INTERIM ADVICE NOTE 104/15

IAN 104/15

THE ANCHORAGE OF POST-INSTALLED FASTENERS AND REINFORCING BARS IN CONCRETE

SUMMARY
This Interim Advice Note provides guidance on design and specification for the anchorage of post-installed fasteners and reinforcing bars in concrete.

INSTRUCTIONS FOR USE
This IAN takes immediate effect.

THE ANCHORAGE OF POST-INSTALLED FASTENERS AND REINFORCING BARS IN CONCRETE

1. INTRODUCTION

1.1 Background

In recent years there has been an increase in the use of fasteners (commonly referred to as ‘anchors’) and reinforcing bars bonded in drilled holes using resin or cementitious grouts in works relating to highway structures, as they can offer a cost-effective solution for making attachments or extensions to existing concrete structures. In this document, ‘fastener’ and ‘anchor’ are used synonymously.

The use of these techniques can mitigate the need for extensive breakout of the parent concrete. They can also have benefits in terms of reducing disruption to the highway network, reducing requirements for traffic management and reducing the duration of the construction programme. However, the design methodology for the anchorage of post-installed fasteners and reinforcing bars is not covered in existing Highways Agency standards. In addition, with the exception of some specific applications, the Specification for Highway Works does not include clauses covering work of this nature.

1.2 Scope

This Interim Advice Note covers the design and specification of post-installed fasteners (which include expansion anchors, undercut anchors and bonded anchors) and reinforcing bars in concrete.

The scope of this Interim Advice Note is limited to post-installed metal fasteners and reinforcing bars for structural applications and attachments to structural components in concrete where failure could:

i) result in collapse or partial collapse of the structure, or
ii) cause risk to human life, or
iii) lead to significant economic loss.

For the avoidance of doubt, plastic anchors, such as those covered by ETAG 020, and metal anchors for multiple use in non-structural applications (e.g. anchors covered by ETAG 001 Part 6) are outside the scope of this Interim Advice Note. In the case of any proposal to use plastic anchors (e.g. anchors covered by ETAG 020) or metal anchors for multiple use in non-structural applications where failure could result in collapse or partial collapse of the structure, cause risk to human life, or lead to significant economic loss, the performance criteria should be agreed with the Overseeing Organisation through the submission of an Aspect not Covered by Standards application.

This Interim Advice Note does not cover post-installed anchors for vehicle restraint systems, permanent bollards, traffic signs, lighting columns or CCTV masts. These applications are addressed in other implemented standards and/or the Specification for Highway Works.

1.3 Purpose

The purpose of this Interim Advice Note is to set out design methodologies and model specification clauses that are acceptable to the Highways Agency, within the context of the various European and National standards and guidance in the subject.

1.4 Existing Guidance Documents and Standards

The European Organisation for Technical Approvals (EOTA) has produced a series of Guidelines for European Technical Approvals (ETAGs). These documents set test and assessment criteria against which products not covered by any relevant harmonised EU standard can be awarded a European Technical Approval (ETA) and have a European Technical Approval Certificate. Following the full implementation in July 2013 of the Construction Products Regulations (CPR), ETAGs are going to be replaced by European Assessment Documents (EADs), against which a European Technical Assessment (ETA) can be issued, which will replace the European Technical Approval. European Technical Approval Certificates issued before the implementation of the CPR are still valid until their expiry date.

To obtain a CE mark, products not covered by a harmonised EU standard must have an ETA accompanied by a Declaration of Conformity (Declaration of Performance under the CPR), which includes the factory control and supervision requirements appropriate to the system of attestation of conformity (system of Assessment and Verification of Consistence of Performance under the CPR) required in the relevant ETAG/EAD for the intended use of the product.

At present, there are no harmonised EU standards for anchors, and the ETAGs against which ETAs can be awarded include ETAG 001 ‘Metal anchors for use in concrete’, ETAG 020 ‘Plastic anchors for multiple use in concrete and masonry for non-structural applications’ and ETAG 029 ‘Metal injection anchors for use in masonry’. For the avoidance of doubt, products covered by ETAG 020 and ETAG 029 are outside the scope of this Interim Advice Note.

In particular, ETAG 001 comprises 6 Parts (General, Torque-controlled expansion anchors, Undercut anchors, Deformation-controlled expansion anchors, Bonded anchors and Anchors for multiple use for non-structural applications) and 4 Annexes (A-Details of tests, B-Tests for admissible service conditions, C-Design methods and E-Assessment of metal anchors under seismic action). As noted in Section 1.2, products covered by Part 6 are outside the scope of this Interim Advice Note.

The EOTA has produced a series of Technical Reports (TR), which are supporting reference documents complementary to the ETAGs.

The relevant TRs for anchors are TR 18 ‘Assessment of torque-controlled bonded anchors’, TR 20 ‘Evaluation of anchorages in concrete regarding resistance to fire’, TR 23 ‘Assessment of post-installed rebar connections’, TR 29 ‘Design of bonded anchors’ and TR45 ‘Design of metal anchors for use in concrete under seismic actions’.

