AEFAC

Australian Engineered Fasteners & Anchor Council

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

AEFAC

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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Presentation Outline

1. Overview of AEFAC
2. Introduction to Post-Installed Anchors
3. Common Applications
4. Mechanics of Post-Installed Anchors
5. Factors influencing Performance
6. Failure Modes
7. Suitability Qualification
8. Selection
9. Design
10. Installation – General
11. Examples of Failures

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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 – 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 – 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 – Aims

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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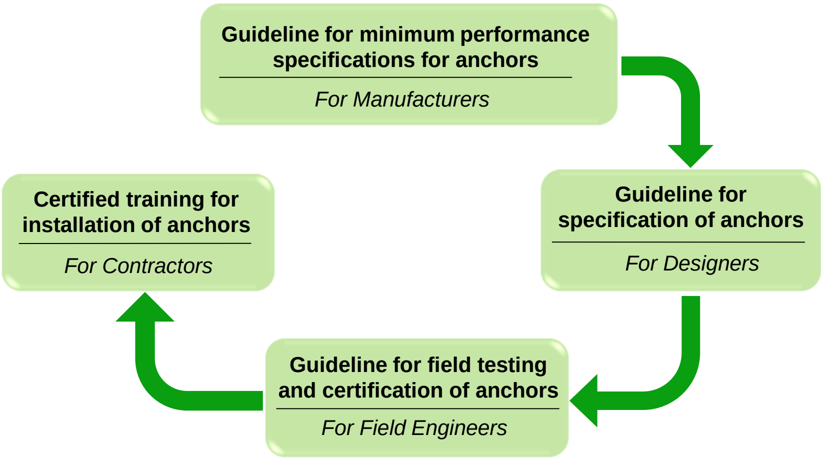
Overview of AEFAC – Planned Outputs



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Overview of AEFAC – Formation

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

12 month journey:
- Concept development
- Lobbying
- Engagement

Formed to stop anchor failures!

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Participants

Swinburne University of Technology
Ancon Building Products
Hilti
Hobson Engineering
ITW Construction Systems Pty Ltd – Ramset – Reid
Powers
Würth

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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
Members: James Murray-Parkes (Hobson), Johannes Krohse (Wurth), Neil Hollingshead (ITW), Ramil Crisolo (Hilti), Tarun Joshi (Powers)

General Members (near future)
Other industry participants

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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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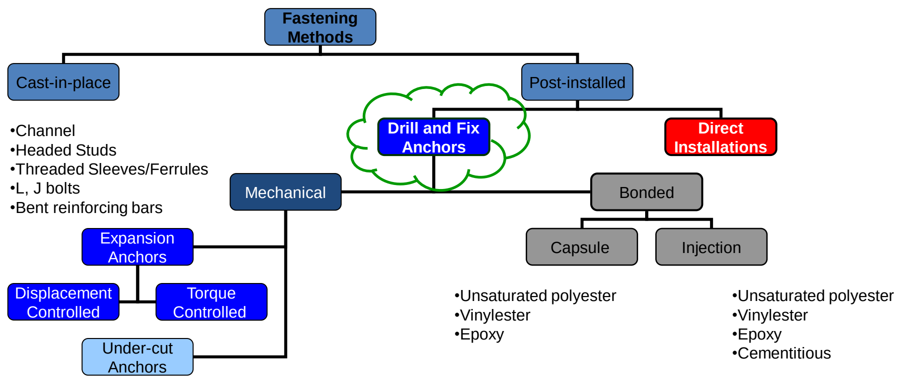
Family of Anchors



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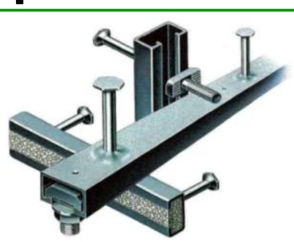
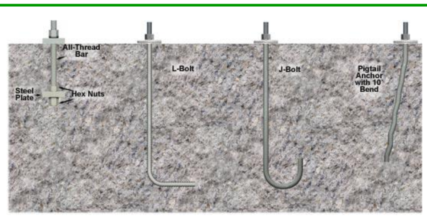
Cast-in-place anchors





Pros
- **High loading capabilities with mechanical Interlock**
- **Less sensitive to installation errors**
- **Can be installed in heavily reinforced elements**
- **The structure can be pre-designed by appropriate reinforcement to withstand external loads**

