.

9.2.12 — HAC AND HAC-T DESIGN: TOP OF SLAB INSIDE CORNER WITH PAIR OF ANCHOR CHANNEL

Tension: To account for the influence of the adjacent corner anchor channel, the corner distance is reduced by assuming the concrete crack follows the path of least resistance and considering the corner distance where the “crack” of each anchor channel overlaps. For the concrete failure modes in tension, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner generates a concrete cone with the radius of c_{cr,N}. The distance between the closest anchor heads is defined as x, as shown in the Figure 9.2.12.1-a. These channels should be analyzed using a fictitious c_{cr,N} of (x/2). To evaluate channel a and b the anchor channel is modelled in Profis anchor channel software with c_{cr,N} of x/2. With limiting the edge the concrete breakout strength in tension is reduced by the modification factor for corner effect ψ_{co,N}.

Perpendicular shear: For the concrete failure modes in shear, the stresses in the concrete induced by the two anchors of the anchor channels closer to the corner change the concrete behavior. The concrete crack does not follow the idealized failure plane (c_{cr,V}) but the path of least resistance. This concept is illustrated in Figure 9.2.12.1-b. The fictitious edge can be taken in between the distance (a+b) for analyzing the anchor channel a and b depending on whichever anchor channel needed more concrete. To evaluate channel a and b the anchor channel is modelled with c_{cr,V} distance in between distance (a+b). With limiting the edge, the concrete breakout strength in shear is reduced by the modification factor for corner effect ψ_{co,V}.

Figure 9.2.12.1-a — Inside Corner — Tension.

Figure 9.2.12.1-b — Inside Corner — Shear Perpendicular

Interior angle corners with headed stud HAC channel loaded only in tension or forces in all three directions: The distance between the closest anchor heads is defined as x, as shown in Figure 9.2.12.1-a. These channels should be analyzed using a fictitious c_{cr} of (x/2).

Same concept can be used for analyzing acute and obtuse degree inside corners with headed studs anchor channel.

Figure 9.2.12.1-a — Inside Corner — Tension.

Figure 9.2.12.1-b — Inside Corner — Shear Perpendicular
9.2.13 — HAC AND HAC-T DESIGN: PARALLEL CHANNELS

Two TOS or BOS channels:
Currently, AC232 excludes parallel anchor channels. Hilti anchor channel analysis of parallel anchor channels are based on ACI 318 provisions. The analysis of the concrete breakout strength in shear is based on ACI 318 principles in conjunction with AC232 design methodology.

All steel failure modes are in accordance to ESR-3520.

Concrete breakout strength in shear of parallel anchor channels is per ACI 318 concepts pertaining to dividing the concrete between the two channels.

**Perpendicular Shear**

**Case 1:** One assumption of the distribution of forces indicates that half of the shear force would be critical on the front anchor and the projected area. For the calculation of concrete breakout, $c_{\text{ai}}$ is taken as $c_{\text{ai,a}}$.

**Case 2:** Another assumption of the distribution of forces indicates that the total shear force would be critical on the rear anchor and its projected area. This assumption needs to be considered only when anchors are welded to a common plate independent of "s". In the case of anchor channels, this condition is applicable for "filled" holes conditions.

This provision is checked for parallel double channels in order to confirm that the total available concrete between the back channel of the parallel channels and the front edge has sufficient capacity to take the total shear force experiencing by the system.

Front anchor channel analysis: Refer Figure 9.2.13.2 and 9.2.13.3. The perpendicular concrete breakout strength of front channel should be evaluated using the concrete edge distance of $c_{\text{ai,y}}$. The front anchor channel should be loaded with half of the total shear force acting on the double anchor channel system. This is required to be checked following ACI 318-14 chapter 17 section commentary Fig17.5.2.1b case I. This is shown in Figure 9.2.13.1.

Back anchor channel analysis: Refer Figure 9.2.13.5 and 9.2.13.6. The perpendicular concrete breakout strength of the back channel should be evaluated using the concrete edge distance of $c_{\text{ai,y}}$. The back anchor channel should be loaded with the total shear force acting on the double anchor channel system. This is required to be checked following ACI 318-14 chapter 17 section commentary Fig17.5.2.1b case II. This is shown in Figure 9.2.13.4.

Both Case 1 and Case 2 should be evaluated to determine which controls for design.
Tension

Both the front and back anchor channels are analyzed in tension using an imaginary concrete edge of x/2 as shown in Figure 9.2.13.7, if both anchor channels are equally loaded.

Please note that the location of imaginary concrete edge can be optimized according to the magnitude of tensile forces each anchor channel is experiencing as shown in Figure 9.2.13.8. The imaginary edge is assumed at a distance of 3/4x from the back channel, if the back channel is experiencing a larger tension force.

Alternatively, the spacing method can be used to determine the spacing modification factor $\psi_s$ for the anchor in consideration, considering the effect of the anchors of the channel parallel to the one in consideration. Please note that there is no need to assume the imaginary edge in between the channel when spacing method is used. The actual perpendicular edge distance of the channel has to be considered, while calculating the edge modification factor $\psi_{ed}$. Refer Figure 9.2.13.8.

Please refer to the formula below for finding the spacing modification factor for anchor a1 of channel a.

$$V_{ua,x} = \frac{1}{1 - \left(\frac{x_{a1,a2}}{x}\right)^2}$$

The edge modification factor for anchor channel a is given below.

$$\psi_{ed,a} = \frac{C_{a1,a2}}{C_{a1,a}}$$

The edge modification factor for anchor channel b is given below.

$$\psi_{ed,b} = \frac{C_{a1,a2}}{C_{a1,a}}$$

Longitudinal shear

The longitudinal shear force $V_{ua,x}$ is applied at an eccentricity, as shown in Figure 9.2.13.10. This eccentricity creates the force $V_{ua,x}$ on anchor channel b in opposite to the direction of $V_{ua,x}$. Where as anchor channel a experiences the longitudinal force in the direction of $V_{ua,x}$. Having infinite sides edges on both sides will create breakout planes perpendicular to the edge as seen in the Figure 9.2.13.10. For analyzing anchor channel a the front edge of $c_{a1,a}$ is considered. For analyzing anchor channel b the edge available in between the two channels is used, which is x (c_{a1,b} - c_{a1,a}) as shown in Figure 9.2.13.10.
9.2.14 — HAC AND HAC-T DESIGN: PARALLEL CHANNELS TOP AND BOTTOM

One BOS and another TOS channels: BOS away from TOS

Concrete breakout strength in shear of parallel anchors is per ACI 318 concepts pertaining to dividing the concrete between the two channels. Principles of ACI 318 should be used while evaluating the concrete breakout capacity of all the concrete failure modes.

Perpendicular Shear

**TOP OF SLAB embed:** Shear forces on TOS and BOS are $V_{uy,a}$ and $V_{uy,b}$ respectively. The front edge of the TOS embed is checked against the $V_{uy,a}$ force. For the calculation of concrete breakout, $c_{uy,a}$ is taken as $c_{uy,a}$.

**Another assumption of the distribution of forces indicates that the total shear forces would be critical on the rear anchor and its projected area.**

This provision is checked for parallel double channels in order to confirm that the total available concrete between the BOS channel and the front edge has sufficient capacity to take the total shear force experienced by both channels.

**BOTTOM OF SLAB:** The perpendicular concrete breakout strength of the BOS channel should be evaluated using $c_{uy,b}$ as the concrete edge distance of $c_{uy,b}$. The BOS anchor channel should be loaded with the total shear force ($V_{uy,a} + V_{uy,b}$) acting on both anchor channels. The height ($h$) used in the analysis is $h$ as shown in Figure 9.2.14.6.
Tension

TOS and BOS: In the case shown in figure 9.2.14.8 the two anchor channels are drifted apart so much so that the failure planes in tension do not intersect. The idealized failure plane is represented by brown line while the red line represents the path of least resistance. For the concrete failure modes in tension, the stress in the concrete induced by the two anchors of the anchor channels closer to each other change the concrete behavior. The concrete crack does not follow the idealized failure plane (C_{cr}) but the path of least resistance. This concept is illustrated in figure 9.2.14.8 and Figure 9.2.14.9.

The front edge concrete for the BOS anchor channel is as taken as 0.5x in the analysis. The TOS channel is modeled as having a back edge of 0.5x. The distance x is defined as the shortest straight line connecting one anchor stud to another as shown in the Figure 9.2.14.8 and Figure 9.2.14.9.

Please note that the location of the imaginary line in between channel a and b can be optimized in accordance to the amount of tension experienced by each channel as needed.

Longitudinal shear

TOS and BOS anchor channels

The longitudinal shear force V_{uax,a} and V_{uax,b} is applied at the center line of the anchor channel, as shown in Figure 9.2.14.10-a and Figure 9.2.14.10-b. Having infinite sides edges on both sides will create breakout planes perpendicular to the edge as seen in the Figure 9.2.14.10-a and Figure 9.2.14.10-b. For analyzing anchor channel “a” the front edge of C_{cr,a} is considered subjecting it to shear force of V_{uax,a}. For analyzing anchor channel “b” the edge of C_{cr,b} is used against the total shear force (V_T = V_{uax,a} + V_{uax,b}) following the ACI 318-14 provision as shown in Figure 9.2.14.10-b.

BOS and TOS channels: BOS under from TOS

BOS and TOS: This section describes the conditions where two anchor channels are placed one on top of the other, facilitating the connection above and below the slab. For analyzing these conditions it is recommended to assign half of the concrete height to the TOS channel and half to the BOS channel.

In Figure 9.2.14.11 the failure planes are drawn in tension and in Figure 9.2.14.12: failure planes are drawn for perpendicular shear. An imaginary line is drawn at the intersection of these failure planes limiting the height of the slab to h/2 for each anchor channel analysis.

The location of the imaginary line can be optimized. More concrete in height can be assigned to the channel subjected to more shear force.
**BOS and TOS Channel intersecting**

The two channels may be installed at top and bottom of slab as seen in the Figure 9.2.14.13. The simulations were performed at the University of Rijeka with configuration as seen in Figure 9.2.14.14, Figure 9.2.15.1, and Figure 9.2.15.6. With these simulations following design procedure has been concluded.

Top channel and bottom channel should be analyzed separately considering the total height of the substrate. The interaction of the breakout planes of the two top and bottom channels are taken into account by using the interaction equation below. This interaction equation combines the concrete breakout utilizations of top and bottom channels, hence including the effect of the two overlapping concrete breakout planes into the design.

\[
\beta_{\text{BOS},V,T} = \left( \frac{N_{\text{d},V}}{N_{\text{d},T}} \right)^{1.67} + \left( \frac{V_{\text{d},V}}{V_{\text{d},T}} \right)^{1.67} + \left( \frac{N_{\text{d},T}}{N_{\text{d},V}} \right)^{1.67} + \left( \frac{V_{\text{d},T}}{V_{\text{d},V}} \right)^{1.67} \leq 1.0
\]

**Concrete Breakout in shear**

The concrete breakout in shear failure modes needs to be modified in order to take into account of metal deck when HAC or HAC-T anchor channels are used:

**Concrete breakout strength in shear**

This dimension h effects concrete breakout strength in perpendicular shear. This will change the factor \( \Psi_{h,V} \).

The dimension h in the formula below for \( \Psi_{h,V} \) factor should be taken as h as shown in Figure 9.2.15.1-b and Figure 9.2.15.2-b.

Please refer to anchor channel theory for more information on concrete breakout in shear.

The concrete breakout in shear failure modes needs to be modified in order to take into account of metal deck when HAC or HAC-T anchor channels are used:

**Concrete Breakout in tension**

The concrete breakout capacity in tension will get reduced with having the \( c_{a1,2} \) is less than \( c_{a1,1} \) as seen in Figure 9.2.15.1-a and Figure 9.2.15.2-a. The imaginary line is drawn to simulate the effect of metal deck. It is recommended to limit the available concrete for tension to be \( c_{a1,2} \). The following modification should be incorporated in the design by modelling the edge \( c_{a1,2} \) or manually changing the reduction factor in report if profil does not allow modelling at edge \( c_{a1,2} \) because of minimum edge requirement. Reduction factor for edge is as seen below. In this equation minimum of \( c_{a1,1} \) or \( c_{a1,2} \) is used.

\[
\Psi_{h,T} = \Psi_{h,V} \left( \frac{c_{a1,2}}{c_{a1,1}} \right)^{1.5}
\]
9.2.16 — HAC AND HAC-T DESIGN: INTERMEDIATE FACE OF SLAB ANCHOR CHANNEL WITH COLUMN CONFLICT

When there is a column conflict in an intermediate condition, it is recommended to have the bracket extended and determine the bolt forces. The anchor channel is analyzed using a side distance of x. This side edge is used since the concrete breakout plane gets interrupted by the presence of column.

![Figure 9.2.16.1 — FOS With Column Conflict — Section View.](image)

9.2.17 — CASE II: PERPENDICULAR SHEAR

The method described in sections 9.2.2 to 9.2.16 for shear force perpendicular is the case I of the perpendicular shear. The case II of the perpendicular shear should also be checked, where the concrete breakout planes are in longitudinal direction due to perpendicular shear. The worst results of the two cases should be taken into consideration. This will be the controlling load case, where the side edge distance is small and perpendicular shear capacity is more than longitudinal capacity due perpendicular shear. We will see this case to be the controlling one, when HAC Edge anchor channel is used at a small side edge. Refer section 9.6 for more information on HAC Edge.

For a shear force parallel to an edge, \( V_{c2} \), shall be permitted to be 2.5 times the value of the shear capacity determined from ESR-3520 equation 30 with the shear force assumed to act perpendicular to the edge.

![Figure 9.2.17— Anchor channel arranged perpendicular to the edge and loaded parallel to the edge.](image)

9.3 — HAC CRFoS U DESIGN

International Council Code Acceptance Criteria 232 (AC232) only covers anchor channel with rounded headed anchors, I-anchors and straight deformed reinforcing bars. Historically, the verification of the pull-out strength of the reinforcing bar has been based on the development length. Therefore, the pullout strength is calculated in accordance with ACI 318. ACI 318 requires a minimum reinforcing bar length of 12 in. AC232 requires anchor channels with reinforcing bars that meet splice length requirements.

HAC CRFoS U come with predetermined reinforcing bar lengths that comply with the development length requirements of ACI 318. Moreover, its design model ensures that the pullout strength of the reinforcing bar is not exceeded and the combined shear and tension concrete utilization meets the required concrete interaction equation. However, there may be applications such as lightweight concrete where the splice lengths may not be met.

Additional testing conducted by Hilti validates the similarities in the behavior of an anchor channel with rounded headed anchors and reinforcing bar anchors. Naturally, there are differences in some specific failure modes. Hence, the design of HAC CRFoS U follows the principles of AC232 and ACI 318. For further code compliance, the steel strengths of HAC CRFoS U are based on testing protocols of AC232.

The published steel strength of HAC CRFoS U were derived based on testing protocols of AC232. The overall anchor channel design (i.e. failure modes, load distribution, and concrete and steel assessment) is in accordance with AC232. The main differences between HAC and HAC CRFoS U design models are in the concrete breakout in tension, pull-out, and pry-out.

As is the case with HAC, the design of corners with a pair of channels loaded simultaneously is excluded from AC232. This section provides information about the overall HAC CRFoS U design. Moreover, design guidelines for failure modes not covered by AC232 but applicable to HAC CRFoS U and design guidelines for corners with a pair of channels loaded simultaneously are given in this chapter.

In contrast to anchor channels with rounded head anchors, anchor channels with reinforcing bars with configurations such as HAC CRFoS U do not require the verification of the concrete breakout strength in tension.

**Typical concrete tensile failure mode of HAC**

![Figure 9.3.1 — Concrete breakout in tension of a cast-in anchor channel with rounded stud head anchors (HAC) — Section View.](image)

**HAC CRFoS U loaded in tension**

![Figure 9.3.2 — Concrete failure mode of Cast-in anchor channel with rebar anchors (HAC CRFoS U) — Section View.](image)
Steel Concrete Steel Concrete Steel Concrete
Anchor: $\Phi_{N_{sa}}$
Anchor and channel connection: $\Phi_{N_{sc}}$
Concrete breakout: $\Phi_{N_{cb}}$
Pullout: $\Phi_{N_{pn}}$
Side-face blow-out: $\Phi_{N_{sb}}$
Connection: $\Phi_{N_{sc}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Concrete breakout: $\Phi_{N_{cb}}$
Pullout: $\Phi_{N_{pn}}$
Side-face blow-out: $\Phi_{N_{sb}}$
Connection: $\Phi_{N_{sc}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
Channel bolt: $\Phi_{N_{ss}}$
Bending of channel: $\Phi_{M_{s,\text{flex}}}$
Channel bolt and channel connection: $\Phi_{N_{sc}}$
Concrete edge breakout: $\Phi_{N_{cbo}}$
Concrete edge breakout: $\Phi_{N_{cb}}$
Channel lip: $\Phi_{N_{sl}}$
\( f_d = \text{development length, in.} \)
\( f_y = \text{yield strength of bar} \)

Rebar cover factor is:
- a) the least of the side cover
- b) the concrete cover to the bar or wire
- c) One-half the center-to-center spacing of the bars.

In all cases, \( c_b \) is measured from the center of the bar.

A channel bolt is inserted directly over the anchor and loaded without a fixture.

The test setup is shown in Figure 9.3.7.

**Evaluation of test results:**

The test results show that no hairline cracks were observed under static and simulated seismic conditions prior to failing the connection between rebar and channel profile.

The one diameter kink is provided in CRFoS U anchor channel. Hence in the PROFIS report there will be a \( k \) value of a diameter representing the kink in the rebar.

**Concrete breakout in perpendicular shear:** \( \Phi_{V_{cb,y}} \)

Please refer to anchor channel theory for more information on this failure mode. The design methodology is the same as that of headed stud anchor channel. This check is compliant with ESR 3520.

Tests have been performed on CRFoS U to demonstrate that, in front of slab applications no hairline cracks or spalling in the most critical condition (corner condition and minimum slab thickness) are observed due to the kinked rebar before steel failure of the anchor channel occurs.

The steel strength of the channel lips (\( N_{sl} \)), connection between anchor/rebar and channel profile (\( N_{sc} \)) and anchor (\( N_{sa} \)) is derived from a tension test in a universal testing machine without being cast into concrete (test series 1 in AC232). In this test series one anchor is fixed to the testing frame (see Figure 9.3.6-b).

<table>
<thead>
<tr>
<th>Perpendicular Shear</th>
<th>Concrete Failure Modes</th>
</tr>
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<tr>
<td>Channel bolt: ( \Phi_{V_{cb,y}} )</td>
<td>Concrete Pryout</td>
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<tr>
<td>Channel Lip ( \vphi_{\text{lip}} )</td>
<td>( \Phi_{V_{cb,y}} &gt; \Phi_{V_{cb,y}} )</td>
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<tr>
<td>connection : ( \Phi_{V_{sc,y}} )</td>
<td>( \Phi_{V_{nsa}} )</td>
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<tr>
<td>Rebar ( \Phi_{V_{s,R,y}} )</td>
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**Table:**

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</table>

**Concrete breakout in perpendicular shear:** \( \Phi_{V_{cb,y}} \)

The tests follow AC232 testing guidelines. Refer to anchor channel theory for further clarification. Please refer to table 2.3.4.1 for strength values.

**Connection Anchor and Channel : \( \Phi_{V_{nR,y}} \)**

The tests follow AC232 testing guidelines. Refer to anchor channel theory for further clarification. Please refer to table 2.3.4.1 for strength values.
9.3.1 — HAC CRFoS U DESIGN: INTERMEDIATE FACE OF SLAB ANCHOR CHANNEL

Concrete breakout in tension and pry-out failure modes were not observed in testing, and therefore, they are excluded from the possible failure modes of HAC CRFoS U. The verification of the adequacy of the pull-out strength of the rebar anchors is based on ACI 318. The design ensures the applied rebar forces do not exceed the bond stresses between the rebar and the concrete.

Concrete breakout in perpendicular shear: $\Phi_{V_{cb,x}}$

$\Phi_{V_{cb,x}} > V_{cb,x}$

The tests follow AC232 testing guidelines. Refer to anchor channel theory for further clarification. Please refer to table 2.3.4.3 for strength values.

