CFA Guidance Note:

Fixings for the retention of masonry façades.

INTRODUCTION

This Guidance Note is an extract from "Retention of masonry facades - best practice guide" published by CIRIA [1].
The Construction Fixings Association had a major input to the sections (sections 6.12 – 6.18 and 9.10.0 – 9.10.4) replicated here. The text is taken unchanged, with the exception of section 6.13 which is essentially omitted, and all illustrations are from the guide. The CFA is grateful to CIRIA for their permission to reproduce this extract which gives useful and practical guidance on the design of fixings for façade retention systems. While the majority of guidance is generally in line with that of the CFA and its members some details may differ.

6.12 Fixings for use in permanent connections to façades

6.12.1 Principles

Reliable fixings are an essential part of the permanent retention structure, and attention must therefore be given to satisfactory performance, durability and fire resistance.

Performance requires that the chosen type of fixing is suitable for use in the façade material and that it is competently installed.

> Most problems with fixings arise from an unsuitable choice of fixing type for the particular base material and/or poor installation practice.
>
> The fixing manufacturer's recommendations for selection, installation and use should always be followed.

Durability requires that the fixings will not deteriorate during their design life. Fixings are currently always metal-based. Given the need for corrosion resistance, it is **recommended** that stainless steel or proven non-ferrous alloys are specified and used for permanent façade fixings. This will also eliminate the risk of rust-staining.

Fire resistance requires the fixings and the other component parts of the permanent façade to be adequately fire-protected.

For the design of connections (see Section 6.11) **it is recommended** wherever practicable that restraint provision should be both generous and diffused, using several fixings for each connection rather than one or two larger fixings, to take some account of possible variations in the masonry and in the installation workmanship. Capacity of the fixings must be based on the manufacturer's recommendations, modified as appropriate by the results of preliminary pull-out tests on fixings installed in the actual façade. Individual fixing capacity is affected by both the spacing between adjacent fixings and the distance from a fixing and an adjacent free edge. The manufacturer's trade literature should contain advice on such topics. Guidance on the capacity of fixings in masonry is generally less comprehensive than for fixings in concrete, and in general preliminary testing of the proposed permanent façade fixing type is essential.

For façade retention work there is a good argument for using fixings installed in deeper holes than recommended by the manufacturer. This can enhance pull-out capacity, and provides a more secure anchorage for the fixing farther below the surface of the façade. The use of studding – threaded rodding – rather than bolts makes this change straightforward, as the studding can be specified to the required extended length whereas bolts of this length may not be obtainable.

Installing fixings on the skew rather than all at 90° to the façade will provide a degree of mechanical anchorage into the base material that will enhance the overall strength of the connection. This should be seen as enhancing the factor of safety for the required number of fixings, rather than justifying the use of fewer fixings.

If the fixings have to pass through cavities or voids in the façade, acting in effect as wall ties, then they will need to be checked for resistance to buckling when subject to compression.

Lock-nuts on stud fixings are specified by some designers. They could certainly be considered when the façade is close to a significant source of vibration, such as an underground railway.

6.12.2 Types of fixing

Fixings for permanent façade retention can be categorised broadly as either *through fixings* (see Section 6.13) or *anchors* (see Section 6.14). Both involve drilling into the façade masonry. (A third common type, c*ast-in fixings*, is less relevant when dealing with an existing masonry façade, although they could be used when concrete padstones are inserted into the facade.)

CIRIA Technical Note 137 *Selection and use of fixings in concrete and masonry: interim update to CIRIA Guide 4* gives general guidance on the selection and use of fixings in concrete and masonry (CIRIA, 1991). More recent guidance is available from the Construction Fixings Association, which publishes a series of guidance notes, focusing on anchors (see Section 6.14).

6.13 Through fixings

NOTE: THIS SECTION DEALS WITH FIXINGS MADE BY DRILLING THROUGH THE STRUCTURE. IN VIEW OF THE FACT THAT THIS SECTION DOES NOT RELATE TO CONSTRUCTION FIXINGS AS COVERED BY THE CFA THE TEXT HAS BEEN REMOVED FROM THIS GUIDANCE NOTE WITH THE EXCEPTION OF THE LAST SENTENCE WHICH READS:

In practice, there appears to be little evidence of the use of through fixings in façade retention.