TR 29 gives a design method specifically for post-installed bonded anchors, which supplements and modifies the method in Annex C of ETAG 001 and takes into appropriate account the characteristic bond resistance and the combined pull-out and concrete cone failure mode. When obtaining an ETA, the assessment of fitness of the post-installed bonded anchor for its intended use is generally made with reference to both the ETAG 001 and TR 29.

TR 23 sets out a design methodology for post-installed reinforcing bars which is in full compliance with BS EN 1992 (Eurocode 2) and differs from the provisions of Part 5 of ETAG 001, as post-installed reinforcing bars are assumed to have the same behaviour as cast-in reinforcing bars acting in tension only. Some of the tests required for bonded anchors (Part 5 of ETAG 001) are not required, as only pull-out and splitting failure are assumed to occur in post-installed reinforcing bars in tension. When obtaining an ETA, the assessment of fitness of the post-installed reinforcing bar for its intended use is generally made with reference to both the ETAG 001 and TR 23.

Post-installed anchors and reinforcing bars used on Highways Agency works shall have a European Technical Approval (or European Technical Assessment), as this provides assurance regarding the suitability of the product for its intended use.

DD CEN/TS 1992-4 ‘Design of Fastenings for use in Concrete‘ has been published in the draft for development series of the CEN committee for structural Eurocodes. DD CEN/TS 1992-4 comprises 5 Parts (General, Headed fasteners, Anchor channels, Post-installed fasteners/mechanical systems and Post-installed fasteners/chemical systems). Parts 1, 4 and 5 fall within the scope of this Interim Advice Note, which does not include cast-in fasteners.

BS EN 1504 ‘Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and evaluation of conformity – Part 6: Anchoring of reinforcing steel bar’ specifies the requirements for products and systems (generally cementitious grouts or resins) to be used for the anchoring of post-installed reinforcing bars in concrete for structural strengthening to ensure the continuity of reinforced concrete structures.

BS 8539 ‘Code of practice for the selection and installation of post-installed anchors in concrete and masonry’ is a recently published British Standard which gives recommendations to designers, specifiers, manufacturers, suppliers, contractors, installers and testers for the safe selection and installation of anchors inserted into concrete and masonry in drilled holes. It does not cover cast-in fasteners.

1.5 Mutual Recognition

Where there is a requirement in this document for compliance with any part of a “British Standard” or other technical specification, that requirement may be met by compliance with:

(a) A standard or code of practice of a national standards body or equivalent body of any EEA state or Turkey;
(b) Any international standard recognised for use as a standard or code of practice by any EEA state or Turkey;
(c) a technical specification recognised for use as a standard by a public authority of any EEA state or Turkey; or
(d) a European Technical Assessment issued in accordance with the procedure set out in regulation (EU) No305/2011

provided that the relevant standard imposes an equivalent level of performance and safety provided for by the stated Standard or technical specification.

“EEA State” means a state which is a contracting party to the European Economic Area Agreement.

“British Standard” means any standard published by the British Standards Institution including adopted European or other international standards.”

2. APPLICATIONS OF THE TECHNIQUE (SAFETY CRITICAL AND NON-SAFETY CRITICAL)

The anchorage of post-installed fasteners and reinforcing bars in drilled holes has been adopted for a wide range of applications. These include fixing ancillary equipment to concrete surfaces, attaching environmental barriers to structures, provision of extensions to concrete elements (e.g. construction of new parapet upstands), strengthening/extending foundations and substructures, fixing temporary works to the edge of bridges to facilitate parapet replacement, attaching walkways to the sides of structures etc.

It is important to recognise that the implications of an individual anchor failing to perform as expected in service are dependent on the proposed application.

For example, if a structure is extended by anchoring a large number of reinforcing bars into the existing concrete, an individual anchored bar with sub-standard capacity is unlikely to have significant implications. In contrast, if temporary works are attached to the side of a bridge by a small number of fixings, failure of an individual fixing could be very significant and may have severe consequences. The latter example is considered to be a ‘safety critical’ application. The safety critical nature of the proposed application needs to be taken into account in the testing regime adopted, as defined in Section 6. Typical examples of safety critical and non-safety critical applications are given in Table 2.1.

It should be noted that there is currently relatively little information available regarding the behaviour of post-installed anchors and reinforcing bars subject to significant fatigue (cyclic, fluctuating, pulsating) or seismic loads. Where post-installed anchors and reinforcing bars are to be used under these loading conditions, the suitability of the anchor to resist such loads shall be stated in the relevant ETA, and they should be treated as ‘safety critical’ applications.

As discussed in the CFA guidance document ‘Anchor selection’, where a fastener is pre-tensioned and the magnitude of the pre-tensioning force is expected (with appropriate justification) to remain in excess of the SLS design tensile action throughout the specified design life then it may be assumed that the fastener is not subject to significant fatigue loading.

