AEFAC

AEFAC

Australian Engineered Fasteners & Anchor Council

Setting standards for the specification, selection & application of anchors & fasteners in Australia

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Disclaimer

These seminar notes have been prepared for general information only and are not an exhaustive statement of all relevant information on the topic. This guidance must not be regarded as a substitute for technical advice provided by a suitably qualified engineer.

For further information contact David Heath: djheath@swin.edu.au

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Participants

SWINBURNE UNIVERSITY OF TECHNOLOGY

Ancon BUILDING PRODUCTS

HILTI

HOBSON ENGINEERING

ITW

Powers

WÜRTH

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Presentation Outline

1. Overview of AEFAC
2. Introduction to Post-Installed Chemical Anchors
3. Common Applications
4. Types of Chemical Anchors
5. Factors influencing Performance
6. Failure Modes
7. Suitability Qualification
8. General Installation Procedures
9. Selecting the right anchor

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Overview of AEFAC – Industry review

AS3600

Cl. 14.3 (d) Fixings

"In the case of shallow anchorages, cone-type failure in the concrete surrounding the fixing shall be investigated taking into account edge distance, spacing, the effect of reinforcement, if any, and concrete strength at time of loading."

By contrast:

EOTA TR029

Cl. 1.4 Safety

"Anchorages carried out in accordance with these design methods are considered to belong to anchorages, the failure of which would cause risk to human life and/or considerable economic consequences."

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Overview of AEFAC – Industry review

- ✓ Directional advancement of our largely unmonitored industry
- ✓ United approach
- ✓ Improved safety
- ✓ Minimum standards
- ✓ Consistency in test methods and specification
- ✓ Education

➡ **UNIQUE AND EXCITING DEVELOPMENT**

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Overview of AEFAC – Industry Needs

1. Develop technical materials for the specification, selection and application of anchors and fasteners.
2. Appropriate training and education for design engineers and specifiers.
3. Improve installation practices via training and accreditation.
4. Safeguard the quality of anchors and fasteners through standardisation of specification and certification of products.
5. Conduct research and development to advance the industry.

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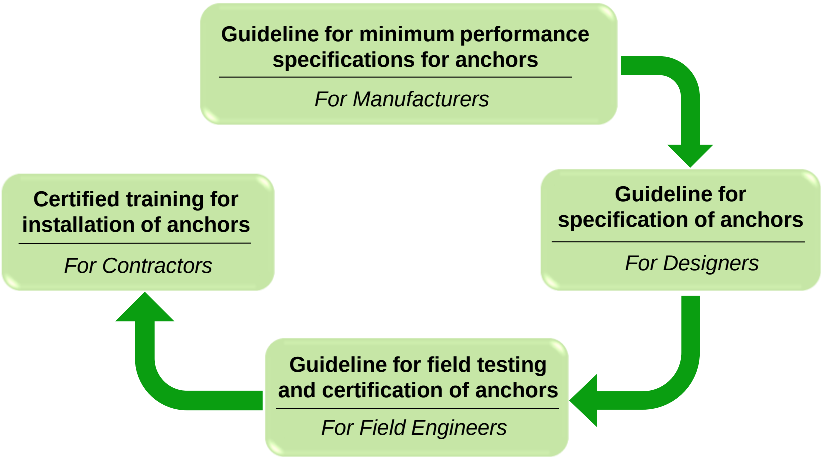
Overview of AEFAC – Industry Needs



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Overview of AEFAC – The concept

Founders

- **Professor Emad Gad**
  Swinburne University of Technology
- **James Murray-Parkes**
  Swinburne University of Technology

12 month journey:
- Concept development
- Lobbying
- Engagement

Stimulated by anchor failure in Melbourne

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Overview of AEFAC – Looking abroad

Europe

- ETAG 001 – Guideline for European Technical Approval of Metal Anchors for use in Concrete
- CEN/TS 1992-4:2009 "Design of fastenings for use in concrete"

United States of America

- ACI 318 – Appendix D *Anchoring to Concrete* (design)
- ACI 355.2 – Qualification of post-installed mechanical anchors in concrete and commentary (qualification)
- ACI 355.4 – Qualification of post-installed adhesive anchors in concrete and commentary (qualification)

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Overview of AEFAC - Organization

Board of Founding Members
Chair: Professor Emad Gad
Ancon, Hilti, Hobson, ITW Construction Systems, Powers, Würth & Swinburne University of Technology

Director
David Heath

Technical Committee
Chair: Gary Connah
Engineering representation from Founding Members, industry participants invited to be Technical Members, plus technical advisors

General Members
Other industry participants

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Overview of AEFAC - Aims

Short Term	Minimum performance specifications for manufacturers Guideline for specification of anchors by engineers Commence lobby of ABCB, Worksafe, Standards Australia Provide educational seminars
Medium Term	Guideline for field testing and certification of anchors Develop certification program for training of installers Continue lobby with ABCB, Standards Australia, Worksafe Further develop educational materials
Long Term	Maintain developed Guidelines/Standards Develop new guidelines for other fasteners Continue the educational development and delivery Develop and maintain a certification database

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Overview of AEFAC - Scope

Initial

- Bonded anchors
- Cast-in anchors (headed studs, cast-in channel)
- Mechanical anchors

Future

- Screws
- Fasteners

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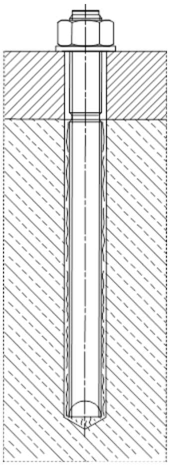
Why are chemical anchors widely used?

- It is a post-installed anchor system.



