Bonded Anchors

BTN 006
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1. Scope and Application

BTN 006 Bonded Anchors states Department of Transport's (DoT) requirements for the design of post-installed bonded anchors used to make structural connections to reinforced concrete members of bridges and tunnels, structural roadway components and other related structural applications. It focusses primarily on the design of the chemical adhesive at the anchor/concrete interface.

Bridge Technical Notes are a Code of Practice. Compliance with Bridge Technical Notes is mandatory.

Other than as stated in this document, Standard Specification Section 680 and other relevant DoT VicRoads Standard Specifications, the provisions of AS5100:2017 must apply. Where this document differs from AS5100:2017, its requirements override those of AS5100:2017.

The requirements in this document are intended to reduce the risk of failure of connections made with bonded anchors.

The design, selection and specification of bonded anchors must be conducted by an engineering consultancy that is, as a minimum, prequalified in accordance with DoT's Prequalification Scheme at the Structures Simple level.

Any design of bonded anchors must also be proof engineered by an engineering consultancy that is prequalified in accordance with DoT's Prequalification Scheme at the Proof Engineer level.

Bonded anchors must have the load-carrying capacity required by the design and sufficient durability to achieve the required design life of the structure.

2. Design

2.1 Design General

Bonded anchors may be one of the following types:

- a proprietary anchor and adhesive system.
- a threaded bar and adhesive.
- a reinforcing bar and adhesive.

The following provisions focus primarily on the design of the anchor/adhesive/concrete substrate interface.

Designers must position bonded anchors to avoid intersection with embedded reinforcement and pre-stressing tendons which can result in damage to reinforcement and pre-stressing tendons. In this context, positional dimensions for bonded anchors must allow for the overall depth and diameter of the required hole.

Designers must select anchor components and chemical adhesives to meet the requirements of the design, the service conditions and the construction methodology.

Standard Specification Section 680 - Bonded Anchors states requirements for the following:

- use of chemical adhesive in holes cut with a diamond-tipped core drill or carbide-tipped rotary hammer.
- use of chemical adhesives appropriate to the nature of the loading, the geometry of the structure and the condition of the existing concrete substrate.
- design life of 50 years and 100 years as required in the specified in-service exposure conditions and any other specific use.

The performance of bonded anchors in cracked concrete varies with the type of anchorage system.

The final arrangement of anchors must comply with the requirements for spacing of anchors and minimum edge-distance required by the design method and the manufacturer's recommendation.

The design of bonded anchors must be in accordance with the following clauses.

2.2 Design Life

Subject to the restrictions stated in this document, bonded anchors may be used for applications in existing or new structures (refer to Clause 2.4) that are required to have a maximum design life of 50 years and 100 years as required in the specified in-service exposure conditions.

For applications in existing structures, bonded anchors must have a design life equal to or greater than the remaining design life of the existing structure in which the components are being connected.

The design life of bonded anchors must be demonstrated by testing in accordance with the relevant European Assessment Documents (EADs) published by the European Organisation for Technical Assessment (EOTA) as it relates to the application to which the bonded anchor is to be used for.

Grade 316 stainless steel anchors may be used for permanent applications in bridges, tunnels and road-

related structures provided they have been formally tested and meet all the specified requirements.

2.3 Restrictions on Use

Bonded anchors **must not** be used in the following circumstances:

- in new structures (also refer to Clause 2.4)
- in existing structures where a positive connection can be adopted (Note 1)
- as tensile continuity connections between beams in adjacent spans and other elements in a bridge superstructure – for example to connect superstructure and substructure components in an integral bridge
- to support tensile loads in any orientation, if failure of an anchor or anchors could result in collapse, instability or failure of a structure or a component - refer Clause-. 2.6 - Bonded anchors in tension
- as holding-down bolts or connections for use of structures and light poles
- as holding-down bolts or connections for steel and concrete bridge barriers and bridge barrier posts except for median bridge barriers connection to existing bridge decks as per Section 2.4
- if the thickness of the concrete substrate into which the anchor is being placed is less than 1.25 x required length of the anchor
- if the concrete substrate into which the anchor is being placed is friable, shows signs of de-lamination or any other defect
- in concrete with characteristic strength less than 20 MPa or greater than 65 MPa. Where the concrete strength is tested and the characteristic strength is found to be greater than 65 MPa then the Designer must adopt 65 MPa in the design.
- Galvanised steel components must not be used as bonded anchors when used with a chemical adhesive in a fatigue loading application i.e., fluctuating stresses with time. (Note 2)

Note 1 - Positive connections are defined as structural connections that are achieved by cast-in fitments such as rag-bolt assemblies, threaded ferrules or by clamping either through or around the full depth of the elements being connected. For example, a threaded rod (or bolt) in a full-depth hole together with a backing plate.

