Australian Engineered Fasteners & Anchor Council

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

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.

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Participants

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.”
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

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.
Overview of AEFAC – Industry Needs

Guideline for minimum performance specifications for anchors
For Manufacturers

Certified training for installation of anchors
For Contractors

Guideline for specification of anchors
For Designers

Guideline for field testing and certification of anchors
For Field Engineers

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
Overview of AEFAC – Looking abroad

Europe
- ETAG 001 – Guideline for European Technical Approval of Metal Anchors 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)

Overview of AEFAC - Organization

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

2. Director
   David Heath

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

4. General Members
   Other industry participants
Overview of AEFAC - Aims

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

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

**Future**
- Screws
- Fasteners
Presentation Outline

1. Overview of AEFAC
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9. Selecting the right anchor

Why are chemical anchors widely used?

- It is a post-installed anchor system.
Why are chemical anchors widely used?

- Smaller edge and spacing requirements.

Why are chemical anchors widely used?

- Protects the embedded part from direct corrosion.
Chemical anchor elements

- Threaded rods
- Rebars
- Internally threaded rods
- Special elements

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How chemical anchors work.

- Combination of “glueing” and keying

Concrete → Mortar → Anchor rod

Cohesive forces ↔ Adhesive forces
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Chemical Anchor Applications

- Structural Fastenings Applications
Chemical Anchor Applications

- Architectural Fastenings

- 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

Types based on chemical composition

Chemical Anchors

Unsaturated Polyester

Vinylester, Epoxy Acrylate, Methacrylate

Epoxy
## 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
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**

- Static Load
- Pulsating Load
- Alternating Load
- Shock Load
- Seismic Load

**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.
Anchor spacing and edge distance

Annular space and distribution of chemical
Type and strength of base material strength

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

Service temperature

![Chart showing the percentage of safe working load vs. temperature in °C. The chart indicates a reduction in load capacity as the temperature increases.](chart.png)

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Parts of an anchoring system

Anchorage performance is always an assembly performance.

Fastened element
Base material
Chemical anchor
Force nomenclature

N, Tension
V, Shear

Possible Failures in Tension

Steel Failure
Concrete Cone
Pullout Failure
Concrete Splitting
Possible Failures in Shear

- Steel Failure
- Concrete Edge
- Steel Bending
- Concrete Pryout

Anchor failures do happen!
Anchor failures do happen!
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How safe is “safe enough”? 
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

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
The significance of accuracy

Widely used anchor design standards

- EOTA Technical Report
  Design of Bonded Anchors
  TR 029

- AC 308
  Acceptance Criteria for Post-installed Mechanical Anchors in Concrete Elements
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.

TR-029 chemical anchor design process
TR-029: Concrete cone strength

Design concrete cone strength

\[ N_{Rd,c} = \frac{N_{Rk,c}}{Y_{Mc}} \]

Characteristic concrete cone strength

\[ N_{Rk,c} = \frac{A_{c,N}}{A_{c,N}^0} \cdot N_{Rk,e} \]

Basic breakout strength of a single anchor

\[ N_{Rk,e} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5} \]

Ratio of Failure Surface Areas

- Actual failure surface area
- Ideal failure surface area of a single anchor

Modification Factors

- Edge distances
- Rebar tension
- Eccentricity

Determination of \( A_{c,N} \)

\[ A_{c,N}^0 = 9 \cdot h_{ef}^2 \]

Section through failure cone

Plan view
TR-029: Concrete cone strength

Sample determination of $A_{c,N}$

- Critical edge distance: $c_{cr,N} = 1.5 \ h_{ef}$
- Critical spacing: $s_{ef,N} = 2 \ h_{ef}$
- $S_1, S_2 < S_{cr,N}$
- $c < c_{cr,N}$
**TR-029: Concrete cone strength**

Sample determination of $A_{c,N}$

![Diagram showing critical edge distance and critical spacing](image)

- Critical edge distance: $c_{cr,N} = 1.5 \cdot h_{ef}$
- Critical spacing: $s_{cr,N} = 2 \cdot c_{cr,N} = 3 \cdot h_{ef}$
- $S_1, S_2 < s_{cr,N}$
- $c < c_{cr,N}$

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

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**TR-029: Concrete cone strength**

Design concrete cone strength

- $N_{rd,e} = \frac{N_{rk,e}}{\gamma_{Mc}}$

Characteristic concrete cone strength

- $N_{ak,e} = N_{rk,e} \frac{\bar{A}_{c,N}}{\bar{A}_{c,N}} \cdot \Psi_{k,N} \cdot \Psi_{k,N} \cdot \Psi_{ef,N}$

