Proposed Australian design standard and installer certification for safety-critical anchors to concrete

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- Ramil Crisolo

www.aefac.org.au

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: aefac@aefac.org.au
OVERVIEW

Part 1
- Australian Engineered Fasteners and Anchors Council
- Safety-critical anchors
- Design methodology
- Case study
- Proposed AEFAC Standard

Part 2
- Post-installed fasteners
- Performance considerations
- AEFAC Installer Certification Program
- Additional resources
- Summary & acknowledgements
AUSTRALIAN ENGINEERED FASTENERS AND ANCHORS COUNCIL

- United approach + improved safety + minimum standards
- Consistency in test methods and specification
- Education to industry

Formed in 2012 to stop anchor failures!

Guidelines for the specification of anchors
For Designers

Minimum performance & standard specification
For Manufacturers

Training & accreditation for installers of anchors
For Contractors

Guideline for field testing & certification of anchors
For Field Engineers

Research & Development
For anchor industry

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AEFAC: David Heath, Jessey Lee

General Members (future)
Other industry participants
SAFETY-CRITICAL ANCHORS
Safety-Critical Anchors

Products
- Significant growth in use of anchor products
- New products entering the market

Governance
- Anchor industry largely relies on self-regulation
- How can you design to best practice?
- No Australian design or testing guidelines (except AS3850)

Conformity assessment
- Lack of conformity assessment culture in Australia
- What does the product conform to?

Safety-critical anchors - failure would risk human life and have potential for considerable economic consequences
A “safe” anchoring system:

1. **PREQUALIFICATION** → Independent testing and assessment (via ETA/ICC) to demonstrate “fit for purpose”

2. **DESIGN** → Rigorous assessment to develop solution for a given application

3. **INSTALLATION** → Informed and competent installer having appropriate supervision
DESIGN METHODOLOGY

AS3600 (2009)
Cl. 14.3 (d) Fixings

“The design strength of this anchorage shall be taken as \( \phi \) times the ultimate strength, where \( \phi = 0.6 \). 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.”
Concrete Capacity Method

- Developed in Europe
- Published in ETAG 001 (1997)
- ACI uses “CCD” (very similar)
- Accurate prediction of the suitability of a specific anchor to a specific application
- Only compatible with anchors that have been tested and assessed in accordance with strict guidelines

Design Methodology

Tension failure modes

- Anchor Fracture
- Concrete Cone
- Pull-out
- Combined Cone & Pull-out
- Splitting
- Blow-out

- Anchor Bolt Fracture
- Channel Lip
- Channel Flexure
- Anchor/Channel Connection
- Supplementary Reinforcement – Anchorage Failure
- Supplementary Reinforcement – Fracture
**Design Methodology**

Shear failure modes

- Fracture (No Lever Arm)
- Bending (Lever Arm)
- Edge Failure
- Pryout Failure

**Example: Concrete cone failure mode (tension)**

\[ N_{\text{res}} = N_{\text{res}} \cdot \frac{A_{r}}{A_{r}} \cdot \psi_{r} \cdot \psi_{r} \cdot \psi_{r} \cdot \psi_{r} \]

- \( N_{\text{res}} \) = characteristic concrete cone strength (no spacing effects, edge effects, etc.)
- \( A_{r} \) = adjustment for effects of fastener spacing and edge effects (can the full inverted rectilinear pyramid cone form?)
- \( \psi_{r} \) = factor accounting for disturbance of stresses in concrete due to an edge
- \( \psi_{r} \) = factor accounting for a dense layer of reinforcement in concrete
- \( \psi_{r} \) = factor accounting for different tension loads on fasteners in a group subjected to eccentric loading
- \( \psi_{r} \) = factor accounting for the influence of a compression force between the fixture and concrete when a bending moment is present

**NB:** Still need to consider other potential modes of failure to determine decisive failure mode!
Software
- Freely available from reputable manufacturers
- Rapidly solve complex designs (minutes vs. hours/days!)
- Include prequalified products (i.e. ETA)
- Compatible with AEFAC Standard (with conversion)

But I’ve been doing it this way for years!
CASE STUDY

- 11.20pm, August 13, 2011, 190 feet (58 m) canopy-fence collapsed onto the 20 lane Interstate Highway 75/85

