OrbiPlate™

DESIGN GUIDE

ANZ

reid™

M20 M16

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Welcome to the Reid™ OrbiPlate™ Design Guide

This concise and systematically presented design guide contains the information required by Specifiers, Engineers and Architects to design structural connections using Reid™ OrbiPlate™.

Selection is made using strength limit state approach on the basis of the design load case and influencing factors on the connection such as concrete substrate compressive strength and edge and spacing distances. The simplified step-by-step method presented in this booklet will allow rapid design and verification of the connection, be it steel to concrete or steel to steel.

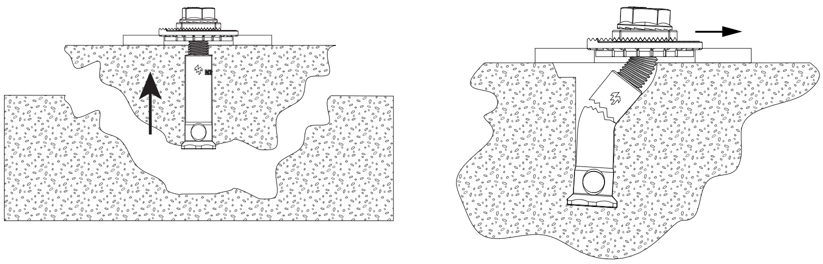
Scope

This Design Guide sets out the minimum requirements for the design of steel to concrete and steel to steel connections utilising Reid™ OrbiPlate™ in order to design safe, serviceable and durable structures.

This guide is limited to using OrbiPlate™ as supplied with either a 50mm long M16 bolt or 60mm long M20 bolt respectively. This limits the fixture thicknesses that are specified in this guide. Where greater fixture thicknesses are required an alternate longer bolt can often be used but the application needs to be carefully considered as the capacities of the connection may be affected. Please contact your ramsetreid™ Engineer for guidance.

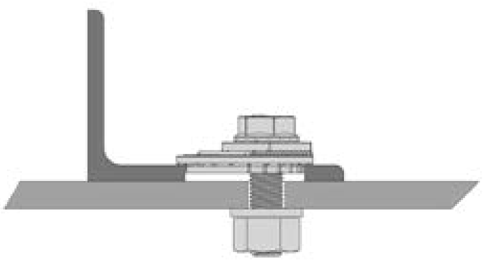
Steel to concrete

For the connection of steel to concrete, this guide is limited to the use of OrbiPlate™ when used in conjunction with the matching Reid™ footed ferrule. In all loading scenarios, the footed ferrule is the limiting factor when using OrbiPlate™ and the performance of the ferrule in shear varies with the fixture thickness. Hence it is critical to design with OrbiPlate™ and the matching Reid™ footed ferrule as a system.



Steel to Steel

For the connection of steel to steel elements, this guide is limited to the use of 20mm OrbiPlate™ as supplied with a M20 x 60 set screw and a matching hex nut and washer supplied by others. This may limit the thickness of the two steel plates to be connected. Where greater fixture thicknesses are required, contact your ramsetreid™ Engineer for guidance.



Introduction

Cumulative tolerances in precast construction.

OrbiPlate™ was invented by John Burke and Allan Walsh in recognition of the effects of tolerances that are prevalent within the precast concrete industry.

For example, when connecting two precast panels with cast in ferrules, the tolerances on the position of an individual insert within a group, the position of the group within the panel, the length of the panel and the site positioning of each panel results in a connection that is often impossible to bolt together with normal clearances.

According to AS3850.2:2015 section, 2.11: "The effects of cumulative tolerances shall be considered. The total accumulation of tolerances shall be not greater than 20 mm when related to set out grids and data".

Hence it is the design Engineer's responsibility to make allowance for cumulative tolerances and OrbiPlate™ is an excellent solution.

NZS 3109:1997 section 5.3 provides similar guidance to AS3850.1:2015 in regard to manufacturing tolerances for precast components.

