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Design of post-installed and cast-in fastenings in concrete



AS 5216:2021

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Design of post-installed and cast-in fastenings in concrete

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Preface

This Standard was prepared by the Standards Australia Committee ME-029, Fasteners, to supersede AS 5216:2018, *Design of post-installed and cast-in fastenings in concrete*.

The objective of this document is to provide minimum design requirements for fastenings used to transmit loads to concrete for safety-critical applications.

Standards Australia acknowledges and thanks the European Committee for Standardization—CEN, Rue de la Science 23, B-1040 Brussels, Belgium for permission to reproduce its content in the development of this document.

Standards Australia thanks the ICC Evaluation Service for permission to reproduce [Clause 4.3.3.2.1](#), equations in [Figure 4.3.3.2.1.2\(A\) and \(B\)](#) and equations in [Figure 4.3.3.2.2.2](#) from AC232:2019, *Anchor Channels in Concrete Elements*. These text and equations are copyright of ICC-ES. All rights reserved.

The major changes in this edition are as follows:

- (a) Design of fasteners for seismic actions.
- (b) Design of anchor channels.
- (c) Design of redundant non-structural systems.
- (d) Design of post-installed reinforcing bar connections.

The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

This document includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by “C” preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the document.

Contents

Preface	ii
Section 1 Scope and general	1
1.1 Scope and application	1
1.1.1 Scope	1
1.1.2 Application	1
1.2 Normative references	2
1.3 Terms and definitions	2
1.4 Notation	11
1.5 Loading on fasteners	17
Section 2 Materials and installation	18
2.1 Types of fasteners and fastener groups	18
2.2 Dimensions of fasteners	19
2.3 Fastener materials	19
2.4 Concrete	19
2.5 Reinforcement	20
Section 3 General design requirements	21
3.1 General	21
3.2 Verifications for design	21
3.2.1 Strength limit state	21
3.2.2 Serviceability limit state	21
3.2.3 Load factors	22
3.2.4 Capacity reduction factors	22
3.3 Concrete condition	23
3.4 Verification of fastener strength	23
3.4.1 General	23
3.4.2 Tensile strength of fastener	24
3.4.3 Shear strength of fastener	28
3.4.4 Combined tension and shear strength of fastener	32
Section 4 Determination of forces acting on fasteners	33
4.1 General	33
4.2 Post-installed fasteners	33
4.2.1 Tension and compression loads	33
4.2.2 Shear loads	35
4.3 Anchor channel	39
4.3.1 General	39
4.3.2 Tension loads	39
4.3.3 Shear loads	40
4.4 Supplementary reinforcement	43
4.4.1 General	43
4.4.2 Applied tension loads	44
4.4.3 Applied shear loads	44
Section 5 Detailing of supplementary reinforcement	46
Section 6 Design for tensile loading	48
6.1 General	48
6.2 Post-installed fasteners	48
6.2.1 General	48
6.2.2 Steel failure	48
6.2.3 Concrete cone failure	48
6.2.4 Pull-out failure	54
6.2.5 Combined pull-out and concrete cone failure for post-installed chemical fasteners	54
6.2.6 Concrete splitting failure	57

6.2.7	Concrete blow-out failure.....	59
6.2.8	Supplementary reinforcement.....	63
6.2.9	Redundant fastenings in non-structural applications.....	63
6.3	Cast-in anchor channel.....	63
6.3.1	General.....	63
6.3.2	Steel failure.....	63
6.3.3	Concrete cone failure.....	64
6.3.4	Pull-out failure.....	68
6.3.5	Concrete splitting failure.....	69
6.3.6	Concrete blow-out failure.....	70
6.3.7	Supplementary reinforcement failure.....	71
Section 7	Design for shear loading.....	72
7.1	General.....	72
7.2	Post-installed fasteners.....	72
7.2.1	General.....	72
7.2.2	Steel failure.....	72
7.2.3	Concrete edge failure.....	73
7.2.4	Concrete pry-out failure.....	80
7.2.5	Supplementary reinforcement.....	81
7.2.6	Redundant fastenings in non-structural applications.....	82
7.3	Cast-in anchor channel.....	82
7.3.1	Shear load acting perpendicular to longitudinal axis of the channel.....	82
7.3.2	Shear load acting along the longitudinal axis of the channel.....	88
Section 8	Design for combined tension and shear loading.....	91
8.1	Steel failure.....	91
8.1.1	Post-installed fasteners.....	91
8.1.2	Cast-in anchor channel.....	91
8.2	Failure modes other than steel.....	93
8.2.1	Post-installed fasteners.....	93
8.2.2	Cast-in anchor channel.....	94
8.3	Additional verification for fasteners with supplementary reinforcement.....	94
8.3.1	Post-installed fasteners.....	94
8.3.2	Cast-in anchor channel.....	95
Section 9	Design for serviceability.....	96
9.1	Verification of serviceability limit state — Displacement.....	96
9.2	Verification of serviceability limit state — Supplementary reinforcement.....	96
Appendix A (normative)	Testing and assessment of fasteners.....	97
Appendix B (informative)	Means for demonstrating conformance to this standard.....	102
Appendix C (normative)	Verification of strength of concrete elements to loads applied by fasteners.....	104
Appendix D (normative)	Design of post-installed reinforcing bar connections.....	106
Appendix E (normative)	Design of redundant non-structural system.....	109
Appendix F (normative)	Design of fastenings under seismic actions.....	112
Appendix G (informative)	Assumptions for the design and installation of fasteners.....	115
Appendix H (informative)	Simplified methods of design for post-installed fasteners.....	117
Bibliography		120

Australian Standard®

Design of post-installed and cast-in fastenings in concrete

Section 1 Scope and general

1.1 Scope and application

1.1.1 Scope

This document specifies minimum requirements for the design of fastenings used to transmit loads to concrete for safety-critical applications.

The fasteners covered in this document are as follows:

- (a) Post-installed fasteners:
 - (i) Mechanical fasteners (e.g. expansion fasteners, undercut fasteners and concrete screws).
 - (ii) Chemical fasteners (e.g. chemical fasteners, chemical expansion fasteners).
- (b) Cast-in anchor channel with rigid connection (e.g. forged or welded) between the channel profile and anchor.

This document also includes requirements for the testing and assessment of post-installed and cast-in fasteners to establish the necessary design parameters for use with this document.

The design provisions in this document are relevant to static, quasi-static and seismic loading that may include tension, shear, bending or torsion moments, or a combination thereof.

The design provisions in this document do not apply to the following:

- (i) Design of fixtures.
- (ii) Design of fastenings for exposure to fire and durability.
- (iii) Design of anchor channel for seismic actions.
- (iv) Fasteners for lifting, transport and erection (e.g. brace inserts, lifting inserts, etc.), headed fasteners, ferrules, headed reinforcement and anchorage for prestressing strands.

NOTE For design actions, fastener products, substrates and applications not covered by the scope of this document, the design engineer should seek technical advice from the fastener supplier in relation to the suitability of the selected fastener for the intended application.

C1.1.1 *The design theory for fastenings embodied in this document utilizes the tensile strength of concrete and is closely based on the design procedure published in EN 1992-4.*

The design and installation provisions of this document have been developed on the assumption that materials used and their maintenance ensure that the installed fasteners will fulfil their intended function for the intended life of the structure.

1.1.2 Application

This document relies upon design parameters and product specifications that define a fastener's suitability for a given application. The testing and assessment of a fastener shall be performed in accordance with the requirements of [Appendix A](#). All necessary design parameters such as characteristic values and product specifications such as geometric and material properties required for

[Sections 2 to 9](#) of this document shall be obtained from an assessment report prepared in accordance with [Appendix A](#).

NOTE 1 The design parameters and product specifications required for use with this document may also be obtained from a current European Technical Assessment for the relevant fastener.

NOTE 2 This standard does not cover site testing of fasteners. Guidance on site testing is available in AEFAC Technical Note 05: Guidelines for Site Testing of anchors Vol.1 – Vol.4.

Concrete members shall be composed of normal-weight concrete without fibres and shall conform to the requirements of [Clause 2.4](#).

Supplementary reinforcement and reinforcing steel inserts in chemical fasteners shall have a ductility class type N in accordance with AS/NZS 4671.

Chemical fasteners intended for applications involving sustained tensile loads shall be qualified for sustained loading applications in accordance with [Appendix A](#).

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents referenced for informative purposes are listed in the Bibliography.

AS 1012.9, *Methods of testing concrete, Method 9: Compressive strength tests—Concrete, mortar and grout specimens*

AS 1170.4, *Structural design actions, Part 4: Earthquake actions in Australia*

AS 1379, *Specification and supply of concrete*

AS 3600, *Concrete structures*

AS 4100, *Steel structures*

AS/NZS 1170.0, *Structural design actions, Part 0: General principles*

AS/NZS 4671, *Steel reinforcing materials*

AEFAC Technical Note 10, *Prequalification and design requirements for fastenings under seismic actions*, Australian Engineered Fasteners and Anchors Council (AEFAC), www.aefac.org.au

EOTA TR049, *Post-installed fasteners in concrete under seismic action*

EAD 330008, *Anchor channels*

EAD 330087, *Systems for post-installed rebar connections with mortar*

EAD 330232, *Mechanical fasteners for use in concrete*

EAD 330499, *Bonded fasteners for use in concrete*

EAD 330747, *Fasteners for use in concrete for redundant non-structural systems*

1.3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

C1.3.16 Concrete blow-out failure is usually experienced by fasteners that have a deep embedment and small side cover.

C1.3.47 *Under-utilized reinforcement in the concrete member may be used for supplementary reinforcement.*

C1.3.48 *The lateral expansion occurs in a torque-controlled expansion fastener due to the application of torque to the fastener during installation. Follow-up expansion may occur due to the application of tensile load.*

1.3.1 action

set of concentrated or distributed forces acting on a structure (direct action), or deformation imposed on a structure or constrained within it (indirect action)

1.3.2 anchor

headed component of anchor channel

Note 1 to entry: In Australian practice, a fastener installed in concrete may be referred to as an “anchor”, such as “mechanical anchor” and “chemical anchor”. For clarity in this document the term “anchor” is reserved for the headed component of the anchor channel.

1.3.3 anchor channel

fastener made of profiled steel element with two or more rigidly connected anchors that are installed into position prior to the casting of concrete (see [Figure 1.3\(B\)](#))

1.3.4 base material

material in which the fastener is installed

1.3.5 bond failure

mode of failure for chemical fasteners characterized by pull-out of the fastener caused by either separation at the interface of the bonding compound and the embedded steel element or between the bonding compound and the base material

1.3.6 capacity reduction factor

factor used to multiply the nominal capacity to obtain the design capacity

1.3.7 cast-in fastener

fastener that is installed into position prior to the casting of concrete (see [Figure 1.3\(B\)](#))

1.3.8 channel bolt

screw or bolt positioned in the steel profile of the anchor channel that is used to connect an element to the anchor channel

1.3.9 characteristic edge distance

distance required between the free edge of a concrete member and the centre-line axis of the fastener in order to develop the characteristic strength of the fastener

1.3.10**characteristic spacing**

specific distance required between two fasteners having the same characteristics in order for the characteristic strength of the fasteners to be achieved

1.3.11**characteristic strength**

5 % fractile strength (value with a 95 % probability of being exceeded with a confidence of 90 %)

1.3.12**chemical fastener**

post-installed fastener that includes a steel element (threaded rod or reinforcing bar) and a bonding compound that transmits loads from the embedded steel element into the base material

Note 1 to entry: Also known as bonded fastener.

1.3.13**chemical expansion fastener**

chemical fastener with an embedded steel element with a profile specially designed such that the application of displacement on it results in follow-up expansion

Note 1 to entry: Also known as bonded expansion fastener.

1.3.14**chemical product**

chemical placed between the wall of the drilled hole in the concrete and the embedded portion of the fastener (see [Figure 1.3\(A\)](#) (e) and (f))

Note 1 to entry: Also known as “bonding compound”, “adhesive” or “chemical”.

