Seismic (earthquake) rated anchors and how are they tested

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C1
Used for attachment of non-structural elements.

C2
Used for connection between structural elements of primary and/or secondary seismic members.

Seismic rated anchors are metal anchors for use in concrete under seismic actions.

They are distinguished under two categories; C1 and C2. C2 is the more stringent case.

These anchors are qualified under ETAG 001 – Annex E (an option for ETAG assessment).

Tests implemented by this annex are undertaken to evaluate the performance of anchors under simulated seismic tension and shear loading, including the effects of cracks, and under simulated seismic crack cycling conditions. (Anchors in plastic hinge zones are not addressed – and must be avoided)

Anchors must comply with ETAG 001 Part 1 to 5 for use in cracked and non-cracked concrete (Options 1 to 6) as part of the qualification in anchor seismic performance categories C1 and C2.

For anchors to qualify as C1 and/or C2 (based on ETAG 001 – Annex E requirements) they must cover the performance in the following table.

C1 vs C2 Test Requirements

CATEGORY	CRACK WIDTH Δ w (mm)	Pulsating Tension Load	Alternating Shear Load	Reference Test up to Failure	Tests under crack cycling	Design Information Determined
	0.5	Yes	Yes	No	No	Tension and Shear Resistance
	0.8	Yes	Yes	Yes	Yes	Tension and Shear Resistance and anchor Displacement

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Designers can calculate the seismic performance requirements of a structure (based on ground acceleration and soil factors) and choose the appropriate category for their choice of anchors.

Annex E - Table 1.1 details the recommended use of the performance categories C1 and C2 to the seismicity (based on ground accelerations) and building importance class. See table below.

Table 1.1 Minimum recommended performance categories for anchors under seismic actions

Seismicity		*Importance Class acc. to EN 1998-1: 2004, 4.2.5*			
	$a_g \cdot S$ [2]	*I*	*II*	*III*	*IV*
Very low[1]	$a_g \cdot S \leq 0{,}05\ g$	*ETAG 001 Part 1 to Part 5*			
Low[1]	$0{,}05\ g < a_g \cdot S \leq 0{,}1\ g$	*C1*	*C1*[3] *or C2*[4]		*C2*
	$a_g \cdot S > 0{,}1\ g$	*C1*	*C2*		

1. *Definition according to EN 1998-1: 2004, 3.2.1.*
2. *$a_g = \gamma 1 \cdot agR$ Design ground acceleration on type A ground (Ground types as defined in EN 1998- 1: 2004, Table 3.1);*
   $\gamma 1$ = importance factor (see EN 1998-1: 2004, 4.2.5);
   a_{gR} = reference peak ground acceleration on type A ground (see EN 1998-1: 2004, 3.2.1); S = Soil factor (see e.g. EN 1998-: 2004, 3.2.2).
3. *C1 for fixing non-structural elements to structures*
4. *C2 for fixing structural elements to structures*

Importance Class	Buildings
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.
II	Ordinary buildings, not belonging in the other categories.
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.

ETAG-001- Annex E details the methods of testing to determine the C1 and C2 performance categories.

Steel type, steel grade and production methods, head configuration, embedment depth and drilling methods are stipulated for each type of test.

The type of anchors that are covered include:

- Torque controlled expansion anchors,
- Undercut anchors (not including concrete screws),
- Concrete screws,
- Bonded anchors and
- Bonded expansion anchors

As mentioned earlier, Australian Standards have adopted AS5216 – 2018 - Design of post-installed and cast-in fastenings in concrete. A technical paper on seismic performance requirements in Australia has been published by AEFAC (Australian Engineered Fasteners and Anchors Council). It provides a comparison and guidelines for considerations of adaption of the European and American seismic performance requirements for fastenings in the Australian seismic conditions.

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