Description	**Are safety risks sensitive to the performance of a small number of anchorages?**	**Are the anchorages subject to significant cyclic loading?**	**Classification** (follows from the answers to the questions in the columns to the left)
Strengthening a pier for impact by constructing a reinforced concrete plinth around existing columns with reinforcing bars anchored into the existing foundation.	No	No	Non-safety critical
Temporary works suspended from the side of a bridge deck to facilitate parapet replacement. The temporary works will be supported by fixings anchored into the edge of the bridge deck.	Yes	No (Wind loads will generate fluctuating stresses, but the temporary works will only be in place for short duration)	Safety critical
Service duct suspended from a bridge deck. The duct will be attached to the deck with resin anchors.	No (If failure of an individual fixing would lead to a section of the duct falling from the bridge and this presents a significant safety risk then the answer would be Yes)	No	Non-safety critical (If failure of an individual fixing would lead to a section of the duct falling from the bridge and this presents a significant safety risk then the application would be classified as safety critical)
Environmental barrier fixed to the edge of a bridge deck using resin anchors.	Depends on whether the failure of a support presents a significant safety risk (e.g. barrier could fall onto live carriageway below)	Yes	Safety critical
Construction of a continuous parapet plinth along the length of a bridge. The plinth will be attached to the existing deck with resin anchored reinforcing bars.	No (If the plinth was fixed to the deck by a small number of bars local to individual parapet posts then the answer would be Yes)	No (Cyclic stresses are low compared with the stresses generated by vehicle impact with the parapet)	Non-safety critical (If the plinth was fixed to the deck by a small number of bars local to individual parapet posts then the application would be classified as safety critical)

Note: Where safety risks are sensitive to the performance of a small number of anchors/rebars, the application may be categorised as non-safety critical if redundancy is built into the design (e.g. provision of five anchors/rebars where the design requires four).

Table 2.1: Typical Examples of Safety Critical and Non-safety Critical Applications

3. DESIGN

3.1 General

Post-installed anchors shall be designed in accordance with the limit state design methods of DD CEN/TS 1992-4 and TR 29 (applicable to bonded anchors only). In this context, ‘post installed anchor’ means an element essentially acting as an anchor bolt (which in the case of bonded anchors is generally a threaded rod, but can also be a reinforcing bar) stressed in tension, shear or combined tension and shear over a relatively short embedment depth, and which can be either mechanically anchored or bonded in concrete.

Post-installed reinforcing bars shall be designed as cast-in rebars in accordance with BS EN 1992 and TR 23. In this context, ‘post-installed reinforcing bar’ means an element (generally a reinforcing bar or a tension rod) bonded in concrete which is intended to behave in the same way to a cast-in reinforcing bar and acts only in tension, with the tensile forces transferred through bond to concrete or to the existing reinforcement over an appropriate anchorage/overlap length. This applies to most situations where existing and new concrete members are to be connected or to be made continuous.

Design actions at the Ultimate Limit State (ULS) and Serviceability Limit State (SLS) shall be evaluated and compared with design resistances and relevant SLS criteria.

The performance of post-installed anchors and reinforcing bars in hardened concrete can be critically sensitive to the quality of workmanship during installation. Against this background, appropriate factors of safety are adopted and load testing of post-installed anchors and reinforcing bars is required. Whilst it is important to ensure that anchors are designed with adequate factors of safety, the use of excessive embedment lengths should be avoided in order to mitigate health and safety risks associated with drilling operations on site. Given that the performance of post-installed anchors and reinforcing bars is sensitive to workmanship, the use of personnel properly trained in the techniques of installation is essential, and it should be noted that both the ETAs and BS 8539 require that the installation is supervised, with the BS 8539 also suggesting that the supervisor certifies the installation.

3.2 Partial Material Factors for ULS Verification

The partial material factors for the steel and concrete related failure modes at ULS to be used to evaluate the design resistance of anchors subject to static or quasi-static and seismic actions are given in DD CEN TS/1992-4, TR 45 and the relevant ETAs as appropriate. For anchors subject to significant cyclic, fluctuating or pulsating loads leading to fatigue the partial material factors are given in DD CEN TS/1992-4.

3.3 SLS Criteria

It is important to consider the deformation of anchors under SLS loads in order to ensure that structural performance, appearance and durability are not impaired. In many applications (e.g. temporary works fixings, strengthening a structure to accommodate accidental loading etc.) deformation control is unlikely to be critical. However, in other cases (e.g. anchors and reinforcing bars subject to long-term loads), careful control of deformation will often be of greater significance.

The characteristic displacement of an anchor under tension and shear loading shall be given in its ETA. Its design value shall not exceed the limiting displacement given in Table 3.1 for short and long-term loading at SLS. The limits in this table are recommended in circumstances where there are no particular adverse implications associated with displacement under load. Where displacement would have significant implications, the designer should adopt alternative application specific limits as appropriate.

	Maximum deformation under short-term loading	Maximum deformation under long-term loading
Tension	0.05d	0.12d
Shear	0.20d	0.30d

Notes:

i. d is the nominal diameter of the anchor/rebar

ii. Short-term deformation limits should be met at temperatures up to the maximum concrete temperature derived in accordance with BS EN 1991-1-5 and its UK National Annex. This may conservatively be taken as 60^{O}C.

iii. Long-term deformation limits should be met at temperatures up to 0.6 times the maximum concrete temperature derived in accordance with BS EN 1991-1-5 and its UK National Annex. This may conservatively be taken as 36^{O}C.