Cons
- **layout and planning problems**
- **Not flexible for fastened part adjustments (change in design)**

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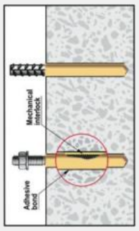
Post-installed anchors

Pros

- High loading capabilities *(can be designed as if cast-in depending on the type of anchor)*
- Flexible for layout adjustments
- Wide range of sizes and types available
- Some may be removed after use in temporary applications
- Immediate loading is possible (mechanical)



Cons

- Less understood
- Difficulties in densely reinforced concrete
- Need skilled trained staff for proper installations
- Proper storage conditions for adhesive systems

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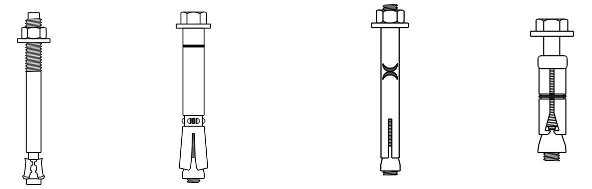
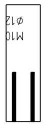
Post-installed anchors

Torque-controlled expansion anchors



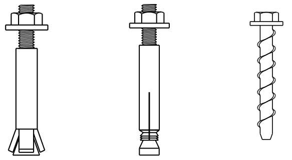
Through-bolt Thick-walled sleeve Thin-walled sleeve Shield-type

Deformation - controlled



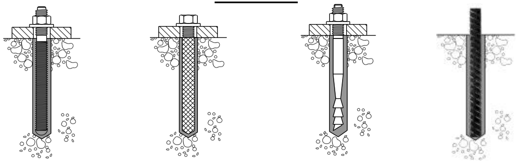
"Drop-in"

Undercut



Undercut Self-undercut Screw

Bonded



Threaded rod Internal thread Torque-controlled Rebar

(Source: Draft BS 8539)

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Post-installed anchors - chemical

Anchor rods

Rebars

Internally threaded rods

Special elements

Plastic sieve

Injection Systems

Capsule Systems

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Post-installed anchor applications

- Steel to Concrete Connections



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Post-installed anchor applications

- Concrete to Concrete Connections


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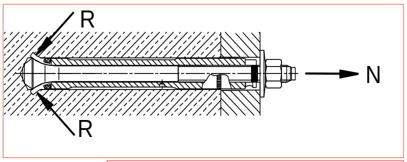
Mechanics

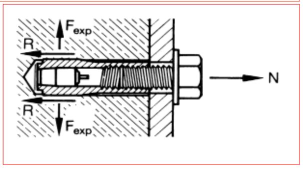
Keying

The tensile load, N, is in equilibrium with the supporting forces, R, acting on the base material



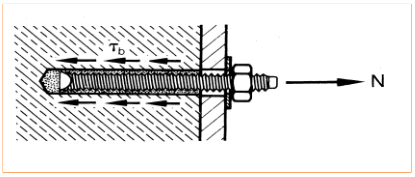
Friction

The tensile load, N, is transferred to the base material by friction, R
To build up the friction an expansion force is necessary



Bonding

An adhesive bond is produced between the anchor rod / rebar and the mortar and between mortar and drill hole walls



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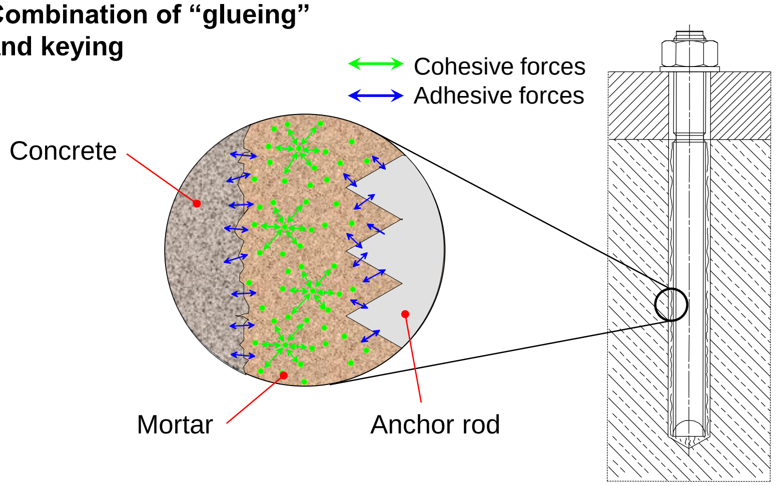
Mechanics – chemical anchors

