TECHNICAL NOTE: CRACKED VERSUS NON-CRACKED CONCRETE

1 SCOPE

This Technical Note provides advice on the classification of concrete with regard to cracking to aid with the selection and installation of anchors in new and existing concrete structures. The advice provided in this document is of a general nature and is consistent with international guidelines ([1], [2]). Information provided should not be considered a substitute for manufacturer's installation instructions or technical advice from your manufacturer. Incorrect diagnosis of the condition of the concrete in which the anchor is to be installed may prevent safety-critical anchors from functioning correctly leading to catastrophic outcomes.

2 TERMINOLOGY

The following terminology and definitions are adopted in this document. Additional terminology and definitions may be found in the AEFAC Anchor Dictionary [3].

Anchor – an assembly comprising base material (concrete or masonry), anchor or anchor group and component fixed to the base material.

Cracked concrete – concrete that is likely to experience cracking during its lifetime; justification should be provided if uncracked properties are adopted.

European Technical Assessment (ETA) – a prequalification for a construction product that represents a favourable technical assessment of its fitness for an intended use. European Technical Approvals issued prior to 1st July, 2013 will remain relevant for their period of validity. The period of validity of a European Technical Assessment is unlimited provided an AVCP system is in place.

Expansion anchor – a type of anchor that engages with the base material via the expansion of its components and that derives its strength through frictional forces.

Extrinsic imposed deformation – deformation experienced in the concrete due to external factors such as thermal expansion/contraction, differential movement of adjoining structural members, etc.

Intrinsic imposed deformation – deformation experienced due to characteristics of the concrete, such as shrinkage.

Non-cracked concrete – concrete that has been demonstrated via stress analysis to remain crack-free in the vicinity of the anchor throughout the design life under all design load considerations.

Option number – a number from 1 to 12 denoting the particular test regime an anchor is tested and assessed against that is also published in the ETA.

Prequalification – the certification for a product attesting to it being fit for its intended use based on an independent testing and assessment program such as a European Technical Assessment.

Supplier – an individual or organisation that supplies anchors.

Undercut anchor – a post-installed anchor that is engaged with the base material via mechanical interlock provided by undercutting the concrete at the embedment end of the anchor. A special drill bit may be required to provide the undercut or this may be achieved by the anchor during installation.

3 DEFINITION OF CRACKED CONCRETE

The term 'cracked concrete' refers to concrete that may experience cracking passing through the plane of the anchor at some time after installation of the system. Cracked concrete does not refer to the state of the concrete at the time of installation and post-installed anchors are not currently designed for installation in existing cracks. There are a multitude of factors that could individually, or collectively, lead to the cracking of concrete during the service life of the anchor.

Concrete may crack due to a variety of reasons. One of the most important design considerations when selecting an anchor is the state of the concrete. Where no guidance is available that indicates the condition of the concrete, the designer should demonstrate via stress analysis, that cracking will not be experienced during the service life of the anchor, if the anchor is to be designed for non-cracked concrete. For all other applications, cracked concrete should be assumed. An appraisal may be performed on existing structures by a competent engineer. Figure 1 illustrates regions in common slab and beam systems that may generally be considered non-cracked concrete. Further guidance on the location of these regions may be found in [4].

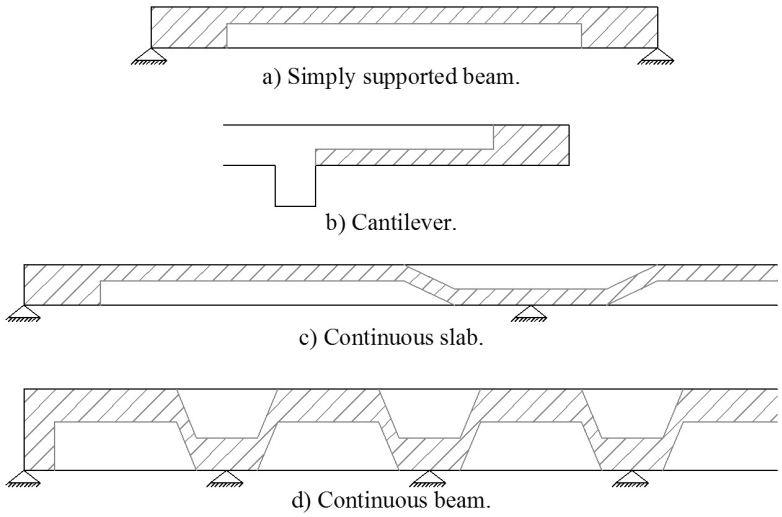

Figure 1: Non-cracked concrete locations (shown as diagonal lines) in common beam and slab systems.

Anchors designed for cracked concrete automatically qualify for use in non-cracked concrete. Where cracked concrete is expected, anchors with Options 1 – 6 in their ETA should be selected, whereas anchors qualified only in non-cracked concrete applications should be selected according to Options 7 – 12 [5].

The condition of the concrete throughout the service life of the anchor should be determined by the designer. A judgement on the condition of the concrete – cracked or non-cracked – may be made on the basis of the following assessment of the stress condition:

$$\sigma_L + \sigma_R \leq \sigma_{adm}$$

where

σ_L = Stresses in the concrete due to external loads, including those applied by the fastener

σ_R = Stresses in the concrete due to intrinsic imposed deformations (such as shrinkage) or extrinsic imposed deformations (such as displacement of supporting members of structure, thermal expansion/contraction, etc.). In the absence of a detailed analysis, prEN 1992-4 suggests σ_R = 3 MPa.

σ_{adm} = Admissible tensile stress for the definition of cracked concrete determined at 28 days with standard curing according to AS 3600 [6]. The recommended value is $\sigma_{adm} = 0$ such that only regions experiencing compression are deemed to be non-cracked.