Concrete edge breakout: $\Phi_{V_{cb,x}}$

$\Phi_{V_{cb,x}} > V_{cb,x}$

The tests follow AC232 testing guidelines. Refer to anchor channel theory for further clarification. Please refer to table 2.3.4.3 for strength values.
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</tr>
</tbody>
</table>
9.3.2 — HAC CRFOS U DESIGN: FACE OF SLAB OUTSIDE CORNER WITH A SINGLE ANCHOR CHANNEL

90 Degree Corner

Tension breakout cone formation is precluded because of having rebars instead of headed studs. Therefore to determine the available concrete for the analysis depends on formation of projected areas due to the concrete breakout cone in shear.

The effect of the reduced side edge distance can also effect the pullout strength of rebar if the cover is so small that it yields the $c_b / d_b$ value less than 2.5. The value of $c_b$ is equal to $c_{b,f}$. Please refer to the Figure 9.3.2.1.

Acute Angle Corner

**Tension:** Acute angle corners do not have the same amount of concrete throughout as 90 degree corners. The rebar can be bend having at least 12" in accordance to ACI-318 as shown in Figure 9.3.2.2. The pullout strength should be calculated by hand using 12" development length. The $c_b$ concrete cover is taken as minimum of the four $s/2$, $c_{b,1}$, $c_{b,2}$ and $c_{b,3}$ dimensions. Please refer to Figure 9.3.2.2 and Figure 9.3.2.3.

**Shear:** To determine the $c_{b,1}$ dimension while analyzing a acute corner, it is recommended to draw the projected area in perpendicular shear as shown in Figure 9.3.2.2. The darkened portion of the concrete is not utilized in the analysis, hence limiting to a shorter $c_{b,1}$ dimension. This is achieved by projecting the intersection of the concrete plane back to other side of the corner. Please refer to Figure 9.3.2.2 and Figure 9.3.2.3 covering the perpendicular shear analysis at acute degree corner. Please refer section 9.2.2 for longitudinal shear method of analysis for acute angle corner for detail analysis of face of slab.

Obtuse Angle Corner

**Shear:** Obtuse angle corners have a greater amount of concrete than in 90 degree corners. The determination of $c_{b,1}$ dimension for perpendicular shear analysis is conservatively assumed as shown in Figure 9.3.2.4. Please refer to Figure 9.3.2.4 covering the perpendicular shear analysis at obtuse degree corner. Please refer section 9.2.2 for analysis of anchor channel subjected to longitudinal shear for obtuse angle corner with single anchor channel on face of slab.

**Tension:** For Tension analysis refer section 9.3.1 pull out in tension. There will not be the concrete breakout cone development in tension. The $c_b$ concrete cover is taken as minimum of the four $s/2$, $c_{b,1}$, $c_{b,2}$ and $c_{b,3}$ dimensions. Please refer to Figure 9.3.2.4 and Figure 9.3.2.5.
9.3.3 — HAC CRFoS U DESIGN: FACE OF SLAB OUTSIDE CORNER WITH PAIR OF ANCHOR CHANNEL

90 Degree Corner
Hilt HAC CRFoS U has a one diameter kink to help facilitate installing the anchor channels as close possible to the corner. This helps the installation of t-bolts close to the corner and hence reduces the length of the bracket used. The anchor channel is pushed away from the corner edge so that the rebars do not intersect at the corner. Please refer to chapter 2 Table 2.2.5.3 for the minimum side edge distance of various CRFoS U channels.

By replacing the headed stud anchors with rebars, the concrete breakout in tension is precluded. The rebar transfers the loads to the concrete via interlock.

Shear: PROFIS Anchor Channel has the “activate corner” option which gives us an opportunity to design the corner. The difference between the design of anchor channels at the corner is that when it comes to the concrete breakout check in perpendicular shear, the capacity is reduced by 20% because of overlapping of the concrete breakout failure planes in perpendicular shear as shown Figure 9.3.3.3. Not multiplying by the corner factor will result in unconservative results for the breakout capacity in perpendicular shear. Please refer Anchor channel theory for more information on concrete breakout in shear.

Please refer section 9.2.3 for detail method of analyzing perpendicular and longitudinal shear for a face of slab 90 degree angle corner with anchor channels on both sides. The section 9.2.3 describes method that includes the influence of the anchor channel on the other side of the corner.

Tension: The tension analysis will follow the section 9.3.1 in determining pullout capacity ΦN. The cb concrete cover is taken as minimum of the four s/2, c1, c2 and c3 dimensions. (s=spacing between rebar) Refer Figure 9.3.3.1 and Figure 9.3.3.2.

Acute Angle Corner
The difference between the behavior of headed stud anchor channel and anchor channel with rebar anchors is that having rebars precludes the concrete breakout cone in tension and pryout. The only determining factor of the side edge distance Ccb is the concrete breakout in shear.

Shear: In order to determine Ccb dimension it is recommended to have a line drawn parallel to edge at a distance hcr, the intersection point of this line is projected back to the edge as illustrated in Figure 9.3.3.4. The shaded concrete region of the Figure 9.3.3.4 is neglected in analysis in order to take into account the effect of the acute angle corner. Model the 90 degree corner with Ccb as the side edge distance to the closest anchor in the PROFIS Anchor Channel software. The concrete breakout strength in shear is reduced by 20% to take into account the utilization of concrete twice in shear following the simplified method of analysis. Please refer section 9.2.3 for detail method of analyzing perpendicular and longitudinal shear for a face of slab acute degree angle corner with anchor channels on both sides. The section 9.2.3 describes method that includes the influence of the anchor channel on the other side of the corner.

Tension: It is made sure that the available rebar length is 12” following the ACI provisions for minimum length in order to rely on rebar theory for transfer of tensile force. The tension analysis will follow the section 9.3.1 without having any reduction in anchorage tension pullout capacity ΦN because of the influence of the other anchor channel. The cb concrete cover is taken as minimum of the four s/2, c1, c2 and c3 dimensions. (s=spacing between rebar) Refer Figure 9.3.3.4 and Figure 9.3.3.5.
9.3.4 — HAC CRFOS U Design: Face of Slab Inside Corner with Pair of Anchor Channel

Inside corners where two anchor channels are present and are loaded simultaneously are outside the scope of AC232. Most of the AC232 provisions can be applied to this type of application. However, the influence of the adjacent anchor channel should be considered, as the concrete strength may be negatively impacted.

**Perpendicular Shear:** This condition can be analyzed by fictitious edge between \(c_{oa} + c_{rb}\) assigning side edge concrete between channel \(a\) and \(b\). The total distance of \((a+b)\) can be divided between the two channels, while analyzing the individual channels. For example if channel \(a\) is loaded more than channel \(b\) than side edge distance of \(3/4(a+b)\) can be assumed for channel \(a\) and side edge distance \(1/4(a+b)\) can be assumed for channel \(b\). Refer Figure 9.3.4.1.

**Tension:** The tension analysis will follow the section 9.3.1 without having any reduction in anchorage tension pullout capacity \(\Phi N_{pn}\) because of the influence of the other anchor channel.

---

**Shear:** Obtuse angle corners with HAC CRFOS U channels:

The side edge distance used in the analysis should be as shown in the Figure 9.3.3.6. Analysis is done using the design methodology of 90 degree corners. Conservatively, the concrete breakout strength in shear is reduced by 20% similar to 90 degree corners. Please refer the section for 90 degree corner. However, in reality corner reduction factor should be less 20% because of the availability of more concrete compared to 90 degree corners.

If the obtuse angle corner does not work by modeling it as a 90 degree corner, contact Hilti for further assistance in optimizing the solution.

Please refer section 9.2.3 for detail method of analyzing perpendicular and longitudinal shear for a face of slab obtuse degree angle corner with anchor channels on both sides. The section 9.2.3 describes method that includes the influence of the anchor channel on the other side of the corner.

**Tension:** The tension analysis will follow the section 9.3.1 without having any reduction in anchorage tension pullout capacity \(\Phi N_{pn}\) because of the influence of the other anchor channel.

---

**Figure 9.3.4.1 — HAC CRFOS U — Inside Corner.**
9.3.5 — HAC CRFOS U DESIGN: COMPOSITE SLABS

The following failure modes need to be modified in order to take account the effect of metal deck:

**Pullout strength in tension**

For FOS anchor channel design on a metal deck, the cover on the rebar where the rebar goes on top of metal deck should be measured from center of rebar to the metal deck. The \( c_v \) value is taken as minimum value of \( x_1 \) and \( x_2 \) in the development length equation. The pullout strength gets reduced due to the reduced cover if the ratio \( c_v/d_1 \) is less than 2.5. Please refer to rebar theory chapter 8 and section 9.2.3 for more information on this failure mode:

\[
K_u = \frac{10}{d_1} \sqrt{\frac{c_v}{f_y}} \left( \frac{2.5}{d_1} \right) \left( \frac{1}{b_1} \right)
\]

Please contact Hilti for additional information.

![Concrete breakout strength in shear](image)

**Concrete breakout strength in shear**

The dimension \( y' \) effects conrete breakout strength in perpendicular shear. This will change the factor \( \Psi_{h,V} \).

The dimension \( h \) in the formula below for the \( \Psi_{h,V} \) factor should be taken as \( h \) as shown in Figure 9.3.5.1.

Please refer to anchor channel theory for more information on concrete breakout in shear.

\[
\Psi_{h,V} = \left( \frac{h}{b_y} \right)^h \leq 1.0
\]

Figure 9.3.5.1 — HAC CRFOS U — FOS — Composite Slabs.

9.3.7 — HAC CRFOS U DESIGN: DESIGN OF FACE OF SLAB ANCHOR CHANNEL WITH COLUMN CONFLICT AT THE CORNER

When there is a column conflict at the corner, the anchor channel is analyzed using a height of the base material as \( x' \).

This dimension \( x' \) effects concrete breakout strength in perpendicular shear \( \Psi_{h,V} \).

The dimension \( h \) in the formula below for the \( \Psi_{h,V} \) factor should be taken as \( h=x' \).

Please refer to anchor channel theory for more information on concrete breakout in shear.

\[
\Psi_{h,V} = \left( \frac{h}{b_y} \right)^h \leq 1.0
\]

See best practices, section 11.5.3

Figure 9.3.6.1 — HAC CRFOS U — FOS — Column Conflict at Corner.

9.3.6 — HAC CRFOS U DESIGN: DESIGN OF ANCHOR CHANNEL FOR OUTSIDE CORNER OF A CURB OR OUTSIDE CORNER WITH COLUMN CONFLICT

See best practices, section 11.5.3

9.4 — HAC AND HAC-T DESIGN: POST TENSIONED SLABS

See best practices, section 11.5.3

9.5 — HAC CRFOS U DESIGN: POST TENSIONED SLABS

See best practices, section 11.5.3

Please contact Hilti at US+CA.HAC@Hilti.com for additional information.
9.6 — HAC EDGE DESIGN

9.6.1 — HAC (T) EDGE, HAC (T) EDGE LITE AND HAC S (T) EDGE

**DESIGN: INTRODUCTION**

Hilti Anchor Channel with the new rebar edge confinement plate (HAC EDGE or HAC EDGE Lite) is a solution for Curtain Wall applications that offers superior concrete edge breakout performance in shear. HAC EDGE changes the traditional concept of anchoring to concrete. Instead of relying on the low capacity of the concrete in tension, it takes advantage of the tensile strength of the reinforcement attached to the anchor channel. HAC EDGE optimizes the shear load transfer from the channel profile into the reinforcing bars and overcomes the challenges with traditional anchor channels with welded reinforcing bars.

HAC EDGE is a new anchoring system that brings value innovation. It copes with today’s fast track construction demands and requirements of the curtain wall industry such as installation tolerance, high wind loads, thin concrete members, and material characteristics of the concrete. This failure mode is controlled by the geometrical dimensions and material characteristics of the concrete.

### Code Compliance of HAC EDGE

HAC EDGE is a system consisting of a rebar edge confinement plate (EDGE plate) non-structurally attached to a Hilti Anchor Channel (HAC). The anchor channel itself is covered in the ESR-3520. Because the EDGE plate is not structurally connected to the anchor channel, the system is decoupled and the EDGE plate does not change the behavior of the anchor channel. Therefore, the design model and technical data can be taken from ESR-3520 for most of the failure modes.

The scope of the current version of AC232 (June 2017) is limited to anchor channels with round headed anchors or t-anchors. Anchor channels with reinforcing bars attached to the anchor channels are not explicitly covered in ESR-3520. The testing protocols of AC232 were used to determine the resistances of HAC in combination with the EDGE plate. The design provisions of AC232 are valid to design 19 out of the 20 failure modes of an anchor channel required per ESR-3520. Only the verification for concrete edge breakout of anchor channels consists of the basic concrete breakout strength of one anchor of the anchor channel multiplied by a series of modification factors that account for the anchor spacing, member thickness, corner effect, state of concrete (cracked or uncracked) and reinforcement in the concrete member.

The basic concrete breakout strength of one anchor without the influence of a corner, member thickness or adjacent anchors in unreinforced concrete is determined as follows:

\[
V_b = \lambda \alpha \lambda_{c_{at}} f'_{c} \left( C_{at} \right) \frac{l}{d} \lambda_{c_{at}} f'_{c}
\]

where:
- \( \lambda \) = Modification for lightweight concrete
  - All-lightweight concrete = 0.75
  - Sand-lightweight concrete = 0.85
- \( \alpha_{c_{at}} \) = Factor to account for the influence of channel on concrete edge breakout strength (10.50, max.)
- \( f'_{c} \) = Specified concrete compressive strength (psi) (8,500 psi, max)
- \( C_{at} \) = Edge distance of anchor channel in direction 1 (in.) (edge to center line of anchor)

### The Weakest Link in Top of Slab Applications

The design of cast-in anchor channels requires the verification of steel and concrete failure modes for tension, shear and combined tension and shear. An anchor channel is only as strong as its weakest link. For curtain wall applications, the weakest link in shear is typically concrete edge breakout failure.

### Standard Anchor Channels

The verification of concrete edge breakout of anchor channels consists of the basic concrete breakout strength of one anchor of the anchor channel multiplied by a series of modification factors that account for the anchor spacing, member thickness, corner effect, state of concrete (cracked or uncracked) and reinforcement in the concrete member.

The basic concrete breakout strength of one anchor without the influence of a corner, member thickness or adjacent anchors in unreinforced concrete is determined as follows:

\[
V_b = \lambda \alpha \lambda_{c_{at}} f'_{c} \left( C_{at} \right) \frac{l}{d} \lambda_{c_{at}} f'_{c}
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where:
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- \( f'_{c} \) = Specified concrete compressive strength (psi) (8,500 psi, max)
- \( C_{at} \) = Edge distance of anchor channel in direction 1 (in.) (edge to center line of anchor)

According to the Figure 9.6.1.3, for standard anchor channels covered in ESR-3520 the shear loads acting on the fixture are transferred through the anchor channel into the concrete via the t-bolts and the anchor elements. The failure occurs in front of the channel profile (2). After reaching the ultimate shear load the concrete in front of the channel is completely separated from the rest of the structure. The shear load decreases with increasing deformation of the channel (3).
In curtain wall applications, the design of the anchor channel typically takes place at one of the last stages of the building design. Oftentimes, the design of the anchorage comes as an afterthought. By the time the anchor channel is sized, the variables that can significantly influence the performance of the anchor channel have been defined. The edge distance is the variable that has the largest impact on concrete edge breakout failure. However, even this variable may have already been defined leaving designers with minimal options. Typically, the edge distance can only be varied in a very narrow band due to the size of the bracket.

Overcoming the Limitations of the Concrete Edge Breakout Strength

Anchor Channels with Welded Reinforcing Bars

To overcome the limitations of the relatively low concrete edge breakout strength close to an edge, often anchor channels with reinforcing bars structurally welded to the back of the channel are used. In analogy to standard anchor channels, the shear loads are transferred into the concrete via the channel profile (1). The failure also occurs in front of the channel profile (2). However, compared to standard anchor channels the shear loads are redistributed to the reinforcing bars. The higher ultimate resistance of the system is reached only with increased deformations and large cracks in front of the channel (3).

Welding reinforcing bars to an anchor channel changes the behavior of the anchor channel in tension and combined tension and shear. When tension forces are applied to the anchor channel, the concrete above the reinforcing bars fails and reduce the concrete cone resistance of the anchor channel. Also, due to the large cracks in front of the anchor channel in case of shear loading, the interaction with concrete cone failure is negatively influenced. These effects are even more pronounced in lightweight concrete structures. Therefore, the negative effect of the welded reinforcing bars should be considered in the design of these types of anchor channels.

HAC EDGE

Utilizing the basic principles of reinforced concrete structures has lead Hilti to develop a new anchor channel system that copes with the curtain wall market needs. Rather than relying on the relatively low tensile capacity of the concrete for the failure mode “concrete edge breakout”, HAC EDGE brings superior concrete edge performance by optimizing the load transfer for small edge distances, thin concrete members, low concrete compressive strengths, and lightweight concrete.

The first loading stage of HAC EDGE is equal to the one of standard anchor channels and anchor channels with welded reinforcing bars (1). After shear loads are applied to the anchor channel, the loads are first transferred from the channel profile towards the free edge of the concrete. The EDGE plate which is held back by the welded reinforcing bars confines the edge, allowing for the formation of compression struts (2). The shear load is transferred back to the reinforcing bars. The ultimate resistance of the system is reached after the reinforcing bars are fully activated (3).

The EDGE plate is not structurally connected to the anchor channel. This allows decoupling of the shear and tension load transfer mechanism. The concrete cone resistance of the anchor channel can be conservatively calculated according to ACI239.

For small edge distances HAC EDGE provides more than 2 times the capacity of traditional top of slab anchor channels where the reinforcing bars are welded to the back of the channel. Moreover, depending on the geometry of the concrete member and location of the anchor channel, HAC EDGE can outperform standard anchor channels without reinforcing bars up to a factor of 5.

Additional Benefits of HAC EDGE

In addition to the high concrete edge breakout in shear performance, HAC EDGE comes with the specified/ordered edge distance to reduce errors in placement, and provide a safer and quicker installation. This goes in hand with Hilti’s mission of building a better future. HAC EDGE reduces the probability of installing the product at the wrong edge distance. The edge distance is the most sensitive variable that has the highest impact on the concrete edge breakout strength in shear. Moreover, the installation of the anchor channel is simplified as the product can easily be secured to the formwork by nailing or screwing the EDGE plate to it. Moreover, HAC EDGE brings overall material savings as it allows the use of smaller facade brackets. The superior concrete shear performance for small edge distances allows the curtain wall bracket to be concealed by the stool trim or gypsym wall, if they are at least 4-5” away from the edge of the building. This eliminates the need of so-called pockets, bringing substantial savings.
9.6.2 — HAC (T) EDGE, HAC (T) EDGE Lite and HAC S (T) EDGE: Design

In this section, an overview of the verifications is given.

All the actions on the anchors are calculated according to AC232. The action on the rebars are calculated with the model of AC232 with a modification of the influence length. A summary of the applied load distributions is given in Table 9.6.2.1.

In case of two elements close to an edge the actions on the anchors are calculated independently for the two channels resistances.

Following considerations are done for the verifications of the three introduced components:

1) HAC-50 and HAC-T50 with reduced embedment depth: no changes to the design is based on ESR3520 and AC232.

2) Lips strengthening element (Clip): in combination with the clip, higher values of $V_{sl,y}$, $V_{sa,y}$ and $V_{sc,y}$ are provided. Seismic design is performed according to the ESR3520: the lip strengthening element is not considered in the seismic calculation nor for load acting towards the slab (wind pressure).

3) With the new Rebar Top of Slab front Plate (EDGE), the rebars and the anchor channel are structurally uncoupled: the connection between the two elements is weak and has no structural function.

For tension loads, the rebars are neglected and all the verifications are performed in the same way as for the standard HAC channels, according ESR3520. The splitting failure (considered in the concrete breakout verification) is not possible when the EDGE front plate is combined ($\psi_{cr,N} = 1.0$) and the concrete is always considered as cracked ($\psi_{c,N} = 1.0$).

For perpendicular shear a new method for concrete edge failure and an additional reduction for the lip failure are introduced. Additionally, the verification of rebar pull-out and rebar steel strength are performed in the same way as for the CRFOS U. Moreover, two remarks are added in Profis, the first concerning the “concrete cone” for shear load and the second concerning the presence of cracks at the sides of the channel. Supplementary reinforcement for perpendicular or for longitudinal shear is not permitted in combination with the EDGE plate.

For longitudinal shear the rebars are neglected and the concrete failure is calculated according to ESR3520. This assumption is conservative since the capacity of unreinforced concrete is lower than that of the edge with the EDGE reinforcement.

All the verifications under combined loads are performed according to ESR3520.

If two anchor channels are placed close to a corner, all the steel verification remain the same. Since the two channels use the same concrete surface, some modification have to be done for all the concrete verifications in order to take the relative influence into account.