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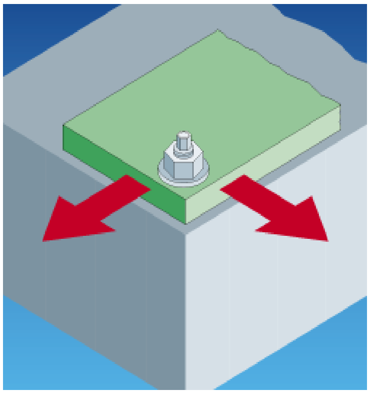
Why are chemical anchors widely used?

- Smaller edge and spacing requirements.



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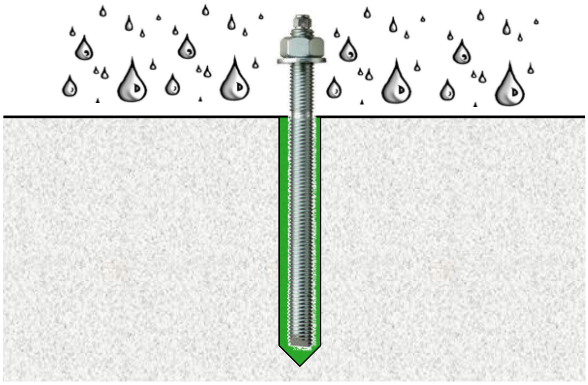
Why are chemical anchors widely used?

- Protects the embedded part from direct corrosion.



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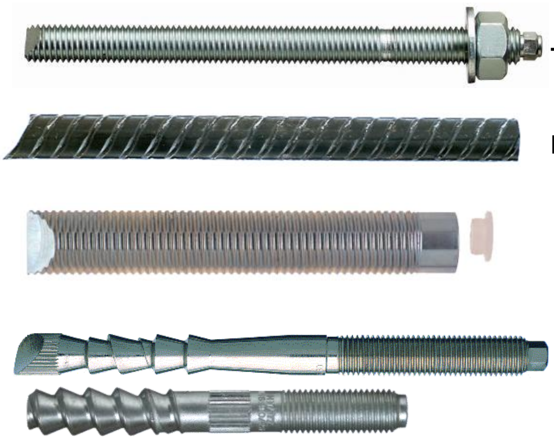
Chemical anchor elements



Threaded rods

Rebars

Internally threaded rods

Special elements

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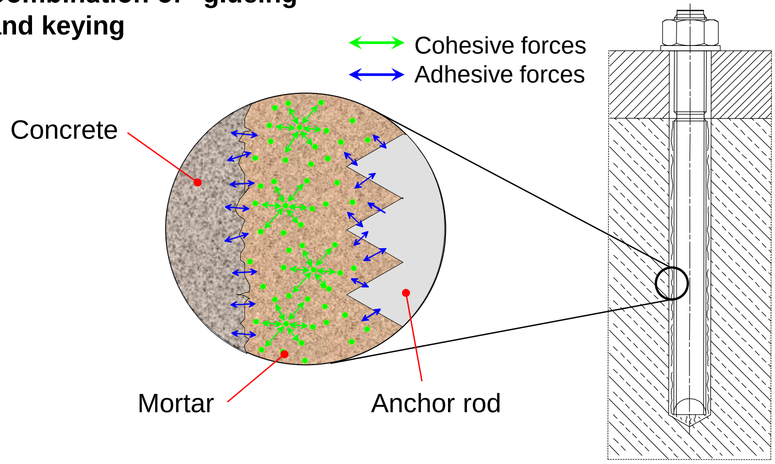
How chemical anchors work.

- **Combination of "glueing" and keying**



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Chemical Anchor Applications

- Structural Fastenings Applications



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Chemical Anchor Applications

- Architectural Fastenings

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Chemical Anchor Applications

- Retrofitting

Chemical Anchor Applications

- Rebar fastening

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Types based on packaging

Injectable

- Flexible to different sizes and variable embedments.

Capsule

- No wasteage
- Faster to install

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Types based on chemical composition

Chemical Anchors

- Unsaturated Polyester
- Vinylester, Epoxy Acrylate, Methacrylate
- Epoxy

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Types based on chemical composition

Unsaturated Polyester | Vinylester, Epoxy Acrylate, Methacrylate | Epoxy

Advantages

- ✓ Low cost
- ✓ Rapid curing times in low temperature environments
- ✓ Less sensitive to mix ratios
- ✓ Good performance in hollow blocks and masonry

Disadvantages

- ❖ Not recommended for high risk applications
- ❖ More sensitive to hole preparation
- ❖ Unsuitable for diamond cored holes and large annular gaps due to shrinkage
- ❖ Limited chemical resistance

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Types based on chemical composition

Unsaturated Polyester | **Vinylester, Epoxy Acrylate, Methacrylate** | Epoxy

Advantages

- ✓ Rapid curing times in low temperature environments
- ✓ Greater strength and chemical resistance relative to polyesters
- ✓ Good performance in damp concrete

Disadvantages

- ❖ More expensive than unsaturated polyester
- ❖ Less sensitivity to hole preparation
- ❖ Limited suitability to diamond cored holes

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Types based on chemical composition

Unsaturated Polyester | Vinylester, Epoxy Acrylate, Methacrylate | **Epoxy**

Advantages

- ✓ Greater strength and chemical resistance relative to polyesters and vinylesters
- ✓ Good performance in damp concrete
- ✓ Better chemical resistance

Disadvantages

- ❖ More expensive than polyester and vinylester
- ❖ Relatively, longer period of curing