Table 3.1: Upper bound deformation limits δ for anchors and reinforcing bars

3.4 Design Life

The post-installed anchors and reinforcing bars should have an expected working life consistent with the required design life for the works. The design methods in DD CEN/TS 1992-4, BS EN 1992-1-1 and test requirements for ETAs in accordance to ETAG 001 require products to be suitable for an intended working life of at least 50 years. This requirement has been adopted as the default requirement in the model specification included in Annex A to this Interim Advice Note. Where a design life in excess of 50 years would ordinarily be required, a product with a design life of 50 years may be used provided the designer is content (based on information provided by the supplier and in relation to the specific application in which the product will be used) that there is reasonable justification for expecting the product to perform satisfactorily for the longer design life. In these circumstances the Structure File should record the need to revisit the issue after 50 years, and it may be appropriate to install additional bars to facilitate future testing.

Anchors shall not be removed and reused elsewhere unless their ETA specifically states that they are suitable for reuse. Where change of use of installed anchors is proposed or the design loads on existing anchors are increased, approval shall be sought from the overseeing organisation through the Departure from Standards process.

It must be emphasized that the conditions of anchors in service shall be monitored as part of the routine inspections undertaken at the structure in which they are installed, in accordance with the inspection procedures of the overseeing organisation. Where anchors will be hidden from view (e.g. anchors above suspended precast panels in a tunnel), removable access panels shall be provided to facilitate future inspection/testing.

3.5 Other Factors

Prior to using post-drilled fasteners and reinforcing bars for any application, the potential implications of drilling into the structure (e.g. possible damage to reinforcement, prestressing tendons etc.) must be taken into account at the design stage. Guidance on this aspect is given in BS 8539. There are many devices available to locate the position and size of existing bars. Where obstructions such as existing reinforcement are anticipated the design of brackets/base plates should take account of the need to relocate anchors.

Wherever possible multiple drilled holes should be staggered in order to avoid creating a line of perforations in the existing concrete. Where a hole has to be re-drilled/cored (e.g. due to an obstruction being encountered or defective concrete being identified) account must be taken of the influence of the aborted hole (which should be repaired) on the performance of the relocated anchor/rebar.

If it is proposed to install anchors and reinforcing bars in repaired concrete surfaces, then account must be taken of the potential for a plane of weakness to exist at the interface between the material used to repair the concrete and the substrate concrete. For shallow repairs one possible approach is to ignore that part of the embedment length which lies within the material used to repair the concrete. However, for proprietary anchors with a fixed embedment depth advice will then need to be sought from the manufacturer regarding the effect on anchor performance. Ignoring the embedment depth in the material used to repair the concrete may also be appropriate for deeper repairs. However, whether or not this is appropriate will depend on the particular circumstances and requires careful consideration. In cases where ignoring the contribution of the repair material in the design of the anchor/rebar is not feasible (e.g. installing an anchor in a thin section) the interface between original and repair concrete should be investigated and taken into account as appropriate. Additional guidance on various aspects affecting the installation is given in BS 8539.

Given the safety factors incorporated in the design methods, it is unlikely that failure of an appropriately installed anchor/rebar will occur in service. However, in the event of an applied load substantially greater than the ULS design load then failure is possible and could take the form of a concrete failure. In circumstances when this would be particularly problematic (e.g. the structural integrity of the bridge could be compromised) it would be prudent to ensure that an upper limit on the strength of the fixing is introduced to ensure that the metal component fails at a lower load than that required to generate a failure in the substrate concrete.

In circumstances where loads to be carried by anchors/rebars have been evaluated in advance, but the contractor is required to select a proprietary product suitable for the applied loads, the following design information should be provided by the designer for the contractor as appropriate:

- The classification of the application (safety critical or non-safety critical)
- Design actions at ultimate limit state and serviceability limit state and their nature (i.e. static or non-static)
- The classification of the concrete (cracked or non-cracked), as defined in DD CEN/TS 1992-4
- Minimum and maximum concrete temperatures
- The characteristic concrete cube strength to be used in the design of the anchors
- Any application specific criteria relating to edge distance, centre spacings and embedment depth, such as a maximum embedment depth, or a pre-determined embedment length.

- Details of the metal component when this has been pre-determined.
- Displacement limits for short and long-term loads at serviceability limit state.
- For anchors subject to axial tension, a minimum value for the test load.
- The number of tests to be carried out during the installation of works anchors.

Further guidance on information to be provided by the various parties is given in BS 8539.

3.6 Design Process for Anchors Subject to Tension and Shear

Step 1
Determine whether the proposed application is safety critical or non-safety critical with reference to the guidance in Section 2.

Step 2
Determine whether the concrete is cracked or non-cracked and evaluate design actions for ULS and SLS.

Step 3
Evaluate the maximum and minimum concrete temperatures in accordance with BS EN 1991-1-5 and its UK National Annex. Alternatively, a minimum concrete temperature of -30^{O} and a maximum concrete temperature of $+60^{O}$C may be assumed.

Step 4
Extract characteristic resistances for all relevant failure modes at ULS from the anchor's ETA for the relevant range of temperatures, derived in accordance with design method A of part 4 of DD CEN/TS 1992-4 (for mechanical anchors) and with the design method of part 5 of DD CEN/TS 1992-4 (for bonded anchors).

Step 5
For each failure mode, the design resistance is obtained from the data in the anchor's ETA by dividing the characteristic resistance by the appropriate partial material factors and applying modification factors which take into account, as appropriate, of characteristic concrete strength, influence of edge distance and spacing, embedment depth, cracked/non-cracked conditions and other influencing factors.