An adjustment to the ESR method for the calculation of concrete cone and concrete edge failure in case of two (or more) channels is described in Sections 9.2.7 to 9.2.17. For longitudinal shear the reinforcement bars are neglected and the ESR method is applied.

Conservative assumptions are done for the 3D load interaction.

### Table 9.6.2.1 — Actions on the anchors.

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<td>Anchor shear parallel</td>
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<tr>
<td>Rebar tension</td>
<td>Mod. AC232</td>
<td>Mod. AC232</td>
</tr>
</tbody>
</table>

**IMPORTANT:** Failure analysis modes evaluated follow ACI 318-14, chapter 17. This DOES NOT include evaluating the base material (e.g. edge-of-slab) capacity to resist compressive forces generated by the fixture. The engineer must ALWAYS verify the base material (e.g. edge-of-slab) design is capable of resisting the applied loading.

For additional information, please contact Hilti at US+CA.HAC@Hilti.com.

**Superposition of tension and shear loads (up to 5 interaction equations)**
9.1 Overview of Hilti Anchor Channel Systems Design
9.2 HAC and HAC-T Design
9.3 HAC CRFoS U Design
9.4 & 9.5 Post Tensioned Slabs
9.6 HAC EDGE Design

HAC-(T) EDGE and HAC-(T) EDGE Lite

TENSION

Concrete Failure Modes

ESR-3520 Sec. 4.1.3.2.2
ESR-3520 Sec. 4.1.3.2.3
ESR-3520 Sec. 4.1.3.2.4
ESR-3520 Sec. 4.1.3.2.5

PERPENDICULAR SHEAR

Steel Failure Modes

Concrete Failure Modes

IMPORTANT! Failure analysis modes evaluated follow ACI 318-14, chapter 17. This DOES NOT include evaluating the base material (e.g. edge-of-slab) capacity to resist compressive forces generated by the fixture. The engineer must ALWAYS verify the base material (e.g. edge-of-slab) design is capable of resisting the applied loading.

For additional information, please contact Hilti at US+CA.HAC@Hilti.com
### REBAR FAILURE MODES

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebar in tension</td>
<td></td>
</tr>
<tr>
<td>Rebar connection</td>
<td></td>
</tr>
<tr>
<td>Anchor rein. steel</td>
<td>Anchor rein. anchorage</td>
</tr>
<tr>
<td>EDGE Rebar pull-out</td>
<td></td>
</tr>
<tr>
<td>SLS Concrete edge</td>
<td></td>
</tr>
<tr>
<td>Anchor rein. anchorage</td>
<td></td>
</tr>
</tbody>
</table>

- **Hilti Method** (Hilti pull-out and Rebar connection are performed in the same way as for the FoS products.)
- **No** (The rebar welding is specified such as to have an higher strength than the rebar itself.)

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### LONGITUDINAL SHEAR

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bolt</td>
<td>Anchor rein. steel</td>
</tr>
<tr>
<td>Channel Lip</td>
<td>Anchor rein. anchorage</td>
</tr>
<tr>
<td>Connection</td>
<td></td>
</tr>
<tr>
<td>Anchor</td>
<td></td>
</tr>
<tr>
<td>Concrete Breakout</td>
<td></td>
</tr>
<tr>
<td>Concrete Pryout</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR-3520 Sec. 4.1.3.2.2</td>
<td></td>
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<tr>
<td>ESR-3520 Sec. 4.1.3.2.2</td>
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<tr>
<td>ESR-3520 Sec. 4.1.3.2.2</td>
<td></td>
</tr>
<tr>
<td>ESR-3520 Sec. 4.1.3.4.3</td>
<td></td>
</tr>
</tbody>
</table>

- **Not permitted**
- **Hilti Method based on ACI**
- **Remark in Profi**
- **Not permitted**

### TENSION

#### Steel Failure Modes

- **Channel bolt**: $\phi_{N_{c}}$
- **Channel Lip**: $\phi_{N_{c}}$
- **Bending of channel**: $\phi_{M_{s,\text{flex}}}$
- **Connection**: $\phi_{N_{sc}}$
- **Anchor**: $\phi_{N_{sa}}$
- **Concrete breakout**: $\phi_{N_{cb}}$
- **Pullout**: $\phi_{N_{pn}}$
- **Side-face blow-out**: $\phi_{N_{sb}}$

#### Concrete Failure Modes

- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.2**
- **ESR-3520 Sec. 4.1.3.2.3**
- **ESR-3520 Sec. 4.1.3.2.3**
- **ESR-3520 Sec. 4.1.3.2.3**

*No splitting possible in combination with the steel plate, concrete always cracked*

### PERPENDICULAR SHEAR

#### Steel Failure Modes

- **Channel bolt**: $\phi_{N_{c}}$
- **Channel Lip**: $\phi_{N_{c}}$
- **Connection**: $\phi_{N_{c}}$
- **Anchor**: $\phi_{N_{sa}}$
- **Concrete Breakout**: $\phi_{N_{cb}}$
- **Concrete Pryout**

#### Concrete Failure Modes

- **ESR-3520 Sec. 4.1.3.2.3**
- **ESR-3520 Sec. 4.1.3.4.2**

*If the clip is selected $V_{c},V_{p},V_{sb}$ are changed in clip direction, and only critical*
### HAC-(T) EDGE, HAC-(T) S EDGE, HAC-(T) C EDGE and HAC-(T) EDGE Lite

#### TENSION

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bolt: $\Phi N_c$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Channel lip: $\Phi N_{cs}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Bending of channel: $\Phi M_{s,\text{flex}}$</td>
<td>$\Phi M_{u,\text{flex}}$</td>
</tr>
<tr>
<td>Connection: $\Phi N_{sc}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Anchor: $\Phi N_{sa}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Concrete breakout: $\Phi N_{cb}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Pullout: $\Phi N_{pn}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Side-face blow-out: $\Phi N_{sb}$</td>
<td></td>
</tr>
</tbody>
</table>

The capacity of channel lip is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

The capacity of anchor is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

The concrete breakout capacity of anchor channel is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.2.7.1, 2.2.7.2, 2.2.7.3, 2.2.16.1, 2.2.16.2 and 2.2.16.3 of chapter 02 for parameters and section 7.3.2 of anchor channel theory chapter 07 for analysis.

The capacity of connection is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

The capacity of anchor is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

#### LONGITUDINAL SHEAR

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<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
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</thead>
<tbody>
<tr>
<td>Channel bolt: $\Phi N_{c}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Channel lip: $\Phi N_{cs}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Connection: $\Phi N_{sc}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Anchor: $\Phi N_{sa}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
</tbody>
</table>

The capacity of channel lip is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

### REBAR FAILURE MODES

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebar connection: N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Rebar in tension: Not permitted</td>
<td>Not permitted</td>
</tr>
<tr>
<td>Anchor rein. steel: Hilti Method based on ACI</td>
<td>Hilti Method based on ACI</td>
</tr>
</tbody>
</table>

*No splitting possible in combination with the steel plate, concrete always cracked.*

### Anchor Reinforcement Steel

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor: $\Phi N_{sa}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
<tr>
<td>Anchor rein. steel: Anchor rein. anchorage</td>
<td>Anchor rein. anchorage</td>
</tr>
</tbody>
</table>

The capacity of anchor is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

### Anchor and Channel Reinforcement Steel

<table>
<thead>
<tr>
<th>Steel Failure Modes</th>
<th>Concrete Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor: $\Phi N_{sa}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
</tbody>
</table>

The capacity of anchor is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.3.17 and 2.3.5 of chapter 02.

### Concrete Breakout Reinforcement Steel

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Anchor: $\Phi N_{sa}$</td>
<td>$\Phi N_{cb}$</td>
</tr>
</tbody>
</table>

The concrete breakout capacity of anchor channel is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.2.7.1, 2.2.7.2, 2.2.7.3, 2.2.16.1, 2.2.16.2 and 2.2.16.3 of chapter 02 for parameters and section 7.3.2 of anchor channel theory chapter 07 for analysis.

$\Psi_{cp,N} = 1.0$ if the EDGE (C) steel plate is activated.

$\Psi_{c,N} = 1.0$ always if the EDGE (C) steel plate is activated: with the EDGE (C) front plate concrete is always considered as cracked.
Pull out: $\Phi_{N_{pu}}$

$\Phi_{N_{pu}} > N_{max}$

The anchor pull out capacity is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to table 2.2.7.1, 2.2.7.2, 2.2.7.3, 2.2.16.1, 2.2.16.2 and 2.2.16.3 of chapter 02 for parameters and section 7.2.2 of anchor channel theory chapter 07 for analysis.

Side-face blow-out: $\Phi_{N_{sb}}$

$\Phi_{N_{sb}} > N_{max}$

The concrete side-face blow-out capacity is in accordance to ESR-3520 Sec. 4.1.3.2.5. Please refer to table 2.2.7.1, 2.2.7.2, 2.2.7.3, 2.2.16.1, 2.2.16.2 and 2.2.16.3 and table 2.2.16.1, 2.2.16.2 and 2.2.16.3 of chapter 02 for parameters and section 7.2.2 of anchor channel theory chapter 07 for analysis.

Anchor reinf. anchorage: $\Phi_{N_{ca}}$

$\Phi_{N_{ca}} > N_{max}$

The anchor reinf. anchorage capacity is in accordance to ESR-3520 Sec. 4.1.3.2.3. Please refer section 7.2.2 of anchor channel theory chapter 07 for analysis.

ANCHOR REINFORCEMENT STEEL: $\Phi_{N_{ca,s}}$

$\Phi_{N_{ca,s}} > N_{max}$

The anchor reinf. steel capacity is in accordance to ESR-3520 Sec. 4.1.3.2.2. Please refer to section 7.2.2 of anchor channel theory chapter 07 for analysis.

Channel lip : $\phi_{V_{sl}}$

$V_{sl,y} > V_{bl}$

The value of $V_{sl,y}$ is valid only if the center-to-center distance between the channel bolt under consideration and adjacent channel bolts, $s_{bl}$ is at least $s_{bl,cr,V}$. If this requirement is not met then the value of $V_{sl,y}$ must be reduced as follow:

$$V_{sl,y} = V_{sl,y,techical data} \times \frac{1}{1 + \sum_{i=1}^{n} \left( \frac{1}{s_{bl,i}} - \frac{1}{s_{bl,cr,V}} \right)}$$

$$s_{bl,cr,V} = s_{bl,cr,V} - 0.9d_{bl} \geq 3d_{bl}$$

The critical bolt spacing for shear load for the HAC-50.

where

$$V_{sl,y} = \Phi_{V_{sl,y}} \times V_{sl,y,techical data}$$

$\Phi_{V_{sl,y}}$ is the factor for the nominal strength of the channel lip to take up tension loads of ESR 3520 (1) (eq. 5 in 4.1.3.2.2).

The bolt shear forces are considered only if acting in the same direction. If one bolt is loaded in the opposite direction no positive effect on the factor is considered.
With the spacing \( s_{cb,y} \) = 240 mm the critical spacing at \( c_{a1} = 200 \) mm assumes that there is no influence anymore on the lip strength. \( s_{cb,y} \) becomes 3 times the bolt diameter \( d_s \) as specified in ESR3520.

The reduction factor \( \Psi_{s,si} \) is smaller with the edge distance and from \( c_{a1} = 200 \) mm it is influenced of the EDGE front plate on the lip strength becomes.

With lip strengthening element (Clip) according Hilti technical data. The reduction factor \( \Psi_{s,si} \) is applied:

\[
\Psi_{s,si} = \frac{1}{1 + \frac{d_s}{s_{cb,y}}} \quad \text{(in clip direction)}
\]

Verifications:

Without Clip: The capacity of connection is in accordance to ESR-3520 Sec. 4.1.3.2.2 and according to Hilti technical data. Please refer to table 2.3.22 and 2.3.6 of chapter 02. With lip strengthening element (Clip) if the clip is selected, in direction of the clip \( V_{cs,y} \) is increased to \( V_{cs,y,clip} \) according Hilti technical data. In the opposite direction, the standard value of \( V_{ui} \) are applied:

\[
\Psi_{s,si} \cdot V_{cs,y} \geq V_{ui} \quad \text{(in opposite direction)}
\]

Concrete pryout strength: \( \Psi_{v_{pp}} \)

Verifications:

\[
\Psi_{v_{pp}} \cdot V_{pp,y} \geq V_{ui,y} \quad \text{Loadings in shear}
\]

The capacity of anchor is in accordance to ESR-3520 Sec. 4.1.3.3.4. Please refer to table 2.2.7.1, 2.2.7.2 and 2.2.7.3 of chapter 02 for parameters and section 7.4.2 of chapter 07 of anchor channel theory for analysis.
If two corners are available, $\Psi_{cr,V}$ for second corner is calculated and multiplied by the first. For narrow members $2h_{cr,V} < c_{cr}$, with a thickness $h < h_{cr,V}$ the same prescriptions as in AC232 are adopted and the edge distance $c_{cr}$ in the calculation of $V_b$ shall not exceed the following value of $ca_{1,red}$:

$$c_{cr} = \max \left( \frac{(c_{max} - b_h - 2h_{cr,V})}{2}, \frac{h_{cr,V}}{2} \right)$$

$$\Psi_{cr,V} = 1.0\text{ modification factor for cracked concrete, always 1.0}$$

**Determination of anchor and rebar forces acting on the channel**

In combination with the EDGE front plate all the actions on the anchors (tension, perpendicular and longitudinal shear) are calculated with the method of AC232.

The tension load on the rebars is also calculated with the model of AC232, with a modification of $\ell_{inf}$ as specified below.

**Rebar tensile forces (Hilti Method):**

$\Phi_{N_s,R}$

Rebar tensile forces (Hilti Method):

$$\sigma_s = \frac{V}{A_s}$$

where $V$ is the total shear load, $A_s$ is the cross-sectional area of the rebar, and $\sigma_s$ is the rebar stress.

**Rebar tensile forces (Hilti Method):**

$\Phi_{N_s,R}$

Rebar: $\Phi_{N_s,R}$

The capacity of steel rebar Hilti Method is in accordance to ESR-3520 Sec. 4.1.3.3.3. Please refer to table 2.3.23.1 of chapter 02.

**EDGE Steel strength of rebar : $\Phi_{N_s}$**

The capacity of steel rebar Hilti Method is in accordance to ESR-3520 Sec. 4.1.3.3.3. Please refer to table 2.3.23.1 of chapter 02.

In general an verification acc. to ACI 318-11 is performed by comparing a development length with a provided length. Due to the fact that the provided length as well as the diameter of the rebar is fixed a possible (virtual) "anchorable" force (stress) in the rebar is "back"-calculated. For the verification this "anchorable" force $N_{anch}$ will be compared with the acting force $N_{V_a}$ on the rebar.
Concrete breakout in shear

“Reinforcing bars comprising part of the Hilti Anchor Channel (HAC) system are proportioned to meet the development length provisions of the code as they apply to cases where anchorage development for fully fy is not required. The concrete member in which the anchor channel is installed shall be in conformance with the requirements of the code for reinforced concrete and designed for the load introduced by the anchor channel.”

Remark for SLS crack width

The characteristic crack width at the side of the channel is calculated based on empirical equation.

\[ N'_{\text{cr}} \text{ (KN)} \] is the force on the rebar at the serviceability level and is obtained with the safety factor for serviceability:

\[ N'_{\text{cr}} = \frac{N_{\text{cr}}}{\gamma_{\text{s}} \gamma_{\text{r}}} \text{ (KN)} \]

\( N_{\text{cr}} \) is the maximum of the factored shear load of the first and the last rebar (R1 and R4 in Figure 9.6.2.9).

\( \gamma_{\text{s}} \) reduces the shear loads which are defined for strength verification to a service level and should be selected by the user in Profis >Options >Project options>safety factors. The current “safety factor for 1st crack in SLS check” should be renamed in “Shear factor for serviceability crack width check” (Figure 9.6.2.12). \( \gamma_{\text{s}} \) will be assumed 1 as default.

Remark in Profis:

If the calculated \( w_s \leq 0.3 \text{ mm} \): Cracking of the concrete may occur at service load levels. The characteristic crack width is less than 0.3 mm (0.012 in.). This value is calculated based on experimental investigations on anchor channels loaded in shear in unreinforced concrete slabs.

If \( w_s \geq 0.3 \text{ mm} \): Cracking of the concrete may occur at service load levels. The characteristic crack width is \( x \text{ mm} \) (\( x \text{ in.} \)). This value is calculated based on experimental investigations on anchor channels loaded in shear in unreinforced concrete slabs. The crack widths are smaller in case of reinforcement in the slab. The data obtained with experimental program performed for the development and qualification of HAC EDGE.
Concrete breakout strength for parallel shear: The concrete breakout strength for parallel shear is calculated according ESR for both channels are verified independently and neglecting the EDGE front plate. The concrete utilization of both edges is then combined in a conservative way as described in the next paragraph.

**Channel Lip strength: \( \Phi_{V_{ax}} \)**

\[ \Phi_{V_{ax}} > V_{ax} \]

This check is in accordance to ESR-3520 Sec. 4.1.3.3.2, 4.1.3.4.2

Please refer to table 2.3.18.1 and 2.3.22.3 for strength values.

**Anchor strength: \( \Phi_{V_{ax}} \)**

\[ \Phi_{V_{ax}} > V_{ax} \]

This check is in accordance to ESR-3520 Sec. 4.1.3.3.2, 4.1.3.4.2

Please refer to table 2.3.18.1 and 2.3.10.1 for strength values.

**Connection Anchor and Channel: \( \Phi_{V_{ax}} \)**

\[ \Phi_{V_{ax}} > V_{ax} \]

This check is in accordance to ESR-3520 Sec. 4.1.3.3.2, 4.1.3.4.2

Please refer to table 2.3.18.1 and 2.3.10.1 for strength values.

**Concrete breakout strength for parallel shear: \( \Phi_{V_{ax}} \)**

\[ \Phi_{V_{ax}} > V_{ax} \]

Please refer to anchor channel theory for more information on this failure mode. The design methodology is same as of headed stud anchor channel. This check is compliant with ESR-3520 section 4.1.3.4.4. Refer Anchor channel theory Section 7.4.4

Required verifications under combined tension and shear loading

If forces act in more than one direction the combination of loads has to be verified. Anchor channels subjected to combined axial and shear loads shall be designed to satisfy the following requirements by distinguishing between steel failure of the channel bolt, steel failure modes of the channel and concrete failure modes.

Steel failure of channel bolts under combined loads (ESR-3520)

If forces act in more than one direction the combination of loads has to be verified. Anchor channels subjected to combined axial and shear loads shall be designed to satisfy the following requirements by distinguishing between steel failure of the channel bolt, steel failure modes of the channel and concrete failure modes.

Steel failure of channel bolts under combined loads (ESR-3520)

\[ \beta_{\text{V-ax}} \leq 1.0 \]

\[ \beta_{\text{V-ax}} \leq 1.0 \]

Steel failure modes of rebar channels under combined loads (ESR-3520)

a) For connection between anchor and channel

\[ \beta_{\text{V-ax}} \leq 1.0 \]

\[ \beta_{\text{V-ax}} \leq 1.0 \]

\[ \beta_{\text{V-ax}} \leq 1.0 \]

\[ \beta_{\text{V-ax}} \leq 1.0 \]

\[ \beta_{\text{V-ax}} \leq 1.0 \]

It is permitted to assume reduced values for \( V_{sa} \) and \( V_{sc} \) corresponding to the use of an exponent \( \alpha = 2 \). In this case the reduced values for \( V_{sa} \) and \( V_{sc} \) shall also be used.
b) At the point of load application

\[ \beta_{b,\text{sl},x,y} = \left( \frac{N_{\text{cm}}}{M_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},x}}{M_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},y}}{M_{\text{cm}}} \right) \leq 1.0 \]

\[ \beta_{b,\text{sl},x,y} = \left( \frac{M_{\text{cm}}}{N_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},x}}{M_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},y}}{M_{\text{cm}}} \right) \leq 1.0 \]

\[ \beta_{\text{sl},x,y} \leq 1.0 \] highest utilization under tension loading per per t-bolt

\[ \beta_{\text{sl},x,y} \leq 1.0 \] highest utilization under shear loading \( \perp \) per t-bolt

\[ \beta_{\text{sl},x,y} \leq 1.0 \] highest utilization under shear loading parallel to per t-bolt

\[ \beta_{\text{sl},x,y} \leq 1.0 \] highest utilization under tension loading per per t-bolt

\[ \alpha = 2.0 \] for rebar channels with \( V_{\text{cb},x} \leq N_{\text{a}} \)

\[ \alpha = 1.0 \] for rebar channels with \( V_{\text{cb},x} > N_{\text{a}} \)

It is permitted to assume reduced values for \( V_{\text{cb},x} \) corresponding to the use of an exponent \( \alpha = 2.0 \). In this case the reduced values for \( V_{\text{cb},x} \) shall also be used.

