



CFA Guidance Note: Resin Bonded Anchors

1 Introduction

Bonded anchors have earned an enviable reputation as problem solvers for applications where often other anchors may not be suitable or may not be strong enough. With these types of anchor resin is inserted into pre-drilled holes, bonding the fixing element e.g. threaded rod, to the base material and once cured the fixture can be assembled. Bonded anchors come in many formats, but generally they consist of two components, which when mixed cure to form a very hard material bonding the fixing element to the hole wall. Resin formulations differ significantly between manufacturers and between products so the performance of the resin under different conditions will vary, therefore, suitability and performance of the product / application combination must be assessed individually.

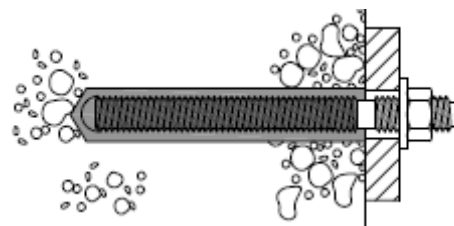
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2 Scope

Only bonded anchors where the component proportions are controlled by the anchor system are covered in the scope. Bulk systems where component volumes are measured by the installer are not covered.

Fixing elements can be simple threaded rod (studding), rebars, internally threaded sockets or other shapes for the embedded portion.



Standard installation with threaded rod

3 Versatile Problem Solvers

Strength and versatility

Usually the resin bond is stronger than the base material and ultimate strength is governed by anchor rod specification. They offer stress free anchorages which will not damage weak substrates and can be placed closer to edges and to each other than other techniques. Appropriately formulated resin anchors cope with base materials as diverse as concrete and hollow block, rock and aerated concrete, stone and perforated brick.

Wide ranging applications

Bonded anchors cover as wide a range of applications as any fixing technology available, they include: Structural connections transferring high loads into slim columns and beams; fixing sanitary ware to hollow masonry; holding down bolts for steel columns; tying back existing masonry to steel structures. For applications in lightweight aerated concrete, there are injection resin systems available with a special drill bit which creates a conical hole within these soft base materials, for safer load transfer and higher capacity.

The ability to anchor irregular shapes lends itself to grouting in starter bars and architectural features such as balustrade sections.

Special systems are available for holding down motorway safety barriers, remedial wall ties, safety harness eyebolts, ladder restraint systems and many more. There are special systems available with approval for applications with dynamic loading such as fixing jet fans or holding down machinery or lifts. Some resins, if approved by special testing, are also suitable to withstand the shock loads of fall arrest systems.

Mining and tunnelling engineers use resin anchor systems which can be set deep into rocks for roof stabilisation. With care most systems can be installed overhead and some can be installed underwater while many are suitable for installation and use in permanently damp conditions.

4. New Developments

Some CFA members have developed resin bonded anchor systems that do not require separate cleaning of the drilled hole. These may be related to standard glass capsules where cleaning with blow out pump and no brushing is sufficient. The latest developments include special fixing elements and fall into the category of torque-controlled bonded anchors and/or have special hollow core drill bits with a vacuum attachment. Regarding these special systems following the manufacturers installation instructions is critical. Also confirm with the manufacturer whether or not performance is reduced without hole brushing. *Systems using special multi-cone studs [see 6.3] and holes drilled with hollow-core drills may achieve the same performance as fully brushed holes.* There are also resin formulations available with reduced curing time, offering faster installation with subsequent saving on installation. Refer to [11.5] on installation temperature.

5. BS 8539: Code of practice for the selection and installation of post-installed anchors in concrete and masonry

The code of practice sets out the roles and responsibilities of everyone involved in the use of fixings in safety related applications from the manufacturer and distributor through the specifier to the contractor, installer and tester. If correctly implemented the failure of construction fixings due to incorrect selection, unauthorised changes of specifications and poor installation will become a thing of the past as will accidents, injuries and deaths not to mention economic consequences.