6.14 Anchor types

As their name suggests, anchors rely for their strength on being anchored into the masonry. There are three generic types that can be considered for façade retention schemes:

- expansion anchors
- bonded anchors
- undercut anchors.

Within each type may be found a variety of designs – the illustrations below are of typical anchors and are not intended to show or favour any particular proprietary anchor.

It is important that the anchor type chosen for a façade retention scheme should be suitable for use in the base material of the façade.

All three types of anchor are suitable for use in concrete, but the choice is limited when anchors are to be installed in masonry, particularly older brickwork as is often encountered in façade retention schemes. The Construction Fixings Association (CFA) has published a guidance note, *Anchor selection*, which includes a table relating the suitability of anchor type to the particular base material. This has been supplemented by a later guidance note *Fixings for brickwork and blockwork* (Construction Fixings Association, 1995 and 1997). These publications identify four types of anchor as "suitable" (**•**) or of "limited suitability" (o) for use in masonry, as shown in Table 6.3 below. (The original table left blank spaces for anchor types that were, by implication, not considered suitable for particular base materials; Table 6.3 here inserts "x" for this case.)

It will be seen that, for solid brickwork – the commonest material likely to be encountered in a façade retention scheme – the Construction Fixings Association considers only the bonded anchor and the thin-walled sleeve expansion anchor to be suitable.

Stone is probably the second commonest façade material; again, only these two forms of anchor, and also the undercut anchor, are considered suitable.

Blockwork is rarely found in façade retention work, but a choice of anchor type exists, particularly for the relatively stronger dense aggregate blocks.

Table 6.3 ***Suitability of anchor types in masonry façade base materials***

Key • **suitable** o **limited suitability** **x not suitable**	**BASE MATERIAL**						
	Brick		**Block**				**Stone**
ANCHOR TYPE	**Solid**	**Perforated**	**Dense aggregate**	**Solid light aggregate**	**Hollow light aggregate**	**Aerated**	
Shield (torque-controlled expansion)	o	o	o	x	x	x	o
Thin-walled sleeve (torque- controlled expansion)	•	o	•	o	x	x	•
Undercut	x	x	x	x	x	x	o
Bonded anchor	•	•	•	•	•	•	•

The following descriptions of the various anchor types gives more detail of their mode of behaviour and their suitability for use in masonry.

6.15 Expansion anchors

These incorporate shells, cones, sleeves, or wedges that are expanded on installation to grip the sides of drilled holes. Expansion anchors are of two basic categories: torque-controlled and deformation-controlled.

In torque-controlled anchors, the tightening of the nut or bolt activates the expansion mechanism, and the holding power of the anchor within the base material is directly related to the tightening torque used.

There are four basic types of torque-controlled expansion anchor:

- thick-walled sleeve, or heavy-duty anchors (see Figure 6.3)
- thin-walled sleeve anchors
- shield anchors
- throughbolts (see Figure 6.4).