Source: www.wsbtv.com
Case Study

- Nobody was injured, no vehicles damaged
- Canopy-fence collapsed onto 20-lane Interstate Highway 75/85
- Investigation found:
  - Bridge opened seven years earlier (2004)
  - Anchors were subjected to sustained load that was substantially lower than (approx. ¼ of) the design service load
  - Voids 1 – 1.5 inches in length detected at rear of holes
  - Wet epoxy extracted from holes (7 years after installation)
  - Laboratory studies revealed different material composition in different areas and hardener-rich and resin-rich areas
  - Adhesive was susceptible to creep
PROPOSED AEFAC STANDARD

Overview
- Based on European guidelines (prEN 1992-4)
- ‘Adaptation’ required: notation and terminology, referencing local standards, material properties, etc.
- Fundamental design procedure unchanged
- Compatible with products having ETAs
- Proposed referencing in Building Code of Australia
- Currently available for public comment (www.aefac.org.au)
PROPOSED AEFAC STANDARD

Scope

- **Post-installed fasteners**
  - Mechanical anchors (expansion anchors, undercut anchors & concrete screws)
  - Chemical anchors (bonded anchors, bonded expansion anchors)

- **Cast-in fasteners**
  - Headed fasteners
  - Anchor channel

PROPOSED AEFAC STANDARD

Development Committee

- Alithread Industries Pty Ltd
- Ancon Building Products
- Australian Building Codes Board
- Australian Engineered Fasteners and Anchors Council
- Australian Steel Institute
- Australian Window Association
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Concrete Institute of Australia
- Edith Cowan University
- Engineers Australia
- Hilti (Aust.)
- Housing Industry Association Ltd
- Hobson Engineering Company Pty Ltd
- ITW Construction Systems
- National Precast Concrete Association Australia
- Simpson Strong-Tie
- Stanley Black & Decker Australia Pty Ltd (Powers)
- Swinburne University of Technology
- Würth Australia Pty Ltd
PROPOSED AEFAC STANDARD

Part 1 (overview)
- Materials and installation
- Determination of forces acting on fasteners
- Design for tensile loading
- Design for shear loading
- Design for combined tension & shear loading
- Design for serviceability
- Design for fatigue loading

Robust design methodology considering all modes of failure.

PROPOSED AEFAC STANDARD

Part 2 (overview)
- Test requirements for fasteners
- Assessment requirements for fasteners
- Manufacturing requirements
- Alternative path (products with an ETA)

Ensures fasteners are ‘fit for purpose’ and compatible with AEFAC Standard Part 1.
PROPOSED AEFAC STANDARD

Why the proposed AEFAC Standard is important

- Consistency in terminology, notation and design data
- Greater certainty for specification of safety-critical fasteners
- Ability to easily distinguish quality fasteners
- Transparent testing and assessment of fasteners
- More flexible and efficient designs
- Seeking to align representation in the BCA/NCC with other types of safety-critical connections (e.g. welds, bolted connections, etc.)

Greater reliability, greater safety, reduced risk of failure!

“The best anchor is only as good as its installation”
POST- INSTALLED FASTENERS

CATEGORIES

Fastening methods

Cast-in
- Channel
- Headed inserts
- Threaded sleeves/ferrules
- L-, J-bolts
- Bent reinforcement

Post-installed

Drill & fix

Mechanical
- Expansion anchors
- Undercut anchors
- Displacement controlled
- Torque controlled

Direct installation

Bonded
- Capsule
- Unsaturated polyester
- Vinylester
- Epoxy

Injection
- Unsaturated polyester
- Vinylester
- Epoxy
- Cementitious
**Post-installed Fasteners**

**Chemical Anchors: Types**

- **Injectable**
  - Flexible to different sizes and variable embedment depths.

- **Capsule**
  - No wastage
  - Faster to install

**Chemical Anchors: Components**

- Anchor rods
- Internally threaded rods
- Rebar
- Special elements

- Sieves
- Injection Systems
- Capsule Systems
POST-INSTALLED FASTENERS

APPLICATIONS: STEEL TO CONCRETE CONNECTIONS

APPLICATIONS: CONCRETE TO CONCRETE CONNECTIONS
PERFORMANCE CONSIDERATIONS

INSTALLATION

1. Drill
2. Clean (blow, brush)
3. Inject
4. Insert anchor rod
5. Cure before installing fixture & correct torque
**Performance Considerations**

**Installation**

- Static mixer nozzle must not be shortened

Unmixed ➔ Mixed

Waste product until even consistency achieved

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**Performance Considerations**