CFA has published a series of forms designed to speed up the various stages of selecting an anchor, to help make sure the correct information is gathered and to facilitate its communication to other stakeholders as appropriate during the life of the fixing from selection through acquisition to installation, testing and commissioning.

The following forms are available from the CFA at: <http://www.the-cfa.co.uk/publications-and-downloads/cfa-8539-forms/>

- CFA Form 8539/01 Design Information
- CFA Form 8539/02a Anchor Specification
- CFA Form 8539/02b Anchor Recommendation
- CFA Form 8539/03 Installation Certificate
- CFA Form 8539/04 Test Request
- CFA Form 8539/05 Compliance Checklist

6. Resin Anchor Formats

Resin anchors typically consist of a metal element fixed into the substrate by means of a resin mortar system.

6.1 Injection Cartridge Systems

Injection cartridge systems are preferred for variable embedment depths and for "difficult" shaped components. Resin components are carried in separate compartments of a cartridge held in a special dispenser. They are mixed by a series of vanes in a special nozzle as they are expelled from the cartridge. Unused resin can be kept without deterioration (subject to shelf life). Waste is restricted to that contained in the nozzle. The amount of resin used can be tailored to the application which is ideal for use in materials containing voids such as light weight aggregate blockwork.

Special mesh sleeves facilitate use in hollow blocks and perforated bricks. With each fresh cartridge some resin must be expelled to waste, until an even colour is achieved demonstrating that proper mixing is taking place. Refer to the manufacturers instructions for guidance on specific products.



Typical injection cartridge and static mixer nozzle

6.2 Capsule Systems

For a fixed embedment depth, capsule systems have the benefit of delivering the correct amount of all components in the right proportions into the hole and so lend themselves to use in homogeneous materials without voids i.e. solid concrete and solid masonry.

Spin-In Capsule Systems

The term "Spin-in" has been adopted only for this Guidance Note to differentiate this type from the "Hammer-in" type. "Spin-in" formats include GLASS, FOIL and SOFT SKIN.

Glass Capsules



Example of "spin-in" glass capsule

The original capsule format. A glass capsule contains the resin, a quartz sand aggregate and a catalyst, usually in a small secondary phial. An anchor rod with a chisel point end is driven into the capsule using a drilling machine on *rotary hammer* to mix the components. The shape of the end of the rod is crucial to correctly mix the components and to permit the rod to be fully embedded in the hole.

The relatively large size of the aggregate (compared to injection systems) and the crushed glass becomes part of the aggregate. The aggregate and installation (by machine) contributes to hole cleaning, with less rigorous hole cleaning required, compared to injection systems.



Example of threaded rod with hex drive, depth mark and chisel point for installation with spin-in capsules

Soft Skin & Foil Capsules

Soft skin and foil resin anchors installation is similar to spin-in capsules in that an anchor rod with a chisel point (like shown above) is spun into the capsule using a drilling machine set on *rotary* only. The construction of Soft Skin capsules may give a shorter shelf life than for Glass and Foil capsules. Always check "use by" / expiry date.



Example of soft-skin foil capsule

Hammer-In Capsules

Originally developed to provide a quick installation solution for starter bars by hammering deformed bar directly into special resin capsules they are now also offered by some

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manufacturers for use with threaded anchor rods. A special glass capsule is inserted into the hole and the deformed bar or threaded rod is then hammered directly into the capsule drawing the catalyst through the resin. Some hammer-in capsules are directional, i.e. the catalyst is only at one end of the capsule which must be placed toward the outer end of the hole. The capsule has an arrow indicating which way the capsule should be inserted. With this type inserting the capsule the wrong way round will result in zero holding power. Special hammering adaptors are available for use with rotary hammer drilling machines to set both rebar or threaded anchor rods and while rebars may also be set using a conventional hammer of suitable weight, this technique should not be applied to threaded rods unless threads are protected. Note that hole diameters are different for rebar and threaded rod.