Step 6
The tensile and shear design resistances of the anchor are taken as the lowest tension and shear design resistance obtained for the various failure modes, respectively. Verification at ULS for tension, shear and combined tension and shear is made in accordance with part 4 and part 5 of DD CEN/TS 1992-4 for mechanical and bonded anchors, respectively.

Step 7
With reference to load/displacement data given in the ETA valid for the proposed product/application, check that predicted displacement for SLS action under short and long term loads is acceptable. It may be assumed that displacement is proportional to applied load.

Note: Where load/displacement data for a particular embedment depth/concrete strength/bar diameter is not available, data applicable to a smaller embedment depth/lower concrete strength/smaller bar diameter may be used.

Step 8
Evaluate the test load to be applied. An axial test load should be applied on site to a number of installed anchors carrying tension and/or shear as defined in Section 6, to evaluate the quality of the installation. For anchors carrying tension the test load should be a minimum of 1.1 times the ULS design tensile action, but should not exceed 1.1 times the ULS design tensile resistance. For anchors carrying shear, the test load should be equal to or greater than the ULS design tensile resistance, but should not exceed 1.1 times the ULS design tensile resistance.

3.7 Design Process for Post-Installed Reinforcing Bars

Post-installed bonded reinforcing bars, which comply with the definition of Section 3.1, shall be designed in accordance with BS EN 1992 and TR 23. It should be noted that this design method assumes that the bars are unable to carry any shear load, and the shear is carried through the concrete interface by means of a roughened surface and the interlock of new concrete into this; if this is not sufficient, shear lugs or post-installed anchors carrying shear should additionally be provided.

Step 1
Determine whether the proposed application is safety critical or non-safety critical with reference to the guidance in Section 2.

Step 2
Determine whether the concrete is cracked or non-cracked and evaluate design actions for ULS and SLS in accordance with BS EN 1992.

Step 3
Evaluate the maximum and minimum concrete temperatures in accordance with BS EN 1991-1-5 and its UK National Annex. Alternatively, a minimum concrete temperature of -30 and a maximum concrete temperature of +60^{O}C may be assumed.

Step 4
Extract, from the data in the post-installed reinforcing bar's ETA derived in accordance with the procedure in TR 23, the design values for the ultimate bond resistance for different concrete strengths and bar diameters for the relevant range of temperatures and cracked/non-cracked conditions.

Note:
Where the ultimate bond resistance of post-installed reinforcing bars in the ETA is not given for the various range of temperatures and cracked/non cracked conditions (i.e. only a general bond resistance value is given), the characteristic bond resistance of the same reinforcing bars (bonded with the same grout/resin) given in the ETA for use as an anchor may be considered, and the lowest of the two values adopted.

Step 5
Evaluate, in accordance with BS EN 1992-1-1 and TR 23 and based on the design values for the ultimate bond resistance evaluated in step 4, the minimum and design values of the anchorage length and the lap splice length, taking into account the cover and spacing limitations for different drilling methods and the influence of cracked/non-cracked conditions and other influencing factors identified in the ETA.

Step 6
With reference to load/displacement data given in the ETA valid for the proposed product/application, check that predicted displacement for SLS action under short and long term loads is acceptable. It may be assumed that displacement is proportional to applied load.

Note: Where load/displacement data for post-installed reinforcing bars is not available in the ETA, data contained in the ETA where the reinforcing bar (bonded with the same grout/resin) is used as an anchor may be used for checking compliance with SLS deformation limits. In addition, where load/displacement data for a particular embedment depth/concrete strength/bar diameter is not available, data applicable to a smaller embedment depth/lower concrete strength/smaller bar diameter may be used.

Step 7
Evaluate the test load to be applied. An axial test load should be applied to a number of post-installed reinforcing bars on site as defined in Section 6, to evaluate the quality of the installation. The test load should be a minimum of 1.1 times the ULS design tensile action but should not exceed 1.1 times the ULS design resistance.

4. TYPE OF GROUT/RESIN

4.1 General

For bonded post-installed anchors and reinforcing bars, the anchoring products (generally cementitious grouts, resins or a mixture of these) shall have, together with the accompanying anchor/reinforcing bar, an ETA assessed for its intended use in accordance with ETAG 001 and, for torque-controlled bonded anchors and post-installed reinforcing bars, with TR 18 and TR 23 respectively. The anchoring products used for bonded post-installed reinforcing bars shall conform to BS EN 1504-6.

Selection of an appropriate grout/resin requires consideration of the environment and conditions to which the anchorage will be exposed during and after installation. Some general guidance on these issues is provided in CIRIA Technical Report C537 ‘The use of epoxy, polyester and similar reactive polymers in construction’.

4.2 Fire and Heat

Fire is unlikely to be a significant consideration for most highway structures. However, in circumstances where the risk of exposure to extreme heat or fire is increased, or the implications of anchors failing in a fire situation are severe, the effects of fire and any mitigation should be included in the development of the design.