Basic breakout strength of a single anchor

- $N_{bc,e} = k_3 \cdot \sqrt{f_{cd,core}} \cdot h^{1.5}$

Ratio of Failure Surface Areas

- $A_{c,N} \cdot \Psi_{k,N} \cdot \Psi_{k,N} \cdot \Psi_{ef,N}$

Modification Factors

- $\Psi_{k,N} \cdot \Psi_{k,N} \cdot \Psi_{ef,N}$

- Edge distances
- Rebar
- Tension Eccentricity
**TR-029: Concrete cone strength**

**Determination of $\Psi_{ec,N}$**

\[
N_{ec,C} = N_{ek,C}^{0} \cdot \frac{A_{c,N}}{A_{k,N}} \cdot \Psi_{e,N} \cdot \Psi_{ec,N} \cdot \Psi_{ek,N}
\]

\[
\Psi_{e,N} = \frac{1}{1 + 2\varepsilon_{e,N}^2 \delta_{e,N}} \leq 1
\]

Center of anchors in tension

Resultant tensile load line of action

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**TR-029 chemical anchor design process**

**Failure Modes in Tension**
- Steel: Pure Tension
- Concrete: Core
- Concrete: Combined Core + Pullout
- Concrete: Splitting

**Design Strength in Tension**

**Failure Modes in Shear**
- Steel: Pure Shear
- Steel: Bending
- Concrete: Edge
- Concrete: Pullout

**Design Strength in Shear**

**Tension & Shear Interaction**
**TR-029: Pullout strength**

Basic pullout strength of a single anchor

\[ N_{Rk,p} = \pi \cdot d \cdot h_m \cdot \tau_Rn \]

Ratio of Failure Surface Areas

\[ c_{sp,fp} = \frac{S_{sp,fp}}{2} \]
\[ S_{sp,fp} = 20 \cdot d \cdot \left( \frac{\tau_{fmeq}}{7.5} \right)^{0.6} \]

Modification Factors

\[ N_{Ed,p} = \frac{N_{Rk,p}}{\gamma_M} \]

\[ N_{Ed,p} = N_{Rk,p} \cdot \frac{A_{PM}}{A_{PM}} \]

**TR-029 chemical anchor design process**

Failure Modes in Tension
- Steel: Pure Tension
- Concrete: Cone
- Concrete: Combined Cone + Pullout
- Concrete: Splitting

Design Strength in Tension

Tension & Shear Interaction

Failure Modes in Shear
- Steel: Pure Shear
- Steel: Bending
- Concrete: Edge
- Concrete: Pullout

Design Strength in Shear
TR-029: Shear bending strength

\[
V_{Rd,sm} = \frac{V_{Rk,sm}}{\gamma_{Mf}}
\]

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

TR-029 chemical anchor design process

Failure Modes in Tension
- Steel: Pure Tension
- Concrete: Core
- Concrete: Combined Core + Pullout
- Concrete: Splitting

Design Strength in Tension

Tension & Shear Interaction

Failure Modes in Shear
- Steel: Pure Shear
- Steel: Bending
- Concrete: Edge
- Concrete: Pullout

Design Strength in Shear
TR-029 chemical anchor design process

Basic pullout strength of a single anchor

\[ V_{kd,c} = \frac{V_{bk,c}}{\gamma_{Mc}} \]

\[ V_{bk,c} = \frac{A_{ke} \cdot f_{c}}{A_{ke}} \cdot \frac{A_{ke} \cdot f_{c}}{A_{ke}} \cdot \frac{A_{ke} \cdot f_{c}}{A_{ke}} \cdot \frac{A_{ke} \cdot f_{c}}{A_{ke}} \]

Ratio of Failure Surface Areas

Modification Factors

TR-029 chemical anchor design process

Failure Modes in Tension

- Steel: Pure Tension
- Concrete: Core
- Concrete: Combined Cone + Pullout
- Concrete: Splitting

Design Strength in Tension

Failure Modes in Shear

- Steel: Pure Shear
- Steel: Bending
- Concrete: Edge
- Concrete: Pull-out

Design Strength in Shear

Tension & Shear Interaction
**TR-029 tension and shear interaction**

\[ \beta_N = \frac{N_{sd}}{N_{rd}} \]

\[ \beta_V = \frac{V_{sd}}{V_{rd}} \]

- \( N_{rd} \) = Design value of tension resistance
- \( N_{sd} \) = Design value of acting tension load
- \( V_{rd} \) = Design value of shear resistance
- \( V_{sd} \) = Design value of acting shear load

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Proper Installation is key to performance

Installation of Injectable Chemical Anchors

- Chemical Dispenser
- Chemical Tube
- Mixing Nozzle
- Blow-out pump
- Cleaning brush
The significance of the mixing nozzle

Installation of Injectable Chemical Anchors
Installation of Injectable Chemical Anchors

Sieves / Perforated sleeve

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

Threaded rod setting tool

Threaded rod with wedge tip

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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”
Anchor Selection

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

What is the base material? Solid or hollow?
What is the drilling method? Anchor orientation?
Curing time required?
What is the load bearing strength required?
What is the required service temperature?

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