6.3 Torque-Controlled Bonded Anchors

Developed to achieve the highest performance in cracked concrete, and to meet the exacting requirements for European Technical Approvals / Assessments for this material. These anchors use specially developed anchor rods set in special capsules or injection resin. They must be tightened to the manufacturer's recommended tightening torque to make them work in cracks. They offer benefits over torque controlled metal anchors in terms of close edge and spacing criteria but the stresses induced in the concrete means that edge and spacing distances may be greater than ordinary resin bonded anchors when set in non-cracked concrete.



Example of torque controlled anchor rod, tapered cones transfer loads through resin in cracked concrete.

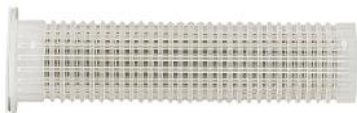
6.4 Fastening Components

For general purpose anchoring bonded anchors are used with fully threaded anchor rods or rods made from deformed bar with a threaded end to accept a nut.

Internally threaded sockets can be used with most systems to accept hexagon headed bolts.

Mesh sleeves, of plastic or steel, are available for use with injection and systems, to control resin in hollow, perforated or voided materials.

Mesh and perforated sleeves

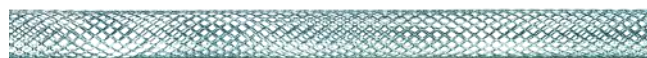


Plastic for perforated brickwork and hollow block

End cap



For injection systems for hollow and overhead



Wire - for long studs in poor masonry

Internally threaded sockets



Standard - knurled surface or external thread

Special, for shallow embedment, with anti-rotation fins and tapered ridges for pullout resistance



To ensure the manufacturer's performance is achieved only anchor rods supplied by the manufacturer, or made to the manufacturer's specification in terms of both form, e.g. chisel point, and material specification, should be used. Refer to the ETA or the manufacturers data for allowable designs and specifications of anchor rods.

7. Resin Formulations

Bonded anchors use resins of various formulations: polyester; vinylester (epoxy acrylate); pure epoxy; cementitious; hybrids.

Although pure cementitious formulations are not covered in this guidance note, hybrids are and the formulation is commonly a mix of organic (resin) and inorganic (cement), with the benefit of higher bond resistance (adhesion) in less well cleaned holes.

There are two basic families, those cured by a catalytic action (chain-growth polymerisation) and those cured by direct mixing of the components (step-growth polymerisation).

CATALYTIC CURING

A catalyst initiates the curing of the resin itself. Exact mix proportions of catalyst and resin are not critical nor does the catalyst have to be mixed with all of the resin. A chain-reaction will propagate through the mix as long as most of the base resin is exposed to some catalyst. This happens automatically with capsule and injection systems. Most resins for anchoring fall into this category. They have names like Polyester, Vinylester (epoxy acrylate) and others. There is little point in trying to categorise them as characteristics and performance vary within these types from one make to another depending on formulation. Installation parameters also vary even for the same nominal type of resin. Specifiers should choose the best type for the application according to the performance and characteristics of the system under consideration. Nowadays most resin bonded anchors are styrene free formulations which may offer benefits where anchors are to be set in confined spaces. Styrene, as used in some types of resin, is believed to be harmful to health in the unmixed state, but inert once the resin has cured.

NON-CATALYTIC CURING

In this type the two resin components will cure only in direct contact with each other (step-growth polymerisation). Curing does not spread through the resin as with catalytic resins so mixing must be thorough and proportions correct. Injection systems must be extruded through the mixer nozzle supplied with the individual product to guarantee thorough mixing. Epoxy resin (not to be confused with "Epoxy acrylate") is the only non-catalytic resin currently available and is usually supplied in an injection cartridge system. Epoxy resin exhibits very low shrinkage so generally higher performance is achieved in larger holes diameters where shrinkage has more of a negative impact on performance. *Note: shrinkage of all resin systems is factored into the data during testing for an ETA, therefore using the recommended hole diameters is paramount to achieving the published ETA performance.*

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8. Health and Safety

All proprietary resin systems may be specified and installed with complete confidence for the safety of the installer and building occupants provided adequate ventilation is provided and the simple precautions made clear with all products are followed.