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



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11. **Examples of Failures**

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Strength of substrate

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

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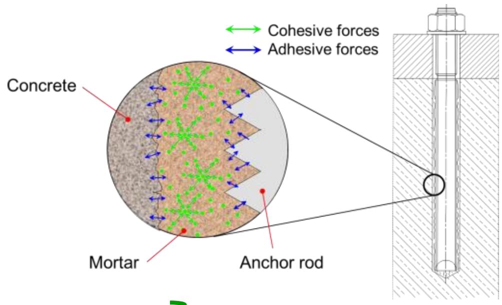
Performance considerations – hole preparation



- 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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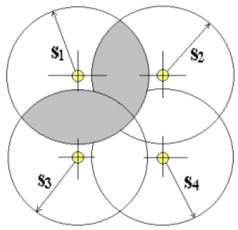
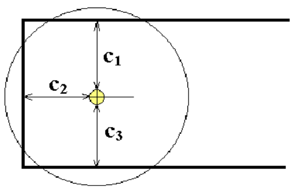
Anchor spacing and edge distance





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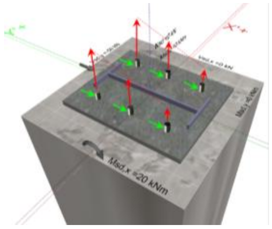
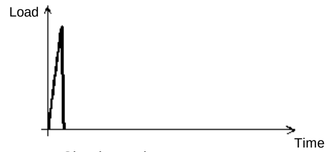
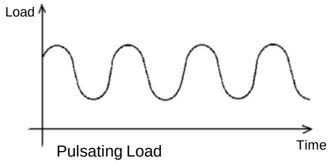
Performance considerations – type of load



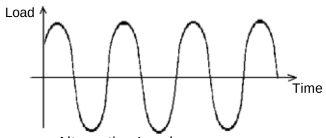
Static Load



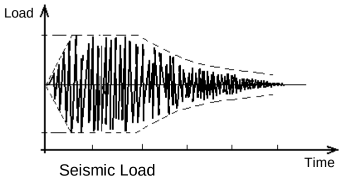
Shock Load



Pulsating Load



Alternating Load



Seismic Load

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Performance considerations - mechanical

- Proper installation eg tightening torque
- Acceptable “load to deformation” behaviour
- Perform on a long term basis - functionality
- Smaller edge and spacing requirements might cause problems with some mechanical anchors
- Variety of versions for different applications
- Capable of very high loadings

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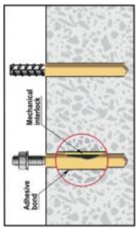
Performance considerations – generic chemical

- Very sensitive to installation procedure – requires thorough hole cleaning
- Require careful handling and storage
- Must have an acceptable “load to deformation” behaviour.
- Must perform on a long term basis.
- Smaller edge and spacing requirements are possible – especially as there is no pre-stress due to installation.
- Variety of versions for different applications.
- Capable of very high loadings.
- Capable of resisting dynamic loads
- Must be non-toxic



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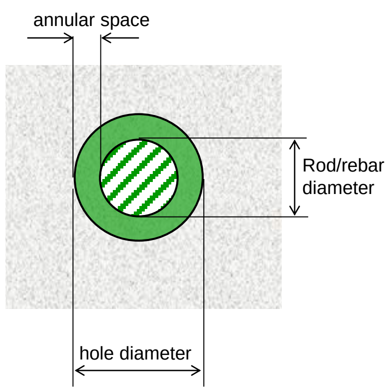
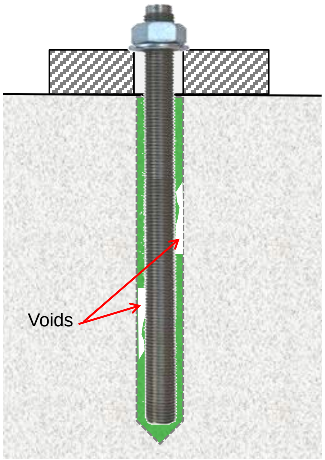
Annular space and distribution of chemical