1.3.15**combined pull-out and concrete cone failure**

possible mode of failure of chemical fasteners characterized by bond failure in the lower portion of the embedded fastener and concrete cone failure in the upper portion of the embedded fastener

1.3.16**concrete blow-out failure**

mode of failure characterized by spalling of the side face of the concrete member that is confined to a region adjacent to the head of the fastener

Note 1 to entry: This failure mode does not involve concrete break-out at the top surface of the concrete member.

1.3.17**concrete cone failure**

mode of failure characterized by the formation of a cone or wedge of concrete surrounding a fastener or group of fasteners that become separated from the base material

1.3.18**concrete pry-out failure**

mode of failure characterized by the formation of a concrete spall on the opposing side of the fastener, relative to the direction of shear loading

1.3.19**concrete screw**

post-installed fastener installed into a pre-drilled hole that contains threads to engage with the concrete via mechanical interlock

1.3.20**concrete splitting failure**

mode of failure characterized by cracks in the concrete member which form in the plane of the axis of the fastener

1.3.21**deformation-controlled expansion fastener**

post-installed fastener installed into a pre-drilled hole that requires an internal plug in the sleeve to be driven via a hammer during the setting procedure of installation, resulting in lateral expansion of the fastener

Note 1 to entry: A follow-up expansion behaviour does not exist.

Note 2 to entry: Also known as “drop-in fastener” or “knock-in fastener”.

1.3.22**edge distance**

distance between the free edge of the concrete member and the centre-line axis of the fastener

1.3.23**effective embedment depth**

length of the fastener that is considered to effectively engage the base material, which is generally smaller than the total length of the fastener that is embedded (see [Figure 1.3\(C\)](#))

1.3.24**European Technical Assessment****ETA**

prequalification for a fastener, which represents technical assessment of its fitness for an intended use

1.3.25**fastener**

type of device that is post-installed into hardened concrete or cast into concrete and is made from a material that conforms to the design and testing requirements of this document

1.3.26**fastener group**

two or more fasteners having identical dimensions and characteristics whose spacing does not exceed the fastener's characteristic spacing and act to support the same attachment

1.3.27**fastening**

assembly comprising fastener(s) to secure a fixture to the concrete base material

1.3.28**fastening for safety-critical applications**

fastening whose failure may result in collapse or partial collapse of the structure, endanger human life, result in the loss of functionality of importance level 4 structures and/or causing considerable economic loss

Note 1 to entry: Safety-critical applications may include fastenings to structural or non-structural elements.

1.3.29**fixing point**

fastening or single fastener

1.3.30**fixture**

element that is being secured to the base material via fasteners

1.3.31**headed fastener**

cast-in fastener that derives its tensile strength via mechanical interlock between its head and the base material

1.3.32**load**

value of a force appropriate to an action

1.3.33**mechanical interlock**

mechanism of load transfer involving the bearing of a surface of the fastener against a surface of the base material

1.3.34**minimum edge distance**

minimum distance required between the free edge of the concrete member and the centre-line axis of the fastener to facilitate adequate placing and compaction of concrete for cast-in fasteners and to avoid damage during installation of post-installed fasteners

Note 1 to entry: The minimum edge distance is product dependent and is determined in accordance with [Appendix A](#).

1.3.35**minimum member thickness**

minimum thickness of the concrete member in which a fastener is to be installed

Note 1 to entry: The minimum member thickness is product dependent and is determined in accordance with [Appendix A](#).

1.3.36**minimum spacing**

minimum distance required between the centre-line of two fasteners to facilitate adequate placing and compaction of concrete for cast-in fasteners and to avoid damage to the concrete during installation of post-installed fasteners

Note 1 to entry: The minimum spacing is product dependent and is determined in accordance with [Appendix A](#).

1.3.37**non-structural element**

elements attached to and supported by the structure but are not contributing to the load resisting system

1.3.38**option number**

term, used in a European Technical Assessment, that limits the specification of a fastener on the basis of various application parameters

Note 1 to entry: Application parameters include concrete strength and condition, edge/spacing criteria and loading direction.

1.3.39**post-installed fastener**

fastener that is installed in concrete in the hardened state (see [Figure 1.3\(A\)](#))

1.3.40**post-installed reinforcing bar**

reinforcement that is anchored into matured concrete using adhesives in drilled hole

1.3.41**pull-out failure**

mode of failure characterized by either the fastener pulling out of the concrete prior to the onset of concrete modes of failure (concrete cone, concrete blow-out, concrete splitting), or by the body of the fastener pulling through the expansion sleeve in the case of a mechanical fastener prior to the development of full concrete strength

1.3.42**redundant system**

statically indeterminate system of at least 3 fixing points and attached non-structural element

1.3.43**spacing**

as applicable:

- (a) The distance between the centre-line of post-installed fasteners.
- (b) The distance between anchors in anchor channel or the distance between channel anchor bolts (see [Figure 1.3\(D\)](#)).

1.3.44**statically indeterminate system**

at least 3 supports or 3 fixing points, so that the system can retain its static stability after the loss of any redundant support or fixing point by allowing alternative load paths

1.3.45**steel failure of fastener**

mode of failure characterized by fracture of steel fastener parts

1.3.46**structural elements**

elements of the structure which are part of the load resisting system

1.3.47**supplementary reinforcement**

reinforcement specifically designed to tie a concrete break-out body to the remainder of the concrete member that resists the load applied to the fastener upon splitting of the concrete

1.3.48**torque-controlled expansion fastener**

post-installed fastener installed into a pre-drilled hole that develops its tensile strength via friction between its sleeves that expand laterally against the wall due to a wedge being drawn up behind the sleeves

1.3.49**undercut fastener**

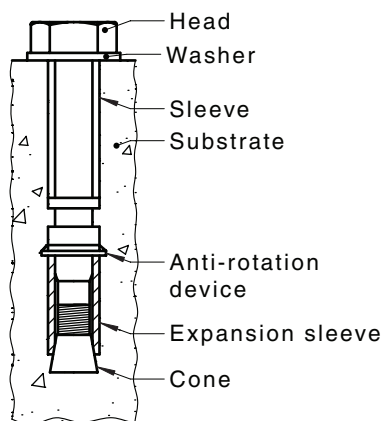
type of post-installed fastener that derives its tensile strength via mechanical interlock between its head and an undercut region in the base material at the head of the fastener, which is achieved via a special drill or by the fastener during installation

1.3.50**x-direction**

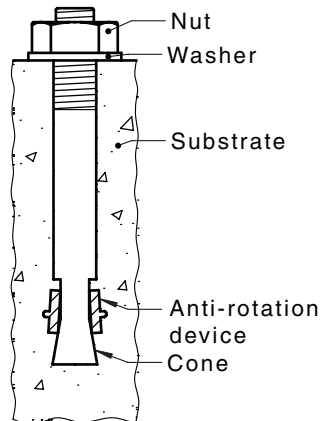
direction along the longitudinal axis of the channel (see [Figure 1.3\(E\)](#))

1.3.51**y-direction**

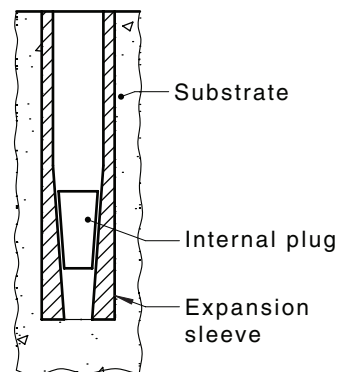
direction perpendicular to the longitudinal axis of the channel (see [Figure 1.3\(E\)](#))



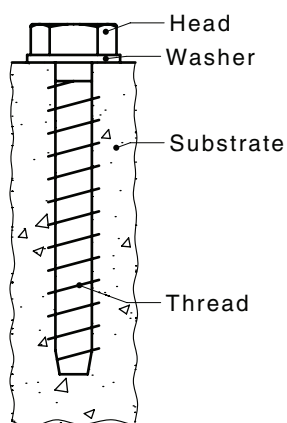
(a) Torque-controlled expansion fastener



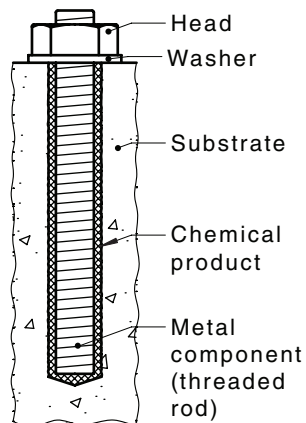
(b) Stud (expansion) fastener



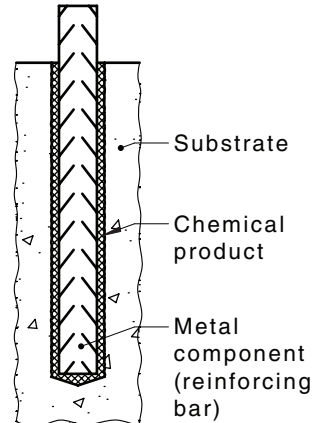
(c) Displacement-controlled expansion fastener