9. Specifiers' Check List

In addition to loading criteria and other selection criteria (see [3]) check the resin characteristics against service and installation requirements for the following:

- Base material solid, perforated or hollow.
- Service temperatures.
- Service condition of base materials e.g. permanently damp.
- Installation conditions e.g. wet holes, type of drilling

Specify the following:

- Resin material, embedded part (anchor rod/socket etc) including finish.
- Special components for perforated or hollow materials or for overhead installation (injection systems).
- Precise installation method including equipment.
- Installation temperature range and curing times.- Tightening torque to suit base material.
- Also refer to Section 5 on BS8539

10. Base Materials

No other fixing technology offers the diversity of applications as bonded anchors and this is in no small part due to the wide range of possible base materials. CFA members offer bonded anchor systems for non-cracked concrete, cracked concrete, for casting new concrete to old, with rebars and there are even some systems suitable for use in seismic zones. Fixing into masonry is also a typical application, either solid masonry with standard threaded rod or perforated/hollow masonry with the use of a mesh sleeve which helps retain the resin around the threaded rod. Another traditionally difficult anchorage is onto cladding, where a long mesh sleeve can be used to bridge the cavity and fix into the structural wall.

11. Installation Procedures

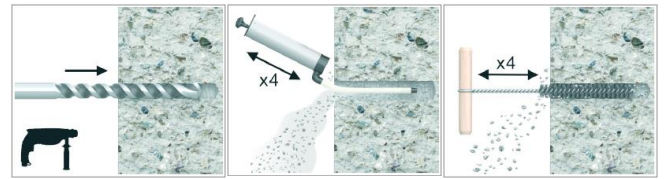
ASPECTS COMMON TO ALL TYPES

Installation principles follow those shown in the CFA Guidance Note on the subject^[5].

Before installation:

Read and follow the manufacturers instructions as they may vary by product and manufacturer

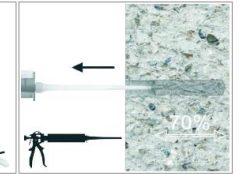
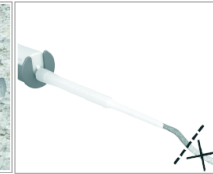
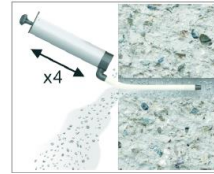
- Check use by date of resin materials
- Check base material temperature
- Check working (gel) time
- Check availability of necessary equipment
- Wear protective equipment as necessary: Eye and Hearing protection when drilling; Eye protection when setting resins overhead; Gloves when handling resin systems



1. Drill hole to the required diameter and depth

2. Blow or vacuum the dust from the hole

3. Brush the hole



4. Blow or vacuum the dust from the hole

5. Dispense to waste until even colour is obtained

6. Inject resin from the base of the hole, slowly withdrawing the nozzle as the hole is 70% filled



7. Immediately insert stud, slowly and with a slight twisting

8. Leave undisturbed for the full curing time

9. Attach fixture and tighten nut to the required torque

Example of installation procedure with injection system

11.1 Drilled Holes

In concrete drill using rotary hammer, SDS-Plus up to Ø20mm and SDS-Max up to Ø40mm.

When installing deep embedment anchorages, as with rebar, it may be preferable to use diamond core drills, however, these create some issues for resin bonded anchors. The hole wall produced is very smooth and generally reduces the bonding ability of the resin. Roughening of the hole wall may be required and some manufacturers provide approved systems for this. A further issue is that some diamond drilling techniques require water to lubricate and cool the drilling tips and this will leave a slurry coating the hole wall that requires careful cleaning – usually flushing with water, then blowing with air followed by the standard brushing technique. As only some resins are approved for use in diamond drilled holes refer to the manufacturers data for precise recommendations for hole cleaning and check if the bond resistance is reduced when installed into these holes or indeed if installations are covered by the ETA with this drilling technique.