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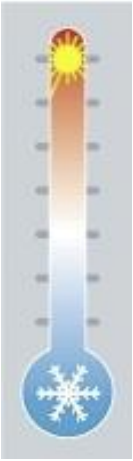
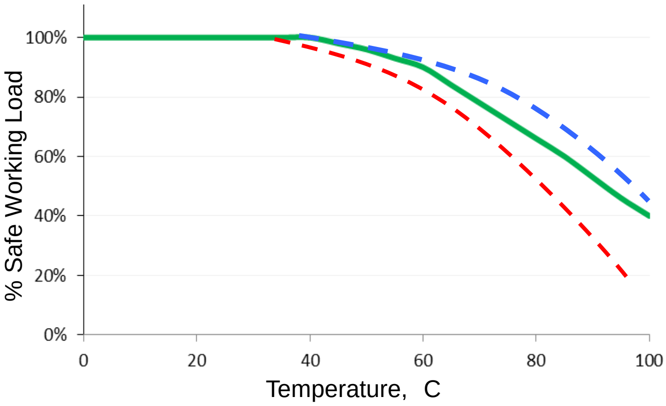
Service temperature



But… Performance is product-dependent!



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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
- ❖ More sensitive to temperature effects

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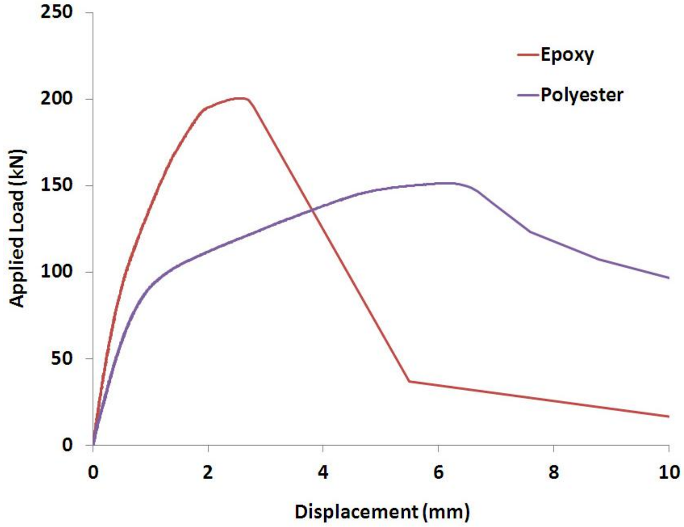
Epoxy vs Polyester



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Presentation Outline

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Failure modes

Anchorage performance is always an assembly performance.

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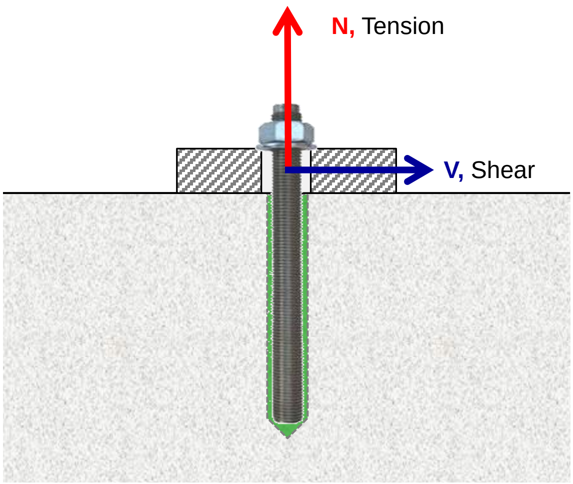
Failure modes