Concrete failure modes of anchor channels under combined loads

A verification for each anchor is needed:

\[ \beta_{\text{sl},x,y} = \left( \frac{N_{\text{cm}}}{M_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},x}}{M_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},y}}{M_{\text{cm}}} \right) \leq 1.0 \]

\[ \beta_{\text{sl},x,y} = \left( \frac{N_{\text{cm}}}{V_{\text{cm},x}} \right) + \left( \frac{N_{\text{cm}}}{V_{\text{cm},y}} \right) \leq 1.0 \] highest anchor utilization for tension loading between:

- blow out \( (N_{\text{a}}) \)
- pull out \( (N_{\text{a}}) \)
- concrete breakout \( (N_{\text{a}}) \)
- anchor reinforcement (if available \( N_{\text{a}} \), \( N_{\text{a}} \))

\[ \beta_{\text{sl},x,y} = \left( \frac{V_{\text{cm},x}}{M_{\text{cm}}} \right) + \left( \frac{V_{\text{cm},y}}{M_{\text{cm}}} \right) \leq 1.0 \] highest utilization under shear loading \( \perp \) per t-bolt

\[ \beta_{\text{sl},x,y} \leq 1.0 \] highest utilization under shear loading parallel to per t-bolt

\[ \beta_{\text{sl},x,y} \leq 1.0 \] highest utilization under tension loading per per t-bolt

\[ \alpha = 2.0 \] for rebar channels with \( V_{\text{cb},x} \leq N_{\text{a}} \)

\[ \alpha = 1.0 \] for rebar channels with \( V_{\text{cb},x} > N_{\text{a}} \)

Concrete failure modes of anchor channels under combined loads

9.6.3 — HAC (T) EDGE, HAC (T) EDGE LITE AND HAC S (T) EDGE DESIGN: IN METAL DECK APPLICATIONS

The capacity of anchor channel should be reduced because of the presence of a metal deck. The following failure modes should be modified:

- EDGE pull-out strength of rebar: In general an verification according to ACI 318-11 is performed by comparing a development length with a provided length. Due to the fact that the provided length as well as the diameter of the rebar is fixed a possible (virtual) "anchorage" force (stress) in the rebar is "back" calculated. For the verification this "anchorage" force \( N_{\text{a}} \) will be compared with the acting force \( N_{\text{a}} \) on the rebar.

Please refer to the section: 9.6.2 of this chapter for the method of calculating the forces at the rebar \( N_{\text{a}} \).

\[ N_{\text{a}} = N_{\text{a}}^{\text{min}} \]

\[ f_{y} = \text{yield strength of reinforcement [psi]} \]

\[ \kappa = 1.0 \] for normal-weight concrete

\[ \kappa = 0.75 \] for sand-lightweight concrete

\[ \kappa = 0.75 \] for sand-lightweight concrete

\[ f_{c} = \text{concrete cylinder compressive strength [psi]} \]

\[ K_{\text{p}} = 0 \] no transverse reinforcement is taken into account

\[ c_{\text{p}} \leq 2.5 \] influence of concrete cover

\[ \text{The } c_{\text{p}} \text{ cover on the rebar where the rebar goes on top of metal deck should be measured from center of rebar to the metal deck. The } c_{\text{p}} \text{ value is taken as minimum value of } x_{\text{c}} \text{ in the development length equation. The pullout strength gets reduced due to the reduced cover if the ratio } c_{\text{p}}/d_{\text{p}} \text{ is less than 2.5. Please refer to rebar theory and design of anchor channel design code chapters 7 and 8 for more information on this failure mode.} \]

The concrete cover gets affected when the anchor channel is in a metal deck. This affect cannot be modelled in PROFIS. PROFIS anchor channel software takes the \( c_{\text{p}} \) as the \( c_{\text{p}} \) which is \( h_{\text{ch}} + 0.5d_{\text{p}} \). For the available product this \( x_{\text{c}}/d_{\text{c}} \) value is greater than 2.5, hence the capacity is not reduced because of the cover effect. Therefore check needs to be reevaluated by measuring the \( c_{\text{p}} \) as seen in Figure 9.6.3.1 and Figure 9.6.3.2.

The ratio \( x_{\text{c}}/d_{\text{c}} \) is determined and if it is less than 2.5 then the capacity needs to be reduced. If value of the ratio is \( x_{\text{c}}/d_{\text{c}} \), then the capacity is reduced by the ratio of \( 5/2^{5} \). Refer Figure 9.6.3.1

Concrete breakout strength in shear

This dimension of height of substrate effects concrete breakout strength in perpendicular shear check. This will change the factor \( \Psi_{\text{cb},x} \). It is recommended to model the concrete thickness as seen in the Figure 9.6.3.1.

The dimension \( h \) in the formula below for \( \Psi_{\text{cb},x} \) factor should be as shown in Figure 9.6.3.1.

Please refer to anchor channel design code for more information on concrete breakout in shear.

[Diagram of concrete breakout in shear]
Concrete breakout strength in tension:

An imaginary line is drawn to simulate the effect of metal deck by drawing the breakout cone in tension. It is recommended to limit the available concrete for tension to be $C_{B1,2}$ if $C_{B1,1}$ is more than $C_{B1,2}$. The following modification should be incorporated by modelling edge $C_{B1,1}$ as the edge or manually changing the reduction factor in the report, if profis does not allow modelling the edge due to minimum edge requirement. Reduction factor for edge is as seen below. Please refer to the section 7.2.3 of anchor channel theory for more information in regards to variable $C_{B1,1}$ Refer Figure 9.6.3.2.

$$\psi_{an N} = \left( \frac{C_{B1,1}}{C_{B1,2}} \right)^{0.5} \leq 1.0$$

**Figure 9.6.3.2 — HAC EDGE, HAC EDGE Lite and HAC S EDGE — Composite slab — Shear In.**

### 9.6.4 — HAC (T) EDGE, HAC (T) EDGE Lite and HAC S (T) EDGE Design: Top and Bottom of Slab Outside Corner Single Anchor Channel

**90° corners**

The concrete strengths in tension and shear of the anchor channel may be reduced (depending on how far the anchor channel is away from the corner) since the concrete cones may not be fully developed.

The design methodology is fully in accordance with the previous sub-chapter section 9.6.3 of Design of Anchor channel, only difference additional check described below.

Following concrete breakout in perpendicular shear is evaluated:

- Concrete breakout strength — perpendicular shear, direction, $y$ + accordance to Hilti method section 9.6.3 of Design of Anchor channel chapter
- Concrete edge breakout strength — perpendicular shear, direction, $x$ + along longitudinal axis according to acc. to ESR-3520 section 4.1.3.3

It has been observed during testing of HAC (T) EDGE, HAC (T) EDGE Lite or HAC S (T) EDGE that concrete tends to break towards the side edge as seen in Figure 9.6.4.1, introducing the need to check the concrete breakout in perpendicular shear direction $x$ + along the longitudinal axis of the anchor channel. Having small side edge to the Concrete edge breakout strength — perpendicular shear, direction, $x$ + along longitudinal axis is checked and gets compared to the concrete breakout strength — perpendicular shear, direction, $y$ + which ever controls gets printed in the profis calculation report. The concrete shear strength in $+y$ (perpendicular to channel axis) is not the controlling failure mode when anchor channel is installed at the corner because of the edge plate confinement.

Concrete edge breakout strength — perpendicular shear, direction, $x$ + along longitudinal axis:

Refer to the equation below

$$\psi_{con N} = \frac{C_{cr,N}}{a_{1,2}}$$

### 9.6.4.1 — HAC (T) EDGE, HAC (T) EDGE Lite or HAC S (T) EDGE — Side breakout in perpendicular shear when Anchor channel is installed at the corner.

**Figure 9.6.4.1 — HAC (T) EDGE, HAC (T) EDGE Lite or HAC S (T) EDGE — Side breakout in perpendicular shear when Anchor channel is installed at the corner.**

**Figure 9.6.4.2 — TOS or BOS HAC EDGE single channel — Shear along perpendicular to axis $y$.**

**Figure 9.6.4.3 — TOS or BOS HAC EDGE single channel at certain distance — Shear along longitudinal axis $x$.**

![Image](image-url)
Acute and obtuse corners

Please refer section 9.2.7 for details on analyzing the obtuse and acute angle corner with single anchor HAC EDGE channel at the corner. Also refer 9.6.3 and 9.6.4 on details for analyzes and all the failure modes and interaction that needed to be taken into consideration.

9.6.5 — HAC (T) EDGE, HAC S (T) EDGE

DESIGN: TOP AND BOTTOM OF SLAB OUTSIDE CORNER WITH PAIR OF ANCHOR CHANNELS

Corner Rebar Top of Slab (EDGE C)

In order to install two EDGE front plates close to an edge some modifications to the geometry of the product are needed. Indeed, the rebar location of one EDGE Plate (EDGE C) needs to be lower, in order to avoid clashing with the rebars of the adjacent corner channel. This is illustrated in Figure 9.6.5.1.

For this application, one element is a standard EDGE and the second is the so-called Corner Rebar Top of Slab (EDGE C) front plate.

The EDGE C front plate is 20 mm higher and has the rebar 14 mm deeper in order to cross those of the other EDGE element. This is illustrated in Figure 9.6.5.1. For this application, one element is a standard EDGE and the second is the so-called Corner Rebar Top of Slab (EDGE C) front plate.

The vertical distance of the rebar center point from the concrete rebars remains the same as described in chapter 02. geometrical dimensions, as well as the position and number of the rebars. The influence length is assumed as ℓin = 1.5s.

Figure 9.6.5.2 — Example for the calculation of rebar forces in accordance with the triangular load distribution method for an anchor channel with four rebars. The influence length is assumed as ℓin = 1.5s.

The software also allows users to design even the most complex applications such as seismic, corners, and applications in lightweight concrete and thin slabs.

PROFIS Anchor Channel allows users to quickly and accurately model anchor channel system applications. Through a simple, user-friendly interface, the verification of 20 anchor channel failure modes and 5 interaction equations can be done in seconds.

PROFIS Anchor Channel allows users to design anchor channels with anchor reinforcement. Moreover, the so called anchor channels with “rebars” (HAC CRFoS U and HAC EDGE) are available. The software also allows users to design even the most complex applications such as seismic, corners, and applications in lightweight concrete and thin slabs.
The introduction of a design methodology for cast-in anchor channels brought significant benefits to the cast-in industry. Two major examples are the ability to optimize and confidently design an anchor channel system without relying on engineering judgment. On the other hand, it brought two major drawbacks; the design is highly complex and very time consuming.

Hand calculations for up to 25 failure modes, up to 5 interaction equations, different load combinations, varying t-bolt position along the anchor channel, bracket tolerance, substrate geometry, etc. becomes quite unpractical. Moreover, designing via Excel spreadsheets or Mathcad sheets becomes risky and time consuming.

To cope with such drawbacks, Hilti developed PROFIS Anchor Channel software. It is design technology that allows users to quickly and accurately model anchor channel systems. Through a simple, user-friendly interface, PROFIS Anchor Channel designs anchor fastenings for static and seismic applications in concrete, according to the most current building codes, approvals, and standards.

Hilti has continuously invested in PROFIS Anchor Channel over the last 8 years. It is an ever improving software for an ever changing market. PROFIS Anchor Channel is the simplest and safest way to design Hilti Anchor Channel Systems. Similar to the product, the software brings added value to the design community. The software is available for free and can be downloaded from Hilti’s website, and link below:


Innovate
- Portfolio of solutions for the most challenging applications.
- User-friendly interface to explore different design options.
- State of the art calculations.
- No design boundaries.

Optimize
- Find the most cost-effective solution for your project.
- Productivity increase; all failure modes checks in real time at the click of a button.
- Explore different bracket geometries for an optimum fixture and anchor channel design.

Comply
- Design models based on ICC ESR-3520, ACI 318, and/or AC232.
- Anchor channels tested according to AC232.
- Ensure general welfare.
- No more engineering judgments backed up by your P.E. license.

PROFIS ANCHOR CHANNEL SOFTWARE AT A GLANCE

- 3D graphics interface
- Anchor channels in seismic design category C,D, E, or F
- Load resolution at bolts and Torsional moments
- Instantly and automatically utilization updates
- Lightweight concrete
- Detailed analysis report
10.2 Download the Software

1. Open website and click on PROFIS Anchor Channel Software

2. Log in or register

Add to Cart
10.3 PROFIS ANCHOR CHANNEL TUTORIAL

10.3.1 CREATE A NEW PROJECT IN PROFIS ANCHOR CHANNEL

Region
Select the region to reflect the Imperial or Metric system and display available products in your region.

Design Standard
The software selects the default design standard of the selected region. The design standard can be changed depending on project’s requirements.

Choose a blank top or face of slab project, open an existing file, or open a saved template based on your most common conditions.

Select the appropriate design standard for your project.

10.3.2 PROFIS ANCHOR CHANNEL OVERVIEW

- QUICK ACCESS TOOLBAR
- RIBBON
- GRAPHICS/MODEL WINDOW
- ANCHOR CHANNEL AND T-BOLT SELECTION WINDOWS
- PRODUCT FILTER
- RESULTS WINDOWS
- ERROR MESSAGES, WARNINGS WINDOW
10.3.2.1 QUICK ACCESS TOOLBAR

- **a** Start window
- **b** New project
- **c** Open existing project
- **d** Save
- **e** Project Options
- **f** Design Report
- **g** Online Technical Library
- **h** PROFIS Rebar Online
- **i** PROFIS Anchor Software

**Start window**

**General**
- Allows changing the region without having to start a new project.

**Company details**
- Specifier information can be added. This information will be displayed in the final report.

**Workspace**
- Change program language
- Change PROFIS Anchor Channel Scheme

**Report options**
- Select report paper size of report
- Select report language

**Project options**

**Project details**
- Project information can be added. This information will be displayed in the final report.

**Company details**
- Specifier information can be added. This information will be displayed in the final report.

**Units**
- Select preferred units. The work space will be updated accordingly.

**Safety factors**
- For ACI based, the only two relevant fields are “weighted average load factor” and “Factor for serviceability crack width check”

**Weighted average load factor**
- Only applicable when HAC EDGE is used. Software checks if cracking of the concrete occurs at service levels and used this factor to unfactor the shear force.
- This factor shall be equal to the shear load factor. For instance, if ASCE 7-05 is used, this factor shall be equal to 1.6. If ASCE 7-10 is used, this factor shall be equal to 1/0.6 = 1.667

**Factor for serviceability crack width check**
- Select the required safety factor for serviceability crack width. Serviceability is typically checked using nominal strengths (1.0) at service loads. See section 9.6.2 for additional information.

**Always check for updates**
- Hilti is continuously adding new features to the software. Keeping the software updated allows you to take advantage of all the features the software has to offer.
10.3.2.2 BASE MATERIAL TAB

Concrete

If analysis indicates no cracking at service load levels, the use of uncracked concrete can be justified.

Cracked concrete
If analysis indicates cracking at service load levels.

All-lightweight concrete (ALWAC) $\lambda = 0.75$
San lightweight concrete (SLWC) $\lambda = 0.85$
See section 5.1.2 for additional information.

Base material
Select the concrete cylinder compressive strength of the substrate. Drop menu provides incremental of 1000 psi. For a specific cylinder compressive strength, click on “Customize” option and input the specific value.

Uncracked concrete

Cracked concrete

Supplementary reinforcement

Corner of Slab

- Activates pair of channels in a corner.
- Only symmetric corners are allowed. For unsymmetrical corners, use the highest loads.
- Analysis assumes both corner channels are loaded simultaneously.

Top of slab corner
Face of slab corner

Supplementary reinforcement

- Straight edge reinforcement
- Condition B Tension
- Condition B Shear
- Suppl. reinforcement

Edge reinforcement
When cracked concrete is selected, the existing reinforcement is taken into account for the Sl's modification factor for the concrete breakout strength of an anchor channel under shear loads.

Wc = 1 for anchor channels in cracked concrete with no supplementary reinforcement

Wc = 0.9 for anchor channels in cracked concrete with edge reinforcement of $\frac{1}{4}$ in (6.35 mm) or greater (5/8 in (15.9 mm) or greater (11.9 mm) or greater) placed at the top of the channel or the edge, and with the edge reinforcement enclosed in slabs with a diameter of $\frac{7}{8}$ in (22.2 mm) or greater (11.9 mm) or greater) spaced in slabs a minimum of 4 in (100 mm) maximum.

When uncracked concrete is selected, the positive effect of supplementary reinforcement is not considered.
Supplementary reinforcement

**Straight edge reinforcement**
- Condition B Tension
- Condition B Shear

**Tension - Condition A or Condition B factor**
Supplementary reinforcement acts to restrain the potential concrete breakout but is not designed to transfer the full design load from the anchor into the structural member. The presence of supplementary reinforcement has an impact on the $\phi$ factor of the concrete failure model.

Condition A:
- Applies where supplementary reinforcement is present, except for pull-out. For the supplementary reinforcement an explicit design is not required but the arrangement of the reinforcement should generally conform to that of the anchor reinforcement shown in Fig. RD.5.2.9 in the ACI 318-11 Appendix D.
- Concrete breakout $G = 0.70$
- Concrete side face breakout $\Phi = 0.75$

Condition B:
- Applies where supplementary reinforcement is not present.
- Pull-out $G = 0.70$
- Concrete breakout $G = 0.70$
- Concrete side face breakout $\Phi = 0.70$

**Shear - Condition A or Condition B factor**
Supplementary reinforcement acts to restrain the potential concrete breakout but is not designed to transfer the full design load from the anchor into the structural member. The presence of supplementary reinforcement has an impact on the $\phi$ factor of the concrete failure model.

Condition A:
- Applies where supplementary reinforcement is present, except for pull-out. For the supplementary reinforcement an explicit design is not required but the arrangement of the reinforcement should generally conform to that of the anchor reinforcement shown in Fig. RD.5.2.9 in the ACI 318-11 Appendix D.
- Concrete breakout $G = 0.70$
- Concrete side face breakout $\Phi = 0.75$

Condition B:
- Applies where supplementary reinforcement is not present.
- Concrete breakout $G = 0.70$
- Concrete side face breakout $\Phi = 0.70$

Inspection Type

**Periodic inspection**
- HBC-C-N $\rightarrow \phi = 0.55$
- HBC-T $\rightarrow \phi = 0.65$

**Continuous inspection**
- HBC-C-N $\rightarrow \phi = 0.65$
- HBC-T $\rightarrow \phi = 0.75$

In case of continuous inspection the value for $V_{sl,x}$ for the size M12 can be taken for all channel sizes HAC-40F through HAC-70 F as $V_{sl,x} = 2,021$ lb (9.0 kN).

10.3.2.3 ANCHOR PLATE

**Anchor reinforcement**

Anchor reinforcement precluded concrete breakout. See sections 7.3 and 7.4 for additional information.

**Fastening group**

This feature adds another bracket to the anchor channel. Although the analysis assumes the brackets are loaded simultaneously, the configuration and loads can be different.
Anchor reinforcement

Top and face of slab brackets

- Removes bracket; allows to input loads on the t-bolts
- Inserts flat plate

Face of slab brackets

Anchor plate thickness

- Select plate/bracket thickness

Stand-off installation

- No stand-off
- Stand-off installation with clamping
- Stand-off installation with grouting
- Stand-off installation with bracket support

10.3.2.4 BOLT LAYOUT

Bolt layout

- Select number of t-bolts (8 maximum per bracket)
- Asymmetric position of bracket and t-bolts
- Channel filling with HIT-HY 100 allows to “lock” the t-bolts in position and transfer longitudinal forces.
- Filling of the channel with HI-HY 100 is NOT needed to transfer longitudinal forces if HBC-C-N or HBC-T are used.
10.3.2.5 STEEL PROFILE

<table>
<thead>
<tr>
<th>Base material</th>
<th>Anchor plate</th>
<th>Bolt layout</th>
<th>Steel profile</th>
<th>Loads</th>
<th>Calculation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height:</td>
<td></td>
<td></td>
<td>Steel profile</td>
<td></td>
<td>X-direction</td>
<td>0 in</td>
</tr>
<tr>
<td>Width:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y-direction</td>
<td>0 in</td>
</tr>
</tbody>
</table>

Steel profile allows adding a profile to the bracket. This is an aesthetics feature. It does not impact the design nor does it add load eccentricities.

