TECHNICAL NOTE

AEFAC
Australian Engineered
Fasteners and Anchors Council

AEFAC - TN06

CRACKED VERSUS NON-CRACKED CONCRETE

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1. Scope

This Technical Note provides advice on the classification of concrete with regard to cracking to aid with the selection and installation of fasteners in new and existing concrete structures. The advice provided in this document is of a general nature. 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 fastener is to be installed may prevent safety-critical fasteners 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 Fastener Dictionary [1].

Anchor: see Fastener.

Cracked concrete: concrete that is likely to experience cracking during its lifetime

European Technical Assessment (ETA): a prequalification for a construction product that represents a favourable technical assessment of its fitness for an intended use.

Expansion fastener: a type of fastener 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.

Fastener: an assembly comprising base material (concrete or masonry), fastener or fastener group and component fixed to the base material

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 fastener throughout the design life under all design load considerations.

Option number: a number from 1 to 12 denoting the particular test regime a fastener 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 fasteners.

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

3. Definition of cracked concrete

The term 'cracked concrete' refers to concrete that may experience cracking passing through the plane of the fastener 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 fasteners 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 fastener.

Concrete may crack due to a variety of reasons. One of the most important design considerations when selecting a fastener 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 fastener, if the fastener 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 [2].

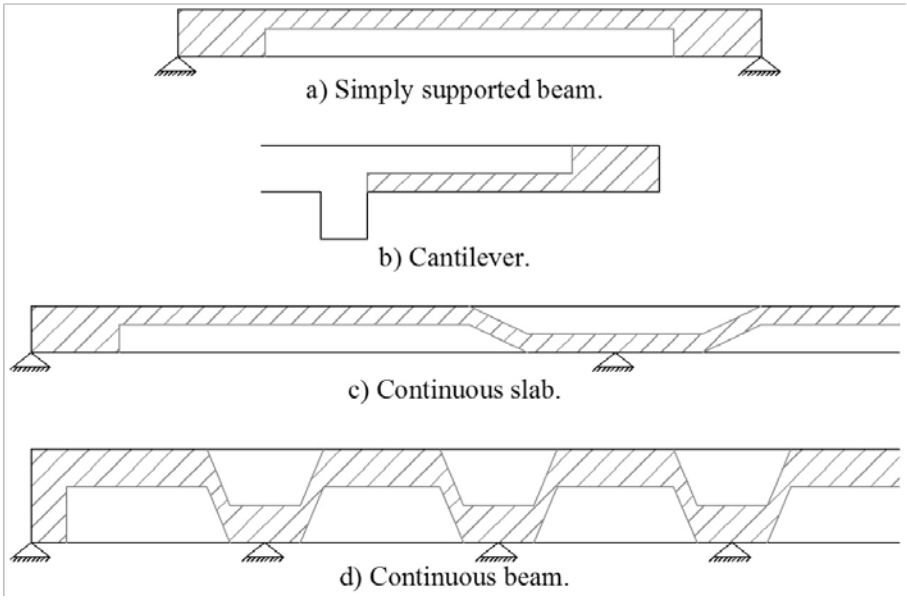

Figure 1: Non-cracked concrete locations (shown as diagonal lines) in common beam and slab systems

Fasteners designed for cracked concrete automatically qualify for use in non-cracked concrete. Where cracked concrete is expected, fasteners with Options 1 – 6 in their ETA should be selected, whereas fasteners qualified only in non-cracked concrete applications should be selected according to Options 7 – 12 [3, 4].

The condition of the concrete throughout the service life of the fastener 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 as given in AS 5216 [5]:

$\sigma_L + \sigma_R \leq f'_{ct}$

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 the restraint of intrinsic loads (such as shrinkage) plus stresses due to extrinsic imposed deformation (such as displacement of supporting members of structure, thermal expansion/contraction, etc). In the absence of a detailed analysis, AS 5216 suggests σ_R = 3 MPa.

f'_{ct} = Characteristic uniaxial tensile strength of concrete, calculated according to AS 3600 [6]. The recommended value is f'_{ct} = 0 such that only regions experiencing compression are deemed to be non-cracked.

Both σ_L and σ_R should be calculated assuming uncracked 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

A fastener 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 fastener will continue to function as intended in the event that a crack of limited width, passes through the plane of the fastener during its design life [8]. EADs for post-installed chemical and mechanical fasteners limits crack widths (w_k) to w_k = 0.3 mm for quasi-permanent loads. For seismic prequalification of fasteners, the crack width is increased to 0.5mm or 0.8mm depending on the requirements of C1 or C2 prequalification [10].

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

Resistances for cracked concrete are lower than for non-cracked concrete. The relevant tables in prequalification documents (cracked or non-cracked concrete) should be used to determine the resistance of the fasteners. Generally, the strength of a fastener may be up to 30% greater in non-cracked concrete [9].

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 [5, 8].

5. Selection of a suitable fastener

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 fastener may be installed in a pre-existing crack.

The condition of concrete with regard to cracking is a key design consideration. 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 fastener, by the design engineer.

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

A fastener 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 fastener under consideration has not been independently tested and assessed to perform in cracked concrete and received appropriate prequalification such as an ETA.
3. If the structure incorporates seismic design, analysis reveals the concrete remains crack-free throughout the seismic event.

Note that in order for a fastener to successfully function in a seismic event, it should have the appropriate prequalification (EOTA TR 049) [10]. 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 fasteners to be positioned in a tension (cracked) zone, yet be designed for non-cracked concrete on the provision that the actuation of the fastener 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 fastener by way of an assessment of the stress condition. In order for a fastener 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 fastener products that have prequalification for cracked concrete. The fastener 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 fastener's service life, ii) the fastener 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] AEFAC, Technical Note: AEFAC Fastener Dictionary, Australian Engineered Fasteners and Anchors Council. www.aefac.org.au

[2] 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

[3] EAD 330232, Mechanical fasteners for use in concrete, EOTA

[4] EAD 330499, Bonded fasteners for use in concrete, EOTA

[5] Standards Australia, AS 5216: Design of post-installed and cast-in fastenings in concrete, SAI Global, Sydney, 2018

[6] Standards Australia, AS 3600: Concrete structures, SAI Global, Sydney, 2018

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

[8] AEFAC Technical Note, Prequalification of post-installed and cast-in anchors, Australian Engineered Fasteners and Anchors Council. www.aefac.org.au

[9] Eligehausen, Rolf, Rainer Mallée, and John F. Silva., Anchorage in concrete construction. John Wiley & Sons, 2006.

[10] TR 49, Post-installed fasteners in concrete under seismic action, EOTA

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