(d) Screw fastener



(e) Chemical fastener with threaded rod insert



(f) Chemical fastener with rebar insert

Figure 1.3(A) — Identification of components of post-installed fasteners

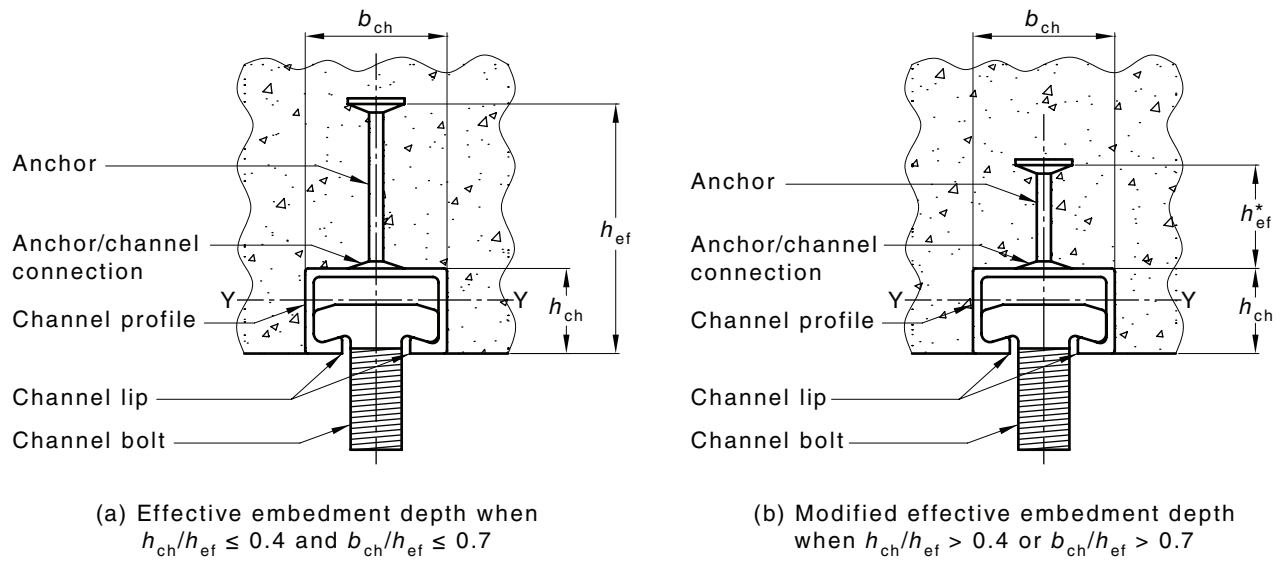


Figure 1.3(B) — Identification of components of an anchor channel

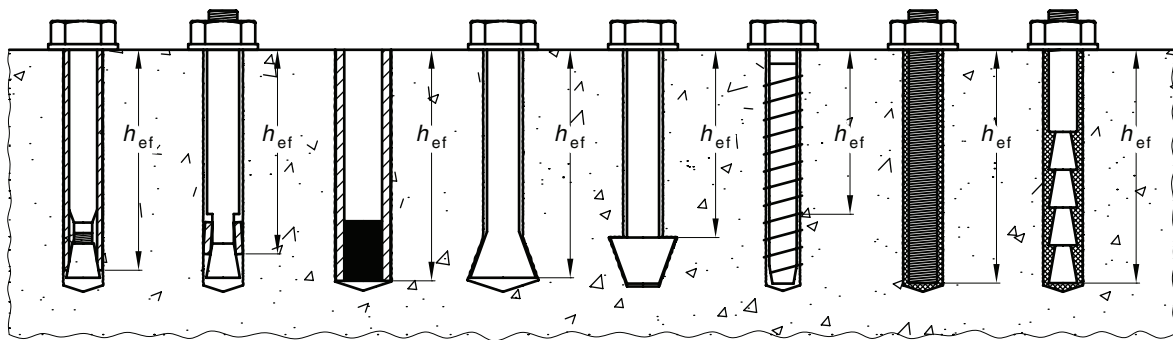
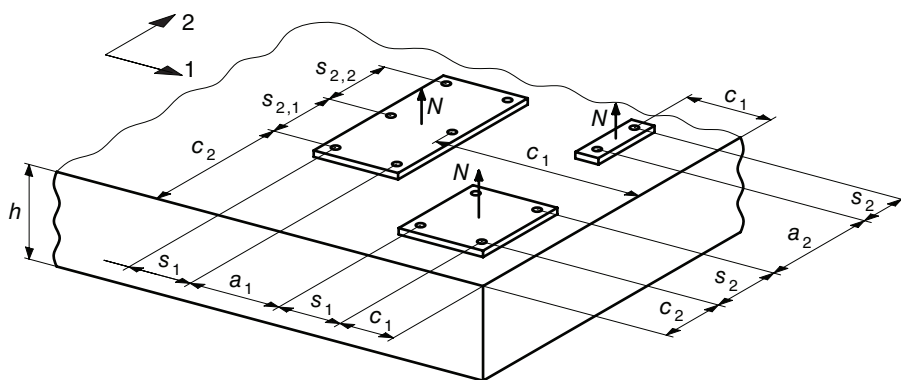
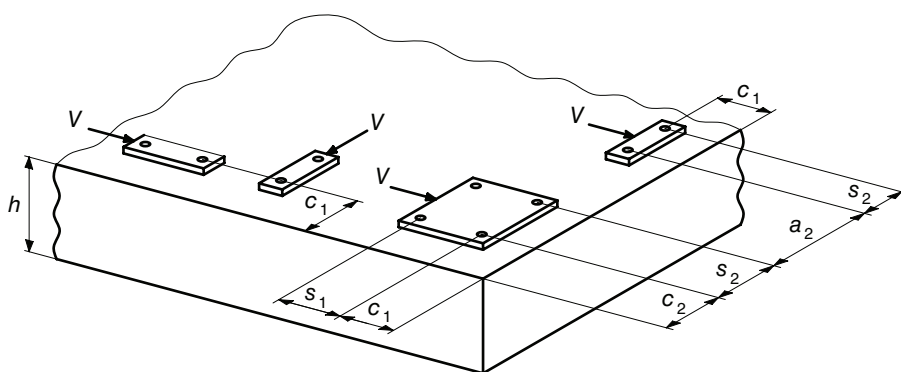


Figure 1.3(C) — Identification of effective embedment depth (h_{ef}) for post-installed mechanical and chemical fasteners



(a) Application of tensile load to fastenings



(b) Application of shear load to fastenings

NOTE Under tensile loading direction 1 is perpendicular to the edge and direction 2 is parallel to the edge. Under shear loading, the indices for spacing and edge distance depend on direction in which the verification is to be performed (direction 1 is perpendicular to edge in direction of applied load, direction 2 is perpendicular to direction 1).

Figure 1.3(D) — Definition of spacing and edge distance for fixtures containing fasteners to concrete

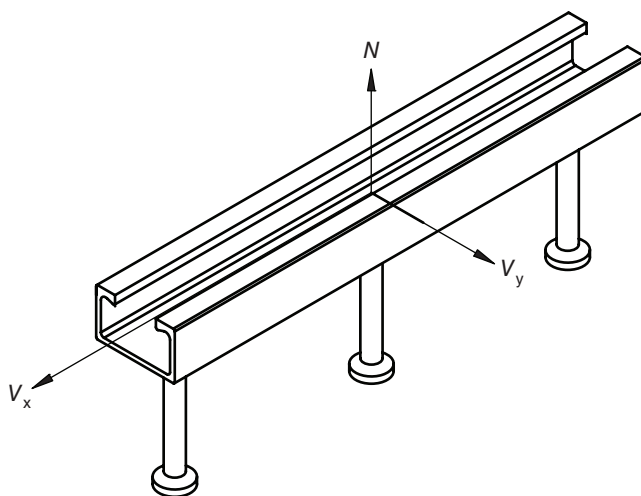


Figure 1.3(E) — Load direction in anchor channel

1.4 Notation

The symbols used in this document, including their definitions, are listed below.

Unless specified otherwise, nominal units for length are millimetres and nominal units for material strength are megapascals.

Symbol	Definition
A_c	= actual projected area of the failure cone of the fastener
$A_{c,N}$	= actual projected area of the failure cone of the fastener that is limited by adjacent fasteners and edges of the concrete member under tensile loading
$A_{c,Nb}$	= actual projected area for the failure of fastener in blow out failure limited by adjacent fastener, the edges of the concrete member and member thickness
$A_{c,V}$	= actual area of idealized concrete break-out body of a fasteners under shear loading
A_h	= loadbearing area of the head of a fastener
A'_1	= ordinate on the normalized load distribution triangle with base length $2l_i$
$A_{p,N}$	= actual bond influence area of a single chemical fastener
$A_{s,re}$	= stress cross-sectional area of the reinforcement
A_c^0	= reference projected area of the failure cone of the fastener
$A_{c,N}^0$	= reference projected area of the failure cone of the fastener under tensile loading
$A_{c,Nb}^0$	= reference projected area of a single fastener for concrete blow-out failure
$A_{c,V}^0$	= reference projected area of the break-out body of a fastener under shear loading
$A_{p,N}^0$	= reference bond influence area of a single chemical fastener for combined pull-out failure and concrete cone failure
a	= spacing between the outermost fasteners of adjacent fastener groups or between the outermost fasteners and an individual fastener
a_3	= distance between the assumed point of restraint of the fastener loaded in shear and the surface of the concrete
b_{ch}	= width of the anchor channel
b_{fix}	= width of fixture
c	= edge distance from the centre-line axis of a fastener or centre-line axis of anchor channel
C1	= Seismic performance category 1 (see Appendix F)
C2	= Seismic performance category 2 (see Appendix F)
c_{cr}	= edge distance of a single fastener required to ensure the characteristic strength of the fastener is achieved
$c_{cr,N}$	= edge distance of a single fastener required to ensure the characteristic strength of the fastener is achieved when loaded in tension
$c_{cr,Np}$	= edge distance of a single fastener required to ensure the characteristic strength of the fastener is achieved for a chemical fastener under tensile loading
$c_{cr,sp}$	= characteristic edge distance in the case of concrete splitting under load
$c_{cr,V}$	= edge distance of a single fastener required to ensure the characteristic strength of the fastener is achieved when loaded in shear
c_{max}	= maximum edge distance to the fastener
c_{min}	= minimum edge distance of the fastener
c_1	= edge distance of fastener in direction 1
c_2	= edge distance of fastener in direction 2
$c_{2,max}$	= greatest edge distance parallel to the direction of loading

Symbol	Definition
$c'_{cr,N}$	= modified edge distance of a single fastener required to ensure the characteristic strength of the fastener is achieved when loaded in tension in a narrow member
$c'_{cr,Np}$	= modified characteristic edge distance of a chemical fastener for combined pull-out and concrete cone failure
d	= diameter of fastener bolt or thread diameter of the stud
d_a	= diameter of an anchor in an anchor channel
d_b	= nominal diameter of a reinforcing bar
d_{ef}	= effective depth of supplementary reinforcing bar
d_f	= diameter of the clearance hole in the fixture
d_h	= diameter of the head of the fastener
d_{nom}	= external diameter of the fastener
E_c	= modulus of elasticity of concrete
E_s	= modulus of elasticity of steel
e	= eccentricity of applied load
e_N	= eccentricity of the resultant tension force acting on a group of fasteners relative to the centroid of the fasteners loaded in tension
e_s	= distance between the centre-line of supplementary reinforcement and the line of action of the design shear force
e_V	= eccentricity of the resultant shear force acting on a group of fasteners relative to the centroid of the fasteners loaded in shear
e_1	= eccentricity of the applied shear load relative to the concrete surface, neglecting the thickness of a levelling grout or mortar
F_{Rk}	= characteristic strength of fastener
F_{Rk}^0	= single value representing the basic characteristic strength of a fastener
f	= distance between the head of the fastener and the upper or lower surface of the concrete member
f_{sy}	= characteristic yield strength of reinforcement
f_{yf}	= yield tensile strength of fastener
f_{uf}	= ultimate tensile strength of fastener
f'_c	= characteristic compressive strength of concrete measured via cylinder tests at 28 days
f'_{ct}	= characteristic uniaxial flexural tensile strength of concrete
h	= concrete member depth in which the fastener is installed
h_{ch}	= height of anchor channel
$h_{cr,sp}$	= minimum concrete member depth corresponding to $c_{cr,sp}$
$h_{cr,V}$	= characteristic member thickness for a fastener loaded in shear
h_{ef}	= effective embedment depth of a fastener
h_{min}	= minimum concrete member depth
h'_{ef}	= modified effective embedment depth
h_{ef}^*	= modified effective embedment depth for anchor channel
I_y	= moment of inertia of channel relative to the y-axis of the channel
$k_{cr,N}$	= parameter relating to cracked concrete loaded in tension
$k_{cr,V}$	= parameter related to cracked concrete loaded in shear
k	= parameter related to the calculation or verification of strength of a fastener against a given mode of failure
$k_{ucr,N}$	= parameter relating to uncracked concrete loaded in tension

Symbol	Definition
$k_{ucr,V}$	= parameter for uncracked concrete loaded in shear
k_3	= parameter relating to the state of the concrete for combined pull-out and concrete cone failure for a chemical anchor
k_4	= parameter relating to concrete splitting failure that depends on the type of fastener
k_5	= parameter related to the state of the concrete for the determination of the characteristic concrete blow-out strength of an individual fastener
k_7	= parameter related to the determination of the characteristic shear strength
k_9	= parameter related to the calculation of the basic characteristic shear strength of a single fastener against concrete edge failure
L_{st}	= development length of a bar for a tensile stress less than the yield stress
l_a	= lever arm of the shear force applied to the fastener
l_f	= parameter related to the length of the fastener
l_i	= length from an anchor in an anchor channel over which a linear distribution of load is assumed (also known as influence length)
l_1	= minimum anchorage length of supplementary reinforcement
$M_{Rk,s}$	= characteristic flexural strength
$M_{Rk,s,flex}$	= characteristic flexural strength of an anchor channel
$M_{Rk,s}^0$	= reference characteristic flexural strength of a fastener
M^*	= design bending moment
M_{ch}^*	= design bending moment experienced by anchor channel due to the application of design tensile load (N_{ch}^*)
$n_{ch,N}$	= number of fasteners within a distance equal to $s_{cr,N}$ of the fastener under consideration under tensile loading
$n_{ch,V}$	= number of fasteners within a distance equal to $s_{cr,V}$ of the fastener under consideration under shear loading
N_i	= tension force applied to a fastener that influences the performance of the fastener under consideration
N_o	= tension force in the fastener under consideration
$N_{Rk,c}$	= characteristic tensile strength of a fastener or a group of fasteners to concrete cone failure
$N_{Rk,cb}$	= characteristic tensile strength of a fastener or a group of fasteners to concrete blow-out failure
$N_{Rk,i}$	= characteristic tensile strength of a fastener or group of fasteners to failure mode "i"
$N_{Rk,p}$	= characteristic tensile strength of a fastener or a group of fasteners to pull-out failure
$N_{Rk,s}$	= characteristic tensile strength of a fastener to steel failure
$N_{Rk,sp}$	= characteristic tensile strength of a fastener or a group of fasteners to concrete splitting failure
$N_{Rk,s,a}$	= characteristic tensile strength of a fastener in anchor channel against steel fracture
$N_{Rk,s,c}$	= characteristic tensile strength of a fastener in anchor channel against failure of the connection between the anchor and channel profile
$N_{Rk,i}$	= characteristic tensile strength of a fastener to failure mode "i"
$N_{Rk,s,l}$	= characteristic tensile strength of a fastener in anchor channel against local failure by flexure of the channel lips
N_{Rk}^0	= reference characteristic tensile strength of a fastener
$N_{Rk,c}^0$	= reference characteristic tensile strength of a fastener to concrete cone failure
$N_{Rk,cb}^0$	= reference characteristic tensile strength of a fastener to concrete blow-out failure
$N_{Rk,p}^0$	= reference characteristic bond strength of a fastener to pull-out failure