Feature only available with a base plate.

10.3.2.6 LOADS

Strength Design according to ACI 318-11

Input loads

Allows the user to input the loads in a tabular format, rather than utilizing the workspace model. Applied loads shall be Strength Level (LRFD factor – design loads).

Tolerance

This field allows to select the left and right tolerance of the t-bolts along the anchor channel. PROFIS Anchor Channel looks for the t-bolt(s) position along the anchor channel that yields the highest utilization, unless selected otherwise.

Tolerance: +/- 0 in

Analysis based on the nominal t-bolt location.

Tolerance: +/- ch. Length

Analysis based on the t-bolt location along the channel that yields the highest utilization.

Select static design if applied loads are static loads.

Select this option when designing per ACI 318-11 if anchor design included earthquake forces for attachment into structures assigned to Seismic Design Category C, D, E or F. Refer to the model code ACI 318-11 for specific seismic parameters.

See section 7.6 of this brochure for additional information.
10.3.2.7 RESULTS

**Design report**
- Select report type; detailed or short report
- Select t-bolt length
- Project details and company details will be printed in the report header.
- Select report options

**Specification (PROFIS BIM/CAD Library)**
- Click on PROFIS BIM/CAD Library and it will direct you to the page shown below
- Drag figure to the selected program (i.e. AutoCAD)
Technical information

- Takes you to the only Hilti technical library page

10.3.2.8 VIEW

<table>
<thead>
<tr>
<th>Base material</th>
<th>Anchor plate</th>
<th>Shift layout</th>
<th>Steel profile</th>
<th>Loads</th>
<th>Calculation</th>
<th>Result</th>
<th>View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation</td>
<td>2D-view</td>
<td>2D-view</td>
<td>2D-view</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Filter and Results windows
- Rotate, zoom, or select a 2-D view
- Show or hide Filter and Results windows
- Show or hide various items in the graphics window
- Transparent view of base material can be selected

10.3.3 GRAPHICS/MODEL WINDOW

Substrate, bracket geometry and configuration can be adjusted in the workspace/model window

Zoom in and zoom out

Zooming in and zooming out can be easily achieved by scroll up (zoom in) or down (zoom out) using the scroll wheel of the mouse.

Rotate the view around the vertical axis

Right click (hold it) and move the mouse left (rotates clockwise) and right (rotates counter-clockwise). The model will rotate around the vertical axis.

Rotate the view around the horizontal axis

Right click (hold it) and move the mouse up or down. The model will rotate around the horizontal axis.

Move the view along the horizontal axis

Left click (hold it) and move the mouse left and right. The model will move along the horizontal axis.

Move the screen in and out

Left click (hold it) and move the mouse up and down. The model will zoom in and out.
10.3.4 ANCHOR CHANNEL AND BOLT SELECTOR WINDOW

**Step 1: Anchor channel type**
Select the desired anchor channel type

- **Top of slab applications**
  - Anchor channel type
  - Anchor channel size and profile type
  - Anchor channel length
  - Anchor channel effective embedment depth
  - Number of anchors
  - Distance from end of channel to first anchor
  - Usable anchor channel length
  - T-bolt type, steel grade, and steel grade

- **Face of slab applications**
  - Anchor channel type
  - Anchor channel size and profile type
  - Anchor channel length
  - Anchor channel effective embedment depth
  - Number of anchors
  - Distance from end of channel to first anchor
  - Usable anchor channel length
  - T-bolt type, steel grade, and steel grade

**Step 2: Anchor channel size and profile type**
Select the desired anchor size and profile type; smooth lips (HAC) or serrated lips (HAC-T)

- Anchor channels for top of slab applications
  - Anchor channel type
  - Anchor channel size and profile type
  - Anchor channel length
  - Anchor channel effective embedment depth
  - Number of anchors
  - Distance from end of channel to first anchor
  - Usable anchor channel length
  - T-bolt type, steel grade, and steel grade

- Anchor channels for face of slab applications
  - Anchor channel type
  - Anchor channel size and profile type
  - Anchor channel length
  - Anchor channel effective embedment depth
  - Number of anchors
  - Distance from end of channel to first anchor
  - Usable anchor channel length
  - T-bolt type, steel grade, and steel grade

**Step 3: Anchor channel length**
Select the desired anchor channel length. Standard anchor channel configurations (standard lengths with fixed number of anchors) are given in PROFIS Anchor Channel.

- “User defined” allows users to input a custom channel length using the least possible number of anchors without exceeding the maximum allowable anchor spacing. Contact Hilti for custom configurations.

**Notes**
- Anchor channels for top of slab applications can be used in face of slab applications and vice-versa.
- Anchor channels for top of slab applications
  - Anchor channels for face of slab applications

**Example**
- Anchor channel configuration: HAC-70 CRFoS U
  - Anchor channel type: HAC
  - Anchor channel size and profile type: CRFoS
  - Anchor channel length: 70
  - Anchor channel effective embedment depth: 3
  - Number of anchors: 5
  - Distance from end of channel to first anchor: 1
  - Usable anchor channel length: 67
  - T-bolt type: CR, steel grade: S

**Terminology**
- The term after the length (i.e. + 3) indicates the number of rebars.
Step 4: Anchor channel embedment depth

Select the required anchor size and profile type; smooth lips (HAC) or serrated lips (HAC-T).

Two different effective embedment depths are offered for HAC-50 only. The 3.701 effective embedment depth allows HAC-50 to be used in a 4" slab.

Smooth channel lips

Serrated channel lips

Step 5: T-bolt type, steel grade, and steel grade

Select the required anchor size and profile type; smooth lips (HAC) or serrated lips (HAC-T).

Step 6: T-bolt diameter

Select the required t-bolt diameter

10.3.5 PRODUCT FILTER

Product filter simplifies the anchor channel system portfolio
10.3.6 RESULTS WINDOW

Results window provides real-time utilization.

10.3.7 ERROR MESSAGES, WARNINGS WINDOWS

Error messages, warnings windows provide information about applications where the configuration does not meet the minimum requirements (i.e., minimum edge distance, minimum member thickness, minimum bolt spacing) or configurations that are not recommended (i.e., unstable configuration, longitudinal loads without HBC-C-N, serrated channels or grouting of the anchor channel).

This window also provides fixes for errors.
This chapter provides best practices for cast-in anchor channels. It provides some additional information for designers, reviewers, installers, and inspectors. The ultimate goal is to allow for the most model code-compliant, feasible solution, based on the project’s schedule.

11. BEST PRACTICES

11.1 MODEL CODE COMPLIANCE

Introduction

Building codes are series of regulations, co-created by politicians and building professionals. Building codes govern the design, construction, repair or alteration and general maintenance of buildings. The main purpose of building codes are to protect public health, safety, and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority.

Depending on the project, building codes may be enforced at the international, federal, state, and/or local levels. Municipalities can adopt building model codes set forth by the model code, the International Building Code (IBC).

The concrete chapter of the International Building Code, references ACI 318 Building Code Requirements for Structural Concrete, the standard for concrete design and construction. ACI 318-11 Appendix D and ACI 318-14 Ch. 17 provide design requirements for anchors in concrete used to transmit structural loads by means of tension, shear, or a combination of tension and shear between (a) connected structural elements; or (b) safety-related attachments and structural elements.

11.1.1 DESIGN OF SPECIALTY INSERTS

IBC 2012 1909

Anchorage to concrete — Strength Design

1909.1 Scope. The provisions of this section shall govern the strength design of anchors installed in concrete for purposes of transmitting structural loads from one connected element to the other. Headed bolts, headed studs, and hook (J-or-L-) bolts cast in concrete and expansion anchors and undercut bolts cast in concrete and expansion anchors and undercut anchors installed in hardened concrete shall be designed in accordance with Appendix D of ACI 318 as modified by Section 1905.1.9 and 1905.1.10, provided they are within the scope of Appendix D.

The strength design of anchors that are not within the scope of Appendix D of ACI 318, and amended in Sections 1905.1.9 and 1905.1.10, shall be in accordance with an approved procedure.

Approved: Acceptable to the building official or authority having jurisdiction.

Building Official: The officer or other designated authority charged with the administration and enforcement of this code, or a duly authorized representative.

104.1 General. The building official is hereby authorized and directed to enforce the provisions of this code. The building official shall have the authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be compliance with the intent and purpose of this code. Such policies and procedures shall not have the effect of waiving requirements specifically provided for in this code.

104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or methods of construction shall be approved where the building official finds that the proposed design is satisfactory and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

104.11.1 Research reports. Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from approved sources.

104.11.2 Tests. Whenever there is insufficient evidence of compliance with the provisions of this code, or evidence that a material or method does not conform to the requirements of this code, or in order to substantiate claims for alternative materials or methods, the building official shall have the authority to require tests as evidence of compliance to be made at no expense to the jurisdiction. Test methods shall be as specified in this code or by other recognized test methods, the building official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the building official for the period required for retention of public records.
Cast-in anchor channels systems are slotted connections consisting of a steel channel, anchor element, and matching t-bolts. Therefore, anchor channel systems are considered specialty inserts.

Specialty inserts are excluded from the Anchoring to Concrete provisions of ACI 318. Acceptance Criteria 232 (AC232) was developed to show anchor channels systems for recognition under the IBC. AC232 provides testing and design guidelines for cast-in-anchor channel systems. Although, specialty inserts are not within the current scope of ACI 318, AC232 Section 3.0 Design Requirements provides recommended additions to the ACI 318 anchor to concrete provisions that permit the design of anchor channel systems as if they were included in AC 318.

AC232 removes the boundaries of manufacturers technical data and limitations of testing data. Additionally, it takes into consideration additional design parameters that have not been neglected in the past such as cracked concrete, supplementary reinforcement, anchor reinforcement, 95 percent fractile, member thickness, etc.

Anchor channel design in accordance to an ICC-ES Acceptance Criteria will help show compliance with the model code. It protects public health, safety, and general welfare. When the design is model code compliant reduces the risk of delays or job site shut downs due to noncompliant designs.

Only anchor channels with rounded headed anchors or I anchors and straight deformed bars are covered by AC232. Therefore, only HAC can be shown compliant with an ESR. However, there are still applications that require the use of anchor channels not fully covered by AC232, such is the case of HAC CRFoS U and HAC EDGE.

For applications outside the scope of AC232, Hilti has developed design models based on applicable testing protocols and design provisions of AC232. For failure modes outside the scope of AC232 (i.e. pullout strength of a rebar), the principles of AC232 and ACI 318 are followed.

AC232 is a relatively new acceptance criteria. Seismic provisions were only added in 2015. The long term goal is to provide a work frame that covers all applications encountered in a project and anchor channels needed to meet the required design parameters.
11.2.2 HAC VS HAC-T PRICE INDEX

Figure 11.2.1 — Price index of HAC and HBC

Figure 11.2.2 — Price Index of HAC and HAC-T
11.2.3 ANCHOR CHANNEL SELECTION USING PRICE INDEX CHARTS — EXAMPLE

**Step 1 Original layout**

The plan view below illustrates the original anchor channel recommendations for the typical, corner zones, and jamb conditions of a building. Curtain wall façade is present on the south side of the building. Recommendations are as follows:

- **Typical zone:** HAC-40 91/350 F with (2) HBC-C 8.8 F M12x60 @ 6” O.C.
- **Corner Zone:** HAC-50 106/300 F with (2) HBC-C 8.8 F M12x60 @ 6” O.C.
- **Jamb:** HAC-50 106/300 F with (2) HBC-C 8.8 F M12x60 @ 6” O.C.

![Figure 11.2.3.1 Embed layout, plan view](image)

**Step 2 Check HAC index chart**

Based on the price scale chart, HAC-50 106/300 F (unit value ≈ 0.24) is a more feasible solution than HAC-40 91/350 F (unit value ≈ 0.26).

![Figure 11.2.3.2 Price index](image)

**Step 3 Check structural feasibility for the more feasible solution**

- Check structural suitability of HAC-50 106/300 F at typical conditions.

**Additional feedback:**

- The use of a bigger channel profile does not always mean a more expensive solution. There are other factors such as number of anchors, type of anchor, economies of scale, etc. that may impact pricing.
- The use of a bigger channel profile only indicates a profile with higher steel strengths. There are other failure modes that may be decisive and are influenced by the number of anchors and bolt spacing.
- It is always good practice to ensure the specified product will meet the project’s schedule. For typical anchor channel lead times, see section 2.4.

**Step 4 Check if the more feasible makes sense.**

- HAC-50 106/300 F is structurally adequate at typical, corner zones, and jamb conditions. It is also a more feasible solution than HAC-40 91/350 F.
- Using one channel for the entire south face of the building simplifies the anchor channel installation as it reduces the probability of installation errors. Therefore, change HAC-40 91/350 F to HAC-50 106/300 F.

**Note:** Sometimes, selecting for a more feasible solution for a specific condition may not be practical. Check if the savings justify the potential embed layout complexities.

**Step 5 Original layout**

Change original recommendations for the original typical conditions. Use HAC-50 106/300 F at the typical and corner zone conditions.

![Figure 11.2.3.3 Optimized embed layout, plan view](image)
11.3 HAC DESIGN OPTIMIZATION

Introduction

For projects where thousands of conditions are covered by one anchor channel type, using a $15 vs $18 dollar solution could ultimately bring significant cost savings. This section provides work-arounds to help designers optimizing the anchor channel selection without having to select a more expensive anchor channel. The guidelines or work-arounds discussed in the next section require minimum impact to the design and it is generally acceptable. Always evaluate the overall cost of each solution considering the entire requirements of the entire system.

The following recommendations are intended to be used when the anchor channel is over utilized up to 10%-15%, with minimum or no impact to the fixture and without change the substrate conditions (i.e. using stirrups, supplementary reinforcement, increasing edge distance, etc.) The logical option is always using a bigger channel (except when HAC-70 is the channel under consideration) and therefore, this option is never discussed in the next guidelines.

General guidelines

• Increasing t-bolt spacing helps to distribute the load amongst the anchors more efficiently. When the channel is slightly overutilized, consider increasing bolt spacing to reduce the acting loads at the critical anchor, reducing the overall utilization in the most utilized anchors.

• Depending on the design parameters and application type, utilizations exceeding the 100% utilization by 3% may be acceptable.

• If concrete interaction yields utilizations within 110% for static loads, try using ACI 318 interaction equations for concrete. This is only valid for concrete and for failure modes cover by ACI 318 or AC232.

• When channel lip or anchor-channel connection exceeds the utilization, consider adding a bolt with smaller channel rather than increasing channel size.

• Price difference between M12 and M16 bolts is minimum. Try to avoid combining different t-bolt sizes ease installation.

• Closer edge distances do not always mean higher utilizations, if the back-span or prying leg is increased. The concrete strength may be reduced but the acting loads at the t-bolts may be reduced by a larger value.

• Consider the HAC Price index, specially at the typical conditions.

• Brackets may be wide enough to allow increasing the t-bolt spacing and use a more feasible channel.

• Brackets may provide enough room to reposition the slotted hole in order to increase the edge distance or reduce the wind load eccentricities, without the need of creating a new die.

• Check structural drawings to verify if supplementary reinforcement (i.e. straight edge reinforcement or Condition A) can be assumed.

11.3.1 WORK-AROUND IN TENSION

Concrete: Concrete breakout, $\Phi_{N_{b,c}}$
Pullout, $\Phi_{N_{p}}$
Blowout, $\Phi_{N_{b}}$

Steel: Anchor $\Phi_{N_{a}}$
Connection anchor-channel, $\Phi_{N_{c}}$

WORK-AROUND: SPREAD THE LOADS AMONGST THE ANCHORS IN A MORE EFFICIENT WAY.

Increasing the bolt spacing is possible when the bracket allows (i.e. J-hook type bracket). Also, consider the cost difference between using a bigger channel size versus increasing the width of the bracket.

By increasing the t-bolt spacing, the loads are redistributed amongst the anchors in a more efficient way. Thus, reducing the acting loads at the critical anchor. Figure 11.3.1.1 illustrates this concept. Left side of Figure 11.3.1.1 has a relatively small t-bolt spacing. Therefore, t-bolt 1 and t-bolt 2 transfer most of the loads to the center anchor. Right side of figure 11.3.1.1 has the same configuration but with increased t-bolt spacing. As a result, the loads at the center anchor are significantly reduced.

Figure 11.3.1.1 optimization of load distribution from t-bolts to anchors
Example

As-is
Design status: Not ok
Anchor channel: HAC-50 106/300 F
Utilization: 107%
Bolt spacing: 5.00"  
Anchor channel Price Index: 0.24

Solution option 1: use HAC CRFoS U
Design status ok
Anchor channel: HAC-50 356/300 F CRFoS U
Utilization: 64%
Bolt spacing: 5.0"
Anchor channel Price index: 0.51

Solution option 2: use longer HAC with increased bolt spacing
Design status ok
Anchor channel: HAC-50 106/450 F
Utilization: 100%
Bolt spacing: 7.125"
Anchor channel Price Index: 0.335

Conclusion:
Solution option 2 provides a price differential index of 0.175 (0.51-0.335). This is roughly 73% on HAC savings by just increasing the t-bolt spacing by 2.125! 

Bending of channel, $\Phi_{M_{b,\text{flex}}}$

WORK-AROUND: INCREASE T-BOLT SPACING OR REDUCE ANCHOR SPACING

Flexure of the anchor channel is another failure mode where the resistance is derived via testing and cannot be increased. However, the applied flexural forces can be reduced by increasing the t-bolt spacing or reducing the anchor spacing.

The applied bending moment at the channel is derived under the simplified model where the channel profile is treated as a simple supported beam, with a span equal to the anchor spacing.

See price index to determine if it is more feasible to use a bigger anchor channel or to add an anchor.

Channel lip, $\Phi_{N_{sl}}$

WORK-AROUND: ADD A T-BOLT, ADD AN ANCHOR OR INCREASE T-BOLT SPACING

The channel lip strength is a value derived via testing. The design strength of the channel lip may be reduced if the t-bolt spacing spaced closely is less than 2 times the width of the channel profile, (2bch) and are loaded simultaneously (in tension).

One of the 5 interaction equations requires the verification of the channel lip in tension combined with the flexural strength of the channel profile. The applied bending moments can be reduced by reducing the anchor spacing.

The work around for applications where the channel lip strength is not adequate is adding a t-bolt or increasing the t-bolt spacing. This is generally acceptable at corner conditions. For typical conditions, adding a t-bolt may have the same cost as going to a bigger channel size. For other applications, the use of a bigger channel profile may be required.
Optimize fixture

REPOSITION SLOTTED HOLE TO INCREASE BACK-SPAN AND REDUCE WIN LOAD ECCENTRICITIES

Oftentimes, a minor modification to the location of the slotted hole, without requiring a new die may help saving thousands of dollars.

Nominal bracket and WL information

- \( x_1 = 2.5 \text{ in.} \)
- \( e_{WL} = 2.5 \text{ in.} \)
Slotted hole allows for \( \pm 1^{\circ} \) up and down tolerance

Additional information

- \( c_a = 3.5 \text{ in.} \)
- WL = 3500 lb (factored)
  (only will load is applied, for illustration purposes)
- Concrete compressive strength = 4,000 psi

Assume (2) t-bolt spaced at 6’ O.C.

For analysis purposes, the critical bracket position is down. Therefore, for analysis purposes, the \( x_1 \) value is reduced by 1 in. while the \( e_{WL} \) is increased by 1 in.

**Nominal Dimensions**

**Bracket Down Dimensions**

- \( x_1 = 1.5 \text{ in.} \)
- \( e_{WL,1} = 3.5 \text{ in.} \)

HAC-60 148/300 F with (2) HBC-C 8.8F M16x60 yields a utilization of 100%. Concrete breakout in tension is the governing failure mode.

In summary, the nominal dimensions need to be manually adjusted to account for the critical bracket position.

HAC-60 148/300 F with (2) HBC-C 8.8F M16x60 yields a utilization of 100%. Concrete breakout in tension is the governing failure mode.

**Optimized fixture: move the anchor channel and the slotted hole 1 in. down.**

The figure below (left) shows the original configuration; the anchor channel has an edge distance (cat) equal to 3.50 in. The right figure shows the new anchor channel location; the edge distance is equal to 4.50 in.

Note that the overall bracket geometry has not been changed. Moreover, the position of the ‘J’ bracket does not change neither.