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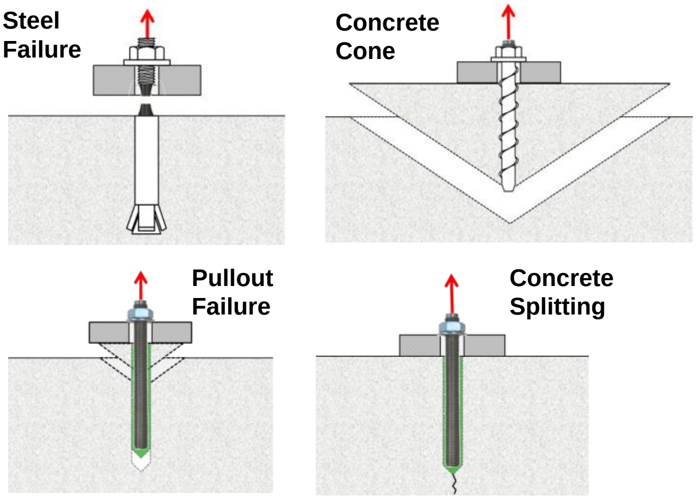
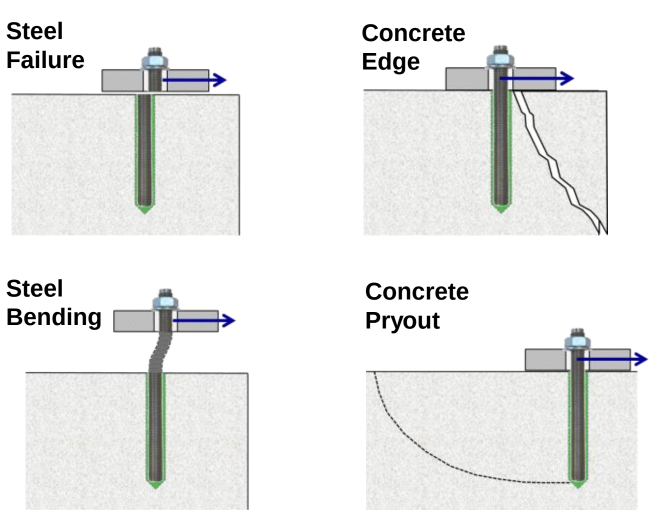
Failure modes - Tension



Failure modes - Tension

Failure modes - Shear



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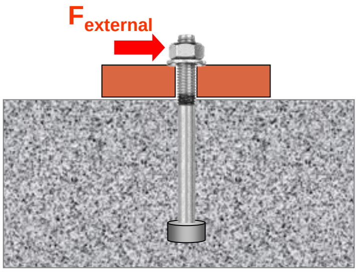
Failure modes – Shear (without lever arm)



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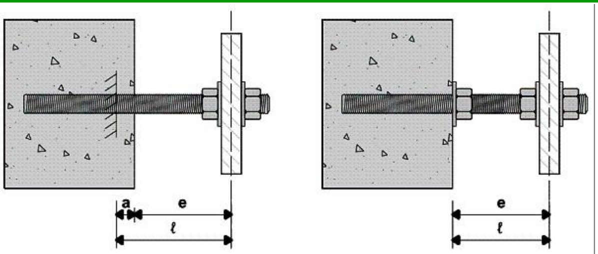
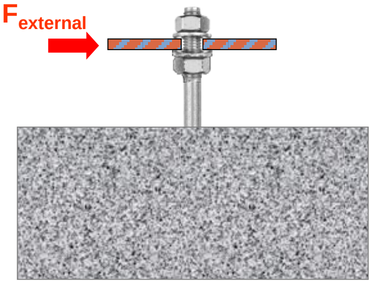
Failure modes – Shear (with lever arm)





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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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Presentation Outline

John's Anchor

Resin bonded anchor

threaded rod

resin capsule

Suitable for:
Concrete ≥ B15 (uncracked), dense natural stone

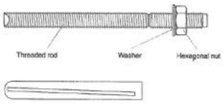
For fixing of:
General steel construction, posts, channels, connecting steel plates, warehouse storage systems, brackets, balustrading, windows, crash barriers, scaffolding, sign support bridges, machines, claddings, connecting reinforcement, shuttering fixing, etc.

Discription

The resin bonded anchor consists of a resin capsule and the threaded rod , a washer and nut. The resin capsule consists of resin, hardener and quartz aggregat.

threaded rod

resin capsule



Bob's Anchor

chemical anchors

resin capsule

threaded rod

Suitable for:
Concreate > B15 ,dense natural stone,masonry

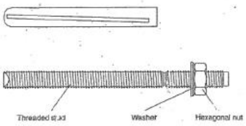
For fixing of:
Safety criticle structural application,such as , general steel construction, posts,channels, Connecting steel plates , warehouse storage systems,brackets , balustrading , windows, crash barriers,scaffolding,sign support-bridges,machines,claddings,connecting reinforcement,shuttering fixing,atc.