Symbol	Definition
$N_{Rk,sp}^0$	= reference characteristic tensile strength of a fastener to concrete splitting failure
N^*	= resultant design tensile load applied to a fastener or group of fasteners
N_a^*	= design tensile load acting on an individual anchor in the anchor channel
N_c^*	= design compressive force
N_{cb}^*	= design tensile load acting on one channel bolt in the anchor channel
N_{ch}^*	= design tensile load applied to anchor channel
N_g^*	= design value of resultant tensile load applied to a group of fasteners
N_h^*	= design tensile load acting on the most stressed fasteners in the group
$N_{h,re}^*$	= design tensile force resisted by supplementary reinforcement
N_i^*	= design tensile force resisted by each anchor in the anchor channel
N_{re}^*	= design tensile force acting on the supplementary reinforcement
n	= number of fasteners
n_{ch}	= number of fasteners in an anchor channel within a distance equal to the characteristic spacing of the fastener under consideration
$n_{ch,V}$	= number of anchors that are within a distance $s_{cr,V}$ to the anchor under consideration
R_d	= design resistance of a fixing point, determined in accordance with Appendix A depending on the boundary conditions
	= ΦR_u
R_u	= nominal capacity of the fastener
S^*	= design force acting on a fixing point with one or more fasteners
s	= distance (spacing) between two fasteners
	= spacing of anchors in anchor channel
s_{cbo}	= actual spacing of anchor channel bolts
s_{cr}	= spacing that is required for a fastener to develop its characteristic resistance
s_{crit}	= critical spacing under shear loading caused by a torsion moment applied to a fixture secured by the fasteners
$s_{cr,N}$	= spacing that is required for a fastener to develop its characteristic tensile strength
$s_{cr,Nb}$	= spacing that is required for a fastener to develop its characteristic tensile strength against concrete blow-out failure
$s_{cr,Np}$	= spacing that is required for a fastener to develop its characteristic tensile strength against pull-out failure
$s_{cr,sp}$	= spacing that is required for a fastener to develop its characteristic tensile strength against concrete splitting failure
$s_{cr,V}$	= spacing that is required for a fastener to develop its characteristic shear strength against concrete edge failure
s_i	= distance between fastener under consideration and neighbouring fastener
$s_{l,v}$	= characteristic spacing of anchors for channel lip failure under shear loading
s_{max}	= maximum centre-to-centre spacing of fasteners
s_{min}	= minimum centre-to-centre spacing of fasteners
s_1	= spacing of fasteners in direction 1
s_2	= spacing of fasteners in direction 2

Symbol	Definition
$s'_{cr,Np}$	= modified spacing that is required for a fastener to develop its characteristic tensile strength against pull-out failure
T^*	= design torque applied to fixture
t	= thickness of anchor plate
t_{fix}	= thickness of fixture in contact with the fastener
t_{grout}	= thickness of a layer of grout
t_h	= thickness of the head of the headed fasteners
V_i	= shear force applied to a fastener that influences the performance of the fastener under consideration
V_o	= shear force in the fastener under consideration
$V_{Rk,c}$	= characteristic shear strength of a fastener or a group of fasteners to concrete edge failure
$V_{Rk,cp}$	= characteristic shear strength of a fastener or a group of fasteners to pry-out failure
$V_{Rk,i}$	= characteristic shear strength of a single fastener or group of fasteners to failure mode "i"
$V_{Rk,s}$	= characteristic shear strength of a fastener to steel failure
$V_{Rk,s,a}$	= characteristic shear strength of anchor against steel fracture
$V_{Rk,s,c}$	= characteristic shear strength of anchor channel against failure of the connection between anchor and channel
$V_{Rk,s,l}$	= characteristic shear strength of anchor channel to flexural failure of channel lip
$V_{Rk,s,M}$	= characteristic shear strength of a fastener to steel failure when a lever arm is present
V_u	= shear capacity of concrete element determined in accordance with AS 3600
$V_{Rk,c}^0$	= reference characteristic shear strength of a fastener to concrete edge failure
$V_{Rk,s}^0$	= reference characteristic shear strength of a fastener to steel failure
$V_{Rk,sm}^0$	= reference characteristic shear strength of a fastener accounting for ductility
V^*	= design shear load applied to a fastener or group of fasteners
V_a^*	= design shear load acting on one anchor in anchor channel
V_{cb}^*	= design shear load acting on one channel bolt in the anchor channel
V_{ch}^*	= design shear load applied to anchor channel
V_g^*	= design shear load acting on a fastener group
V_h^*	= design shear load acting on the most loaded fastener in a group
w_k	= width of concrete crack
z	= internal lever arm of a fastening calculated according to the theory of elasticity
α	= parameter
α_{sus}	= ratio of sustained loads (permanent actions and permanent component of variable actions) to the total value of actions acting on the fastener at ultimate limit state
α_M	= parameter accounting for the degree of restraint of a lever arm
α_V	= angle between the applied load and the direction perpendicular to the free edge under consideration
β	= parameter
δ_d	= permissible displacement of fastener for serviceability limit state
ε_c	= strain in concrete
ε_s	= strain in steel
ϕ	= capacity reduction factor
ϕ_c	= capacity reduction factor for concrete

Symbol	Definition
ϕ_i	= capacity reduction factor for strength of fastener or fastener group for failure mode “i”
ϕ_{inst}	= capacity reduction factor for installation
ϕ_{Mc}	= capacity reduction factor for concrete break-out failure, edge break-out failure, concrete blow-out failure and pry-out failure
ϕ_{Mp}	= capacity reduction factor for pull-out failure
ϕ_{Ms}	= capacity reduction factor for steel failure
ϕ_{Msp}	= capacity reduction factor for concrete splitting failure
$\phi_{Ms,ca}$	= capacity reduction factor for the connection between anchor and channel in tension and shear
$\phi_{Ms,flex}$	= capacity reduction factor for steel failure of anchor channel in flexure
$\phi_{Ms,i}$	= capacity reduction factor for steel failure mode
$\phi_{Ms,l}$	= capacity reduction factor for local failure of anchor channel by bending of lips in tension and shear
$\phi_{Ms,re}$	= capacity reduction factor for tensile failure of supplementary reinforcement
$\phi_{s,l}$	= capacity reduction factor for steel failure of anchor channel
ψ_c	= parameter accounting for the influence of the concrete compressive strength on the strength of the fastener
$\psi_{ch,c,N}$	= parameter accounting for the influence of a corner on the tensile strength of an anchor in an anchor channel to concrete cone failure
$\psi_{ch,c,Nb}$	= parameter accounting for the influence of a corner on the tensile strength of an anchor in an anchor channel to concrete blow-out failure
$\psi_{ch,c,V}$	= parameter accounting for the influence of a corner on the shear strength of an anchor in an anchor channel to concrete edge failure
$\psi_{ch,e,N}$	= parameter accounting for the influence of an edge of the concrete member on the concrete cone strength of an anchor in an anchor channel
$\psi_{ch,h,Nb}$	= parameter accounting for the influence of thickness of the concrete member on the tensile strength of the anchor in an anchor channel to concrete blow-out failure
$\psi_{ch,h,V}$	= parameter accounting for the influence of member thickness on the shear strength of the anchor in an anchor channel to concrete edge failure
$\psi_{ch,s,N}$	= parameter accounting for the influence of neighbouring anchors on the tensile strength of the anchor in an anchor channel
$\psi_{ch,s,Nb}$	= parameter accounting for the influence of neighbouring anchors on the characteristic tensile strength of the anchor in an anchor channel to concrete blow-out failure
$\psi_{ch,s,V}$	= parameter accounting for the disturbance to the distribution of stresses in the concrete on the shear strength of an anchor in anchor channel
$\psi_{ch,90^\circ,V}$	= parameter accounting for the influence of shear loads acting parallel to the free edge of the concrete member
$\psi_{ec,N}$	= parameter accounting for the influence of eccentricity of the resultant load in a fastener group on tensile strength
$\psi_{ec,Nb}$	= parameter accounting for the influence of eccentricity of loading on the concrete blow-out strength of a fastener group
$\psi_{ec,Np}$	= parameter accounting for eccentricity of loading on a fastener group for pull-out failure
$\psi_{ec,V}$	= parameter accounting for the influence on shear strength of the eccentricity of the resultant load acting on a fastener group
$\psi_{F,N}$	= reduction factor applied to the tensile strength to account for the uneven distribution of the loads
$\psi_{F,V}$	= reduction factor applied to the shear strength to account for the uneven distribution of loads
$\psi_{g,Nb}$	= parameter accounting for the influence of a group effect on the tensile strength of a fastener to concrete blow-out failure
$\psi_{g,Np}$	= parameter accounting for the influence of a group effect on the tensile strength of a fastener to pull-out failure

Symbol	Definition
$\psi_{h,sp}$	= parameter accounting for the influence of concrete member thickness on the splitting strength of a fastener under tensile loading
$\psi_{h,V}$	= parameter accounting for the influence of concrete member thickness on the shear strength of a fastener
$\psi_{l,V}$	= parameter accounting for the spacing of channel bolts on the flexural strength of channel lips
$\psi_{M,N}$	= parameter accounting for the influence of a compression force between the fixture and concrete on the tensile strength of a fastener
ψ_{re}	= parameter accounting for the shell spalling factor
$\psi_{re,N}$	= parameter accounting for the shell spalling effect due to a dense layer of reinforcement
$\psi_{re,V}$	= parameter accounting for the effect of reinforcement located at the edge
ψ_s	= parameter related to the distribution of stresses in the concrete due to the proximity of the fastener to an edge
ψ_{sus}	= factor accounting for the effects of sustained loading on bond strength
$\psi_{s,N}$	= parameter accounting for the influence on tensile strength of a fastener of the disturbance to the distribution of stresses in the concrete due to the proximity of a fastener to an edge of the concrete member
$\psi_{s,Nb}$	= parameter accounting for the influence on shear strength of a fastener to concrete blow-out failure, of the disturbance to the distribution of stresses in the concrete due to the proximity of a fastener to an edge of the concrete member
$\psi_{s,Np}$	= parameter accounting for the influence on tensile strength of a fastener to pull-out failure, of the disturbance to the distribution of stresses in the concrete due to the proximity of a fastener to an edge of the concrete member
$\psi_{s,V}$	= parameter accounting for the influence on shear strength of a fastener of the disturbance to the distribution of stresses in the concrete due to the proximity of a fastener to an edge of the concrete member
$\psi_{g,Np}^0$	= parameter accounting for the influence of a group effect on the tensile strength of a fastener to pull-out failure
ψ_{sus}^0	= product dependent factor accounting for the effects of sustained loading on bond strength
$\psi_{\alpha,V}$	= parameter accounting for the influence of the angle of the applied load on the shear strength of a fastener
σ_L	= stresses experienced in the concrete due to external loads including those applied to the fastener
σ_{st}	= tensile stress in reinforcement
σ_R	= stresses induced in the concrete due to the restraint of intrinsic loads plus stresses due to extrinsic imposed deformation
τ_{Rk}	= characteristic bond strength
$\tau_{Rk,c}$	= characteristic bond strength for assessing the spacing of chemical fasteners
$\tau_{Rk,cr}$	= characteristic bond strength for cracked concrete
$\tau_{Rk,ucr}$	= characteristic bond strength uncracked concrete

1.5 Loading on fasteners

The design provisions in this document are relevant to static, quasi-static and seismic loading that may include tension, shear, bending or torsion moments, or a combination thereof.

A fastener shall have a nominal prequalification for static loading in accordance with [Appendix A](#).

NOTE The mechanism for transfer of axial compression should be through direct bearing of the fixture on the concrete or via a suitable grout.