Guidance on the resistance of mechanical anchors to fire is given in DD CEN/TS 1992-4 and in TR 20; the provisions are also valid for bonded anchors with regards to the resistance to fire of the anchor/reinforcing bar itself, but do not consider the effect of reduced strength of the grout/resin at elevated temperature, which may be the controlling factor in this case. For bonded anchors or reinforcing bars subjected to fire requirements, specialist advice and data should be sought from the product manufacturer. For bonded post-installed reinforcing bars, the manufacturer should declare the reaction to fire classification of the anchoring product in accordance with BS EN 1504-6, and can often provide data relating to the temperature at which bond strength weakens significantly. When a structure is exposed to extreme heat or fire, the temperature at relatively shallow depths within the concrete will often be much lower than that at the concrete surface. Therefore, in many cases where the primary load effect is axial tension, the effects of fire can be mitigated by increasing the embedment depth to compensate for the loss of bond strength close to the surface of the concrete.

4.3 Hole Formation

Hole formation and injection/curing of the anchoring product shall be performed in accordance with the instructions contained in the ETA of the system used and shall be in accordance with DD CEN/TS 1992-4.

The use of diamond core drilling and the installation of grout/resin into wet or flooded holes is permitted only when specifically stated in the ETA of the anchoring system. It should be noted that some grouts are not approved for use with diamond core drilled holes. Further guidance is given in BS 8539.

5. TYPE OF ANCHOR / REINFORCING BAR

For permanent and temporary works, anchors and reinforcing bars shall be stainless steel unless they are fully encased in concrete (i.e. with cover complying with the requirements of the design standard and specification relevant to the application), in which case they may be carbon steel. Also, carbon steel should not be used when the bars are subject to long-term loading which could lead to excessive concrete cracking. It may also be appropriate in some cases to specify stainless steel for fully encased applications, for example in those elements of highway structures most at risk from chloride attack like parapet edge beams, substructures in splash zones adjacent to carriageways, below movement joints on associated bearing shelves, on substructures in marine environments, superstructures subject to spray and in road tunnels.

It should be noted that where anchors pass through bridge deck waterproofing, action should be taken to ensure the integrity of the waterproofing.

Care must be taken to ensure appropriate isolation of dissimilar metals. Stainless steel reinforcement should not be lapped onto bars where corrosion has already started or where chloride levels or half cell readings would indicate corrosion may be imminent, as there are concerns that corrosion resistance may be impaired in this situation and the existing carbon steel may already be active and be vulnerable to bi-metallic corrosion with the stainless steel.

In certain circumstances, it may be appropriate to specify anchors consisting of internally threaded sockets. These can facilitate rapid replacement of a damaged attachment or bolt.

Stainless steel reinforcing bars shall conform to BS 6744. Stainless steel reinforcing bars and parts of anchors (e.g. threaded rods, washers, nuts) for use in highway works should be austenitic steel grades with 16.5 to 18.5% chromium, 10 to 13% nickel and 2 to 3% molybdenum content (A4 or A5 grade) or equivalent corrosion resistant duplex steel grades, in accordance with BS EN ISO 3506 and BS EN 10088. However, for exposed fixings in particularly aggressive environments (e.g. tunnels), stainless steel with a higher level of corrosion resistance (HCR steels), generally austenitic steel grades with about 20% chromium, 20% nickel and 6% molybdenum content or equivalent duplex steel grades shall be used. Further guidance on stainless steel grade selection is given in Annex B of BS 6744 and in BS 8539.

When carbon steel for post-installed reinforcing bars fully encased in concrete is used, carbon steel reinforcing bars shall conform to BS 4449.

6. TESTING

The performance of anchors/anchored reinforcement can be very different to that anticipated at design stage. For example, performance may be heavily influenced by workmanship and/or environmental conditions. For this reason, on site tensile tests on a sample of installed anchors/reinforcing bars is required in all cases.

Tests on sacrificial anchorages (as opposed to works anchorages) shall be undertaken when testing works anchors/reinforcing bars is not possible due to geometric constraints (e.g. restricted access or bent bars). Where testing of sacrificial anchorages is proposed in lieu of testing works anchorages, ensuring an appropriate quality of workmanship for the works anchorages is particularly important. Tests on sacrificial anchorages should, as far as reasonably practicable, replicate the conditions and installation methods applicable to the works anchorages. Wherever possible, sacrificial anchorages should be located on the structure in the vicinity of the proposed works anchorages.

The recommended load test is based on the requirements of BS 5080 Part 1. The test arrangement set out in BS 5080 Part 1 involves applying an axial tensile load to a threaded component. This requires some modification when testing ribbed reinforcing bars. Two approaches to testing are currently in use for anchored reinforcing bars. The first involves cutting a thread into the exposed end of the bar; load is then applied to the bar by means of a nut on the threaded section of bar. This approach is usually limited to tests on sacrificial anchorages. The second approach is to apply a coupler to the bar and to apply load to the bar via the coupler. This approach can be used for testing sacrificial or works anchorages. Careful consideration shall be given to safety during load testing; in particular, any proposal to apply load to a bar via a coupler shall be considered in consultation with the manufacturer of the coupler. Further guidance on the arrangement for load testing of anchorages on site is given in the CFA document ‘Procedure for site testing construction fixings’.

BS 5080 Part 2 includes details of a shear test. Although the shear test provides a more direct indication of the shear capacity for anchorages subject to shear, the axial test is more readily undertaken on site and is considered to provide an appropriate level of assurance regarding quality of workmanship.