Discription

The chemical anchor consists of a resin capsule and the threaded stud ,a washer and nut.The resin capsule consists of synthetic resin,hardener and quartz aggregat.

resin capsule

threaded stud



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Presentation Outline

John's Anchor

Ultimate loads [kN] of single anchors with large axial and edge spacings (Mean values, uncracked concrete)[3)]

R resin bonded anchor			R8	R10	R12	R16	R20	R24	R30
Axial tension	B25 gvz [1)]	N_u	19.0*)	30.2*)	43.8*)	66.4	122.8	174.0	230.0
	A4	N_u	22.2	33.0	48.6	66.4	122.8	174.0	–
	≥ B45 gvz [1)]	N_u	19.0*)	30.2*)	43.8*)	81.6*)	127.4*)	183.6*)	286.0
	gvz [2)]	N_u	25.0	36.4	55.0	84.0	163.0	218.0	286.0
	A4	N_u	25.0	36.4	55.0	84.0	163.0	218.0	–
Shear load	≥ B25 gvz [1)]	V_u	11.4*)	18.1*)	26.3*)	49.0*)	76.4*)	110.1*)	175.0*)
	gvz [2)]	V_u	17.6*)	27.8*)	40.5*)	75.4*)	117.6*)	169.4*)	269.3*)
	A4	V_u	15.4*)	24.4*)	35.4*)	65.9*)	102.9*)	105.6*)	–

*) Steel failure decisive
1) The values apply to rods with the strength classification 5.8 (standard version)
2) The values apply to rods with the strength classification 8.8 (special version, not available as standard version)
3) The ultimate loads are valid for ambient temperatures

Bob's Anchor

Ultimate loads [kN] of single anchors with large axial and edge spacings (Mean values, uncracked concrete)[3)]

CHEMICAL ANCHOR				KR8	KR10	KR12	KR16	KR20	KR24	KR30
axial tension	B25	gvz[1)]	N_U	19.0*)	30.2*)	43.8*)	66.4	122.8	174	230
		A4	N_U	22.2	33	48.6	66.4	122.8	174	-
	B25	gvz[1)]	N_U	19.0*)	30.2*)	43.8*)	81.6*)	127.4*)	183.6*)	286
		gvz[2)]	N_U	25	36.4	55	84	163	218	286
		A4	N_U	25	36.4	55	84	163	218	-
shear load	B25	gvz[1)]	V_U	11.4*)	18.1*)	26.3*)	49.0*)	76.4*)	110.1*)	175.0*)
		gvz[2)]	V_U	17.6*)	27.8*)	40.3*)	75.4*)	117.6*)	169.4*)	269.3*)
		A4	V_U	15.4*)	24.4*)	35.4*)	65.9*)	102.9*)	105.6*)	-

*) Steel failure decisive
1) The values apply to rods with the strength classification 5.8 (standard version)
2) The values apply to rods with the strength classification 8.8 (special version ,not available as standard version)
3) The ultimate loads are valid for ambient temperatures

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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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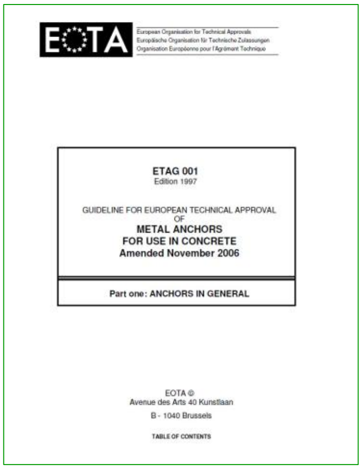
Widely used anchor design standards


EOTA
European Organisation for Technical Approvals
Europäische Organisation für Technische Zulassungen
Organisation Européenne pour l'Agrément Technique

ETAG 001
Edition 1997

GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL
OF
METAL ANCHORS
FOR USE IN CONCRETE
Amended November 2006