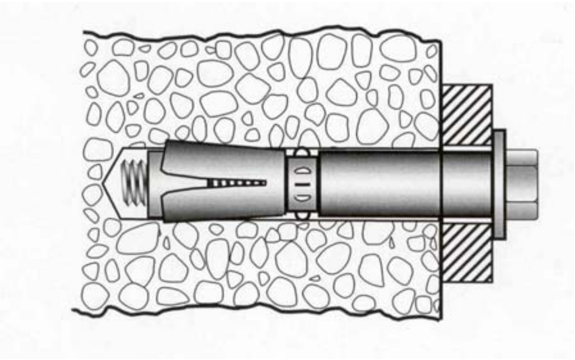


Figure 6.3 *Thick-walled sleeve expansion anchor as used in concrete*

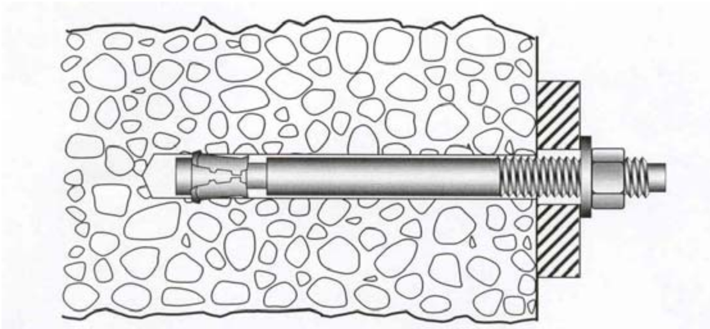


Figure 6.4 *Throughbolt expansion anchor as used in concrete*

In deformation-controlled anchors, the degree of expansion is controlled by the relative displacement of the expander cone within a sleeve, usually by hammering a tapered plug down inside an internally tapered shell (see Figure 6.5).

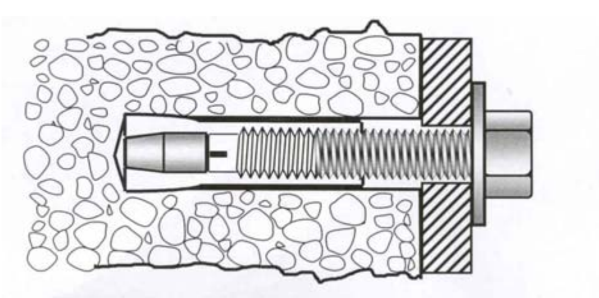


Figure 6.5 *Deformation-controlled expansion anchor as used in concrete*

Expansion anchors are well suited to use in concrete, for which most are intended, but their suitability in masonry is variable and limited:

- types with *limited* suitability in masonry are thin-walled sleeve anchors and shield anchors; these may work in reasonably strong, solid (ie unperforated) bricks, and in diameters up to 20 mm overall
- types that are *not* suitable for use in masonry are thick-walled sleeve anchors (whose excessive expansion cracks bricks), throughbolts (whose expansion segments are too small to work effectively) and deformation-controlled socket anchors (with which the shock loads from hammering during setting can often crack the bricks).

Given the nature of their action, expansion anchors are not likely to be effective when used in perforated or hollow masonry units, low-strength units such as lightweight aggregate or aerated blockwork, or in masonry with voided or degraded mortar. Bonded anchors will usually be more suitable for these materials, as discussed below.

Competent workmanship is always essential – drilling the hole to the manufacturer's recommended diameter is crucial to the successful use of an expansion anchor.

6.16 Bonded anchors

As their name implies, bonded anchors are bonded to the base material and rely on this bond for their grip. They do not generate expansion forces within the base material. As such they are suitable for use in weak and voided masonry, as well as in stronger and sounder materials. This characteristic probably contributes to the widespread use of bonded anchors in permanent façade retention fixings.

There are two generic types of bonded anchor, one using resin and the other based on cement.

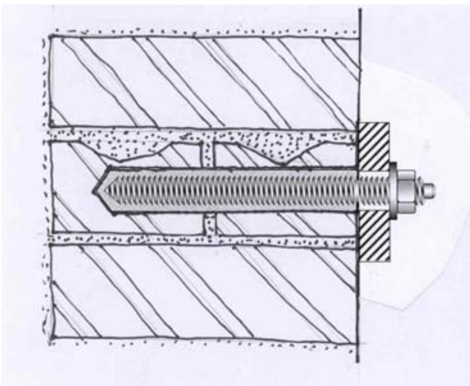
6.16.1 Resin anchors (also known as chemical anchors)

Resin or chemical anchors are bonded into drilled holes using a two-part adhesive of resin and hardener that is mixed during installation, together with a filler or aggregate; it then cures chemically.

There are two types of resin anchor system.
1. The capsule system.
2. The injection system.