The number of load tests shall be a minimum of 3% (10% for safety critical applications) of the total number of anchorages proposed in the works, subject to a minimum of 3 anchorages for any discrete area with different size and type of anchorage, different concrete strength and different installation team. For works involving the installation of very large numbers of anchors (e.g. > 1000), the percentage of anchors/rebars to be tested can be reduced with the agreement of the Technical Approval Authority.

If one failure is encountered, the reason for failure should be investigated and the number of anchorages tested in that discrete area should be doubled.

7. REINSTATEMENT

It will normally be necessary to remove/cut-back temporary anchors/reinforcing bars on completion of temporary works and to effect an appropriate concrete repair. However, this may not be appropriate if they are to remain in place for possible re-use in the future. Any proposal to retain temporary anchors/reinforcing bars shall be discussed with the HA Structures Advisor.

8. AS-BUILT RECORDS

Details of anchorages for permanent works applications and temporary works applications left in place shall be recorded on as-built drawings. The information recorded on the as-built drawings shall include hole diameter, method of hole formation, embedment depth, grout/resin details, metal component details and design resistance details. Copies of the ETA and other supporting test data, which may also include the installation record signed by the installation supervisor, shall be retained in the Structure File.

9. SPECIFICATION

A model specification is given in Annex A for use in works relating to highway structures.

In general, where there is conflict between the requirements of the model specification and manufacturer's recommendations, the model specification takes precedence when more onerous. However, where the manufacturer's product specific recommendations are more conservative, onerous or restrictive than the model specification, it is imperative that the manufacturer's recommendations are complied with.

10. FURTHER INFORMATION

If you have any questions regarding this document, please contact:

standards_feedback&enquiries@highways.gsi.gov.uk

Queries regarding the application of this document with respect to individual structures should, in the first instance, be raised with local HA Structures Advisors.

Note: This document was notified in draft to the European Commission in accordance with Directive 98/34/EC, as amended by Directive 98/48/EC.

11. NORMATIVE REFERENCES

EOTA ETAG 001 – Guideline for European Technical approval of metal anchors for use in concrete: Part 1 to 6 (and Annex A to C and E)

EOTA Technical Report TR 18 – Assessment of torque-controlled bonded anchors

EOTA Technical Report TR 20 – Evaluation of anchorage in concrete concerning resistance to fire

EOTA Technical Report TR 23 – Assessment of post-installed rebar connection

EOTA Technical Report TR 29 – Design of bonded anchors

EOTA Technical Report TR 45 – Design of metal anchors for use in concrete under seismic actions

Note: EOTA documents are available from the European Organisation for Technical Approvals (EOTA) website: www.eota.be.

BS EN 1992 - Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings; Part 2: Concrete bridges – design and detailing rules

DD CEN/TS 1992-4 – Design of fastenings for use in concrete

BS EN 1504 – Products and systems for the protection and repair of concrete structures – definitions, requirements, quality control and evaluation of conformity: Part 1 to 10

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

BS EN 1991-1-5 – Eurocode 1: Action on structures – Part 1-5: General actions – thermal actions

BS 6744 – Stainless steel bars for the reinforcement of and use in concrete – requirements and test methods

BS EN ISO 3506 – Mechanical properties of corrosion-resistant stainless steel fasteners: Part 1 to 4

BS EN 10088 – Stainless steels: Part 1 to 5

BS 4449 – Steel for the reinforcement of concrete – weldable reinforcing steel – bar, coil and decoiled product - specification

BS 5080 – Structural fixings in concrete and masonry: Part 1 and 2

BD 62 – As built Operational and Maintenance Records for Highway Structures (DMRB 3.2.1)

12. INFORMATIVE REFERENCES

EOTA ETAG 020 – Guideline for European Technical Approval of plastic anchors for multiple use in concrete and masonry for non-structural applications: Part 1 to 5 (and Annex A to C)

EOTA ETAG 029 – Guideline for European Technical Approval of metal injection anchors for use in masonry (and Annex A to C)

Note: EOTA documents are available from the European Organisation for Technical Approvals (EOTA) website: www.eota.be.

CFA (Construction Fixing Association) – Guidance note: Anchor selection

CIRIA Technical Report C537 – The use of epoxy, polyester and similar reactive polymers in construction

CFA (Construction Fixing Association) – Guidance note: Procedure for site testing construction fixings

ANNEX A – MODEL SPECIFICATION

AR1770/01 Materials

AR1770/01.1 Post-installed anchors and reinforcing bars shall have a European Technical Approval (or European Technical Assessment). The ETA and other supporting documentation shall be stored in accordance with the records management procedures of the overseeing organisation as described in BD 62 'As built Operational and Maintenance Records for Highway Structures (DMRB 3.2.1)'.

AR1770/01.2 Resins and cementitious grouts for post-installed reinforcing bars shall conform to BS EN 1504-6.

AR1770/01.3 Resin and cementitious grouts shall be suitable for the proposed inclination of the hole. Resin shall be stable in the cured condition over the temperature range of -30^{O} to +60^{O}C and be resistant to mechanical and chemical degradation under normal service conditions in a highway environment. The resin shall have an indicative working life of at least 50 years.