Part one: ANCHORS IN GENERAL

EOTA ©
Avenue des Arts 40 Kunstlaan
B - 1040 Brussels

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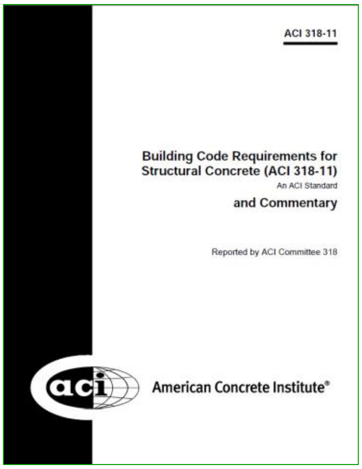
ACI 318-11

Building Code Requirements for Structural Concrete (ACI 318-11)
An ACI Standard
and Commentary

Reported by ACI Committee 318

American Concrete Institute®

ACI 318-11

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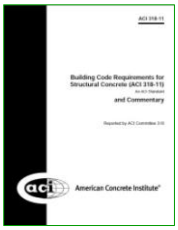
Concrete Capacity Design model



- 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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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. **Selection**
9. Design
10. Installation – General
11. Examples of Failures

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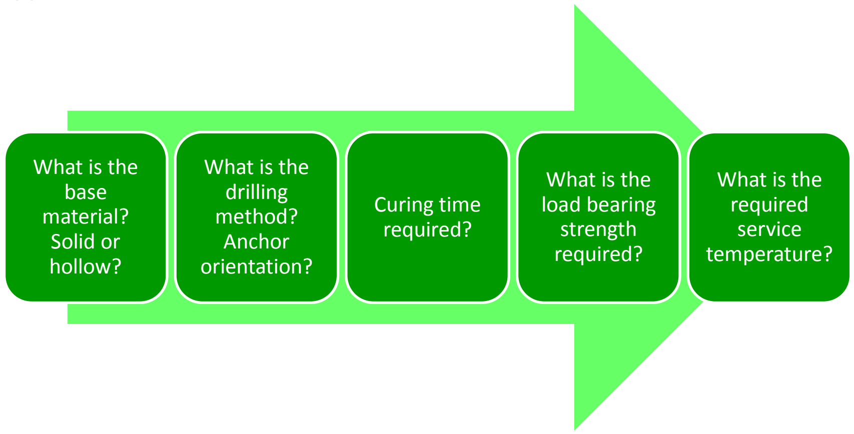
Anchor Selection

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



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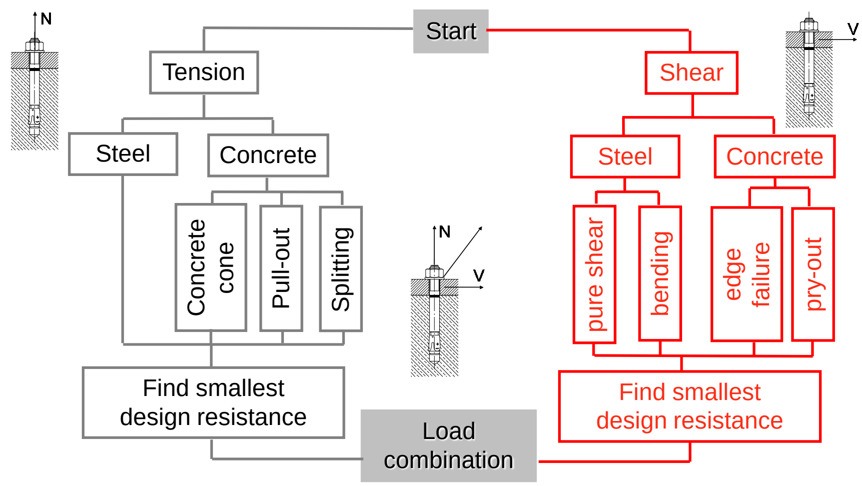
Anchor Design



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Anchor Design – tension example (bonded anchor)

Steel Capacity

$$N_{Rk,s} = A_s.f_{uk}$$

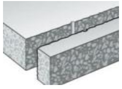
Concrete Capacity (Use $c_{cr,N}$ and $s_{cr,N}$)

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

Anchor Group

Pull-Out Capacity (Use $c_{cr,Np}$ and $s_{cr,Np}$)

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



Splitting Capacity (Use $c_{cr,sp}$ and $s_{cr,sp}$)

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

Actual member depth

Edge influence Eccentricity Dense Reinforcement

$$N^0_{Rk,c} = k_1\sqrt{f_{ck,cube}}.h_{ef}^{1.5}$$
$$k_1 = 7.2 \text{ (for cracked concrete)}$$
$$k_1 = 10.1 \text{ (for non-cracked concrete)}$$