Section 2 Materials and installation

2.1 Types of fasteners and fastener groups

This document is applicable to the design of individual fasteners and fastener groups. All fasteners in a group shall be of the same type, size and depth. The transfer of load to fasteners in a group occurs via the fixture as specified in [Section 4](#).

Design parameters such as material strength and product dimensions, and suitable applications for the fastener shall be determined in accordance with [Appendix A](#).

This document is limited to the configuration of fasteners shown in [Figure 2.1\(A\)](#) with the following conditions:

- (a) Without hole clearance, all edge distances, all load directions.
- (b) With limited hole clearance, no edge effects [$c_i \geq \max(10h_{ef}, 60d_{nom})$], all load directions.
- (c) With limited hole clearance, close to an edge [$c_i < \max(10h_{ef}, 60d_{nom})$], tension-only loads.

In addition to the configurations listed above, this document also covers configurations illustrated in [Figure 2.1\(B\)](#) that have limited hole clearance, are close to an edge [$c_i < \max(10h_{ef}, 60d_{nom})$], and include loading in all directions.

NOTE Hole clearance is the difference between the diameter of the fixture and the outside diameter of the fastener. Limited hole clearance is defined in [Table 4.2.2.1](#).

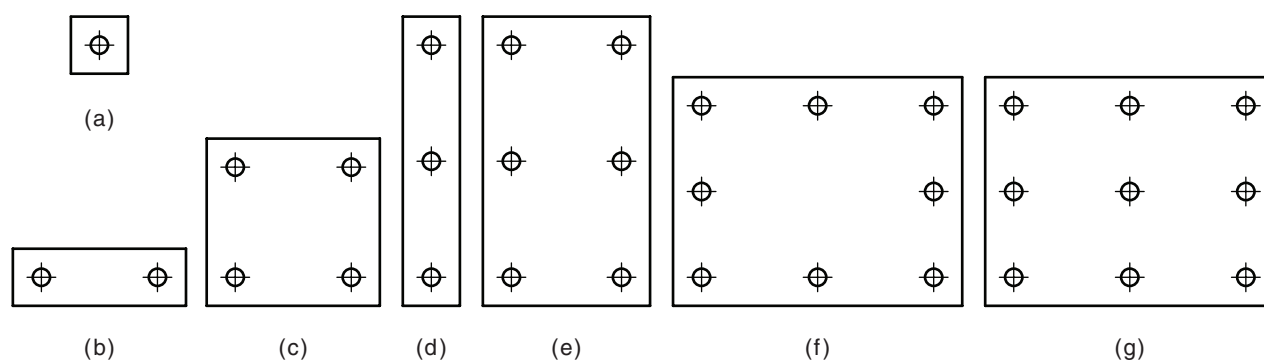


Figure 2.1(A) — Configurations of fasteners remote from edges

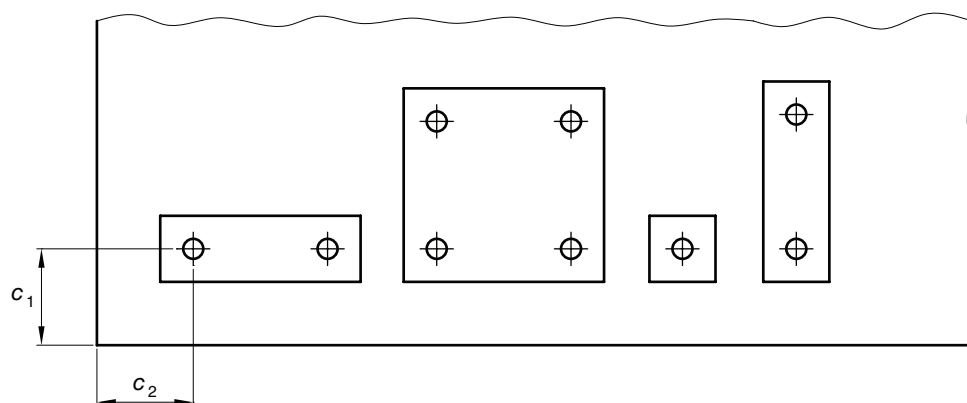


Figure 2.1(B) — Configurations of fasteners close to an edge

2.2 Dimensions of fasteners

This document is limited to fasteners with a minimum thread size or nominal diameter equal to 6 mm. The maximum diameter of the fastener for tensile loading applications is not limited; however, for shear loading applications the diameter of the fastener shall be limited to 60 mm.

The effective embedment depth of a fastener (h_{ef}) shall be determined in accordance with [Appendix A](#) and shall have a minimum value of $h_{ef} \geq 40$ mm.

The effective embedment depth of chemical fasteners shall be limited to $h_{ef} \leq 20d_{nom}$.

For statically indeterminate non-structural applications, when in case of failure the load can be distributed to other fasteners and in accordance with the limits provided in pre-qualification document and in accordance with [Appendix A](#), a minimum size, effective embedment depth and member thickness could be reduced as follows:

- (a) Minimum nominal diameter or shaft diameter for screws ≥ 5 mm.
- (b) Effective embedment depth of fasteners $h_{ef} \geq 30$ mm.
- (c) Effective embedment depth of fasteners in case of internal exposure $h_{ef} \geq 25$ mm.
- (d) Minimum thickness of the substrate ≥ 80 mm unless otherwise specified in prequalification document.

NOTE The effective embedment depth is determined in accordance with [Appendix A](#) and is generally less than the nominal embedment depth of the fasteners [see [Figure 1.3\(C\)](#)].

2.3 Fastener materials

This document is limited to fasteners that have a material tensile strength $f_{uf} \leq 1,000$ MPa, with the exception of concrete screws that do not have a limit.

C2.3 *Materials used for the manufacturing of fasteners covered in this document include the following:*

- (a) Carbon steel — ISO 898-1, ISO 898-2, AS/NZS 4291.1, AS/NZS 4291.2, AS/NZS 4671.
- (b) Stainless steel — ISO 3506, AS/NZS 4671.
- (c) Malleable cast iron — AS 1832.

2.4 Concrete

Concrete members shall exhibit a characteristic compressive strength at 28 days (f'_c) in the range of 12 MPa to 90 MPa, with either the strength grade determined in accordance with AS 1379, or the compressive strength determined statistically from compressive strength tests in accordance with AS 1012.9. The strength grade(s) of concrete that a fastener is used in shall be in accordance with [Appendix A](#).

The characteristic compressive strength (f'_c) for design purposes shall not exceed 60 MPa.

NOTE The range of strength grade(s) of concrete in which a fastener has a prequalification in accordance with [Appendix A](#) may be more restrictive than the range of concrete strength covered by this document.

The density of normal-weight concrete shall be taken as 2 400 kg/m³.

C2.4 *The Concrete Capacity Method has been calibrated up to a concrete compressive strength equal to 60 MPa. Adopting the strength predicted by the Concrete Capacity Method at 60 MPa for concrete*

strengths between 60 and 90 MPa is conservative. The prediction of fastener performance between 60 and 90 MPa requires additional testing. (continued)

2.5 Reinforcement

Where the fastening design includes supplementary reinforcement to resist loads, the reinforcement steel shall conform to the requirements of AS/NZS 4671.

NOTE 1 The performance of fasteners is influenced by the quality of installation. This document assumes a minimum standard has been applied in the installation of fasteners. Guidance on the installation of fasteners is given in [Appendix G](#).

NOTE 2 Guidance on assumptions related to installation practice, the nature of errors that may compromise performance and how to assess an installer's competency is given in [Appendix B](#).

Section 3 General design requirements

3.1 General

Post-installed and cast-in fasteners for safety-critical applications for use in concrete shall be designed for ultimate limit state and serviceability limit state in accordance with the requirements of AS/NZS 1170.0 and the requirements of this document.

NOTE 1 A simplified design procedure for post-installed fasteners in [Appendix H](#) may be used instead of the provisions of [Clause 6.2](#) (tensile strength), [Clause 7.2](#) (shear strength), and [Clauses 8.1.1](#) and [8.2.1](#) (strength against combined tension and shear loading), which account for all loading directions and modes of failure.

The provisions of AS 3600 and the strength verification requirements of [Appendix C](#) shall apply, to ensure the safe transmission of loads from the fastener to the supports of the concrete member.

Fastener edge distance and spacing shall only be specified with positive tolerances.

The distance between the outermost fasteners of adjacent groups or between individual fasteners or individual fasteners and outermost fasteners in groups shall be at least equal to $a \geq s_{cr,N}$ to calculate the characteristic resistance for concrete modes of failure.

Aborted holes shall be neglected in design, provided they have been filled with mortar at least equal to the base material strength and not less than 40 MPa.

NOTE 2 In the event that it has been necessary to fill aborted holes with mortar, the fastener in the vicinity of the aborted holes should not have an installation torque applied or be loaded until the mortar has achieved its full strength.

Design of post-installed fasteners used to transmit seismic actions by means of tension, shear or a combination of tension and shear shall be conducted in accordance with [Appendix F](#).

3.2 Verifications for design

3.2.1 Strength limit state

The fastener shall be designed for the ultimate limit state to ensure that the design action effect (S^*) does not exceed the design capacity (ϕR_u) as follows:

$$S^* \leq \phi R_u \quad 3.2.1$$

where

S^* = design action effect on the fastener resulting from the ultimate limit state design loads, determined in accordance with the requirements of AS/NZS 1170.0 and [Section 4](#)

ϕ = capacity reduction factor, determined in accordance with [Clause 3.2.4](#)

R_u = nominal capacity of the fastener, in accordance with [Sections 6](#) to [8](#)

3.2.2 Serviceability limit state

Design for the serviceability limit state shall limit deflections in accordance with [Section 9](#) using the assessment determined in accordance with [Appendix A](#).

Cracking in concrete shall be considered for applications involving supplementary reinforcement or an embedded base-plate close to an edge.

3.2.3 Load factors

Load factors and load combinations shall be determined in accordance with AS/NZS 1170.0.

3.2.4 Capacity reduction factors

The capacity reduction factor for concrete accounting for fastener sensitivity to installation (ϕ_{Mc}) is product dependent (see [Table 3.2.4](#)).

The capacity reduction factors for ultimate limit state vary according to mode of failure and shall be taken from [Table 3.2.4](#).

NOTE Fasteners are sensitive to installation practice. Improper installation may lead to compromised performance.

Table 3.2.4 — Capacity reduction factors for modes of failure of post-installed and cast-in fasteners

Mode of failure	Capacity reduction factor
Steel failure — Fasteners	
Tension	$\phi_{Ms} = 5f_{yf}/(6f_{uf}) \leq 1/1.4$
Shear — with and without lever arm	$\phi_{Ms} = f_{yf}/f_{uf} \leq 0.8$ when $f_{uf} \leq 800$ MPa and $f_{yf}/f_{uf} \leq 0.8$ $= 2/3$ when $f_{uf} > 800$ MPa or $f_{yf}/f_{uf} > 0.8$
Steel failure — Anchor channels	
Tension — anchors and channel bolts	$\phi_{Ms} = 5f_{yf}/(6f_{uf}) \leq 1/1.4$
Shear — with and without lever arm	$\phi_{Ms} = f_{yf}/f_{uf} \leq 0.8$ when $f_{uf} \leq 800$ MPa and $f_{yf}/f_{uf} \leq 0.8$ $= 2/3$ when $f_{uf} > 800$ MPa or $f_{yf}/f_{uf} > 0.8$
Connection between anchor and channel in tension and shear	$\phi_{Ms,ca} = 1/1.8$
Local failure of channel lips by bending under tension and shear	$\phi_{Ms,l} = 1/1.8$
Connection between channel bolt and channel lips in x direction	$\phi_{Ms,l,x} = \phi_{inst}\phi_{Ms,l}$
	$\phi_{inst}^a =$ determined according to Appendix A for anchor channel
Flexural failure of channel profile	$\phi_{Ms,flex} = 1/1.15$
Steel failure — Supplementary reinforcement	
Tension	$\phi_{Ms,re} = 0.8$
Concrete failure — Tension and shear	
Concrete cone failure, concrete edge failure, concrete blow-out failure, pry-out failure	$\phi_{Mc} = \phi_c\phi_{inst}$
	$\phi_c = 1/1.5$ in general
	$\phi_{inst} = 1.0$ for anchor channel in tension and shear
	≤ 1.0 for post-installed fasteners in tension, determined in accordance with Appendix A $= 1.0$ for post-installed fasteners in shear
Concrete splitting failure	$\phi_{Msp} = \phi_{Mc}$
Pull-out failure	
Pull-out failure, combined pull-out and concrete cone failure	$\phi_{Mp} = \phi_{Mc}$

^a ϕ_{inst} is the product dependent factor to account for sensitivity to installation. See [Appendix A](#).