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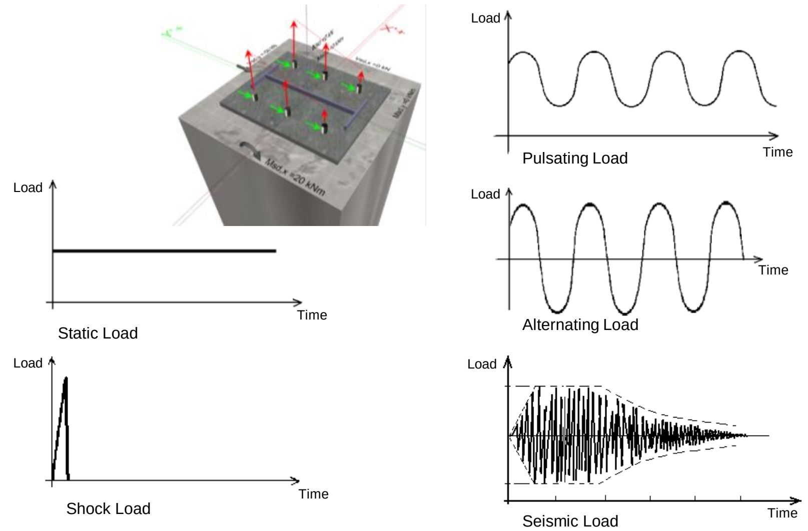
Type of load



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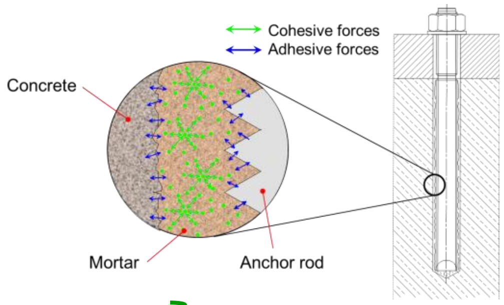
Hole preparation



- Hammer drilled hole
- Diamond cored hole
- Wet and dry holes
- Well cleaned hole

The chemical anchor should be suitable to conditions of the hole and the type of drilling method.

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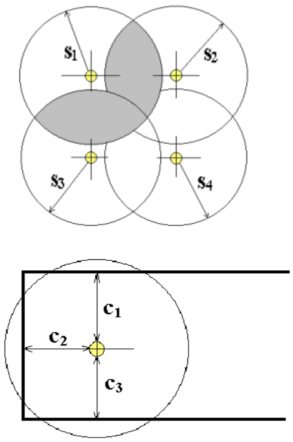
Anchor spacing and edge distance



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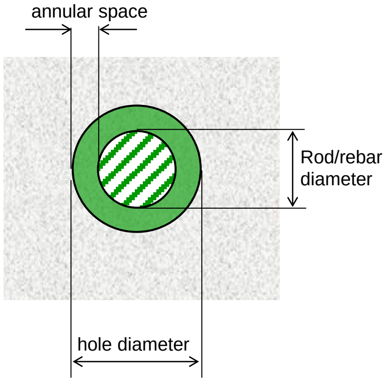
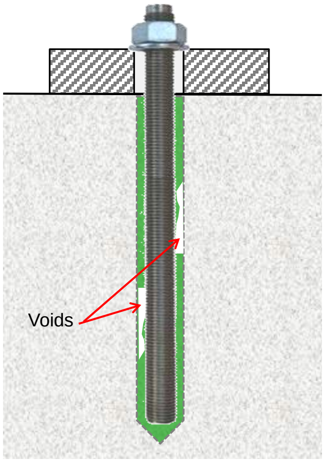
Annular space and distribution of chemical





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Type and strength of base material strength

- Hollow base materials
- Solid Bricks
- Concrete / Natural Stone

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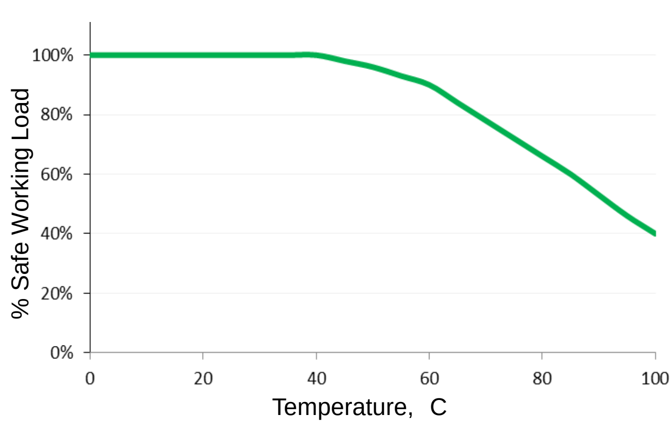
Service temperature



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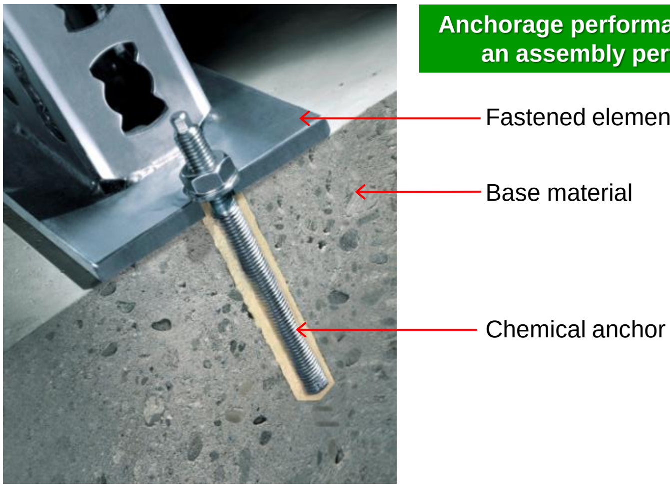
Parts of an anchoring system



Anchorage performance is always an assembly performance.