Note 2 – DoT is unaware of any testing of bonded anchors certified to a current European Technical Assessment (ETA) which is based on EOTA European Assessment Document (EAD) that have utilised galvanised steel components. DoT has the following concerns:

- DoT (VicRoads) practice has been to limit the use of galvanised components to permanently dry conditions only, where design life is 25 years or less which is less than the 50 and 100 year design life nominated.
- There is typically a high degree of variability in the zinc coating and a potential exists for initiation of galvanic corrosion in the non-passive environment which will affect the durability of the bonded anchor.
- The coating thickness may affect the shape of the bar which reduces the 'mechanical' grip within the bonded anchor.

2.4 Permitted Uses

Subject to appropriate design considerations, selection of adhesive and the restrictions on use stated in this document, bonded anchors are suitable for use in applications where they are subjected primarily to axial compressive forces and shear forces transverse to the anchor – for example:

- as longitudinal shear connectors in bridge-deck overlays.
- in side-mounted bridge barriers provided that the tensile force arising from impact is resisted by a cast-in bar embedded in the overlay. i.e. the lower connector bars which would be in compression if impacted.
- to attach small lightweight items such as small pipes (<150mm diameter), conduits and cables to a structure.

Bonded anchors may be used in concrete that is subject to formation of flexural cracks provided that the adhesive is pre-qualified for use in cracked concrete, and this is supported by manufacturer's test data. However, the capacity of the anchor may be substantially reduced in this case and must be verified (Standard Specification Section 680 provides additional installation requirements for cracked concrete applications).

Bonded anchors may be used in the connection between median bridge barriers and existing concrete bridge decks on existing bridges only.

Bonded anchors may be used for the connection of the shotcrete wall to the bored piles for new bridge abutments and retaining walls in top down construction.

2.5 Design of the Bonded Anchor

The type of anchor and chemical adhesive must be appropriate to the serviceability and ultimate limit state requirements of the design.

Consideration must be given to the probable failure mechanism of the bonded anchor and the effect of such a failure on the stability and durability of the structure.

Designers and Proof Engineers must consider the risk of progressive failure and ensure that in the event of failure of an anchor, this does not lead to progressive failure of the remaining anchors.

Designers and Proof Engineers must consider the effects of erection methodology which may result in variations in the load applied to bonded anchors which function as a group.

Design of bonded anchors must be in accordance with one of the following depending on the anchor type (refer Clause -.2.1):

- proprietary fasteners - a Concrete Capacity (CC) method as described in AS 5216, ETAG Annex C, TR 029 or ACI 318:2014
- reinforcing or threaded bars - reinforcement theory, which must comply with the requirements of AS5100.5 - Bridge Design (Concrete).

Design loads and load factors must be determined in accordance with AS5100.2 - Bridge Design (Design Loads).

The required number and size of anchors must be determined in accordance with one of the methods listed in this clause such that:

$$S^* \leq \Phi R_u$$

where for the load effect being considered:

Φ = capacity reduction factor required by the design method

R_u = nominal ultimate strength of the connection

S^* = design action effect

The bonded anchors must be designed for all loading combinations and adoption of the worst case for the design.

If the strength of an adhesive material in a bonded anchor is known to diminish over time, the reduced strength at the end of the design life of the adhesive material must be used for the purposes of the design.

2.6 Bonded Anchors in Tension

If it is not possible to use a cast-in anchorage or to achieve a positive connection, bonded anchors may be used in tension subject to the following conditions:

- use is subject to compliance with Standard Specification Section 680 - Bonded Anchors.
- use is subject to the written approval of the Superintendent – refer to Standard Specification Section 680 - Bonded Anchors for further detailed requirements.
- use is subject to compliance with all other parts of this Bridge Technical Note.
- if a bonded anchor is required to support a sustained tensile load, the chemical adhesive must be one that has been subjected to approved testing for long-term displacement, the results of which enables the long-term displacement and strength properties of the anchor to be quantified.
- the predicted creep must not affect the serviceability and durability of the structure – for example if it results in excessive crack-width.
- bonded anchor connections must be tested in accordance with Standard Specification Section 680 - Bonded Anchors.
- the required number and size of anchors must be determined in accordance with one of the methods listed in Clause 2.5 subject to the application of an additional reduction factor $\boldsymbol{\Phi_{BAT}}$ to the design for the adhesive anchor components such that:

$$S^* \leq \Phi \Phi_{BAT} R_u$$

Φ_{BAT} = additional reduction factor for bonded anchors in tension which must be adopted as shown in Table 1.