The manufacturing tolerances contained in table 5.1 of NZS3109:1997 for panel dimensions and positioning of fasteners and groups of fasteners exceed the equivalent within AS3850.2:2015, making the effects of cumulative tolerances very important in New Zealand.

OrbiPlate™ minimum edge distances for steel fixtures

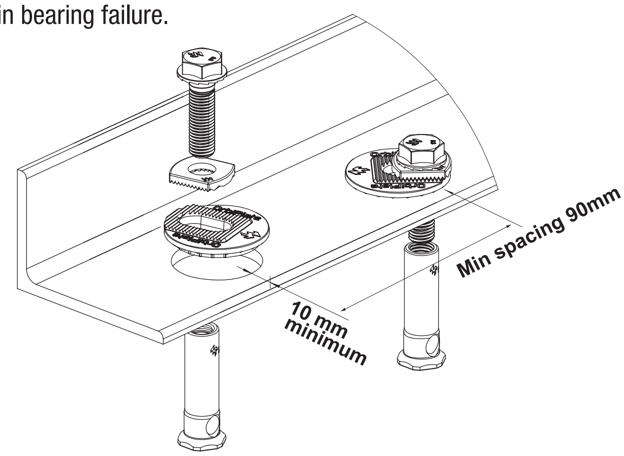
The minimum edge distance of 10mm from the edge of the fixture hole to a single edge of the fixture contained within this design guide is conservative yet is well below that detailed within AS4100-1998, section 9.6.2.

OrbiPlate™ is able to be used much closer to an edge than a standard bolted connection because in shear, the much larger hole and bearing area of the large washer resists the "ply in bearing force" as defined in AS4100-1998 section 9.3.2.4 & NZS3404.1:1997 9.3.2.4.

AS4100-1998 section 1.5.1 states that "This standard shall not be interpreted so as to prevent the use of materials or methods of design or construction not specifically referred to herein, provided the requirements of section 3 are complied with".

NZS 3404 part 1-1997 section 1.5 covers the use of alternate materials or methods. It states "designing using methods and or materials not covered in the standard shall be permitted provided the requirements of section 3 are complied with.

Hence the minimum edge distance of 10mm is appropriate to either cut or formed edges and is more than sufficient to prevent tear out or ply in bearing failure.



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We have developed this set of easily recognisable icons to assist with product selection.

PERFORMANCE RELATED SYMBOLS

Indicates the suitability of product to specific types of performance related situations.

Has good resistance to cyclic and dynamic loading. Resists loosening under vibration.

Suitable for elevated temperate applications. Structural anchor components made from steel. Any plastic or non-ferrous parts make no contribution to holding power under elevated temperatures.

Anchor has an effective pull-down feature, or is a stud anchor. It has the ability to clamp the fixture to the base material and provide high resistance to cyclic loading.

May be used close to edges (or another anchor) without risk of splitting the concrete.

Suitable for use in seismic design.

MATERIAL SPECIFICATION SYMBOLS

Indicates the base material and surface finish to assist in selection with regard to corrosion or environmental issues.

Zn — **Steel Zinc Plated** to AS1789-2003. Recommended for internal applications only.

GAL — **Steel Hot Dipped Galvanised** to AS4680-2006. For external applications.

GENERAL NOTATION

a = actual anchor spacing (mm)
a_c = critical anchor spacing (mm)
a_m = absolute minimum anchor spacing (mm)
A_b = reinforcing bar stress area (mm^2)
A_s = stress area (mm^2)
A_{st} = stress area of reinforcing bar (mm^2)
b_m = minimum substrate thickness (mm)
d_b = bolt diameter (mm)
d_f = fixture hole diameter (mm)
d_h = drilled hole diameter (mm)
e = actual edge distance (mm)
e_c = critical edge distance (mm)
e_m = absolute minimum edge distance (mm)
f'_c = concrete cylinder characteristic compressive strength (MPa)
f'_{cf} = concrete flexural tensile strength (MPa)
f_{sy} = reinforcing bar steel yield strength (MPa)
f_u = characteristic ultimate steel tensile strength (MPa)
f_y = characteristic steel yield strength (MPa)
h = anchor effective depth (mm)
h_n = nominal effective depth (mm)
g = gap or non-structural thickness (mm)