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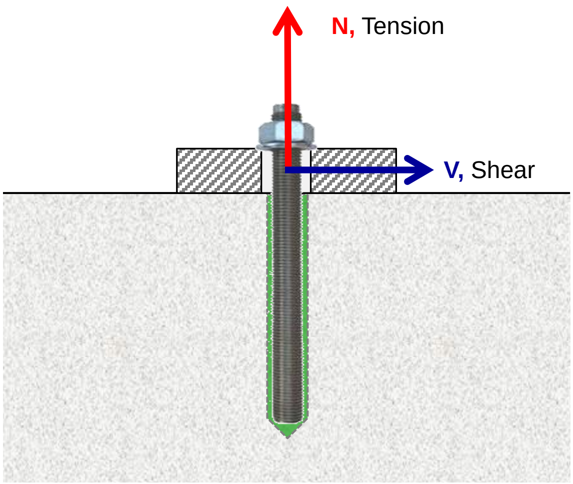
Force nomenclature



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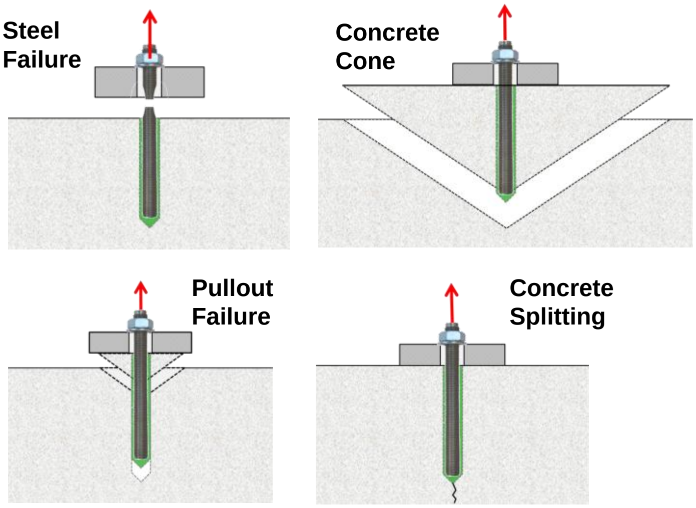
Possible Failures in Tension



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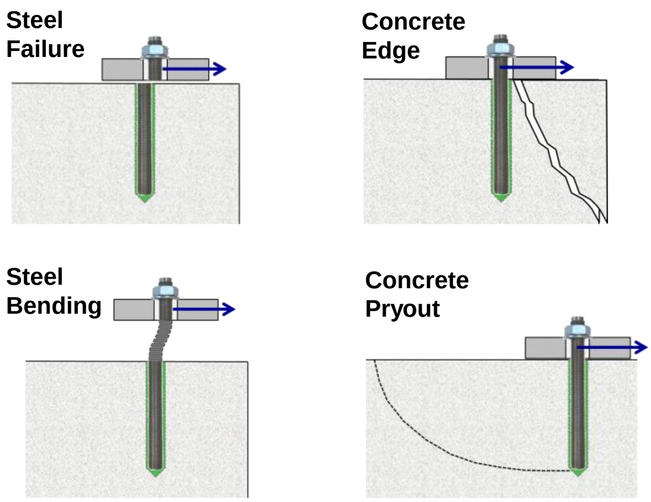
Possible Failures in Shear



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Anchor failures do happen!

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Anchor failures do happen!

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Anchor failures do happen!

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How safe is "safe enough"?

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Who may be involved if an anchor fails?

- Manufacturer
- Contractor
- Designer/Engineer/Specifier
- Project Manager
- Project/Property Owner
- Responsible Government Entity

- Complying manufacturing processes
- Properly designed and specified anchors
- Properly installed and inspected anchors

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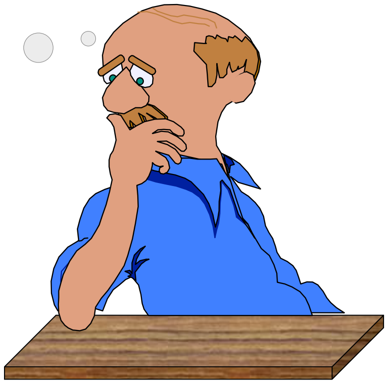
Areas of qualification

- Which product will I use?
- How will I know that it is really fit for purpose?



1. Manufacturing of the products
2. Compliance to design codes/standards
3. Performance of the products

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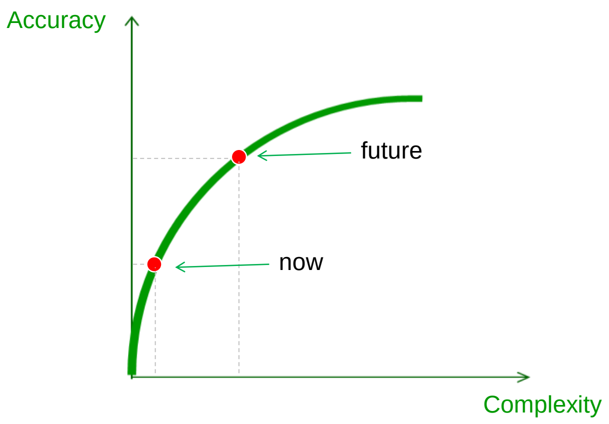
The significance of accuracy