**Optimized fixture**

**Nominal Dimensions**

**Bracket Down Dimensions**

- \( x_2 = 3.5 \text{ in.} \)
- \( e_{WL,2} = 1.5 \text{ in.} \)

Edge distance, \( c_{a1} = 4.50 \text{ in.} \)

HAC-40 91/300 F with (2) HBC-C 8.8F M16x60 yields a utilization of 94%. Connection anchor-channel is the governing failure mode.
11.4 CAST-IN ANCHOR CHANNEL LAYOUT

Introduction
AC232 brought major benefits to the design community. One of the major benefits is that it removed the limitations bounded by relying on test data only. AC232 provides design guidelines for anchor channels. Having model code compliant design provisions ensures the levels of reliability of the system are met. Safety factors are generally not established via manufacturers but manufacturers follow the IBC.

The publication of AC232 allows for account design provisions that were neglected in the past. Design considerations such as 5 percent fractile, cracked concrete, seismic detailing are common examples. As the industry continues to evolve, s.

11.4.1 ANCHOR CHANNEL LAYOUTS

Ideal layout:
The most cost effective practical layout is having one anchor channel type covering all typical intermediate applications and one anchor channel type covering the corner zones. A third anchor channel type is typically introduced at corner conditions. In an ideal world, this is the perfect layout.

Ideal layout for face of slab applications:
The added benefit of HAC CRFoS U is that it can be used at intermediate applications and corners. Therefore, the anchor channel selection can be reduced to two different anchor channels.

Composite slabs with lightweight concrete:
For applications where the substrate is thin (thinner at pocket zones) and lightweight concrete is used, an anchor channel with rebars (HAC CRFoS U or HAC EDGE) is typically required even at the typical intermediate conditions. For these type of projects, one anchor channel type suitable for the typical intermediate and corner zones simplifies the installation of the anchor channels on the jobsite.

Non-traditional wind pressure distribution:
In some cases, the wind pressures acting at the façade may not allow for an optimum layout. These critically loaded conditions typically occur in less than 5% of the applications. Although introducing additional anchor channel will require additional coordination, these critically loaded areas may require customized solutions that using them throughout the entire strip will considerably increase the cost of the anchor channel.

Bring it all together:
The Hilti Anchor Channel Systems have been engineered keeping ease of installation at its root. It offers a gradual increase in performance while maintaining one t-bolt type compatible with all HAC-40 to HAC-70 channel profiles.

HAC CRFoS U which are commonly used at corner zones in face of slab applications can also be used at the corners. This is one less channel type to worry about.

HAC EDGE comes with the right edge distance simplifying even further its installation while minimizing the probability of installing the product at the right edge distance.

Some layouts cannot be idealized and there are always conditions that may require unique-custom solutions. This section provides different layout and the fundamentals can be applied to your unique project.
11.5 SUBSTRATE CONSIDERATIONS

11.5.1 COMPOSITE SLABS

Composite slabs are one of the most common methods of steel frame floor construction; therefore, it is common substrate for anchor channels. Naturally, the use of anchor channels in composite slabs may bring additional challenges, especially for applications where anchor channel with rebar anchors or shear confinement plate is required.

Addressing the following potential conflicts before installation of the anchor channel system takes place may avoid issues, field fixes, and speed up the installation. Moreover, each condition can be evaluated based on actual conditions.

POTENTIAL CONFLICTS ARE AS FOLLOWS:

- Clashing of rebar with column
- Clashing of rebars with metal deck
- Corner conditions at corner columns
- If rebars extend into the deck, check adequacy of rebar cover.

11.5.2 ALL-LIGHTWEIGHT CONCRETE VS SAND-LIGHTWEIGHT CONCRETE

ACI 318 and AC232 provide a modification factor for lightweight concrete (λ). Light weight concrete is sub-classified into two types: all-lightweight concrete and sand-lightweight concrete. The modification factor for all-lightweight concrete is equal to 0.75 while the modification for sand-lightweight concrete is equal to 0.85.

The use of lightweight concrete in composite slabs is quite common. Generally speaking, anchor channels are constrained by the strength of the concrete. Lightweight concrete is commonly specified for composite slabs. Hence, the concrete strength due to an anchor channel is constrained even further. It is always a good practice to verify the type of concrete specified in the project. On one hand, simply assuming sand-lightweight concrete can result in unconservative results. On the other hand, assuming all-lightweight concrete when sand-light weight concrete is present can yield to more expensive designs.

Chapter 5 (Base Material) provides additional information about all-lightweight concrete and sand-lightweight concrete. Determining what type of lightweight concrete use can present a challenge, as this information is not clearly specified all times.

<table>
<thead>
<tr>
<th>ASTM concrete type</th>
<th>Aggregate grading specification</th>
<th>Concrete unit weight pcf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal-weight</td>
<td>Fine: ASTM C33</td>
<td>145-155</td>
</tr>
<tr>
<td></td>
<td>Coarse: ASTM C33</td>
<td></td>
</tr>
<tr>
<td>Sand-lightweight</td>
<td>Fine: ASTM C33</td>
<td>105-115</td>
</tr>
<tr>
<td></td>
<td>Coarse: ASTM C330</td>
<td></td>
</tr>
<tr>
<td>All-lightweight</td>
<td>Fine: ASTM C330</td>
<td>85-110</td>
</tr>
<tr>
<td></td>
<td>Coarse: ASTM C330</td>
<td></td>
</tr>
</tbody>
</table>

Determination of lightweight concrete type

1) Check General Notes of project’s structural drawings.
2) Check concrete specifications of the project.
3) Reach out to the structural engineer of records for confirmation.

If there is project where there no enough evidence to support the use of sand-lightweight concrete for design purposes of the cast-in anchor channel, always assume all-lightweight concrete, as this is always the most conservative choice.
11.5.3 POST-TENSIONED SLABS

Clashing between embeds and post-tensioned tendons are often overlooked. Clashing between post-tensioned tendons and anchor channels tends to be a common type of field issue. It is always a good practice to coordinate the curtain wall anchorage and posttensioned cables layout, in order to avoid last minute remediations.

Current model codes provide minimal guidance to account for the influence of post-tensioned cables on anchors. The use of cast-in anchor channels in post-tensioned slabs is ideal since compared to other anchoring technologies such as post-installed anchors, it does not require drilling. However, additional measurements need to be taken to ensure the concrete is not overstressed and the concrete capacity of the anchor is not overestimated.

Generally, if the live or dead end of the tendon does not induce additional stresses in the anchorage zone, the capacity of the anchor can be predicted based on applicable anchoring-to-concrete provisions. The anchorage zone of an anchor (concrete volume due to projected area) can be predicted by idealizing the failure planes in shear and tension.

11.5.4 UNCRACKED CONCRETE

Per ACI 318-14, anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, the modification factors for uncracked concrete can be applied. Figure 11.5.4.1 illustrates compression zones in different concrete structures.

11.5.5 CONCRETE CURB

Although concrete curbs tend not to be the predominant condition, it is a typical condition encountered in buildings and presents additional challenges on its own such as reduced geometrical parameter and lower concrete compressive strengths. The following best practices can help to ease the design, approval process, and minimize field fixes.

1) Always verify the concrete compressive strength as it typically different from the slab or beam which is connected to.

2) Design of anchors is limited to the anchor design. Therefore, its design verifies the adequacy of the concrete at a local level; it ensures the concrete can take resist the applied loads. If a cold joint between the main structure and concrete curb is present, ensure there is proper load transfer between both structures. Additional reinforcement may be required.

3) For installation purposes of top of slab applications, it is recommended to leave exposed areas in front and behind the channel to ensure proper concrete compaction and inspection as air pockets tends to be a common field issue in this type of configurations.
11.5.6.4 CONCRETE CONSOLIDATION

The combination of new construction practices, new technologies, and more sophisticated designs is allowing for the construction of buildings in record times. Spans get longer, columns get smaller, slabs get thinner, and lighter construction materials are used. As a result, the construction process has become more complex and best practices have evolved to solve the disputes of modern business. A common field issue encountered in building construction is the formation of air pockets (entrapped air) in the concrete at the anchorage zone.

Air pocket formation occurs due to improperly or no concrete consolidation. Repairing cured concrete with entrapped air is time-consuming, tedious, and can turn out to be quite expensive. Adopting best practices to ensure proper concrete consolidation is performed at the anchorage zone is one of the most effective ways to minimize field issues due to improper concrete consolidation. A couple of extra seconds at each connection point can pay dividends, avoid additional coordination and additional work to an already complex and fast-track work environment where the project’s schedule leaves room for a minimal margin of error.

Proactivity goes a long way. Implementing best practices that ensure adequate concrete consolidation will ensure the anchorage will perform the way it was designed. During pre-construction meetings, emphasize the importance of adequate concrete consolidation at the anchorage zone, especially if the cast-in-anchor is near a confined space or congested zone. Try it out in your next project!

Purpose of Concrete Consolidation

Concrete consolidation helps avoid air pocket formations, honey combs, and removes the entrapped air in the concrete. Adequate concrete consolidation helps ensure the concrete will reach its designed properties as well as helping the concrete reach its designed strength. Moreover, adequate concrete consolidation helps enhance the bond of the concrete with the reinforcing bars and increases the general durability of the concrete. Finally, it helps decrease the permeability and helps minimize its shrinkage and creep characteristics. Figure 11.5.6.4 provides pictures of jobsites with proper concrete consolidation at the anchorage zone.

Concrete Consolidation

Concrete consolidation is defined as the process of removing entrapped air from freshly placed concrete. Several methods and techniques are available, the choice depending mainly on the workability of the mixture, placing conditions, and degree of air removal desired. Some form of vibration is usually employed (1).

The Process of Concrete Consolidation

Although there are different ways to consolidate the concrete, the most effective way to remove entrapped air is vibration. Vibration consists of subjecting freshly placed concrete to rapid vibratory impulses which liquefy the mortar and significantly reduce the internal friction between aggregate particles (1). Figure 11.5.6.5 illustrates a construction member vibrating the concrete at the anchorage zone using a standard immersion vibrator.

Consolidation via standard immersion vibrators is best described as consisting of two stages — the first comprising subsidence or slumping of the concrete, and the second a de-aeration (removal of entrapped air bubbles). The two stages may occur simultaneously, with the second stage underway near the vibrator before the first stage has been completed at greater distances (2). Figure 11.5.6.6 illustrates the two-stage process to best consolidate concrete. If in doubt, always err on the side of more vibration.

Per ACI 309R-05, the procedure for internal vibration shall be as follows (1):

- Concrete should be deposited in layers compatible with the work being done.
- The maximum layer depth should be limited to 20”.
- The depth of the layer should be nearly equal to the vibrator head length.
- The layer should be as level as possible so that the vibrator is not used to move the concrete laterally, as this could cause segregation.
- The vibrator should be systematically inserted vertically at a uniform spacing over the entire placement area.
- The distance between insertion should be approximately 1-1/2 times the radius of influence and should be such that the area visibly affected by the vibrator overlaps the adjacent just-vibrated area.

Figure 11.5.6.1 — Pictures of Conditions with Improper Concrete Consolidation at the Anchorage Zone.

Concrete

Concrete is the combination of four basic components:
- Water
- Cement
- Sand (small aggregate)
- Rock (large aggregate).

When mixed together, hydration, or curing, occurs, where the cement paste acts as a glue binding all of the surrounding aggregates. When concrete is poured, it contains entrapped air. If the entrapped air is not removed and the concrete is hardened in this way, it will negatively impact the expected properties of the concrete. Moreover, it will create serviceability, esthetics, and other issues such as subsidence cracking, and placement lines (1).

Vibrating concrete (right side)

Figure 11.5.6.2 — Loss of Concrete Compressive Strength Through Increase in Entrapped Air (2).

Figure 11.5.6.3 — Pouring and Vibrating Concrete at the Edge of the Slab.

Figure 11.5.6.4 — Pictures of Conditions with Proper Concrete Consolidation at the Anchorage Zone.

Figure 11.5.6.5 — Construction Member Vibrating the Concrete at the Anchorage Zone.
MINIMIZING FIELD FIXES OF CAST-IN ANCHORS

Depending on the amount of entrapped air, the field fix for the anchorage may vary from a simple patch with high strength non-shrinkable grout, installing post-installed headed rebars, or re-pouring a large amount of concrete. The field fix becomes more cumbersome and costlier for areas where anchors are highly loaded and reinforcing bars are used.

To avoid/minimize the number of conditions with entrapped air at the anchorage zone, be proactive. During pre-construction meetings, discuss the following with the concrete contractor:

a) Require concrete consolidation at each anchorage point (the GC will thank you later). Add extra emphasis on heavily reinforced zones, congested areas, confined spaces, areas with minimum reach, and zones where the formwork prevents visibility.

b) Share the best practices and make sure the field personnel know to consolidate the concrete.

References:
1) Guide for Consolidation of Concrete, ACI 309 R-05
2) Cement Concrete and Aggregates Australia 2006 Compaction of concrete (Australia) 1-7
4) The Why and how of consolidating concrete, by Bruce A. Suprenant

11.6 ANCHOR CHANNEL SPECIFICATIONS

Specifier Note: This specification is intended to address the use of cast-in anchor channel for safety-related applications, such as structural connections, earthquake bracing, guard rails, mechanical and electrical equipment support, piping and ductwork support and bracing, cladding, and façade connections, or rebar doweling.

PART 1 — GENERAL

1. SUMMARY

A. Supply of anchor channels used to connect construction members

Specifier Note: Revise paragraph below to suit project requirements. Add/delete section numbers and titles per project requirements and specifier’s practice.

B. Related Sections:

1. Concrete
2. Concrete Accessories
3. Precast Concrete
4. Masonry Accessories
5. Stone
6. Metal Fabrication
7. Curtain Wall and Glazed Assemblies
8. Tunnel Construction

11. TECHNICAL INFORMATION

11.6 ANCHOR CHANNEL SPECIFICATIONS

Specifier Note: Insert appropriate section for the project as referred to below for shop drawings or submittals.

A. General: Submit in accordance with Conditions of the Contract and Division 1 Submittal Procedures Section.

1. Product Data: Submit size and strength capacity information for each anchor channel profile specified in the contract drawings
2. Shop Drawings:

B. Placement Drawings: Submit drawings showing the anchor channel layout and locations required.

C. Structural calculations: Submit manufacturer-provided technical manual and calculation software based on internationally recognized design provisions as referenced in section 1.01 to support the Project Engineer in designing the anchor channels.

1. Submit an evaluation report demonstrating compliance with the 2012 or later International Building Code for cast-in-channel used to resist loading in three load directions

a) Tension load
b. Shear load (perpendicular to the channel axis)
c. Longitudinal load (parallel to the channel axis)

Samples: Representative length and diameters of each type anchor channel shown on the drawings.

Quality Assurance Submittals:
- ICC-ES Evaluation Report showing conformance with current applicable ICC AC232 Acceptance Criteria
- Certificate of Compliance showing compliance of the anchor channel to manufacturer’s published technical specifications
- Manufacturer’s installation instructions

3. QUALITY AND ASSURANCE

A. Manufacturer must have experience in anchoring technology.
B. Manufacturer shall follow a documented quality assurance program and be ISO 9001 and ISO 14001 certified.
C. Manufacturer’s published anchor channel strengths to be confirmed by an independent third party testing agency.
D. Certifications: Unless otherwise authorized by the Engineer, anchor channels shall have one of the following certifications:
   1. ICC-ES Evaluation Report showing conformance with current applicable ICC AC232 Acceptance Criteria
   2. Certificate of Compliance showing compliance of the anchor channel to manufacturer’s published technical specifications

4. DELIVERY, STORAGE AND HANDLING

A. Anchor channels and accessories must be packaged appropriately to help prevent loss or damage during transport
B. All materials received on the jobsite must be stored in a secure and dry location prior to installation

PART 2 — PRODUCTS

1. MANUFACTURERS

Cast-in Anchor Channels and accessories shall be manufactured by
1. Hilti Corp, and supplied in the US by Hilti, Inc., Plano, TX, phone (800) 879-6000;
   and in Canada by Hilti (Canada) Corp, Mississauga, Ontario, (800) 363-4458
2. Jordahl DKG and supplied in the US by Decon USA Inc. (707) 996-5954
   and in Canada by Continental Decon Inc., (800) 363-3266
3. Halfen Anchoring Systems, Converse, TX, phone (800) 323-6896

2. MATERIALS

A. Anchor channels shall consist of either cold formed V-form profile or hot rolled steel channel profiles with round steel anchors mechanically attached to the back of the channel. “L-shaped” anchors securely attached to the back of the channel with fillet welds are also acceptable. The cold formed profiles are made of carbon steel conforming to ASTM A283 Grade C with a minimum yield strength of 30,000psi. The hot rolled profiles conform to ASTM A1011 with a minimum yield strength of 33,000psi. The round anchors must conform to ASTM A108.
B. The anchor channels shall be protected by a hot galvanized finish, or be stainless steel. Hot dipped galvanizing shall be in accordance to ISO 1461 with minimum thickness of 45 mm or be in accordance with ASTM A123. Stainless steel materials shall conform to stainless steel A4 grade 50.
C. T-bolts shall be used to fasten a metal or concrete member to the anchor channel. These bolts shall be designed to meet the manufacturer’s published strengths. The T-bolts must show a mark on the screw indication proper engagement into the channel.
D. Finish:
   1. Hot dipped galvanizing of anchor channels shall be in accordance to ISO 1461 with minimum thickness of 45 mm or conform to ASTM A123.
   2. Hot dipped galvanized T-bolts shall be in accordance to ISO 1461 with minimum thickness of 45 mm or conform to ASTM A153.
   3. Zinc electroplated T-bolts shall have a coating thickness ≥ 8mm or conform to ASTM B633 or EN ISO 4042, A3K.
E. End caps and a LDPE closed-cell foam filler with integrated tear-out strip shall be placed in the channel profile to help prevent concrete from seeping into the channel.
F. Anchor channel fabrication tolerances are ± 3mm for lengths of 300mm or less and ± 6mm for lengths >300mm.
G. Anchor channels and components may be produced according to different international standards if they meet or exceed the standards shown above.

3.01 INSTALLATION

A. The manufacturer’s instructions must be followed to install the anchor channels properly on the formwork.
B. Installer shall affix anchor channels in required locations before concrete is poured. Concrete shall be applied in a continuous pour for each anchor channel, ensuring complete coverage with no voids or gaps, and flush with the outer face of the anchor channel. The appropriate T-bolt shall be used to connect the specified metal or concrete member to the anchor channel after the concrete is cured. The specified torque shall be applied to the T-bolt as listed in the manufacturer’s installation instructions
C. Only the correct type of T-bolts supplied by the anchor channel manufacturer may be used to fasten a metal or concrete member to the anchor channel. The T-bolts are designed to meet the strength limits published by the manufacturer. The setting mark must show proper T-Bolt engagement in the channel
D. No alteration, such as cutting or bending, is permitted of anchor channel legs. Channel may be cut to size only if permitted by manufacturer and performed in accordance with its published instructions

3.02 REPAIR OF DEFECTIVE WORK

A. Installer shall protect anchor channel and accessories from damage.
This chapter provides instructions for use for the different anchor channel systems. Instructions for use may change over time. To verify if the published instructions for use are the latest, please visit our website.

12.1.1 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC AND HAC-T

Instructions include:
1. Check that the anchor channel is securely fastened to the structure.
2. Ensure that the load is distributed evenly.
3. Verify that the anchor channel is properly aligned.
4. Confirm that the anchor channel is properly attached to the structure.
5. Double-check that all connections are tight.

Visit our website for the latest instructions.
12.1.2 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC EDGE LITE, HAC EDGE, HAC-T EDGE LITE, AND HAC-T EDGE

1. Check the installation area and make sure it is clean and free of debris.
2. Place the anchor channel in the designated area.
3. Secure the anchor channel with appropriate fasteners.
4. Ensure proper alignment and orientation.

12.1.3 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC EDGE C AND HAC-T EDGE C

1. Prepare the installation area for the anchor channel.
2. Install the anchor channel according to the provided guidelines.
3. Verify the installation is correct and secure.
4. Finalize the installation by ensuring all parts are properly connected.
12.1.4 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC S EDGE AND HAC-T S EDGE

1. Place the HAC S EDGE or HAC-T S EDGE on the concrete surface.
2. Ensure that the base of the channel is level and secure it with T-bolts or nuts and bolts.
3. Check the alignment and positioning of the channel before proceeding with the installation.

12.1.5 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC S EDGE C AND HAC-T S EDGE C

1. Align the HAC S EDGE C or HAC-T S EDGE C with the required orientation.
2. Secure the channel to the concrete surface using appropriate fasteners.
3. Verify the stability and alignment of the channel after installation.