In masonry attempts at drilling holes should be performed with increasing impact energy. Lowest to highest impact energy; rotary only; rotary percussion; SDS-Plus hammer; SDS-Max hammer. This is critical to the performance of any anchor in masonry as the higher impact energies can damage the masonry unit, create significant spalling of the unit or loosen the brick/block mortar joint. Refer to the ETA and manufacturers' installation instructions for details of the drilling technique e.g. hammer or rotary only, etc.

11.2 Hole cleaning

Drill dust, if not removed effectively, can leave a layer on the hole wall and significantly reduce the bond strength. This varies between products and resin chemistry with pure epoxy, hybrid cartridges (See Section 7: Resin Formulations) and spin-in capsules generally achieving smaller reductions in performance than vinyl ester and polyester resins. Torque-controlled bonded anchors are the least affected by dust in the hole as these types benefit from follow up expansion (See Section 6: Resin Anchor Formats).

11.3 Cleaning Equipment

Equipment for the correct cleaning of standard resin bonded anchors is a blow pump and brush.

Blow pumps come in different capacities and are limited in the depth and diameter of drilled hole that can be cleaned. Refer to the manufacturers' instructions for these limits as it varies depending on the capacity of individual blow pumps.



Standard blow pump

Larger diameter and/or deeper installations will require compressed air to remove the drill dust effectively. *Note: compressed air should be oil-free as oil could potentially affect the resin adhesion.*



Compressed air cleaning gun

Nozzles in both cases should reach the bottom of the drilled hole and manufacturers should be able to give advice on minimum air pressure and procedure for their specific product.

Brush filaments can be made from natural fibres (e.g. horse hair), synthetic (usually nylon) or wire (steel). Softer brushes will remove less dust, whereas a steel brush will remove the most dust and give the greatest adhesion. Adhesion of the resin is based on brush type used in laboratory testing, therefore, if a steel brush is stipulated in the ETA/manufacturers' data, then a steel brush must be used to achieve the published performance. When installing at deeper embedment depths e.g. post-installed rebar applications, manufacturers should be able to provide extensions for both blow pumps and brushes to ensure that holes are cleaned effectively over their entire drilled depth/length.



Example of a steel brush

11.4 Cleaning Procedure

Dry Concrete

Hole should be cleared of drill dust by means of a blow pump with a nozzle which reaches the bottom of the hole, then brushed a number of times and then blown again with a blow pump. Sequence and number of brushes and blows will be specified in the manufacturers' installation instructions and ETA. For deeper embedment depth and/or larger diameter installations compressed air may have to be used as well as brush extensions to reach the bottom of the drilled hole. Refer to Cleaning Equipment for further information.

Wet Concrete

Always check whether resin intended to be used is approved for wet or flooded holes. Bond strength may be reduced therefore always check relevant ETA for individual product performance and installation data. Note that some resin systems require doubling of the curing time when installed in wet holes.

In diamond drilled holes where water is used as a coolant, clean water must be used to flush out the concrete slurry. A hose should be inserted to the bottom of the hole and run until the water runs clear. The hole should then be brushed and flushed out once again with water, until it runs clear. It is recommended that the dry concrete cleaning sequence is then followed i.e. blowing, brushing, blowing. This recommendation is not specific, therefore, the manufacturers installation instructions should always be followed for individual products.

11.5 Temperature

Three temperatures are relevant for resin bonded anchors – storage, installation and service.