The capsule system

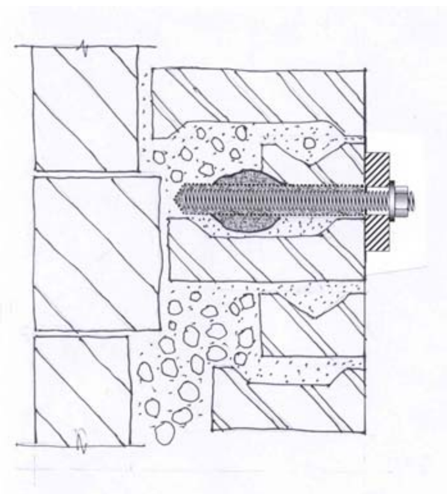
The *capsule* system uses glass, plastic or foil tubes to contain the various components, which are mixed together when a special anchor rod is inserted, see Figure 6.6. In a "spin-in" capsule system, the anchor rod is spun in under rotary hammer action to mix the components. In a "hammer-in" capsule system, the anchor rod is hammered through the (usually glass) capsule to mix the components. The hammer-in resin anchor is really intended for use with rebar, so it is not considered further here, other than to point out that on site it should be made clear which system is being used to ensure the correct installation method is employed.



With the spin-in capsule system, the adhesive components are mixed together as the fixing, mounted on a drill, is rotated into the hole in which the capsule has been placed. With this anchor type, it is again important that the correct hole size is drilled for a given size of fixing, to ensure that the resin fills the void. The system is well-proven for use in concrete, but there is a potential difficulty with using it in masonry. Both the fixing depth and the capsule volume are pre-determined, so that there is no way of knowing (other than by testing) whether some contents of the capsule might have been lost into voids in the base material. This would result in the anchor being incompletely bonded to the base material.

Figure 6.6 *Capsule-type bonded anchor as used in brickwork*

The injection system



An injection system contains the components in two compartments, and mixes them in a special mixer nozzle, from which the mixture is pumped into the hole drilled for the anchor. Depending on the system, the anchor itself may be a threaded rod, threaded rebar or internally threaded socket.

In masonry, where voids are likely, then the injection system comes into its own as the volume of resin injected can be increased to fill the voids. Special mesh sleeves are available to help to control the amount of resin used; see Figure 6.7. Hole cleaning is also slightly less critical with voided or porous masonry, as the resin interlocks into the voids or pores. Bonding with the surface of the hole as such is therefore less important, although thorough hole cleaning is nevertheless recommended.

Capsule systems are generally less suitable in masonry, for which the injection-type system is preferred, particularly with weaker and voided masonry, where it gives greater certainty of filling local voids within the masonry. The injection of adhesive consolidates the masonry, as well as bonding fully to the fixing. The injection method also counters possible absorption of resin or hardener by a dry, thirsty base material, analogous to the loss of moisture in mortar when used with absorbent and unwetted units.

Figure 6.7 *Injection-type bonded anchor as used in a stone-faced façade wall with brick backing and a rubble core*

A persuasive case can be made that injection-type resin anchors are most effective when installed in the mortar bed-joint of masonry, at a junction with the vertical joint. It is argued that the injected resin consolidates the joints, and mobilises at least three units before pull-out failure occurs under load. In comparison, an anchor installed in a single unit, possibly bedded in weak mortar joints, could well fail under a lower pull-out load.

Fire resistance of resin anchors

It is commonly thought that resin anchors have reduced resistance to fire, compared with other forms of fixing, because the heat is conducted into the drilled hole by the metal fixing where it acts on the adhesive, which softens at relatively low temperatures. However, tests reported in CIRIA Technical Note 92 *Indicative fire tests on fixings* indicated that the metal projecting parts of fixing assemblies generally were often the parts which failed during standard fire tests (CIRIA, 1978).

This is supported by test data from various manufacturers, whose conclusions are summarised in the CFA Guidance Note *Fixings and fire* (Construction Fixings Association, 1998):

- the performance of resin-bonded anchors in fire is only marginally lower than that of all-steel anchors
- some anchors may be used unprotected with full recommended loads for exposures up to 30 minutes
- for significant duration of exposure to fire (60 minutes or more), when using any anchoring system at full load, special measures must be employed
- a wide variety of anchor types, including resin-bonded anchors, are available with certified performance at reduced loads for exposures up to 120 minutes
- the capacity of stainless steel anchors in fire may be significantly better than that of carbon steel versions.

The guidance note recommends a variety of approaches to the specification of anchors for applications involving fire ratings.