[Images showing the installation process of HAC S EDGE and HAC-T S EDGE]
12.1.6 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC CRFOS U

1. Place the HAC CRFOS U channel on the substrate.
2. Ensure the channel is properly aligned.
3. Secure the channel with appropriate fasteners.
4. Check the installation for proper alignment and security.

12.1.7 INSTALLATION INSTRUCTIONS FOR HILTI ANCHOR CHANNELS — HAC CRFOS U

1. Install the HAC CRFOS U channel as per the diagram.
2. Ensure the channel is securely fastened in place.
3. Confirm the installation meets all design requirements.
4. Review the installation for any necessary adjustments.
12.1.8 INSTALLATION INSTRUCTIONS FOR HILTI CHANNELS BOLTS — HBC-C

12.1.9 INSTALLATION INSTRUCTIONS FOR HILTI CHANNELS BOLTS — HBC-C-N
12.1.10 INSTALLATION INSTRUCTIONS FOR HILTI SERRATED CHANNELS BOLTS — HBC-T

12.1.11 INSTALLATION INSTRUCTIONS FOR HILTI SERRATED CHANNELS BOLTS — HBC-B
12.1.12 INSTALLATION INSTRUCTIONS FOR HILTI CHANNELS BOLTS (HBC-C) USED IN CONJUNCTION WITH HILTY HIT HY-100 ADHESIVE

13. FIELD FIXES

This chapter provides best practices for cast-in anchor channels. This chapter provides some additional information for designers, reviewers, installers, and inspectors. The ultimate goal is to allow for the most code-compliant, feasible solution, based on the project’s schedule.

Coming soon
This chapter provides a step by step detail explanation of every single failure mode of an anchor channel with rounded head anchors.

14.1 DESIGN EXAMPLES

Figure 14.1.1 — Design example - Facade Connection

Given:

Floor - Floor height = 10.5'
Mullion Spacing = 5'
DL = 14 psf
Wind Pressure (ASD) = 40 psf
Code = ASCE 7-10

Snap shot from structural notes

CONCRETE SHALL BE NORMAL WEIGHT AND SHALL OBTAIN 28 DAY COMpressive STRENGTHS AS FOLLOWS:
A. SLAB-ON-GRADE 3,500 PSI
B. WALLS 6,000 PSI
C. STRUCTURAL SLABS AND BEAMS 5,000 PSI
D. CONCRETE NOT OTHERWISE NOTED 4,000 PSI
E. PILE CAPS
F. COLUMNS SEE SHEET S-001

Seismic provision will not apply since the project is located in SDC B.

Concrete ----
f_c' = 6000psi
c_0 = 0.05
SD1 = 5.00"
λ=1.0 (normal weight concrete)
HAC-50 106/350 F is used with (2) HBC-C 8.8F, M16x60
hef = 4.173 in.
Length: 13.8 in., anchor spacing: 5.906 in., projection: 0.984 in.,
width: bch = 1.650 in., height: hch = 1.220 in.

Please refer to chapter 02 for properties of the channel.
Step 2: Determination of T-bolt Tension and shear forces

Determine the tension forces on the T-bolts. Assume the fixture is rigid. PROFIS Anchor Channel assumes Ec = 30,000 Mpa.

382 lbs
Bracket position: out

Using statics equations, define the concrete stresses under the fixture (σc) in terms of the concrete compressive stress under the fixture (σb). Once FT-bolts is known, the tension force on each T-bolt can be calculated. The applied shear force is distributed equally on each T-bolt.

Substituting the value for x into equation 2 will lead to FT-bolts = 1700lbs.

Tension force on each T-bolt = 1700lbs/2 = 850lbs.

Wind Load: Bracket out
Bracket tolerance: 1.5" in/out
T-bolt spacing: 6"
Side edge distance: 6"
Front edge distance: 5"
Pocket height: 2"
Slab depth: 8"

Design Code

ASCE 7-10

W(1.2L+WL)=40psfx10.5x5=2100lbs
W(L)=41psf=140lbs
DL(Strength level)=1.3x735lbs=955lbs
DL(Strength level)=1.2x735lbs=882lbs

Table: Calculations

<table>
<thead>
<tr>
<th>Code</th>
<th>Discussion</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
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<td>AC</td>
<td>Channel Systems</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Anchor</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>HAC</td>
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<td>3.</td>
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<td>5.</td>
<td>Base material</td>
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<td>6.</td>
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<td>7.</td>
<td>Anchor Channel Design Code</td>
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<td>8.</td>
<td>Reinforcing Bar Anchorage</td>
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<td>9.</td>
<td>Special Anchor Channel Design</td>
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<td>10.</td>
<td>Design Software</td>
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<td></td>
</tr>
</tbody>
</table>

The application is statically indeterminate. Use compatibility equations and statics equations to solve for the location of the neutral axis (x). Once x is known, the tension force on each T-bolt can be calculated. Using the compatibility equations, define the tension force acting on both T-bolts (FT-bolts) in terms of the concrete compressive stress under the fixture (σc).

\[
\begin{align*}
\delta &= \frac{M}{E_c A_{t-bolt}} \\
\delta &= \frac{\sum F_x x}{E_c A_{t-bolt}} \\
\sum F_x x &= E_c A_{t-bolt}\delta \\
\end{align*}
\]

By statics equations, define the shear force per each t-bolt.

\[
V_y = \frac{3500\text{lbs}}{2} = 1750\text{lbs per t-bolt}
\]

Substituting the value for x into equation 2 would lead to FT-bolts = 1700lbs.
Step 3: Determination of worst tolerance

The worst utilization is obtained at 2.895 in. The tolerance interval is [-11.812” and 11.812” (13.8”-2x0.984”).

Please note that the T-bolt forces are applied all along the channel length and the forces at anchors are determined. Then the worst case utilization report will be printed out in Profis anchor channel software. Therefore the bracket can be located anywhere along the available channel length. The anchor element forces are evaluated in this example at the worst location along the channel length.

The T-bolt #1 tension force (850 lb) will have an influence on each anchor element as shown below. The tension forces on anchor elements #1, #2 and #3 resulting from this influence will be defined as $N_{ua1,1}$, $N_{ua1,2}$ and $N_{ua1,3}$ respectively. The influence factor $A_{1,x}$ corresponds to the influence on anchor element $x$ from T-bolt #1. The parameter “s” corresponds to the spacing between each anchor element. The parameter $\ell_{in}$ corresponds to the influence length for T-bolt #1.

The T-bolt #2 tension force (850 lb) will have an influence on each anchor element as shown below. The tension forces on anchor elements #1, #2 and #3 resulting from this influence will be defined as $N_{ua2,1}$, $N_{ua2,2}$ and $N_{ua2,3}$ respectively. The influence factor $A_{2,x}$ corresponds to the influence on anchor element $x$ from T-bolt #2. The parameter “s” corresponds to the spacing between each anchor element. The parameter $\ell_{in}$ corresponds to the influence length for T-bolt #2.

**Figure 14.1.9 — Design example — Profis anchor channel - 3D Back View**

**Figure 14.1.10 — Design example — Profis anchor channel - 3D Front View**

**Figure 14.1.11 — Design example — Anchor Tension Forces**
The highest loaded anchor element in tension does not always control the anchor channel design in tension. The highest utilization, defined by the parameter \( \frac{N_{u,\text{total}}}{\phi N_{\text{t}}(s)} \), controls the design. Therefore, the tension design strengths must be calculated for each anchor element and checked against the total factored tension load acting on that element. The most unfavorably loaded anchor element (highest utilization) controls the design in tension.

The tension forces acting on each anchor element can be determined assuming a triangular force distribution. The triangular force distribution assumes the influence length (\( \ell \) in) does not necessarily coincide with the channel length.

Even when a T-bolt is located directly over one anchor element, the T-bolt load is still distributed to all other anchor elements within the distance \( \ell \) from the T-bolt.

The resulting tension force on each anchor element \( (N_{u,\text{ax}}) \) from the tension force acting on T-bolt \#1 will be proportionate by the factor \( k_1 \) to the distance of the anchor element with respect to the distance \( \ell \) in. Note that the influence length \( \ell \) in does not necessarily coincide with the channel length.

The triangular force distribution assumes the tension force acting on each T-bolt (850 lb) has an influence on each of the anchor elements within a given distance \( \ell \) in from the T-bolt.

The tension forces acting on each anchor element can be determined assuming a triangular force distribution.

### Calculations

#### Step 3: Determination of worst tolerance

**ESR-3520 4.1.2.2**

**Eq (2)**

**Eq (1)**

**Figure 14.1.12 — Design example – effect of t-bolt 1 on anchors**

<table>
<thead>
<tr>
<th>Code</th>
<th>Discussion</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR-3520 4.1.2.2 Eq (2) Eq (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The highest loaded anchor element in tension does not always control the anchor channel design in tension. The highest utilization, defined by the parameter ( \frac{N_{u,\text{total}}}{\phi N_{\text{t}}(s)} ), controls the design. Therefore, the tension design strengths must be calculated for each anchor element and checked against the total factored tension load acting on that element. The most unfavorably loaded anchor element (highest utilization) controls the design in tension. The tension forces acting on each anchor element can be determined assuming a triangular force distribution. The triangular force distribution assumes the influence length (( \ell ) in) does not necessarily coincide with the channel length. Even when a T-bolt is located directly over one anchor element, the T-bolt load is still distributed to all other anchor elements within the distance ( \ell ) from the T-bolt.</td>
<td></td>
</tr>
</tbody>
</table>

\[
A_{1,1} = \frac{1}{(10.56 \text{ in} - 5.906 \text{ in} + 0.1 \text{ in})} = 10.56 \text{ in}
A_{1,1} = 0.45
A_{1,2} = \frac{1}{(10.56 \text{ in} - 0.1 \text{ in})} = 10.56 \text{ in}
A_{1,2} = 0.9905
A_{1,3} = \frac{1}{(10.56 \text{ in} - 0.1 \text{ in} - 5.906 \text{ in})} = 10.56 \text{ in}
A_{1,3} = 0.431
k_1 = \frac{1}{1} \rightarrow k_1 = 0.5342
N_{u,1,1} = (k_1)(A_{1,1})(850 \text{ lb}) = 449.8 \text{ lb}
N_{u,1,2} = (k_1)(A_{1,2})(850 \text{ lb}) = 449.8 \text{ lb}
N_{u,1,3} = (k_1)(A_{1,3})(850 \text{ lb}) = 195.8 \text{ lb}
Check:
N_{u,1,1} + N_{u,1,2} + N_{u,1,3} = 850 \text{ lbs}
OK |

**Figure 14.1.13 — Design example – effect of t-bolt 2 on anchors**

<table>
<thead>
<tr>
<th>Code</th>
<th>Discussion</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR-3520 4.1.2.2 Eq (2) Eq (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The highest loaded anchor element in tension does not always control the anchor channel design in tension. The highest utilization, defined by the parameter ( \frac{N_{u,\text{total}}}{\phi N_{\text{t}}(s)} ), controls the design. Therefore, the tension design strengths must be calculated for each anchor element and checked against the total factored tension load acting on that element. The most unfavorably loaded anchor element (highest utilization) controls the design in tension. The tension forces acting on each anchor element can be determined assuming a triangular force distribution. The triangular force distribution assumes the tension force acting on each T-bolt (850 lb) has an influence on each of the anchor elements within a given distance ( \ell ) in from the T-bolt. The resulting tension force on each anchor element ( (N_{u,\text{ax}}) ) from the tension force acting on T-bolt #1 will be proportionate by the factor ( k_1 ) to the distance of the anchor element with respect to the distance ( \ell ) in. Note that the influence length ( \ell ) in does not necessarily coincide with the channel length. Even when a T-bolt is located directly over one anchor element, the T-bolt load is still distributed to all other anchor elements within the distance ( \ell ) from the T-bolt.</td>
<td></td>
</tr>
</tbody>
</table>

\[
A_{2,1} = \frac{1}{(10.56 \text{ in} - 5.906 \text{ in})} = 10.56 \text{ in}
A_{2,1} = 0 \text{ in}
A_{2,2} = \frac{1}{(10.56 \text{ in})} = 10.56 \text{ in}
A_{2,2} = 1 \text{ in}
A_{2,3} = \frac{1}{(10.56 \text{ in} - 0.1 \text{ in} - 5.906 \text{ in})} = 10.56 \text{ in}
A_{2,3} = 1 \text{ in}
k_1 = \frac{1}{1} \rightarrow k_1 = 0.6941
A_{2,1} = (k_1)(A_{2,1})(850 \text{ lb}) = 0 \text{ lb}
A_{2,2} = (k_1)(A_{2,2})(850 \text{ lb}) = 260 \text{ lb}
A_{2,3} = (k_1)(A_{2,3})(850 \text{ lb}) = 590 \text{ lbs}
Check:
N_{u,2,1} + N_{u,2,2} + N_{u,2,3} = 850 \text{ lbs}
OK |
### Code Discussion Calculations

#### Step 3: Determination of worst tolerance

**ESR-3520 4.1.2.2**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq (1)</td>
<td>The total tension force acting on each anchor element ($N_{uax,1}$) will be the sum of the T-bolt forces ($N_{u1,1}$ + $N_{u2,1}$) acting on that element. A check of the sum of the total tension forces acting on all of the anchor elements should equal the sum of the tension forces acting on all of the T-bolts.</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
N_{u1,1} + N_{u2,1} &= 204.4 \text{ lbs} \\
N_{u1,2} + N_{u2,2} &= 449.8 \text{ lbs} \\
N_{u1,3} + N_{u2,3} &= 195.8 \text{ lbs} \\
N_{u1,1} + N_{u2,1} &= 204 \text{ lbs} \\
N_{u1,2} + N_{u2,2} &= 710 \text{ lbs} \\
N_{u1,3} + N_{u2,3} &= 786 \text{ lbs}
\end{align*}
\]

### Figure 14.1.14 — Design example – Anchor Tension forces

#### Step 4: Determine the flexural moment ($M_{u,\text{flex}}$) acting on the anchor channel.

**ESR-3520 4.1.2.2**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq (2)</td>
<td>The flexural moment ($M_{u,\text{flex}}$) acting on the anchor channel will be determined. The flexural moment occurs at the location of the T-bolt. Assume the channel is a simply supported beam.</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\sum F &= 850 \text{ lbs} - F_1 - F_2 = 0 \\
\sum M &= (850 \text{ lbs})(5.906 \text{ in}) - (F_2)(5.906 \text{ in}) = 0 \\
F_1 &= 14.39 \text{ lbs} \\
F_2 &= 835.61 \text{ lbs} \\
M_{u,\text{flex}} &= 83.6 \text{ in-lb}
\end{align*}
\]

### Figure 14.1.15 — Design example – Anchor Shear forces
Step 3: Determination of Tension forces on anchor element.

### Calculations

**ESR-3520 4.1.2.2 Eq (1)**

The highest loaded anchor element in shear does not always control the anchor channel design in shear. The highest utilization, defined by the parameter \( V_u / \phi \), controls the design. Therefore, the shear design strengths must be calculated for each anchor element and checked against the total factored shear load acting on that element. The most unfavorably loaded anchor element (highest utilization) controls the design in shear.

The shear forces acting on each anchor element can be determined assuming a triangular force distribution.

The triangular force distribution assumes the shear force acting on each T-bolt (1750 lb) has an influence on each of the anchor elements within a given distance \( L \) in from the T-bolt. The resulting shear force on each anchor element \( (V_{ua}) \) from the shear force acting on T-bolt \( #1 \) will be proportionate by the factor \( k_1 = \frac{1}{L} \).

[Diagram of anchor elements and forces]

For a T-bolt load of 1750 lb:

1. **V_{ua1,1} = (k_1)(A_{1,1})(1750 lb)**
2. **V_{ua1,2} = (k_1)(A_{1,2})(1750 lb)**
3. **V_{ua1,3} = (k_1)(A_{1,3})(1750 lb)**

### Example:

**Check:**

\[ V_{ua1,1} + V_{ua1,2} + V_{ua1,3} = 850 \text{ lbs} \]

OK

**Check:**

\[ V_{ua1,1} + V_{ua1,2} + V_{ua1,3} = 850 \text{ lbs} \]

OK

**Figure 14.1.16 — Design example – effect of t-bolt 1 on anchors**

---

**ESR-3520 4.1.2.2 Eq (1)**

The highest loaded anchor element in shear does not always control the anchor channel design in shear. The highest utilization, defined by the parameter \( V_u / \phi \), controls the design. Therefore, the shear design strengths must be calculated for each anchor element and checked against the total factored shear load acting on that element. The most unfavorably loaded anchor element (highest utilization) controls the design in shear.

The shear forces acting on each anchor element can be determined assuming a triangular force distribution.

The triangular force distribution assumes the shear force acting on each T-bolt (1750 lb) has an influence on each of the anchor elements within a given distance \( L \) in from the T-bolt. The resulting shear force on each anchor element \( (V_{ua}) \) from the shear force acting on T-bolt \( #1 \) will be proportionate by the factor \( k_1 = \frac{1}{L} \).

[Diagram of anchor elements and forces]

For a T-bolt load of 1750 lb:

1. **V_{ua2,1} = (k_1)(A_{2,1})(1750 lb)**
2. **V_{ua2,2} = (k_1)(A_{2,2})(1750 lb)**
3. **V_{ua2,3} = (k_1)(A_{2,3})(1750 lb)**

### Example:

**Check:**

\[ V_{ua2,1} + V_{ua2,2} + V_{ua2,3} = 1750 \text{ lbs} \]

OK

**Figure 14.1.17 — Design example – effect of t-bolt 2 on anchors**

---

Note: The images and calculations are representative of the text content and do not show the actual visual representation.
ACI323 strength design provisions require calculation of nominal strengths corresponding to possible failure modes. Each nominal shear strength is multiplied by a strength reduction factor (φ-factor) to obtain a design shear strength. The parameter “% utilization” corresponds to the ratio:

\[
\text{% utilization} = \frac{\text{factored load} (N_\text{ax} \text{ or } V_\text{ax})}{\text{design strength} (\phi N_\text{ax} \text{ or } \phi V_\text{ax})}
\]

where “factored load” corresponds to the total factored load (N_\text{ax} or V_\text{ax}) and “design strength” corresponds to the calculated design strength for the failure mode being considered in tension or shear respectively. Utilizations less than 100% indicate the factored load is less than the design strength, while utilizations greater than 100% indicate the factored load exceeds the design strength. Therefore, the anchor channel design is considered acceptable if all of the utilizations are less than 100%, and the combined interaction checks using these utilizations are satisfied. When both tension and shear loads act on the anchor channel system, combined interaction checks must be made for both steel failure and concrete failure.

### Code | Discussion | Calculations
--- | --- | ---
### Step 3: Determination of Tension forces on to anchor element.

**ESR-3520**

**4.1.2.2**

**Eq (2)**

**Figure 14.1.18 — Design example – Anchor Shear forces**

\[ M_{\text{ax}} = 83.6 \text{ in-lb} \]

**T-bolt forces**

<table>
<thead>
<tr>
<th>Bolt</th>
<th>N^u^b^a^f</th>
<th>V^u^b^a^f</th>
<th>V^u^a^a^f</th>
<th>V^u^a^a^f</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>850</td>
<td>1750</td>
<td>0</td>
<td>1750</td>
</tr>
<tr>
<td>2</td>
<td>786</td>
<td>1618</td>
<td>0</td>
<td>1618</td>
</tr>
</tbody>
</table>

**Anchor element**

<table>
<thead>
<tr>
<th>Anchor element</th>
<th>N^u^b^a^f</th>
<th>V^u^b^a^f</th>
<th>V^u^a^a^f</th>
<th>V^u^a^a^f</th>
</tr>
</thead>
<tbody>
<tr>
<td>a_1</td>
<td>710</td>
<td>1461</td>
<td>0</td>
<td>1461</td>
</tr>
<tr>
<td>a_2</td>
<td>204</td>
<td>421</td>
<td>0</td>
<td>421</td>
</tr>
<tr>
<td>a_3</td>
<td>786</td>
<td>1618</td>
<td>0</td>
<td>1618</td>
</tr>
</tbody>
</table>
Step 4: Steel strength Anchor and connection between anchor and channel profile.

ESR-3520 section 4.1.3.6

Combined tension and shear loads (interaction)

Anchor and connection between anchor and channel (Anchor a3)

The interaction check for steel failure of the channel requires the ratio (factored load acting on the anchor element/anchor element or anchor-channel connection design strength) to be checked using Equation (44) in ESR-3520. $\frac{V_{sa,y}}{N_{sc}}$ to check for steel failure of the channel requires the ratio (factored load acting on the anchor element/anchor element or anchor-channel connection design strength).