AR1770/01.4 Resins and cementitious grouts shall be stored, mixed, incorporated in the works and cured strictly in accordance with the manufacturer's recommended methods and working procedures and as described in the ETA.

AR1770/01.5 Carbon steel reinforcement shall conform to BS4449. Stainless steel reinforcement shall conform to BS6744. In the absence of contract specific requirements specified by the overseeing organisation, stainless steel reinforcing bars and parts of anchors (e.g. threaded rods, washers, nuts) shall be austenitic steel grades with 16.5 to 18.5% chromium, 10 to 13% nickel and 2 to 3% molybdenum content (A4 or A5 grade) or equivalent corrosion resistant duplex steel grades, in accordance with BS EN ISO 3506 and BS EN 10088.

AR1770/02 Installation

AR1770/02.1 Installation of anchors and post-installed reinforcing bars shall be performed in accordance with the methods and working procedures described in the ETA of the anchorage system.

AR1770/02.2 The holes to receive the anchor/reinforcing bar shall be set out in accordance with the contract specific requirements.

AR1770/02/3 The locations of the holes shall be checked using a reinforcement detection device to ensure that the position is clear of reinforcement before drilling is undertaken. The action to take when existing reinforcement obstructs the proposed location of a hole shall be agreed with the overseeing organisation.

AR1770/02.4 Before and after drilling holes the contractor shall ensure that the existing concrete is sound, and that any significant defects such as fractures, cracks and voids in the vicinity of the hole are brought to the attention of the overseeing organisation. Any defective holes shall be re-drilled in new locations to be agreed with the overseeing organisation.

AR1770/02.5 Holes shall be formed in accordance with the manufacturer's instructions using a rotary percussive drill. Diamond cored holes (internally roughened or left smooth) shall only be permitted when specified in the product's European Technical Approval (or European Technical Assessment).-The embedment depth shall not be less than that required by the design and any minimum specified on the contract drawings.

AR1770/02.6 Resins and cementitious grouts shall only be installed at temperatures within the range permitted in the manufacturer's instructions and as described in the ETA.

AR1770/02.7 The contractor shall ensure that the grout/resin fills the hole entirely without air voids following insertion of the reinforcing bar/anchor and that the reinforcing bar/anchor is fully surrounded by the grout/resin. Excess grout/resin shall be removed immediately.

AR1770/02.8 The reinforcing bars/anchors shall be free of rust/contamination that may affect the anchorage bond.

AR1770/02.9 The Contractor shall not insert reinforcing bars/anchors into resin after the gel time (also called open time) referred to in the ETA and shall not disturb the completed installation until the resin is fully cured.

AR1770/03 Testing

AR1770/03.1 Axial load testing in accordance with BS 5080 Part 1 shall be carried out. The requirement in Clause 6 of BS 5080 Part 1 for the reaction of the loading frame to be at least 8A from the axis of the fixing does not apply for embedment depths in excess of 200mm. Where it is not possible to comply with the dimensional limitations of Clause 6 of BS 5080 Part 1, the arrangement shall prevent the reaction forces from influencing the load-carrying capacity by preventing some of the failure modes.

AR1770/03.2 The number of tests to be carried out shall be a minimum of 3% (10% for safety critical applications) of the total number of anchorages proposed in the works, subject to a minimum of 3 anchorages for any discrete area with different each size and type of anchorage, different concrete strength and different installation team. For anchors and reinforcing bars primarily carrying axial tension, the test load shall be a minimum of 1.1 times the ULS design tensile action but should not exceed 1.1 times the ULS design tensile resistance. For anchors primarily carrying shear, the test load shall be equal to or greater than the ULS design tensile resistance, but should not exceed 1.1 times the ULS design resistance.

AR1770/03.3 Cementitious grout anchorages shall not be tested within 5 days of installation.

AR1770/03.4 The location of the test anchorages shall be as directed by the designer and agreed with the overseeing organisation.

AR1770/03.5 Each tested reinforcing bar/anchor shall be loaded incrementally in tension in accordance with BS 5080 Part 1 up to the test load. The number of load increments shall not be less than 5.

AR1770/03.6 Incremental loads shall be held for not less than 30 seconds and the test load for not less than 5 minutes.

AR1770/03.7 Readings shall be taken immediately after applying load and at the ends of the time intervals stated above

AR1770/03.8 The total movement of the anchored reinforcing bar/anchor, less the calculated elongation of the bar/anchor during the test (based on the length of bar/anchor between the concrete surface and the point of load application), shall not exceed 5% of the nominal diameter of the bar/fixing.

AR1770/03.9 Any evidence of slip during loading up to the test load, as demonstrated by a significant change in the slope of the load/extension curve, shall constitute a failure.

AR1770/03.10 If the failure load of any of the tested bars/anchors is less than the required test load then, the testing frequency shall be increased by a factor of 2 and remedial actions, such as increasing the number of anchorages or the embedment depth shall be proposed for consideration by the overseeing organisation.

AR1770/03.11 The overseeing organisation shall be provided with the results of the pullout tests. The results for each test shall include a graph of load/extension. Records of proof load testing undertaken during installation shall be stored in accordance with the records management procedures of the overseeing organisation as described in BD 62.