**Installation**

- **ALL**
  - Cleaning brush
  - Blow-out pump

- **Capsule**
  - Threaded rod setting tool
  - Socket

- **Cartridge**
  - Chemical Dispenser
  - Chemical Tube
  - Mixing Nozzle
PERFORMANCE CONSIDERATIONS

INSTALLATION

AEFAC INSTALLER CERTIFICATION PROGRAM
Until now, performed on an ad-hoc basis – job dependent, product specific
Reasonable errors acceptable, gross errors dangerous
Combination of appropriate training and supervision critical
Clear need for a program to provide:
- Written and practical test
- How to correctly drill
- How to correctly prepare a hole
- Understanding anchor systems
- Understanding risks of errors

**INSTALLER ACCREDITATION PROGRAM**

<table>
<thead>
<tr>
<th>Element</th>
<th>Europe†</th>
<th>U.S.‡</th>
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<tbody>
<tr>
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<tr>
<td>- re-certification (written and practical)</td>
<td>2 – 3 years</td>
<td>5 years</td>
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† Performed on a Member State basis, currently only mandatory in Germany for post-installed rebar connections.
‡ ACI 318-14: “Installer certification and inspection requirements for horizontal and upwardly inclined adhesive anchors subjected to sustained tension loading shall be in accordance with 17.8.2.2 through 17.8.2.4.” (Cl. 17.2.5)
AEFAC INSTALLER CERTIFICATION PROGRAM

- **Written examination**

  - **Practical examination**
    - Part 1: Vertical down installation
    - Part 2: Overhead installation

  - **Certification awarded**

  - **Recertification period**
    - Initial: Three years
    - Additional: Every five years

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**Written Examination**
- 65 multiple choices &/or true false questions
- 5 mandatory questions to answer CORRECTLY
- 60 minutes
- Closed book exam

**Practical Examination (2 trials / day)**
- Vertical down installation
  - Drill hole
  - Clean hole
  - Inject adhesive
  - Insert anchor
- Overhead installation
  - Inject adhesive with piston plug
Re-Examination
- If failed either written/practical exam, re-examination must be taken within 1 year after passing the other exam
- If failed one of the 2 components of practical exam, e.g. overhead installation, only need to retake failed component

Recertification
- First recertification – 3 years
- Subsequent – every 5 years

Important note:
“By completing certification, you have demonstrated that you understood the risks involved in poor installation practices”

Failure to comply after certification awarded
- Certification status revoked
- Potential legal implications!
AEFAC INSTALLER CERTIFICATION PROGRAM

4TH FEBRUARY SOFT LAUNCH
AEFAC Installer Certification Program

4th February Soft Launch
AEFAC INSTALLER CERTIFICATION PROGRAM

4TH FEBRUARY SOFT LAUNCH

ADDITIONAL RESOURCES
Overview of AEFAC
AEFAC members
Education events
Technical Notes
Sample Specifications
Proposed AEFAC Standard
Links to resources

Additional Resources
www.aefac.org.au

- Australian Engineered Fasteners and Anchors Council
  www.aefac.org.au
- European Organisation for Technical Approvals (EOTA)
  - AEFAC endorsed www.eota.eu
- European Technical Approval Guideline 001, Parts 1 – 5, Annex A & B,
  www.eota.eu
  fastenings for use in concrete
- BS 8539:2012 “Code of practice for the selection and installation of post-installed
  anchors in concrete and masonry”
- Construction Fixings Association (UK): www.fixingscfa.co.uk
  - Comprehensive guidance on best-practice for selection and application
- Australian Technical Infrastructure Committee – endorses European design
  - ATIC SP38 & SP39 (see www.apcc.gov.au)
- Standing Committee on Structural Safety (SCOSS) www.structural-safety.org
Anchor industry is safety-critical.
Anchor failures should not happen – they do!
AEFAC has created a body of knowledge and expertise to introduce governance to the Australian anchor industry
The proposed AEFAC Standard seeks to provide a consistent and robust approach to anchor design based on best practice
The AEFAC Installer Certification Program has been developed to equip installers with the skill to ensure that anchors are installed as intended
Collectively, these measures introduced by AEFAC are lifting quality and safety standards in the Australian construction industry.
SUMMARY & ACKNOWLEDGEMENTS

Founding Board Members

Supporting Members