NOTE 1: If the anchor channel in longitudinal shear is completely insensitive to installation and installation conditions, ϕ_{inst} is 1.0. For anchor channels that show sensitivity to the quality of installation, the value of ϕ_{inst} is less than 1.0.

Table 3.2.4 (continued)

Mode of failure	Capacity reduction factor
NOTE 2 Fasteners are sensitive to installation practice. Improper installation may lead to compromised performance. Appendix G has some basic assumptions made for the design and installation of anchors in this document. The value for the capacity reduction factor is generally a fraction since the values are derived from partial safety factors from EN 1992-4 and the accuracy has been maintained to avoid rounding errors.	

3.3 Concrete condition

The concrete in the vicinity of the fastener shall be determined to be either cracked or uncracked. An uncracked condition is such that no cracking of the concrete occurs along the entire embedment length of the fastener under the characteristic combination of loading at the serviceability limit state condition.

An uncracked condition shall be satisfied as follows:

$$\sigma_L + \sigma_R \leq f'_{ct} \quad 3.3$$

where

σ_L = stresses experienced in the concrete due to external loads including those applied to the fastener, calculated assuming an uncracked condition

σ_R = stresses induced in the concrete due to the restraint of intrinsic loads (e.g. shrinkage) plus stresses due to extrinsic imposed deformation (e.g. temperature variation, movement of concrete support), calculated assuming an uncracked condition.

In the absence of a detailed analysis, $\sigma_R = 3$ MPa shall be assumed

f'_{ct} = characteristic uniaxial tensile strength of concrete, calculated according to AS 3600

For concrete members that transmit loads in two directions the above verification shall be performed for both directions.

NOTE 1 It is conservative to assume that the concrete is cracked. The selection of an uncracked condition should be justified by the designer via stress analysis. It is recommended that $f'_{ct} = 0$ (to be conservative).

NOTE 2 Guidance on information that should typically be included in the project specification may be found in [Appendix G](#).

3.4 Verification of fastener strength

3.4.1 General

The ultimate strength of the fastener shall be verified in accordance with [Equation 3.2.1](#) by considering modes of failure under tensile loading ([Clause 3.4.2](#)), modes of failure under shear loading ([Clause 3.4.3](#)) and combined tension and shear loading ([Clause 3.4.4](#)).

The mode of failure calculated to provide the lowest design strength shall be adopted for ultimate limit state design.

3.4.2 Tensile strength of fastener

3.4.2.1 Post-installed fasteners

The design of post-installed fasteners subjected to tensile loading shall be performed in accordance with the verifications listed in [Table 3.4.2.1](#). The mode of failure producing the lowest design strength shall be adopted for design.

NOTE Illustrations of each failure mode are provided in [Figure 3.4.2.1](#).

Table 3.4.2.1 — Verifications required for post-installed fasteners loaded in tension

Mode of failure	Reference		Single fastener	Fastener group	
	Figure	Clause		Most loaded faster	Fastener group
Steel failure of fastener	Figure 3.4.2.1 (a)	6.2.2	$N^* \leq \phi_{Ms} N_{Rk,s}$	$N_h^* \leq \phi_{Ms} N_{Rk,s}$	
Concrete cone failure	Figure 3.4.2.1 (b)	6.2.3	$N^* \leq \phi_{Mc} N_{Rk,c}$		$N_g^* \leq \phi_{Mc} N_{Rk,c}$
Pull-out failure of fastener ^a	Figure 3.4.2.1 (c)	6.2.4	$N^* \leq \phi_{Mp} N_{Rk,p}$	$N_h^* \leq \phi_{Mp} N_{Rk,p}$	
Combined pull-out and concrete cone failure ^b	Figure 3.4.2.1 (d)	6.2.5	$N^* \leq \phi_{Mp} N_{Rk,p}$		$N_g^* \leq \phi_{Mp} N_{Rk,p}$
Concrete splitting failure	Figure 3.4.2.1 (e)	6.2.6	$N^* \leq \phi_{Msp} N_{Rk,sp}$		$N_g^* \leq \phi_{Msp} N_{Rk,sp}$
Concrete blow-out failure ^c	Figure 3.4.2.1 (f)	6.2.7	$N^* \leq \phi_{Mc} N_{Rk,cb}$		$N_g^* \leq \phi_{Mc} N_{Rk,cb}$
Steel failure of supplementary reinforcement	Figure 3.4.2.1 (g)	6.2.8	Design according to AS 3600		
Anchorage failure of supplementary reinforcement	Figure 3.4.2.1 (h)	6.2.8	Design according to AS 3600		
^a Not required for post-installed chemical fasteners.					
^b Not required for post-installed mechanical fasteners.					
^c Exception see Clause 6.2.7.1 .					

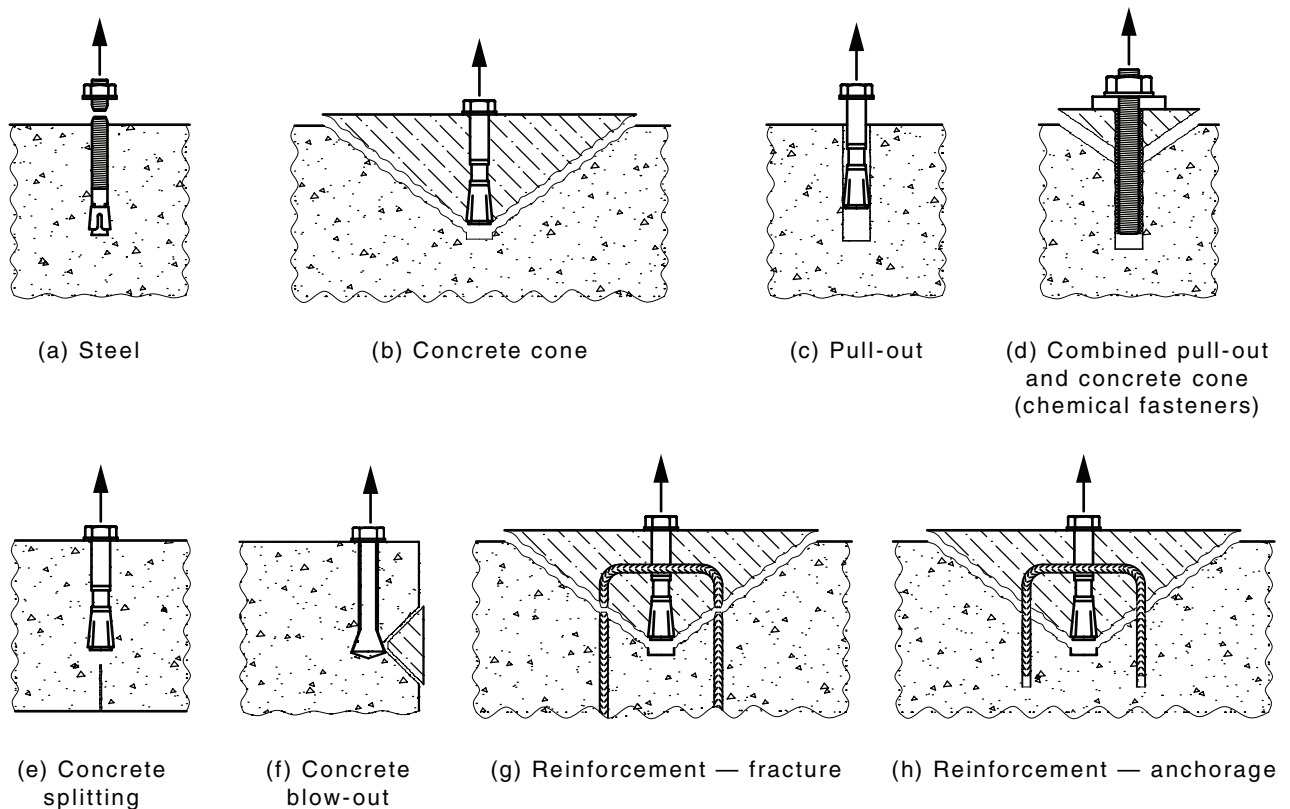


Figure 3.4.2.1 — Modes of failure for post-installed fasteners subjected to tensile loading

3.4.2.2 Cast-in anchor channel

The design of anchor channel subjected to tensile loading shall be performed in accordance with the verifications listed in [Table 3.4.2.2](#). The mode of failure producing the lowest design strength shall be adopted for design.

NOTE Illustrations of each failure mode are provided in [Figure 3.4.2.2](#).

Table 3.4.2.2 — Verifications required for cast-in anchor channel loaded in tension

Mode of failure	Reference		Channel	Most unfavourable anchor or channel bolt
	Figure	Clause		
Channel bolt fracture	Figure 3.4.2.2 (a)	6.3.2		$N^* \leq \phi_{Ms} N_{Rk,s}$
Anchor fracture	Figure 3.4.2.2 (b)	6.3.2		$N_a^* \leq \phi_{Ms} N_{Rk,s,a}$
Connection between anchor and channel	Figure 3.4.2.2 (c)	(see footnote d)		$N_a^* \leq \phi_{Ms,ca} N_{Rk,s,c}$
Local flexure of channel lip (see footnote b)	Figure 3.4.2.2 (d)	(see footnote d)	$N^* \leq \phi_{Ms,l} N_{Rk,s,l}$	
Flexure of channel	Figure 3.4.2.2 (e)	(see footnote d)	$M^* \leq \phi_{Ms,flex} M_{Rk,s,flex}$	
Concrete cone failure (see footnote c)	Figure 3.4.2.2 (f)	6.3.3		$N_a^* \leq \phi_{Mc} N_{Rk,c}$ (see footnote c)

Table 3.4.2.2 (continued)

Mode of failure	Reference		Channel	Most unfavourable anchor or channel bolt
	Figure	Clause		
Pull-out failure	Figure 3.4.2.2 (g)	6.3.4		$N_a^* \leq \phi_{Mp} N_{Rk,p}$
Concrete splitting failure (see footnote c)	Figure 3.4.2.2 (h)	6.3.5		$N_a^* \leq \phi_{Msp} N_{Rk,sp}$ (see footnote c)
Concrete blow-out failure (see footnotes a and c)	Figure 3.4.2.2 (i)	6.3.6		$N_a^* \leq \phi_{Mc} N_{Rk,cb}$ see footnote c)
Steel failure of supplementary reinforcement	Figure 3.4.2.2 (j)	6.3.7	Design according to AS 3600	
Anchorage failure of supplementary reinforcement	Figure 3.4.2.2 (k)	6.3.7	Design according to AS 3600	

a Not required for anchors with $c > 0.5h_{ef}$.

b Most unfavourable channel bolt.

c The most unfavourable anchor shall be determined on the basis of consideration of the load on the anchor in conjunction with the edge distance and spacing.

d Characteristic strength determined in accordance with [Appendix A](#).