Governing failure mode in shear is Anchor/connection - perpendicular shear.

Check:

$\frac{V_{sa,y}}{N_{sc}} = \frac{V_{sa,y}}{N_{sc} = 0.07528}$

$\frac{V_{sa,y}}{N_{sc} = 0.07528}$

Governing failure mode in tension is Connection anchor-channel.

Check:

$\frac{N_{sc}}{V_{sa,y}} = \frac{N_{sc}}{V_{sa,y} = 1.0}$

$\frac{N_{sc}}{V_{sa,y} = 1.0}$

Step 5: Steel strength local flexure channel lip and flexure of channel

ESR-3520 section 4.1.3.2.2

Channel lip strength in tension: ESR-3520 Section 4.1.3.2.2 requires a check to made to determine if the clear distance between two T-bolts ($b_{ch}$) is > the parameter $2b_{ch}$, where both corresponds to the channel width. Values for $b_{ch}$ are given in Table 8-1 of ESR-3520.

If $b_{ch}$ is < $2b_{ch}$, the value for $N_s$ given in ESR-3520 Table 8-3 must be reduced by the parameter calculated using Equation (5) in ESR-3520. Calculate nominal tension strengths ($N_s$) nominal strength corresponding to local failure of channel lips $\Phi N_s$.

Reference ESR-3520 Table 8-1 and Table 8-3.

If $b_{ch}$ is < $2b_{ch}$, the value for $N_s$ given in ESR-3520 Table 8-3 must be reduced by the parameter calculated using Equation (5) in ESR-3520. Calculate nominal tension strengths ($N_s$).

$N_{sl,y} = \frac{b_{ch}}{schb}$

$N_{sl,y} = \frac{b_{ch}}{schb}$

$N_{sl,y} = \frac{schb}{b_{ch}}$

$N_{sl,y} = \frac{schb}{b_{ch}}$

$N_{sl,y} = \frac{schb}{b_{ch}}$

$N_{sl,y} = \frac{schb}{b_{ch}}$

$N_{sl,y} = \frac{schb}{b_{ch}}$

$N_{sl,y} = \frac{schb}{b_{ch}}$

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$N_{sl,y} = \frac{schb}{b_{ch}}$

$N_{sl,y} = \frac{schb}{b_{ch}}$
Code | Discussion | Calculations
--- | --- | ---
Step 5: Steel strength local flexure channel lip and flexure of channel

**ESR-3520** section 4.1.3.6

**Combined tension and shear loads — flexure moment and channel lip (Interaction)**

Channel lip in tension and shear and Flexure of channel in tension. The interaction check for steel failure of the channel requires the ratio (factored load acting on the channel lip or flexure of channel design strength) to be checked using Equation (45) and Equation (46) in ESR-3520. $V_{ub} = 0.06801$

Point of load application — channel lip:

$$\left( \frac{V_{ub}}{N_{ub}} \right)^{\alpha} + \left( \frac{u_{ub}}{u_{ub}} \right)^{\alpha} \leq 1.0$$

Point of load application — flexural moment and channel lip:

$$\left( \frac{M_{ub}}{M_{ub}} \right)^{\alpha} + \left( \frac{u_{ub}}{u_{ub}} \right)^{\alpha} \leq 1.0$$

- $\alpha = 2$ for anchor channels with $V_{sl,y} \leq N_{sl}$
- $\alpha = 1$ for anchor channels with $V_{sl,y} > N_{sl}$

It shall be permitted to assume reduced values for $V_{sl,y}$ corresponding to the use of an exponent $\alpha = 2$. In this case the reduced value for $V_{sl,y}$ shall also be used in Section 4.1.3.3.5a.

**Step 6: Channel bolt strength**

**ESR-3520** section 4.1.3.2.2, 4.1.3.3.2, 4.1.3.4.2

**Channel bolt strength in tension:**

$$\Phi N_{ss} \geq N_{ub}$$

Nominal tension steel strengths for T-bolts are given in ESR-3520 Table 8-7. $N_{ub}$ for an M16 diameter HBC-C 8.8 F T-bolt = 28,235 lb $\Phi = 0.65$

$$N_{ss} = \frac{28,235}{0.65} = 43,862 lb$$

Utilization: 11%

**Channel bolt strength — without lever arm, longitudinal shear included in shear:**

$$\Phi V_{ss} \geq V_{ub}$$

Nominal tension steel strengths for T-bolts are given in ESR-3520 Table 8-7. $V_{ss}$ for an M16 diameter HBC-C 8.8 F T-bolt = 16940 lb $\Phi = 0.60$

$$V_{ss} = \frac{16940}{0.60} = 28,233 lb$$

Utilization: 23%

**ESR-3520** section 4.1.3.6

**Combined tension and shear loads — Channel bolt (Interaction)**

$$\left( \frac{N_{ub}}{N_{ub}} \right)^{\alpha} + \left( \frac{V_{ub}}{V_{ub}} \right)^{\alpha} \leq 1.000$$

Utilization: 4%
Step 7: Concrete strength

<table>
<thead>
<tr>
<th>Code</th>
<th>Discussion</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR-3520 section 4.1.3.2.4</td>
<td>PROFIS Anchor Channel has determined that anchor element #3 controls for pullout in tension. Per ESR-3520 Section 4.1.3.2.4, nominal pullout strength (Npn) is calculated using ACI 318 anchoring-to-concrete provisions. This example is based on ACI 318-14 provisions; therefore, pullout calculations will be per ACI 318-14 Chapter 17.</td>
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### Code Discussion Calculations

#### Step 7: Concrete strength

Concrete breakout strength in Tension continued. This influence takes into consideration the loading on each anchor element as well as the distance (spacing) of these elements from anchor element #2. Reference ESR-3520 Equations (10) and (11) for more information on how to calculate ψ as the distance (spacing) of these elements from anchor element #2. Reference ESR-3520 section 4.1.3.2.3

The parameter $s_{cb,N}$ corresponds to the maximum distance that is assumed with respect to the influence of an anchor element on the anchor element being considered. Any anchor elements that are within $s_{cb,N}$ from the anchor element being considered are assumed to have an influence on that anchor element.

The calculated value for $s_{cb,N}$ will be the same for each anchor element; however, the considered are assumed to have an influence on that anchor element. The parameter $s_{N}$ corresponds to the maximum distance that is assumed with information on how to calculate $s_{cb,N}$.

The calculated value for $s_{cb,N}$ will be the same for each anchor element; however, the number of anchor elements within the distance $s_{cb,N}$ from the anchor element being considered may not always be the same. Reference ESR-3520 Equation (11) for more information on how to calculate $s_{cb,N}$.

- $s_{cb,N} = \text{spacing between each anchor element} = 5.91 \text{ in}$
- $s_{cb,N} = \text{distance of each influencing anchor element from anchor element #3} = 11.812 \text{ in}$
- $s_{cb,N} = \text{distance from anchor element #1 to anchor element #3} = 7.912 \text{ in}$
- $s_{cb,N} = \text{critical anchor spacing for tension loading} (s_{cr,h} = 4.173 \text{ in})$
- $s_{cb,N} = \text{critical edge distance for tension loading} (s_{ed,h} = 5.0 \text{ in})$

The parameter $\psi$ is a modification factor that is used to account for the influence of adjacent anchor elements on the anchor element being considered.

$$\psi_{cb} = \frac{1}{1+\left(\frac{r_{cb}}{s_{cb,N}}\right)^{1.0}}$$

Influence of anchor element #1 on anchor element #3:

$$\psi_{cb,1} = \frac{1}{1+\left(\frac{r_{cb,1}}{s_{cb,N}}\right)^{1.0}} = \frac{1}{1+\left(\frac{11.812}{5.91}\right)^{1.0}} = 0.4758$$

Influence of anchor element #2 on anchor element #3:

$$\psi_{cb,2} = \frac{1}{1+\left(\frac{r_{cb,2}}{s_{cb,N}}\right)^{1.0}} = \frac{1}{1+\left(\frac{5.906}{5.91}\right)^{1.0}} = 0.658$$

Concrete breakout strength in Tension continued...

Calculate the modification factor for edge influence ($\psi_{cb,h}$).

The parameters $c_{cb}$ and $c_{cr}$ correspond to the distance from the center of the anchor element being considered to a fixed edge. $s_{cb,N}$ is measured perpendicular to the anchor channel longitudinal axis, and is considered when calculating the modification factor for edge influence ($\psi_{cb,h}$).

$$s_{cb,N} = \text{critical anchor spacing for tension loading}$$

$$c_{cb} = \text{edge distance of the anchor channel}$$

$$\psi_{cb,h} = \frac{c_{cb}}{s_{cb,N}}$$

$$\psi_{cb,h} = \frac{c_{cb}}{s_{cb,N}} = \frac{1.5 \text{ in}}{5.91 \text{ in}} = 0.2548$$

$$\psi_{cb,h} = \frac{c_{cr}}{s_{cr,h}}$$

$$\psi_{cb,h} = \frac{c_{cr}}{s_{cr,h}} = \frac{5.0 \text{ in}}{4.173 \text{ in}} = 1.195$$

$$\psi_{cb} = \frac{1}{1+\left(\frac{r_{cb}}{s_{cb,N}}\right)^{1.0}}$$

$$\psi_{cb} = \frac{1}{1+\left(\frac{r_{cb}}{s_{cb,N}}\right)^{1.0}} = \frac{1}{1+\left(\frac{11.812}{5.91}\right)^{1.0}} = 0.4758$$

$$\psi_{cb} = \frac{1}{1+\left(\frac{r_{cb}}{s_{cb,N}}\right)^{1.0}} = \frac{1}{1+\left(\frac{5.906}{5.91}\right)^{1.0}} = 0.658$$

[$\psi_{cb,h} = 0.658$]
Concrete breakout strength in Tension continued…

- Calculate the modification factor for corner influence ($\psi_{co,N}$).

- Calculate the modification factor for splitting ($\psi_{cp,N}$).

\[
\psi_{co,N,3} = 1.25.
\]

The parameter $c_{cr,N}$ corresponds to the maximum edge distance that is assumed with respect to values for $c_{a1}$ and $c_{a2}$. Any $c_{a1}$ or $c_{a2}$ value less than $c_{cr,N}$ must be considered.

- The calculated value for concrete breakout in tension ($N_{cb}$) is dependent on the concrete geometry via the modification factors $\psi_{co,N}$ and $\psi_{cp,N}$.

### Concrete is typically assumed to be cracked under normal service load conditions.

If uncracked concrete conditions are assumed, an increase in $N_{cb}$ is performed via the modification factor $\psi_{cr}$. The calculated value for $N_{cb}$ will be used to calculate the nominal concrete breakout strength in tension ($N_{cb}$).

#### Uncracked concrete with no supplementary reinforcement

- $\psi_{cr} = 1$

#### Uncracked concrete with supplementary reinforcement

- $\psi_{cr} = \text{MAX} \left( \frac{c_{a1}}{c_{cr,N}}, \frac{c_{a2}}{c_{cr,N}} \right)$

#### Cracked concrete

- $\psi_{cr} = 1$

### Conclusions

- Concrete breakout strength in Tension for anchor element #3:

\[
\phi_{cb} = 8.11\text{ kips}.
\]

### Table: Summary for Concrete Breakout in Tension

<table>
<thead>
<tr>
<th>Anchor Element</th>
<th>$N_{cb}$ (kips)</th>
<th>% Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor element #3</td>
<td>8.11</td>
<td>100%</td>
</tr>
</tbody>
</table>

Note: The anchor element with the highest % utilization will control the design with respect to concrete breakout failure in tension. Design strengths for this example are summarized in the table on this page titled Summary for Concrete Breakout in Tension.
Concrete pryout strength - perpendicular shear (Anchor #3)

The ICC-ES Acceptance Criteria AC232 includes amendments to the ACI 318 anchoring to concrete provisions. These amendments are given in Section 3.1.3.3.4 of these amendments requires the factor \( \psi \) to be modified when calculating concrete pryout strength in shear. All of the parameters used to calculate \( \psi \) in tension are used except the parameter \((N_{cr}/N_{ub})\). The shear loads acting on the anchor elements are substituted for the tension loads such that \((N_{cr}/N_{ub})\) is used instead of \((N_{cr}/N_{ub})\).

These provisions for calculating concrete pryout strength are also given in ESR-3520 Section 4.1.3.3.4.

Refer to concrete breakout tension influence of anchor element #1 on anchor element #3:

\[
V_{ua,1} = 1461 \text{ lb}
\]

\[
s_2,1 = 6.984 \text{ in}
\]

\[
s_3,1 = 11.812 \text{ in}
\]

\[
s_{1,3} = 5.906 \text{ in}
\]

\[
s_{2,3} = \text{distance from anchor element #2 to anchor element #3 = 11.812 in}
\]

\[
s_{x,1} = \text{distance from anchor element #1 to anchor element #3 = 16.980 in}
\]

\[
V_{cb,3} = V_{b,3}
\]

To calculate \( \psi_{vb,3} \) for Anchor #3:

\[
\psi_{vb,3} = 1.08
\]

Concrete compressive strength value for Anchor #3 will be checked against the factored load acting on anchor element #3 \( N_{un} \) to obtain the % utilization \( (\psi_{vb,3}/\psi_{cb,3}) \).

The anchor element with the highest % utilization will control the design with respect to concrete pryout failure in shear.

---

**Table: Concrete strength**

<table>
<thead>
<tr>
<th>Code</th>
<th>Discussion</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR-3520 Section 4.1.3.3.4</td>
<td>ACI 318-14 Chapter 17</td>
<td>Concrete pryout strength in perpendicular shear for anchor element #3</td>
</tr>
<tr>
<td>( V_{cb,3} = V_{b,3} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_a = \text{Basic concrete breakout strength in shear} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha_a = \text{Modification factor for anchor spacing} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha_c = \text{Modification factor for corner effects} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha_s = \text{Modification factor cracked/uncracked concrete} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \lambda_{vb} = \text{Modification factor for concrete thickness} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( N_{cr} = \text{modified basic concrete breakout strength in shear} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( N_{un} = \text{factored load acting on anchor element #3} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \psi_{vb,3} = 1.08 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{cb,3} = V_{b,3} )</td>
<td></td>
<td></td>
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</table>

**Step 7: Concrete strength**

**ESR-3520 section 4.1.3.3.3, ACI 318-14 Chapter 17**

Concrete breakout strength in perpendicular shear for anchor element #3

\[
V_{cb,3} = V_{b,3}
\]

\[
V_a = \text{Basic concrete breakout strength in shear}
\]

\[
\alpha_a = \text{Modification factor for anchor spacing}
\]

\[
\alpha_c = \text{Modification factor for corner effects}
\]

\[
\alpha_s = \text{Modification factor cracked/uncracked concrete}
\]

\[
\lambda_{vb} = \text{Modification factor for concrete thickness}
\]

Calculate the basic concrete breakout strength in shear \( (V_{cb,3}) \):

\[
V_{cb,3} = \phi_{Vb} V_{cb,3}
\]

\[
\phi_{Vb} = \psi_{vb,3} \lambda_{vb}
\]

\[
\psi_{vb,3} = 1.08
\]

\[
\lambda_{vb} = 0.85
\]

**Condition:**

\[
\psi_{vb,3} = 1.08
\]

\[
\psi_{cb,3} = 1.08
\]

**Concrete edge breakout: \( V_{cb,3} \)**

**Figure 14.1.21 — Design example — reduction factors of \( V_{cb,3} \)**
Concrete breakout strength in perpendicular shear for anchor element #3 continued...

The value calculated for concrete breakout strength in shear ($V_{cb}$) is based on the location of the anchor element being considered. The basic concrete breakout strength in shear ($V_{cb}$) is not dependent on the anchor element being considered, but it is dependent on the concrete geometry via the parameter $c_{cr}$. However, the calculated value for $V_{cb}$ will be the same for each anchor element if the $c_{cr}$ value is the same for each element.

The parameter $u_{V}$ will be dependent on the anchor element being considered and the concrete geometry. Reference ESR-3520 Equation (32) for more information on how to calculate $u_{V}$.

The parameter $s_{cr}$ corresponds to the maximum distance that is assumed with respect to the influence of an anchor element on the anchor element being considered. Any anchor elements that are within $s_{cr}$ from the anchor element being considered are assumed to have an influence on that anchor element. The calculated value for $s_{cr}$ will be the same for each anchor element if the $c_{cr}$ value is the same for each element; however, the number of anchor elements within the distance $s_{cr}$ from the anchor element being considered may not always be the same. Reference ESR-3520 Equation (32) for more information on how to calculate $s_{cr}$.

Calculate the modification factor for anchor influence ($u_{co,V}$):

$$u_{co,V} = \frac{1}{1 - \frac{1}{2c_{cr}}}$$

$$s_{cr} = \frac{1}{2c_{cr}}$$

$$s_{cr} = 0.582$$

Concrete edge breakout: $V_{cr,V}$

$$V_{cr,V} = 1.09\times11.812\text{ in}$$

$$V_{cr,V} = 14.618\text{ lbs}$$

Concrete edge breakout: $V_{co,V}$

$$V_{co,V} = 1.09\times7.61\text{ in}$$

$$V_{co,V} = 8.459\text{ lbs}$$

Concrete edge breakout: $V_{cr,co,V}$

$$V_{cr,co,V} = 1.09\times11.65\text{ in}$$

$$V_{cr,co,V} = 13.00\text{ lbs}$$

Concrete edge breakout: $V_{co,cr,V}$

$$V_{co,cr,V} = 1.09\times11.65\text{ in}$$

$$V_{co,cr,V} = 13.00\text{ lbs}$$

Concrete edge breakout: $V_{cr,co,V}$

$$V_{cr,co,V} = 1.09\times11.65\text{ in}$$

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$$V_{co,cr,V} = 1.09\times11.65\text{ in}$$

$$V_{co,cr,V} = 13.00\text{ lbs}$$
### Code Discussion Calculations

#### Step 7: Concrete strength

**ESR-3520 Section 4.1.3.3.3**

**ACI 318-14 Chapter 17**

Concrete breakout strength in perpendicular shear for anchor element #3 continued...

- Calculate the modification factor for cracked/uncracked concrete ($\psi_{c,V,3}$).

  **Cracked concrete**

  - No supplementary reinforcement
    - $\psi_{c,V} = 1.0$
  
  - With supplementary reinforcement
    - Cracked concrete with edge reinforcement (#4 min.)
      - $\psi_{c,V} = 1.2$
    - Cracked concrete with edge reinforcement (#4 min.) and stirrups (#4 min.) spaced at 4" O.C.
      - $\psi_{c,V} = 1.4$

- Uncracked Concrete

  Anchor channels located in a region of a concrete member where analysis indicates no cracking at service load levels.
  - $\psi_{c,V} = 1.4$

  Note: In order to activate the reinforcement, concrete has to crack. Therefore, if uncracked concrete is assumed, supplementary reinforcement does not impact this factor.

Concrete is typically assumed to be cracked under normal service load conditions. If cracked concrete conditions are assumed, increases in $V_{cb,y}$ permitted via the modification factor $\psi_{c,V}$.
Concrete breakout strength in perpendicular shear for anchor element #3 continued...

ESR-3520 section 4.1.3.3.3
ACI 318-14 Chapter 17

Nominal concrete breakout strength in tension for anchor element #3

ESR-3520 Equation (8)

The calculated value for \( V_{cb} \) will be multiplied by a strength reduction factor (\( \phi \)-factor) to give a design strength \( \phi V_{cb} \). Design strengths for this example are summarized in the table on this page titled Summary for Concrete Breakout in Tension.

The anchor element with the highest \% utilization will control the design with respect to concrete breakout failure in tension.

\( \phi \)-factors for concrete breakout in tension are given in ESR-3520 Table 8-4.

In ACI 318-14:
Condition A
- Supplementary reinforcement is present
- Reinforcement does not need to be explicitly designed for the anchor channel
- Should generally conform to reinforcement shown in Fig. R17.4.2.9 and R17.5.2.3b
- Full development is not required

Condition B
- No supplementary reinforcement

Concrete failure modes of anchor channels under combined loads:

ESR 3520 section 4.1.3.6.3 b) If \( \sum N < 0.2N_{ca} \) then the full strength in shear shall be permitted

\[
\text{Concrete utilization = } \frac{V_{cb}}{\phi V_{cb}} \times 100
\]

For Condition B
- \( \phi = 0.7 \)
- \( \phi V_{cb} = 1876 \text{ lbs} \)
- \( \beta = 0.87 \)
- Concrete utilization = 87%
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