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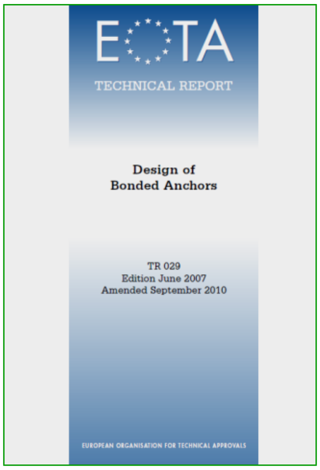
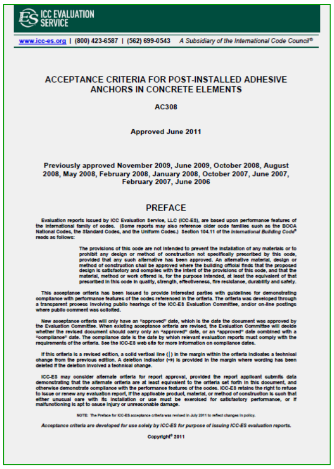
Widely used anchor design standards



TR 029



ICC EVALUATION SERVICE

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ACCEPTANCE CRITERIA FOR POST-INSTALLED ADHESIVE ANCHORS IN CONCRETE ELEMENTS

AC308

Approved June 2011

Previously approved November 2009, June 2009, October 2008, August 2008, May 2008, February 2008, January 2008, October 2007, June 2007, February 2007, June 2006

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes. (Some reports may also reference older code families such as the BOCA National Codes, the Standard Codes, and the Uniform Codes.) Section 104.11 of the *International Building Code®* reads as follows:

> The provisions of this code are not intended to prevent the installation of any materials 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 method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, 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.

This acceptance criteria has been issued to provide interested parties with guidelines for demonstrating compliance with performance features of the codes referenced in the criteria. The criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or on-line postings where public comment was solicited.

New acceptance criteria will only have an "approved" date, which is the date the document was approved by the Evaluation Committee. When existing acceptance criteria are revised, the Evaluation Committee will decide whether the revised document should carry only an "approved" date, or an "approved" date combined with a "compliance" date. The compliance date is the date by which relevant evaluation reports must comply with the requirements of the criteria. See the ICC-ES web site for more information on compliance dates.

If this criteria is a revised edition, a solid vertical line (|) in the margin within the criteria indicates a technical change from the previous edition. A deletion indicator (→) is provided in the margin where wording has been deleted if the deletion involved a technical change.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

NOTE: The Preface for ICC-ES acceptance criteria was revised in July 2011 to reflect changes in policy.

Acceptance criteria are developed for use solely by ICC-ES for purpose of issuing ICC-ES evaluation reports.

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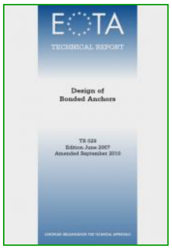
Concrete Capacity Design model



- Highly accurate
- Calculation of load bearing capacities at different load cases and different anchor configurations.
- Highly descriptive of the critical failure modes.
- Requires independently tested test reports to be used as an integral part of the design, installation and qualification process involved in using the anchor.

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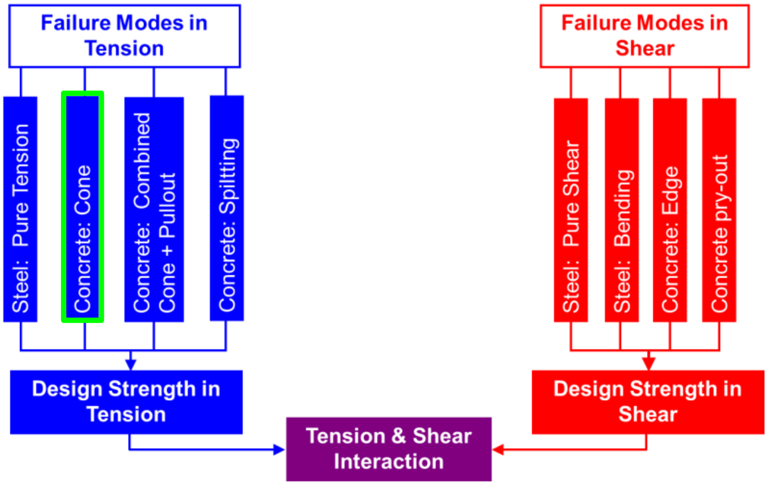
TR-029 chemical anchor design process



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TR-029: Concrete cone strength

$$N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$$

Design concrete cone strength

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N}$$

Characteristic concrete cone strength

Basic breakout strength of a single anchor

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$$

Ratio of Failure Surface Areas

$$\frac{A_{c,N}}{A^0_{c,N}}$$

- $A_{c,N}$: Actual failure surface area
- $A^0_{c,N}$: Ideal failure surface area of a single anchor

Modification Factors

$\psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N}$

- $\psi_{s,N}$: Edge distances
- $\psi_{re,N}$: Rebar
- $\psi_{ec,N}$: Tension Eccentricity

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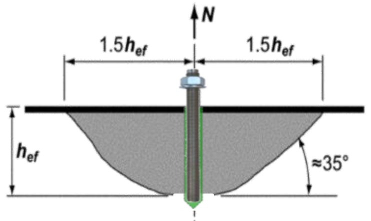
TR-029: Concrete cone strength