Both σ_L and σ_R should be calculated assuming non-cracked concrete and compressive stresses are negative. Where bi-directional stresses are present such as in two-way slabs, the above condition should be satisfied in both directions.

Knowledge of the shrinkage and thermal characteristics of the concrete is essential for crack control. Various factors affect drying shrinkage including external factors (ambient conditions, member geometry) and internal factors (cements, aggregates, admixtures, water content and construction practice) and these reduce with time [7]. For existing structures these factors are less of a concern.

For seismic design, the concrete should be assumed to be cracked unless a comprehensive analysis demonstrates the concrete remains non-cracked throughout the seismic event.

4 PREQUALIFICATION

An anchor that has not been awarded a prequalification for cracked concrete should not be used in cracked concrete. The awarding of a prequalification (such as an ETA) in cracked concrete is a demonstration that the anchor will continue to function as intended in the event that a crack of limited width, passes through the plane of the anchor during its design life [9]. ETAG 001 limits crack widths (w_k) to w_k = 0.3 mm for quasi-permanent loads [5]. Under serviceability loading, there may be short periods where the structure experiences loads above the quasi-permanent loads, resulting in increased crack widths. This situation is accounted for during testing whereby the anchor is subjected to opening and closing cracks where the width is increased to w_k = 0.5 mm.

An anchor qualified for use in cracked concrete automatically qualifies for use in non-cracked concrete. An anchor that has received this prequalification may not be installed in an existing crack. Limitations on anchor performance in cracked concrete are defined in the ETA or may be obtained from the anchor supplier.

Resistances for cracked concrete are lower than for non-cracked concrete and these products are generally more expensive. However, the strength of an anchor may be up to 40% greater in non-cracked concrete, offering potential cost-savings in non-cracked concrete [8].

An ETA is awarded on the basis of a product being favourably assessed for a given Option number which outlines the scope of product's intended use. Options 1 – 6 are valid for cracked and non-cracked concrete, whereas Options 7 – 12 are valid for non-cracked concrete only. Further guidance is available at [9].

5 SELECTION OF A SUITABLE ANCHOR

There are many factors requiring consideration during the selection of a suitable fastening solution. A key design consideration is the condition of the concrete with regard to being cracked or non-cracked. Cracking may only occur at a time after installation. Regardless of prequalification, no anchor may be installed in a pre-existing crack.

The condition of concrete with regard to cracking is a key design consideration as per existing guidelines [10] and the pre-standard prEN 1992-4 [11]. The condition of concrete is commonly overlooked by design engineers even though this is a critical consideration in selecting a suitable fastening solution. The condition of the concrete should be identified prior to selection of a suitable anchor, by the design engineer.

An anchor that has been selected for installation in non-cracked concrete should be accompanied by a justification as to why cracking will not occur.

An anchor should be designed for *cracked* concrete if *any* of the following conditions are *not* met:

1. A stress analysis reveals the combination of intrinsic and extrinsic loads result in tensile stresses lower than the admissible tensile (cracking) stresses in the concrete for all directions under consideration.
2. The anchor under consideration has not been independently tested and assessed to perform in cracked concrete and received appropriate prequalification such as an ETA [5].
3. If the structure incorporates seismic design, analysis reveals the concrete remains crack-free throughout the seismic event.

Note that in order for an anchor to successfully function in a seismic event, it should have the appropriate prequalification (ETAG 001 Annex E) [5]. It is considered best practice to assume all concrete is cracked, for the purpose of selecting an appropriate anchoring solution.

It may be possible for certain undercut and expansion anchors to be positioned in a tension (cracked) zone, yet be designed for non-cracked concrete on the provision that the actuation of the anchor occurs in a compression zone. Specialist advice should be received from the manufacturer for this condition.

6 SUMMARY

The condition of the concrete should be considered during the selection of an appropriate anchor by way of an assessment of the stress condition. In order for an anchor product to function in a satisfactory manner in cracked concrete, it should have a prequalification such as an ETA. There are limits on the nature of cracking that need to be observed even for anchor products that have prequalification for cracked concrete. The anchor should be designed for cracked concrete if any of the following occurs: i) a detailed stress analysis reveals the concrete may crack at some point during the anchor's service life, ii) the anchor does not have a suitable prequalification demonstrating its performance in cracked concrete, or iii) the concrete may crack during a seismic event (for seismic regions).

7 REFERENCES

[1] British Standard 8539 (Draft for Public Comment), "Code of practice for the selection and installation of post-installed anchors in concrete and masonry", BSI Standards Limited 2012

[2] Construction Fixings Association, "Anchor Selection", Guidance Note, www.fixingscfa.co.uk

[3] AEFAC Technical Note, "AEFAC Anchor Dictionary", www.aefac.org.au

[4] British Board of Agrément , "Distinction between cracked and non-cracked concrete", Anchor Bolts for use in concrete – UK Guidance, No 39/10, www.bbacerts.co.auk

[5] ETAG 001 "Guideline for European Technical Approval of Metal Anchors for use in Concrete – Part 1: Anchors in general", European Organisation for Technical Approvals, 2013

[6] AS 3600:2009 "Concrete structures", Standards Australia

[7] Cement Concrete & Aggregates Australia, "Drying shrinkage of cement and concrete", Datasheet, July 2002.

[8] European Tool Committee Guidance Note, "European Technical Approvals for Anchors used in construction", www.fixingscfa.co.uk

[9] AEFAC Technical Note, "Prequalification of post-installed and cast-in anchors"

[10] CEN/TS 1992-4-1 "Design of fastenings for use in concrete – Part 4-1: General", 2009

[11] prEN 1992-4 "Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete", 2013