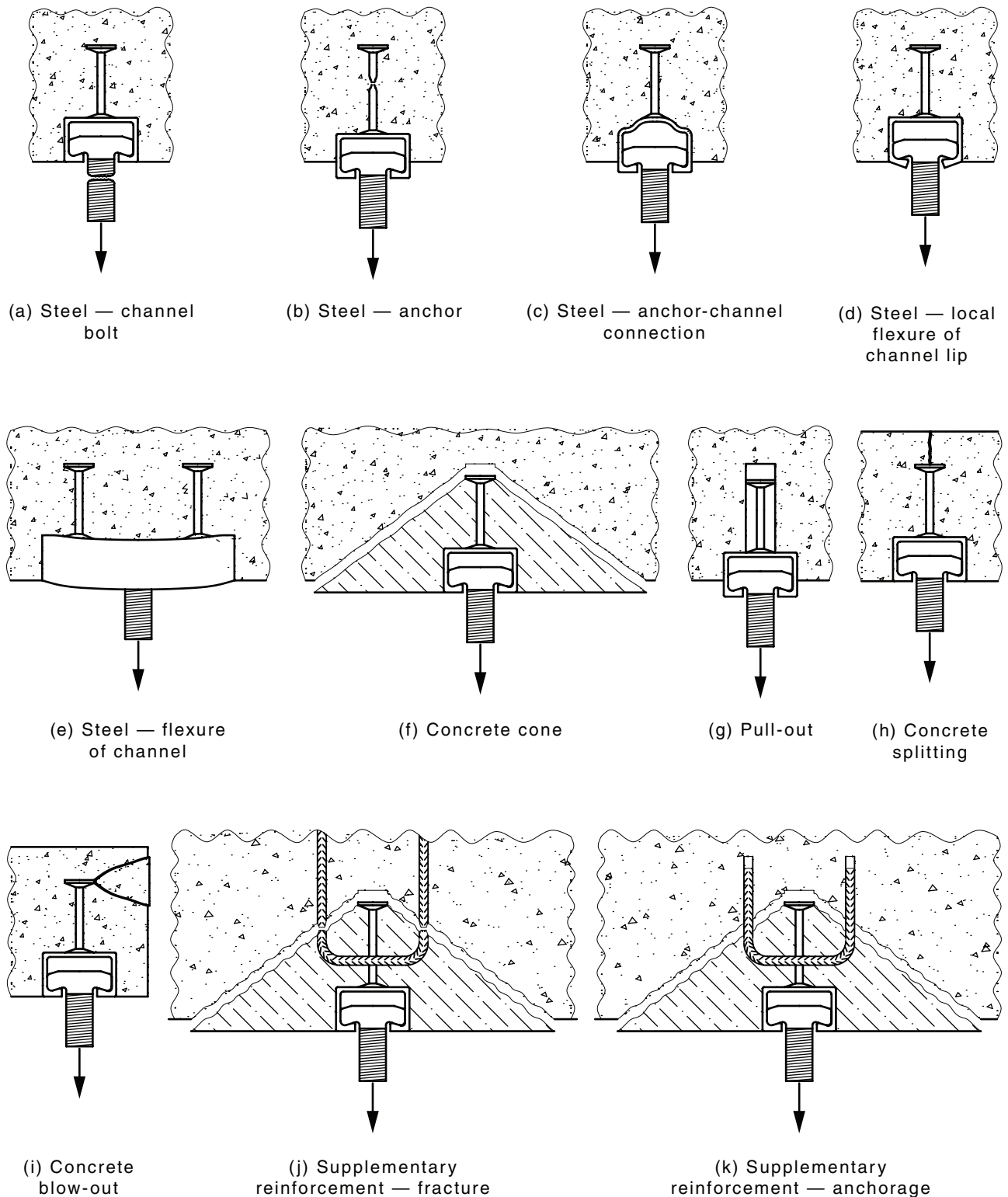


Figure 3.4.2.2 — Modes of failure for cast-in anchor channel subjected to tensile loading

3.4.3 Shear strength of fastener

3.4.3.1 Post-installed fasteners

The design of post-installed fastener subjected to shear loading shall be performed in accordance with the verifications listed in [Table 3.4.3.1](#). The mode of failure producing the lowest design strength shall be adopted for design.

NOTE Illustrations of each failure mode are provided in [Figure 3.4.3.1](#).

Table 3.4.3.1 — Verifications required for post-installed fasteners loaded in shear

Mode of failure	Reference		Single fastener	Fastener group	
	Figure	Clause		Most loaded fastener	Fastener group
Steel failure of fastener without lever arm	Figure 3.4.3.1 (a)	7.2.2.2	$V^* \leq \phi_{Ms} V_{Rk,s}$	$V_h^* \leq \phi_{Ms} V_{Rk,s}$	
Steel failure of fastener with lever arm	Figure 3.4.3.1 (b)	7.2.2.3	$V^* \leq \phi_{Ms} V_{Rk,s,M}$	$V_h^* \leq \phi_{Ms} V_{Rk,s,M}$	
Concrete edge failure	Figure 3.4.3.1 (c)	7.2.3	$V^* \leq \phi_{Mc} V_{Rk,c}$		$V_g^* \leq \phi_{Mc} V_{Rk,c}$
Concrete pry-out failure ^a	Figure 3.4.3.1 (d)	7.2.4	$V^* \leq \phi_{Mc} V_{Rk,cp}$		$V_g^* \leq \phi_{Mc} V_{Rk,cp}$
Steel failure of supplementary reinforcement ^b	Figure 3.4.3.1 (e)	7.2.5	Design according to AS 3600		
Anchorage failure of supplementary reinforcement ^b	Figure 3.4.3.1 (f)	7.2.5	Design according to AS 3600		

^a Exception see [Clause 7.2.4.2](#).

^b The tension force acting on the reinforcement N_{re}^* shall be calculated in accordance with [Clause 4.4.3](#).

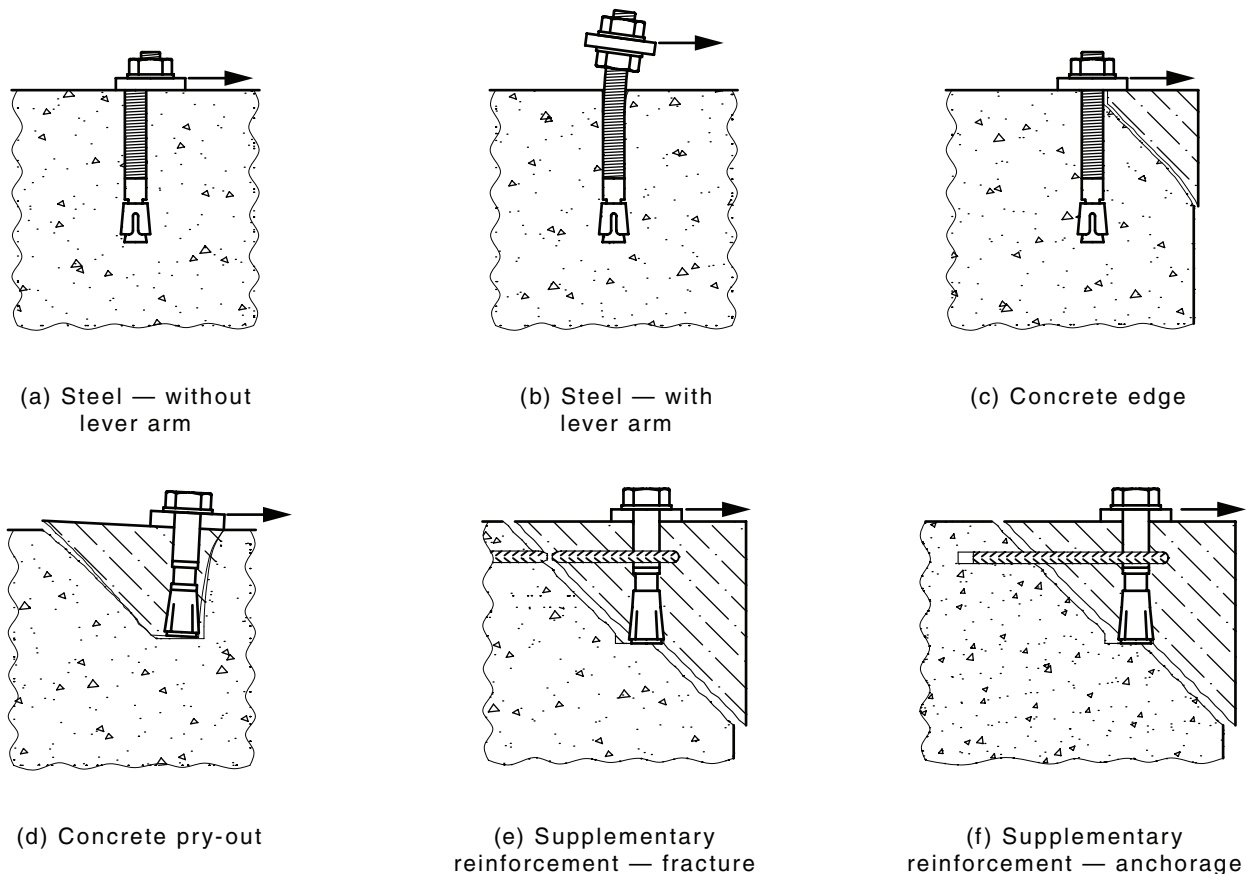


Figure 3.4.3.1 — Modes of failure for post-installed fasteners subjected to shear loading

3.4.3.2 Cast-in anchor channel

3.4.3.2.1 Shear load acting perpendicular to longitudinal axis of the channel

The design of anchor channel subjected to shear loading acting perpendicular to the longitudinal axis of the anchor channel shall be in accordance with the verifications listed in [Table 3.4.3.2.1](#). The mode of failure producing the lowest design strength shall be adopted for design.

NOTE An illustration of each failure mode is provided in [Figure 3.4.3.2.1](#).

Table 3.4.3.2.1 — Verifications required for cast-in anchor channel loaded in shear perpendicular to longitudinal axis of the channel

Mode of failure	Reference		Channel	Most unfavourable anchor or channel bolt
	Figure	Clause		
Channel bolt without lever arm	Figure 3.4.3.2.1 (a)	7.3.2.1		$V_{cb,y}^* \leq \phi_{Ms} V_{Rk,s}$
Channel bolt with lever arm	Figure 3.4.3.2.1 (b)	7.3.2.1		$V_{cb,y}^* \leq \phi_{Ms} V_{Rk,s,M}$
Anchor	Figure 3.4.3.2.1 (c)	7.3.2.1		$V_{a,y}^* \leq \phi_{Ms} V_{Rk,s,a,y}$
Connection between anchor and channel	Figure 3.4.3.2.1 (d)	7.3.2.1		$V_{a,y}^* \leq \phi_{Ms} V_{Rk,s,c,y}$
Local flexure of channel lip ^a	Figure 3.4.3.2.1 (e)	7.3.2.2	$V_y^* \leq \phi_{Ms,l,y} V_{Rk,s,l,y}$	

Table 3.4.3.2.1 (continued)

Mode of failure	Reference		Channel	Most unfavourable anchor or channel bolt
	Figure	Clause		
Concrete edge failure ^b	Figure 3.4.3.2.1 (f)	7.3.1.3		$V_{a,y}^* \leq \phi_{Mc} V_{Rk,c,y}$
Pry-out failure ^b	Figure 3.4.3.2.1 (g)	7.3.1.4		$V_{a,y}^* \leq \phi_{Mc} V_{Rk,cp,y}$
Steel failure of supplementary reinforcement ^b	Figure 3.4.3.2.1 (h)	7.3.1.5	Design according to AS 3600	
Anchorage failure of supplementary reinforcement ^c	Figure 3.4.3.2.1 (i)	7.3.1.5	Design according to AS 3600	
^a Verification for most loaded channel bolt.				
^b The most unfavourable anchor shall be determined on the basis of consideration of the load on the anchor in conjunction with the edge distance and spacing.				
^c The design tensile force acting on the supplementary reinforcement (N_{re}^*) shall be calculated in accordance with Clause 4.4.3 .				