Tension design capacity for	**Tension Additional Reduction Factor ($\boldsymbol{\Phi_{BAT}}$)**
(a) Black steel:	
(i) Bonded anchors subject to tension	0.5
(b) Galvanised steel:	
(i) Bonded anchors subject to tension	0.4 (Note 3)

Table 1: Reduction factors for bonded anchors in tension

Note 3 - Where galvanised steel is used for bonded anchors in tension, an additional reduction factor of 0.8 must be applied to the design on top of the 0.5 factor for those bonded anchors (i.e. 0.5 x 0.8 = 0.4).

2.7 Bonded Anchors in Shear

Bonded anchors may be used in shear subject to the following conditions:

- the required number and size of anchors must be determined in accordance with one of the methods listed in Clause 2.5 subject to the application of an additional reduction factor $\boldsymbol{\Phi_{BAS}}$ to the design for the adhesive anchor components such that:

$$S^* \leq \Phi \Phi_{BAS} R_u$$

Φ_{BAS} = additional reduction factor for bonded anchors in shear which must be adopted as shown in Table 2.

Shear design capacity for	**Additional Reduction Factor ($\boldsymbol{\Phi_{BAS}}$)**
(a) Black steel:	
(i) Bonded anchors subject to shear	1.0
(b) Galvanised steel:	
(i) Bonded anchors subject to shear	0.8

Table 2: Reduction factors for bonded anchors in shear

2.8 Bonded Anchors in Combined Tension and Shear

Bonded anchors may be used in combined tension and shear with the additional reduction factors for individual tension and shear component as specified in Clauses 2.6 and 2.7.

The Designer and Proof Engineer must check the capacity of the bonded anchors for both tension and shear individually and then check for the combined action of tension and shear and adopt the most critical case scenario.

2.9 Bonded Anchors in Fatigue

If it is not possible to use a cast-in anchorage or to achieve a positive connection on existing structures, bonded anchors may be used in fatigue applications subject to the following conditions:

- Fatigue applications are applications where the bonded anchor will be subject to fluctuating stresses over its design life. The requirements of Clause 2.6 also apply for fatigue applications.
- Where bonded anchors are used under fatigue applications the additional fatigue reduction factor Φ_{BAF} shown in Table 3 must be applied in the design of those bonded anchors. The additional fatigue reduction factor Φ_{BAF} must be achieved by the product being supplied by the manufacturer and be supported by independent testing data as per Clause 2.2 and Note 4. Use of the nominated product is subject to the written approval of the Superintendent
- the required number and size of anchors must be determined in accordance with one of the methods listed in Clause 2.5 subject to the application of an additional reduction factors Φ_{BAT} and Φ_{BAF} to the design for the adhesive anchor components such that:

$$S^* \leq \Phi\ \Phi_{BAT}\ \Phi_{BAF}\ R_u$$

Φ_{BAF} = additional reduction factor for bonded anchors in fatigue which must be adopted as shown in Table 3.

Design capacity for	**Fatigue Additional Reduction Factor (Φ_{BAF})**
(a) Black steel: Bonded anchors subject to fatigue loading in tension and/or compression	≤ 0.4 (Note 4)
(b) Galvanised steel:	Not to be used

Table 3: Reduction factors for bonded anchors under fatigue loading

Note 4 - Additional capacity reduction factor for bonded anchors subject to fatigue loading of 0.4 or less is for chemical adhesive products supported by objective documented evidence of independent fatigue testing that must be accepted by DoT Chief Engineer - Roads.

3. Training, Equipment, Workmanship, Installation and Testing

Training, equipment, workmanship, installation and testing must comply with Standard Specification Section 680 - Bonded Anchors. Personnel who have not been appropriately trained shall not install bonded anchors.

Contact Details

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Document Control

This document is subject to periodic review and may be superseded. The revision date is listed in this BTN.

Note that for projects tendered prior to the revision date of this document, there are no retrospective implications of this document unless agreed otherwise with DoT.

Version	Description	Revision	Approved by
1.2	General Amendments	12/02/2021	Chief Engineer - Roads
1.3	Revision of Section 2	4/03/2022	Chief Engineer - Roads