Fire resistance of the permanent restraint fixings is clearly an important consideration in façade retention work. Adequate fire protection of the connections between the façade and the new permanent retention structure will often attract the attention of the building control officer, as loss of restraint to a retained façade in a fire could be a serious danger, risking collapse of the façade without warning during firefighting work, or indeed later.

Creep and durability of the resin

There is evidence that some creep relaxation of the adhesive can occur with time. The allowable loads recommended by manufacturers for resin anchors are typically set at bond stresses below that at which creep can occur. Individual anchor manufacturers can usually provide creep performance data for some at least of their resin anchors, but at present there is no agreed general guidance on the subject.

Polyester resin formulations may suffer a reduction in strength over a period of years when used in permanently damp or saturated base materials. Other formulations such as vinyl ester (sometimes called epoxy acrylate) or methacrylate-based systems, hybrid systems and pure epoxies are generally satisfactory in these conditions, but the manufacturer’s recommendations should be sought for specific applications.

Current systems are proven for durability, and manufacturers should be prepared to support a design life of up to 50 years for normal applications (although none has yet been in service for the duration of a typical design life). Accelerated durability checks are a feature of European Technical Approvals for metal anchors used in concrete, and will presumably be incorporated into the corresponding standards and procedures for anchors used in masonry when these are drafted.

Ambient service temperature limits

All resin formulations can be expected to work satisfactorily in sustained ambient temperatures up to +40°C.

If exposed to high elevated temperatures, in the order of say +60°C, during day-night cycles, as may be experienced behind façade elements in certain hot climates, then a reduction in bond strength may be experienced with some formulations of resin bonding material. The likelihood of this occurring in the United Kingdom is remote. If elevated temperatures from other sources are expected (for example from a nearby flue), then the manufacturer’s advice should be sought. Reference may be made to manufacturers’ graphs relating capacity to temperature for different resins.

Most resin formulations can be expected to function satisfactorily at ambient service temperatures down to -40°C.

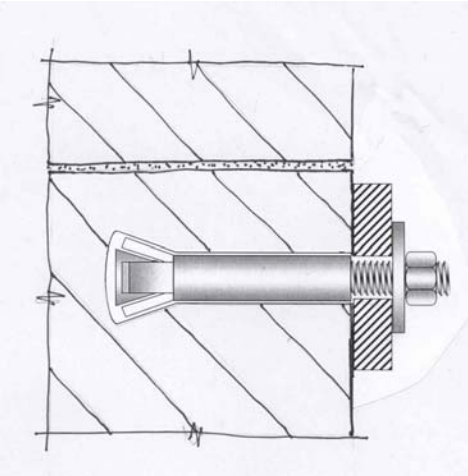
6.16.2 Cementitious anchors

Cementitious anchors are generally similar to resin anchors, but use an injected cementitious grout in place of resin to fill voids in the base material and to bond the anchor to it. The fixing is often supplied with a permeable fabric sleeve (known as a sock), or a flexible perforated metal mesh sleeve. The anchor is inserted into the drilled hole and grout is pumped into the sleeve, which fills and takes up the profile of voids around the fixing. This type of anchor is particularly suitable for use with hollow or perforated masonry units and in voided masonry generally, including rubble stonework. For irregular voids, such as are found in rubble stonework façades, the sock or sleeve should be quite flexible, to allow the grout to take up the profile of the voids. Here a fabric sock may be preferable to a more rigid perforated metal mesh. Either type would be suitable used with perforated bricks, in cavity brickwork, or in hollow blockwork. The injection-type anchor shown in Figure 6.7 could equally be installed using resin or cement grout.

Cementitious anchors are particularly suitable for re-attaching the separated leaves of debonded façade masonry, and for reinstating connection between the leaves of cavity walls where the original ties have corroded, otherwise failed or are deficient. Figure 6.7 shows the anchor used in a stone-faced façade wall with brick backing and a rubble core.

Cement-based grouts have properties similar to mortars, which gives good performance at high temperatures and in damp conditions.