Storage Temperature (unmixed / uncured resin)

Resin bonded anchors should be stored and transported in a controlled temperature environment, generally between 5°C and 25°C, however, refer to the manufacturers data for specific product storage recommendations. Low resin temperatures increase the viscosity and this increases the force required to extrude the resin. The risk with higher extrusion forces is failure of the dispenser, either the handle/trigger or mechanism. High storage/transport temperatures can age, degrade and dry-out the resin creating some significant risks: increased extrusion forces; poor mixing; significantly reduced shelf-life. Storage during transport and on-site should also be considered, as vans and metal containers can experience very high temperatures in direct sunlight. Unmixed bonded anchors i.e. before curing, should also be protected from direct sunlight as UV radiation will also prematurely age the resin.

Installation Temperature

The important temperature during installation is the base material temperature and this can vary significantly depending on ambient air temperature, wind and if the surface is in direct sunlight or in the shade.

All resins are supplied with temperature charts and show an "open" time and a "curing" time. Open time (sometimes referred to as gel time or working time) is the time the installer has to inject the resin (with injection systems) and insert the metal element e.g. threaded bar, rebar, etc. Note: a longer time will be required to install large diameter and/or deep embedment rebars as it takes longer to fill the holes especially when multiple cartridges are required.

Curing (setting) time shows the time required (at specific base material temperatures) before the fixture can be mounted and the anchor torqued and loaded. Many manufacturers produce resins with slower and faster curing. Slow cure resins may be termed “summer” resins and are designed for higher base material temperatures, where anchors can be installed without the resin curing too fast i.e. before the metal element is fully installed. These are particularly useful in countries with higher ambient temperatures than the UK or when installing rebar when a longer open time is required. Fast cure or “winter” resins are useful in reducing the time before the anchor can be loaded with low base material temperatures or they can be used for very fast curing at “normal” temperatures. The main advantage of this is that the anchor could possibly be torqued and loaded within one hour at a base material temperature of 21°C, however, be aware that as open time and curing time are related, winter (fast cure) resins will have very short open times at 21°C – possibly less than two minutes.

Service Temperature

Temperature the cured resin will experience over the lifetime of the anchorage. ETAs will usually provide two temperature ranges, each with a short term (higher value) and long term (lower value) temperature.

Maximum short term temperature is defined in ETAG 001: Part 5 as the upper limit of day/night cycles and freeze/thaw cycles. Long term temperatures are defined as “...constant or near constant temperatures, such as those experienced in cold stores or next to heating installations.”

Example: Temperature Range I: 40°C/24°C; Temperature Range II: 80°C/50°C. In temperature range I, the maximum long term temperature is 24°C, with a maximum short term temperature of 40°C. Temperature range II provides performance data for a maximum long term temperature of 50°C and a maximum short term temperature of 80°C. Check the ETA or manufacturers’ data as temperature range II is a choice for the manufacturer, therefore they can be different for different resin bonded anchors. Note: Bond resistance should be confirmed in the manufacturers’ data as the higher temperature range usually has a lower bond resistance and therefore lower resistance/performance.

11.6 Placing resin

Injection systems. Pump to waste until even colour. Inject to base of hole drawing nozzle back to fill without voids. Use cone systems to retain resin when placing overhead.
Hammer-in capsules. Insert in direction of arrow - VITAL.

11.7 Inserting the anchor rod

Injection. Insert rod with twisting action.
Spin-In capsule. Must be driven in with the rotary action of a powered driver e.g. drilling machine.
Hammer-in capsule. Use drilling machine with adaptors where possible. If hammering threaded rods protect the thread.

11.8 Installation Torque

This ensures the fixture is clamped by inducing a tension greater than the recommended tensile load. It protects the anchor rod and resin bond from being over stressed. Torque should be reduced in weak materials to protect the bond -refer to manufacturer for advice.

12 Potential Installation Problems

12.1 Injection Systems

Resin not fully curing. This has many causes:

- Not discarding a sufficient volume of resin before pumping resin into the hole.
- Expired (out of date) resin.
- Not using the correct mixing nozzle.