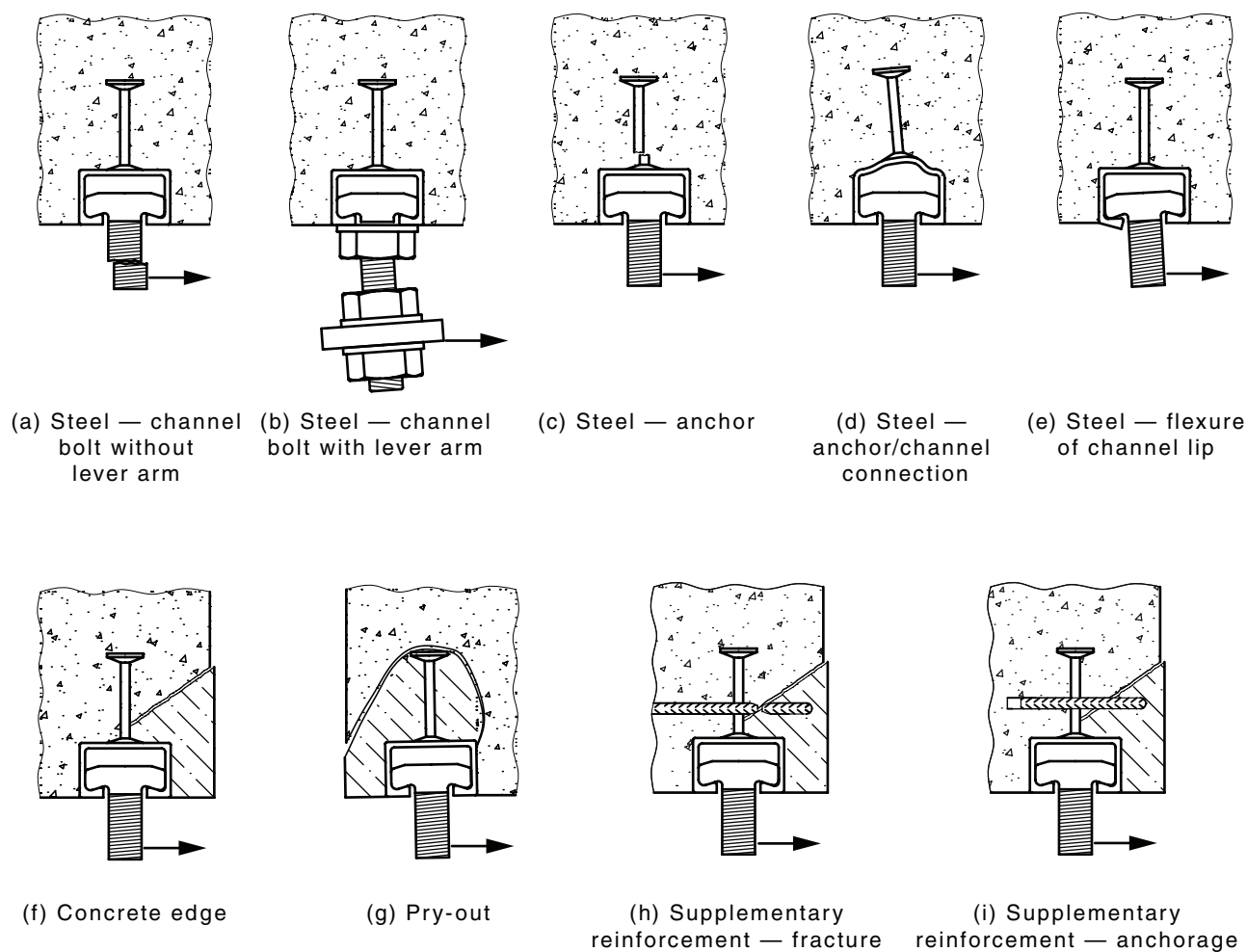


Figure 3.4.3.2.1 — Modes of failure for cast-in anchor channel subjected to shear loading along the perpendicular direction of anchor channel

3.4.3.2.2 Shear load acting along the longitudinal axis of the channel

The design of anchor channel subjected to shear loading acting along the longitudinal axis of the anchor channel shall be in accordance with the verifications listed in [Table 3.4.3.2.2](#). The mode of failure producing the lowest design strength shall be adopted for design.

NOTE An illustration of each failure mode is provided in [Figure 3.4.3.2.2](#).

Table 3.4.3.2.2 — Verifications required for cast-in anchor channel loaded in shear along the longitudinal direction

Mode of failure	Reference		Channel	Most unfavourable anchor or channel bolt
	Figure	Clause		
Channel bolt without lever arm	Figure 3.4.3.2.2 (a)	7.3.2.2		$V_{cb,x}^* \leq \phi_{Ms} V_{Rk,s}$
Channel bolt with lever arm	Figure 3.4.3.2.2 (b)	7.3.2.2		$V_{cb,x}^* \leq \phi_{Ms} V_{Rk,s,M}$
Anchor	Figure 3.4.3.2.2 (c)	7.3.2.2		$V_{a,x}^* \leq \phi_{Ms} V_{Rk,s,a,x}$
Connection between anchor and channel	Figure 3.4.3.2.2 (d)	7.3.2.2		$V_{a,x}^* \leq \phi_{Ms,ca} V_{Rk,s,c,x}$
Connection between channel lips and channel bolt ^a	Figure 3.4.3.2.2 (e)	7.3.2.2	$V_{cb,x}^* \leq \phi_{Ms,l,x} V_{Rk,s,l,x}$	
Concrete edge failure ^b	Figure 3.4.3.2.2 (f) or (g)	7.3.2.3		$V_{a,x}^* \leq \phi_{Mc} V_{Rk,c,x}$
Pry-out failure ^b	Figure 3.4.3.2.2 (h)	7.3.2.4		$V_{a,x}^* \leq \phi_{Mc} V_{Rk,cp,x}$
Steel failure of supplementary reinforcement ^c		7.3.2.5	Design according to AS 3600	
Anchorage failure of supplementary reinforcement ^c		7.3.2.5	Design according to AS 3600	
^a Verification for most loaded channel bolt.				
^b The most unfavourable anchor shall be determined on the basis of consideration of the load on the anchor in conjunction with the edge distance and spacing.				
^c The design tensile force acting on the supplementary reinforcement (N_{re}^*) shall be calculated in accordance with Clause 4.4.3 .				

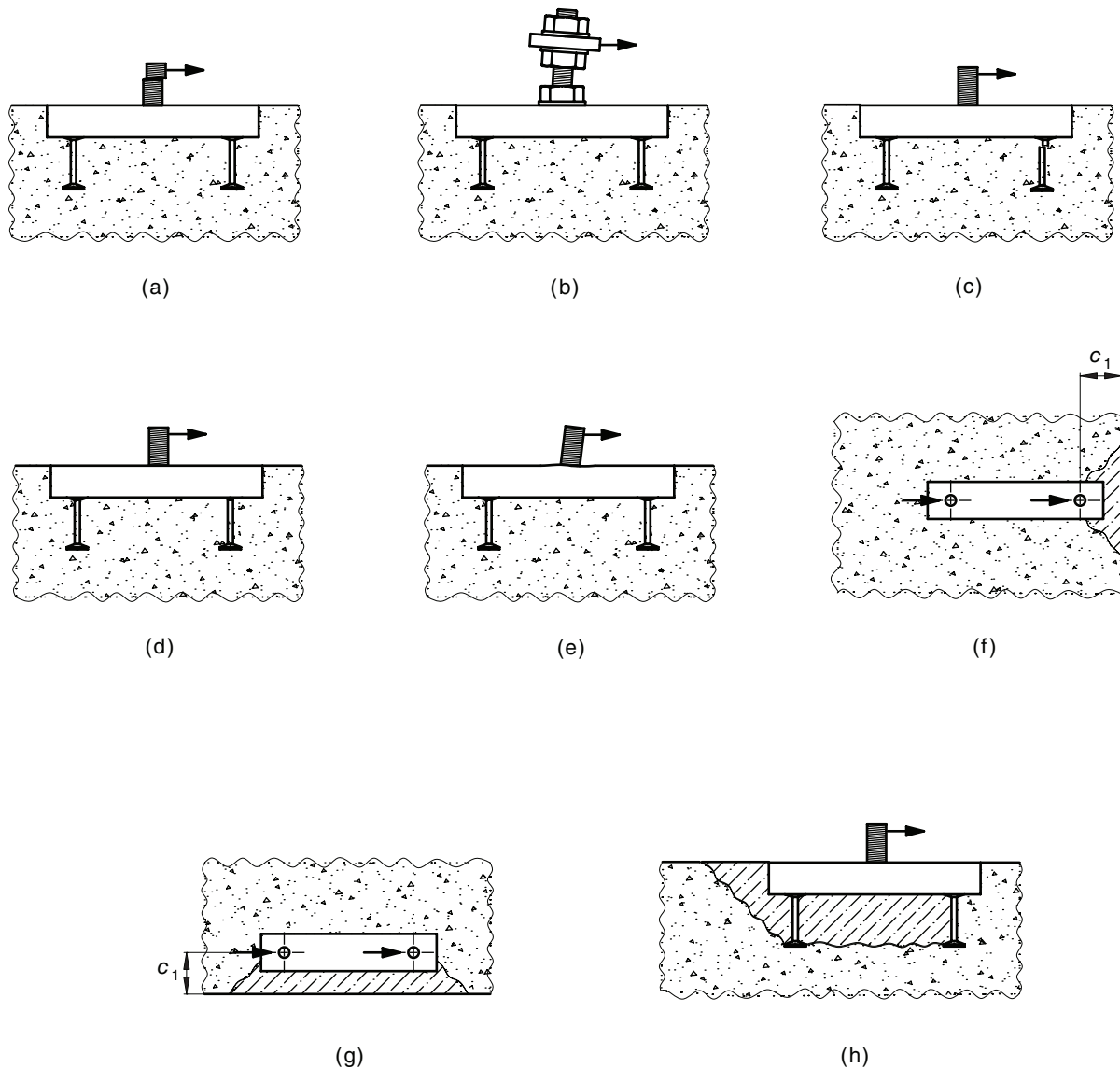


Figure 3.4.3.2.2 — Modes of failure for cast-in anchor channel subjected to shear loading along the longitudinal direction with $n_a = 2$

3.4.4 Combined tension and shear strength of fastener

Verification of strength of post-installed fasteners under combined tension and shear loading shall be in accordance with [Clause 8.1.1](#) (steel failure) and [Clause 8.2.1](#) (modes of failure other than steel).

Verification of strength of anchor channel under combined tension and shear loading shall be in accordance with [Clause 8.1.2](#) (steel failure) and [Clause 8.2.2](#) (modes of failure other than steel).

Section 4 Determination of forces acting on fasteners

4.1 General

The loads applied to fasteners shall be established via elastic analysis at the ultimate and serviceability limit states with loads applied to a fixture being transferred to fasteners as equivalent tension or shear forces.

The frictional force developing between a fixture plate and concrete due to the presence of a bending moment and/or normal compression force shall be neglected for the design of fasteners.

Eccentricity of loading on fasteners and prying forces shall be considered in design.

NOTE For examples of eccentricity of loading on fasteners and prying forces, see [Figure 4.1](#).

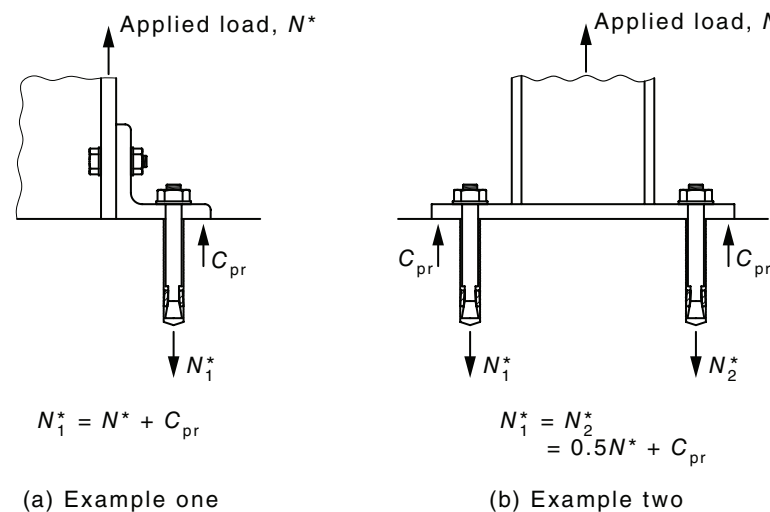


Figure 4.1 — Examples of eccentricity and prying action in fixtures resulting in amplification of tensile forces acting on fasteners

4.2 Post-installed fasteners

4.2.1 Tension and compression loads

When a fixture is subject to a normal force and/or bending moments, the calculation of design loads applied to fasteners shall be based on linear distribution of strains and a linear relationship between stress and strain.

The eccentricity of the resultant design tensile load acting on a fastener group shall be calculated for consideration in the verification of strength against concrete cone failure, combined pull-out and concrete cone failure of chemical fasteners, concrete splitting failure and concrete blow-out failure modes. For the purpose of calculating the eccentricity of the resultant tensile load of the fastener group