6.17 Undercut anchors



These anchors (of which a typical example is shown in Figure 6.8) resemble miniature under-reamed piles, in that the lower part of the sides of an initially cylindrical drilled hole is shaped by a special drill action to form a tapered profile. The undercut anchor is tightened within this hole, and its foot “bells” out rather like the base of an under-reamed pile. The resulting expansion stresses are much lower than in an expansion anchor, and the profile of the undercut anchor provides assured mechanical anchorage within the hole.

These anchors have been specifically developed for use in cracked concrete, in which they work very well. They are not specifically recommended for use in masonry, but may be considered in large masonry units such as building stones, with a good compressive strength, so long as they are not located in or close to mortar joints, where their grip could be impaired. Little test data exists for the use of these anchors in masonry. Consequently, tests must be carried out to establish their performance in a particular façade if their use is being considered.

Figure 6.8 *Undercut anchor as used in stone*

6.18 Selection of fixing type

Current general practice in retaining masonry façades appears to give widest use to the injected resin anchor for fixings, although each of the types described above could find application where its characteristics render it suitable for use in the particular application.

Because of the importance of the façade connections, the following considerations need to be reviewed when making the choice of fixing type.

- Take into account the findings of the façade investigation to date when considering the choice(s) of fixing type.
- If the investigation is incomplete or not yet undertaken, highlight the key information needed to inform the choice of fixing type:
  - masonry units (strength? condition? brick: solid, perforated, cracked, voided? blocks: hollow, solid, lightweight? stone: ashlar, coursed, rubble, degraded rubble infill or hearting?)
  - mortar (presence? condition? voids? unfilled perpends and/or bed joints?)
  - voids and defects (cavity present – intended or otherwise, eg where infill has slumped, cavity wall ties absent or corroded?).
- Consider durability requirements – stainless-steel or non-ferrous fixings are normally appropriate for façade retention on grounds of durability and avoidance of possible rust staining. The appropriate grade of stainless steel or other alloy should be specified for the exposure conditions to be encountered. Bimetallic interaction with the steel frame should be considered, possibly requiring isolation between the components. (See CIRIA publication C524 *Cladding fixings: good practice guidance* (CIRIA, 2000), and the CFA Guidance Note* *Fixings and corrosion* (Construction Fixings Association, 2002).)
- Consider possible environmental effects, such as dampness, in relation to the performance of the fixing. (Certain chemical anchors are sensitive to dampness of the façade fabric during installation or in subsequent service.)
- Consider fire resistance requirements.
- Select possible suitable fixing types, taking account of manufacturer’s guidance where applicable.
- Consider the configuration of the anchor type. If restraint is to be made using bolts or threaded rods, then anchors with internally threaded sockets should be chosen. Resin anchors and other fixings with projecting threaded sections, can be used with threaded adaptors, in which case care must be taken to ensure adequate thread engagement is made on both sides of the connection.
- Consider size and number of fixings – to take some account of possible variations in the masonry and in the installation workmanship, it is recommended that restraint provision should be diffused, making a generous allowance for the number, preferring more small fixings for each connection rather than one or two larger fixings (again based on manufacturer’s guidance). Spacing of fixings affects individual capacity and must therefore be taken into account.
- Plan and initiate test programme using trial fixings, as early as possible, to confirm viability of using preferred fixing type(s) and design basis for fixing strength in the particular façade.
- Specify random testing of working fixings during installation.
- Specify a procedure for checking and recording installation of connections, with inspection completion and sign off.

The CFA Guidance Note* *Anchor selection* may be consulted for advice (Construction Fixings Association, 1995).

9.10 Connections between the façade and the new structure

9.10.1 Preliminary tests on fixings

Testing of the fixings for the permanent connections between the façade in locations and the new structure should be undertaken at this stage if this has not been possible earlier. Satisfactory test results will justify the original choice of fixing type; unsatisfactory results indicate that a different fixing type must be considered and itself be subject to repeat testing.

The intended fixing type should be installed into the back face of the façade in locations where fixings will not be required in the permanent scheme, but where the façade construction is similar to that in locations where permanent fixings are to be installed. Testing to failure should be carried out in tension and shear (as appropriate to the loadings on the permanent fixings).

The preliminary tests should employ the method of installation intended for the working fixings. This method should always follow the manufacturer's recommendations.

Where possible, such testing should be integrated within the investigatory work (see Section 5.8).