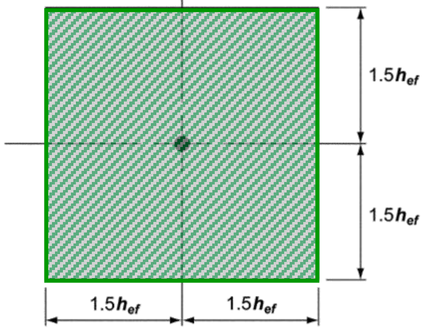
Determination of A $_{c,N}$



Section through failure cone

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$$

$$A^0_{c,N} = 9 \cdot h_{ef}^2$$



Plan view

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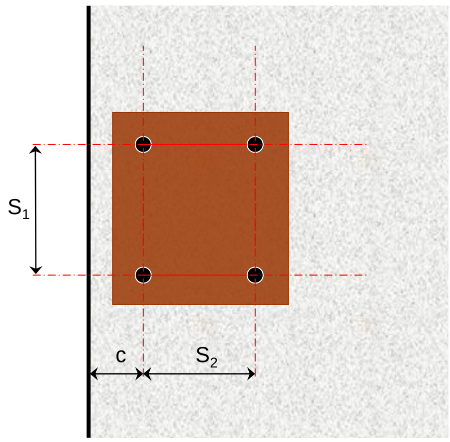
TR-029: Concrete cone strength

Sample determination of $A_{c,N}$



critical edge distance
$c_{cr,N} = 1.5\ h_{ef}$

critical spacing
$s_{cr,N} = 2\ c_{cr,N} = 3\ h_{ef}$

$S_1, S_2 < S_{cr,N}$

$c < c_{cr,N}$

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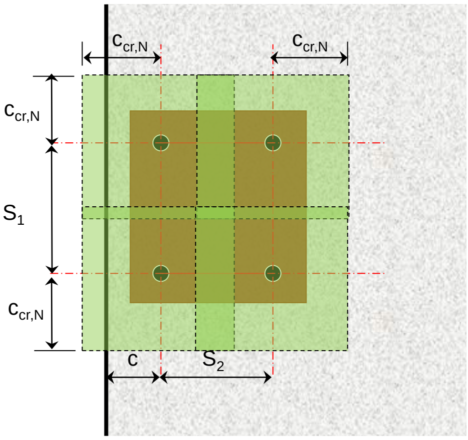
TR-029: Concrete cone strength

Sample determination of $A_{c,N}$



critical edge distance
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$S_1, S_2 < S_{cr,N}$

$c < c_{cr,N}$

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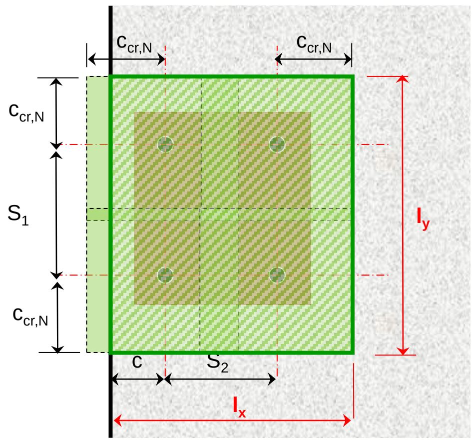
TR-029: Concrete cone strength

Sample determination of $A_{c,N}$



critical edge distance
$c_{cr,N} = 1.5\ h_{ef}$

critical spacing
$s_{cr,N}=2\ c_{cr,N} = 3\ h_{ef}$

$S_1, S_2 < S_{cr,N}$

$c < c_{cr,N}$

$A_{Nc} = (l_x)(l_y)$

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TR-029: Concrete cone strength

$$N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$$

Design concrete cone strength

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N}$$

Characteristic concrete cone strength

Basic breakout strength of a single anchor

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$$

Ratio of Failure Surface Areas

$$\frac{A_{c,N}}{A^0_{c,N}}$$

$A_{c,N}$: Actual failure surface area

$A^0_{c,N}$: Ideal failure surface area of a single anchor

Modification Factors

$\psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N}$

- $\psi_{s,N}$: Edge distances
- $\psi_{re,N}$: Rebar
- $\psi_{ec,N}$: Tension Eccentricity

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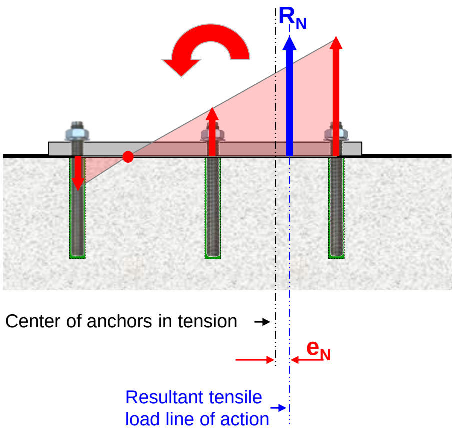
TR-029: Concrete cone strength

Determination of $\Psi_{ec,N}$

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N}$$

$$\Psi_{ec,N} = \frac{1}{1 + 2e_N / s_{cr,N}} \leq 1$$



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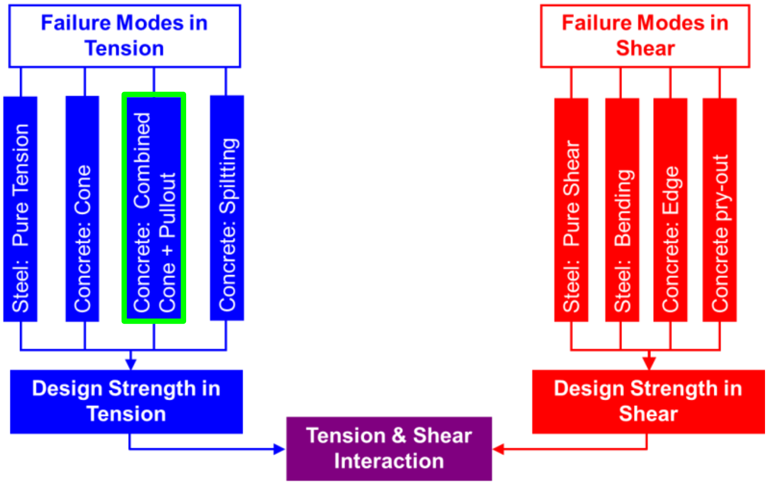
TR-029 chemical anchor design process