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

$$S_{cr,N} = 3.h_{ef}$$
$$S_{cr,Np} = 20.d.\left(\frac{\tau_{Rk,ucr}}{7.5}\right)^{0.5} \leq 3.h_{ef}$$

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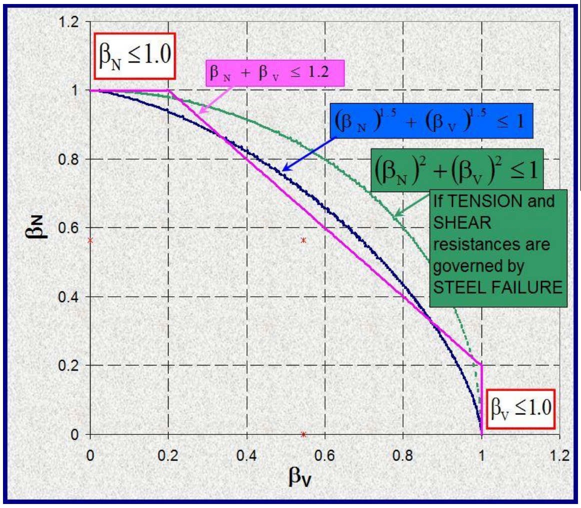
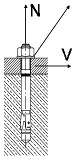
Anchor Design – combined loads



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

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



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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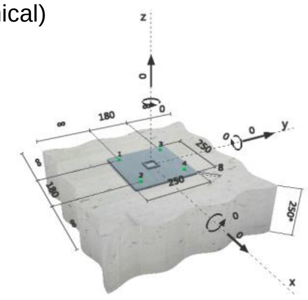
Anchor Design – Guidelines

European
Qualification: ETAG 001, Part 1 – 5
Design: ETAG 001 Annex C
http://www.eota.be/pages/home/

American
Qualification: ACI 355.2 (mechanical) & 355.4 (chemical)
Design: ACI 318 – Appendix D
http://www.concrete.org/general/home.asp

Software exists to design “qualified” anchors. Ask your manufacturer!



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Presentation Outline

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Proper Installation is key to performance

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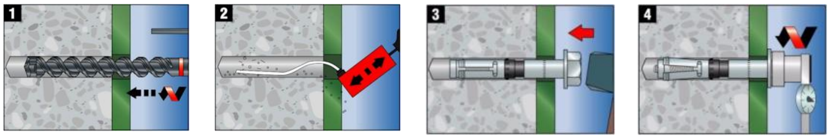
Installation – Mechanical Anchors



Drill Clean Insert Torque

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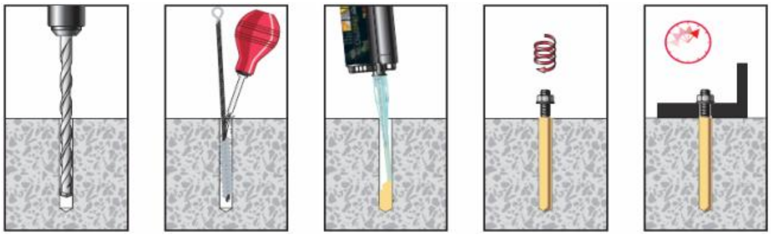
Installation – Chemical Anchors

Waste product until even consistency achieved



Drill Clean Inject Insert Cure

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Tools for Installation

ALL

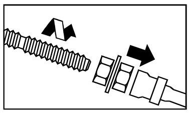
Cleaning brush

Blow-out pump

CAPSULE

Threaded rod setting tool

Socket



CARTRIDGE

Chemical Dispenser

Chemical Tube

Mixing Nozzle

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Anchor failures do happen!

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Summary

- AEFAC is an industry initiative lifting quality and safety standards for the Australian post-installed anchor industry.
- Post-installed anchors offer many benefits such as high load capacity and a flexible layout in diverse substrates.
- Qualification standards exist for quality assurance.
- Comprehensive design guidelines exist, software exists for simplified specification.
- Performance is sensitive to installation procedure.
- Always follow manufacturer's installation instructions.
- If in doubt ask manufacturer's technical support.

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Q & A

THANK YOU!