The testing will confirm the suitability of the proposed fixing type(s) and establish the design strength for the fixings in the particular façade. The approach to testing should follow that set out in BS 5080: Parts 1 and 2 for tension and shear respectively. In 2002 these were the current standards for testing fixings in masonry, although in due course it is expected that the system of European Technical Approval for fixings will be extended from its present scope of fixings in concrete to cover fixings in other substrates. Such fixings will then carry a CE marking.

There is a CFA Guidance Note *Procedure for site testing construction fixings* (Construction Fixings Association, 1994).

9.10.2 Tests on working fixings

Tests on working fixings are intended to confirm that installation practice complies with the procedures adopted for the preliminary tests. Again, the tests should generally follow the recommendations of BS 5080, although the fixings are to be "proof" loaded rather than tested to failure. The recommended test load on installed fixings should be 50 per cent above working load.

The procedure for testing of working fixings should be specified as part of the permanent works design. If drilled-in fixings are being used to tie the façade to the temporary structure, then testing of these should follow a similar regime.

Working tests on fixings should be carried out on at least a percentage of installed fixings. A suggested figure is 10 per cent, although some designers argue that all fixings should be tested. Where only a percentage of fixings is tested, these should be chosen as a representative sample across the whole façade.

Any failure of fixings subject to a working test should be closely investigated to establish the reason(s), which should be remedied – possibly with further pull-out testing – before installation of working fixings is resumed.

9.10.3 Records

A procedure should be set out in the permanent works specification for inspecting and documenting the installation and testing of fixings.

9.10.4 Installing fixings

The installation of the permanent connections to the façade requires a high level of supervision, as it is highly sensitive to workmanship

It is important that the manufacturer's instructions are strictly followed where applicable. For most anchor systems, they can be summarised as follows:

- drill hole to the recommended diameter and depth (for resin anchors this will be related to the capsule type)
- clean the hole thoroughly (for resin anchors it may also be necessary to *dry* the hole)
- insert anchor to the manufacturer's specified procedure, using the manufacturer's setting tools
- tighten to the manufacturer's installation torque as recommended for the base material.

Tightening an anchor to the manufacturer's recommended installation torque is important for all fixings used to clamp a fixture to the base material. It is usually set at a value that will ensure that, on the one hand, the required clamping force is achieved, so the fixture will not move and, on the other hand, that the bolt material will not be overstressed.

It is equally as important for resin-bonded anchors, because it also protects the resin bond from being over-stressed. When resins are used in base materials weaker than concrete, the tightening torque should be reduced in proportion to the reduction in material strength. For some anchor configurations which are not used to clamp a fixture to the base material, such as internally threaded sockets used with threaded rods, it may not be necessary to tighten the anchor.

Particular workmanship issues with resin anchors

On-site testing has identified other potential workmanship issues specific to resin anchors to be:

- mixing the resin components thoroughly
- ensuring that curing takes place for the correct period, including allowance for the retarding effects of low air temperatures.

The drilled hole must be cleaned. It is essential that the sides of the holes are free of dust, otherwise the adhesive will not bond fully to the base material. (This is best achieved by blowing with a large-volume pump or compressed-air line, and then brushing with a round brush slightly larger than the hole diameter. Blowing removes loose dust in the hole, while brushing removes the dust pressed against the sides of the hole during drilling, which would otherwise prevent the resin from bonding with the base material.)

As with all such specialised tasks, proper training and supervision of those responsible for installing the anchors is essential.

Ambient installation temperature limits for resin anchors

Resin anchors of different formulations have different limits for installation temperatures. Lower limits usually vary between -5°C (with very extended curing time) and +5°C, while upper limits go from +20°C to +40°C (at which the curing time would be almost impossibly short). These temperature limits should be indicated on the anchor packaging or the manufacturer's instructions for use, together with recommended curing time and working time for injection systems.

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*This is one of a series of Guidance Notes downloadable free of charge from the CFA website. Also available on the website are articles, FAQs Sample Method Statements and much more material designed to help the specifier and user of fixings. For more details of the Association and its activities and to download Guidance Notes etc go to www.fixingscfa.co.uk

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