High base material temperature may not allow sufficient time to install the metal element e.g. threaded rod. Low base material temperature may prevent the resin from curing or extend the curing time.

Insufficient resin injected into hole. If the hole has voids or the nozzle is not inserted to the bottom of the hole, the performance will be compromised.

12.2 Capsule Systems

Hammering in spin-in capsules or spinning in hammer-in capsules will result in poor mixing.

Some hammer-in capsules are directional and inserting the wrong end first will result in very poor mixing.

Over-spinning spin-in capsules will result in some resin being forced out of the hole and reduce the anchor performance. It is advisable to use the manufacturers recommended studding for spin-in capsules as they have a depth mark making it easier to judge when the studding has reached the bottom of the hole.

12.3 Hole Drilling

Have a contingency plan in place in case of encountering rebar during drilling e.g. fixture with alternative hole positions. Caution! Moments and offset loading can result with alternative hole positions in the fixture and any alternative anchorage design must be recalculated to ensure that individual anchors are not overloaded. The engineer responsible for the installation must make decisions regarding rebar, as it may be acceptable to drill through a percentage of rebar, however, if the slab has pre-stressing tendons then it will be unacceptable to drill through these as it will compromise the structural strength of the concrete. Use of a rebar detector is recommended as avoidance (although not always possible) prevents the complication of redesigning the anchorage.

12.4 Hole Cleaning

Insufficient or improper hole cleaning is the most significant risk to resin bonded anchor performance.

Issues which will reduce the bond strength:

Using a worn brush

Using a nylon brush, when a steel brush is specified

Not brushing the required number of times according to the manufacturers’ installation instructions.

Not clearing the hole of dust from the bottom, before brushing - especially difficult with deeper holes.

13 Fixings and Fire

All anchors, either resin or metal, will eventually lose strength with prolonged exposure to fire, failure often occurring at the bolt head or nut. The durability of resin anchors in fire tests has been shown to be comparable with that of steel anchors. A CFA Guidance Note^[3] elaborates three methods by which anchors, including resin anchors, may be specified for fire rated applications.

14 European Technical Assessments

Resin Bonded Anchors are covered by ETAG 001 Part 1 "Anchors in General", Part 5 "Bonded Anchors" and EOTA Technical Report number 29 (TR029). Design method in TR029 is valid for all types of resin bonded anchors in concrete with the exception of torque-controlled bonded anchors and post-installed rebar connections, however, it does cover rebar as an anchor. Torque-controlled bonded anchors are covered by a combination of ETAG 001, Part 1, Part 2 (Torque-controlled expansion anchors), Part 5 and TR018. Post-Installed rebar connections are assessed against EN1992-1-1: 2004 (EC2) and TR023. EC2 design concept is different from the EOTA EAD design methods and as the applications are more limited e.g. only tension loads and no concrete cone failures, less testing is required and the maximum design resistance is given for different concrete strength classes.

Resin bonded injection anchors in masonry are assessed against ETAG 029 and covers solid masonry units and hollow masonry (with mesh sleeves). Selected types of masonry units are tested and data is provided for these, other types of masonry may also be used in accordance with the ETA provided a prescribed test regime is followed on site.

15 References and Notation

15.1 References

[1]CFA Guidance Note: European Technical Approvals for Construction Fixings

[2]Guideline for European Technical Approval of Metal Anchors for use in Concrete. British Board of Agrément, PO Box 195 Bucknalls Lane, Garston, Watford, WD2 7NG.

[3]CFA Guidance Note: Fixings and Fire.

[4]CFA Guidance Note: Anchor selection.

[5]CFA Guidance Note: Anchor installation.

15.2 Terminology and Notation

ETAG: European Technical Approval Guideline

EAD: European Assessment Document (formerly ETAG)

EOTA: European Organisation for Technical Assessments

TR: Technical Report (by EOTA)

EC2: Eurocode 2: Design of Concrete Structures

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