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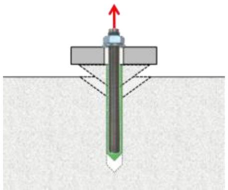
TR-029: Pullout strength



$$N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$$

$$N_{Rk,p} = N^0_{Rk,p} \cdot \frac{A_{p,N}}{A^0_{p,N}} \cdot \psi_{s,Np} \cdot \psi_{g,Np} \cdot \psi_{ec,Np} \cdot \psi_{re,Np}$$

Basic pullout strength of a single anchor

$$N^0_{Rk,p} = \pi \cdot d \cdot h_{ef} \cdot \tau_{Rk}$$

Ratio of Failure Surface Areas

$$c_{cr,Np} = \frac{s_{cr,Np}}{2}$$

$$s_{cr,Np} = 20 \cdot d \cdot \left(\frac{\tau_{Rk,ucr}}{7.5}\right)^{0.5}$$

Modification Factors

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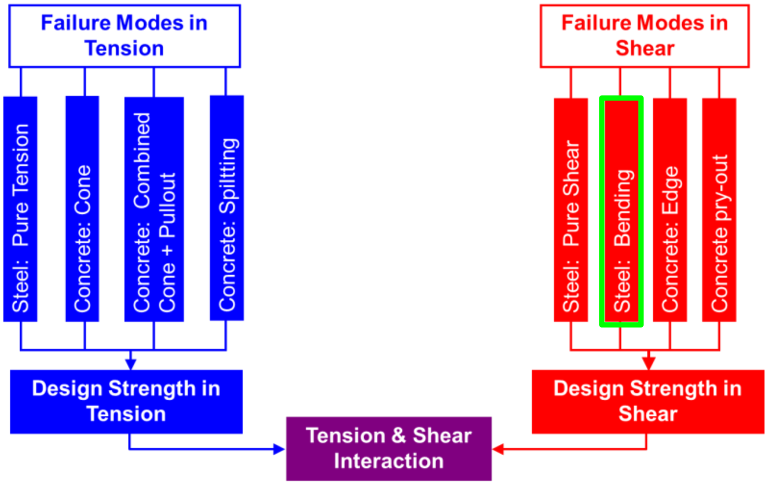
TR-029 chemical anchor design process



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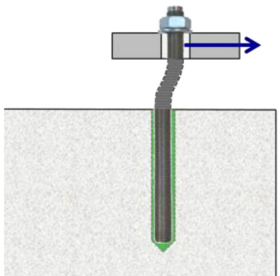
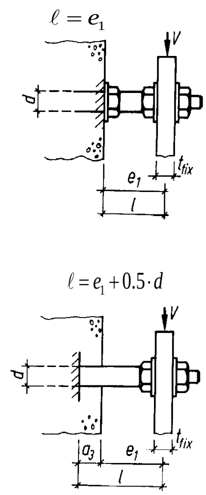
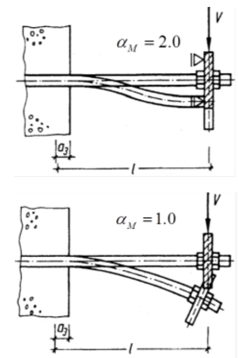
TR-029: Shear bending strength







$$V_{Rd,sm} = \frac{V_{Rk,sm}}{\gamma_{Ms}}$$

$$V_{Rk,sm} = \frac{\alpha_M \cdot M_{Rk,s}}{\ell}$$

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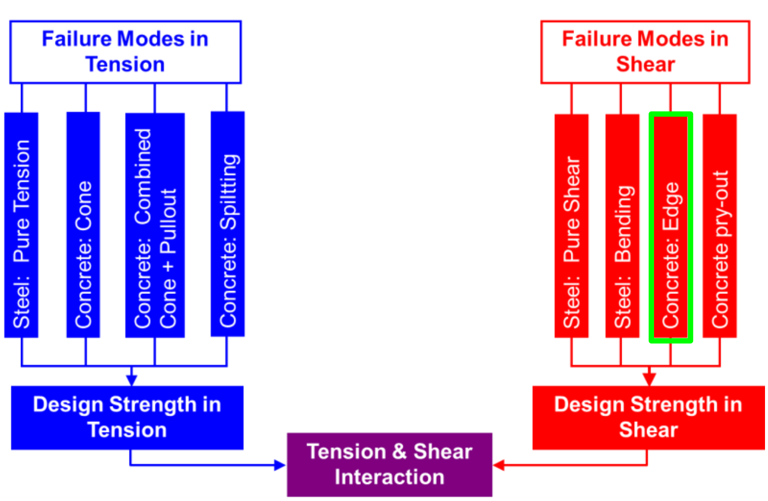
TR-029 chemical anchor design process



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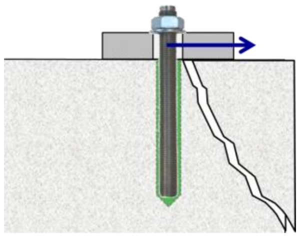
TR-029 chemical anchor design process



$$V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$$

$$V_{Rk,c} = V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$$

Basic pullout strength of a single anchor

$$V^0_{Rk,c} = k_1 \cdot d^{\alpha} \cdot h_{ef}^{\beta} \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5}$$

Ratio of Failure Surface Areas

Modification Factors

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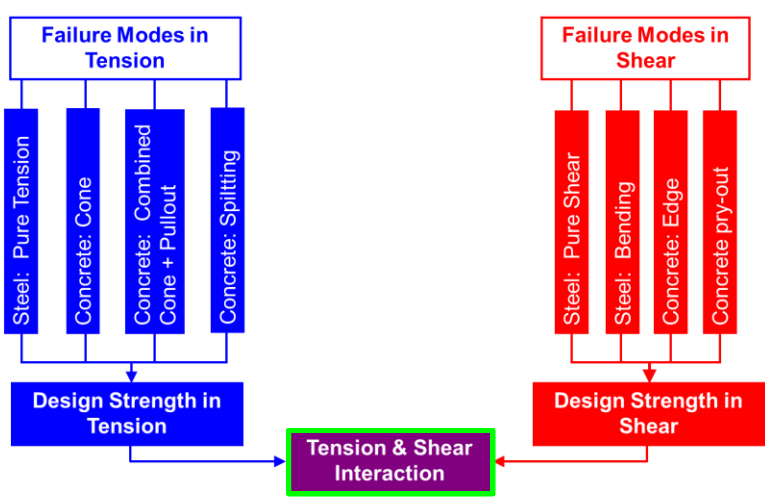
TR-029 chemical anchor design process



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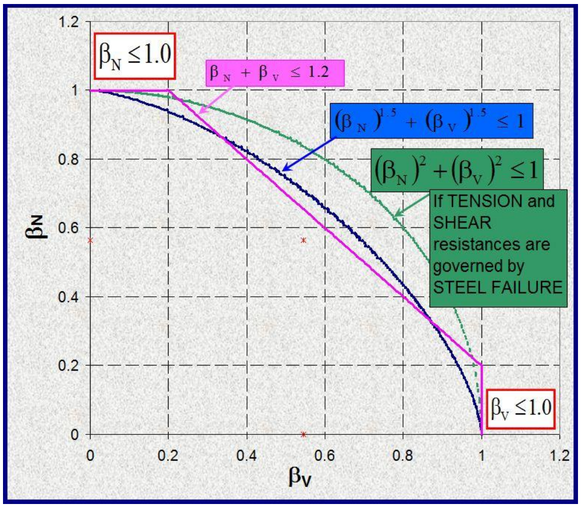
TR-029 tension and shear interaction



$$\beta_N = \frac{N_{Sd}}{N_{Rd}}$$

$$\beta_V = \frac{V_{Sd}}{V_{Rd}}$$

N_{Sd} = Design value of ACTING Tension load

N_{Rd} = Design Value of tension RESISTANCE

V_{Sd} = Design value of ACTING shear load

V_{Rd} = Design Value of shear RESISTANCE

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Presentation Outline

1. Overview of AEFAC
2. Introduction to Post-Installed Chemical Anchors
3. Common Applications
4. Types of Chemical Anchors
5. Factors influencing Performance
6. Failure Modes
7. Suitability Qualification
8. **General Installation Procedures**
9. Selecting the right anchor

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Proper Installation is key to performance

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Installation of Injectable Chemical Anchors

Chemical Dispenser

Chemical Tube

Mixing Nozzle

Blow-out pump

Cleaning brush

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The significance of the mixing nozzle

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Installation of Injectable Chemical Anchors

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Installation of Injectable Chemical Anchors

Sieves / Perforated sleeve

Chemical anchor viscosity must match size of perforations on the sieve.

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Installation of Injectable Chemical Anchors

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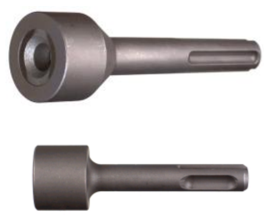
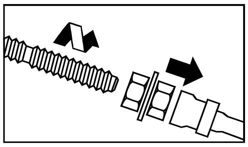
Installation of Capsule Chemical Anchors

Threaded rod setting tool



Threaded rod with wedge tip



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Installation of Capsule Chemical Anchors

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Presentation Outline

1. Overview of AEFAC
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6. Failure Modes
7. Suitability Qualification
8. General Installation Procedures
9. Selecting the right anchor

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Anchor Selection

- Shrinkage must be at an acceptable level to the requirements of the application and the engineer.
- It must have an acceptable "load to deformation" behavior
- It must be properly installed
- It must perform on a long term basis
- It must be "non-toxic"

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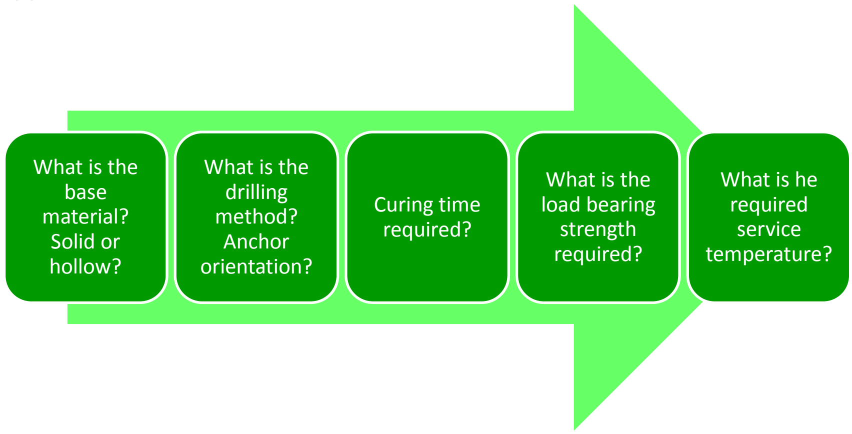
Anchor Selection

The selection of anchor will depend on the requirements of the application.



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Thank you for listening and we hope we helped you understand chemical anchors better.