k_1 = see AS3600 - 2009
k_2 = see AS3600 - 2009
k_3 = see AS3600 - 2009
L = anchor length (mm)
L_e = anchor effective length (mm)
L_{st} = length of reinforcing bar to develop tensile stress σ_{st} (mm)
$L_{sy.t}$ = reinforcing bar length to develop steel yield in tension (mm)
$L_{sy.t\,(nom)}$ = length of reinforcing bar to develop full steel yield in 32 MPa concrete (mm)
L_t = thread length (mm)
n = number of fixings in a group
N_{sy} = tensile steel yield load capacity
N_{ub} = characteristic ultimate tensile adhesive bond capacity (kN)
P_L = long term, retained preload (kN)
P_{Li} = initial preload (kN)
P_r = proof load (kN)
t = total thickness of fastened material(s) (mm)
T_r = assembly torque (Nm)
X_e = edge distance effect, tension
X_{na} = anchor spacing effect, tension

X_{nae} = anchor spacing effect, end of a row, tension
X_{nai} = anchor spacing effect, internal to a row, tension
X_{nc} = concrete compressive strength effect, tension
X_{ne} = edge distance effect, tension
X_{uc} = characteristic ultimate capacity
X_{va} = anchor spacing effect, concrete edge shear
X_{vc} = concrete compressive strength effect, shear
X_{vd} = load direction effect, concrete edge shear
X_{vn} = multiple anchors effect, concrete edge shear
X_{vs} = corner edge shear effect, shear
X_{vsc} = concrete compressive strength effect, combined concrete/steel shear
X_{ns} = Cracked concrete service temperature limits effect
Z = section modulus (mm^3)
ß – = concrete cube characteristic compressive strength (N/mm^2)
μ_T = torque co-efficient of sliding friction
x = mean ultimate capacity
σ_{st} = steel tensile stress
$\sigma_{st\,(nom)}$ = steel tensile stress of reinforcing bar bonded into 32 MPa concrete

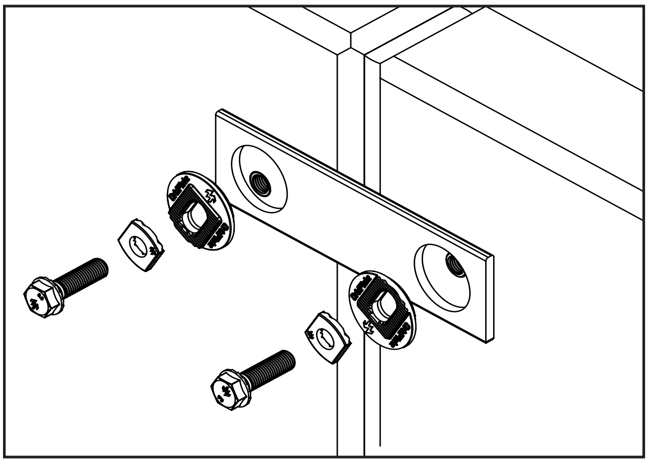
STRENGTH LIMIT STATE NOTATION

M^* = design bending action effect (kN.m)
M_u = characteristic ultimate moment capacity (kN.m)
N^* = design tensile action effect (kN)
N_{tf} = nominal ultimate bolt tensile capacity (kN)
N_u = characteristic ultimate tensile capacity (kN)
N_{uc} = characteristic ultimate concrete tensile capacity (kN)
N_{up} = characteristic ultimate pull-through capacity (kN)
N_{ucr} = factored characteristic ultimate concrete tensile capacity (kN)
N_{ur} = design ultimate tensile capacity (kN)
N_{urc} = design ultimate concrete tensile capacity (kN)
N_{urp} = design ultimate pull-through capacity (kN)

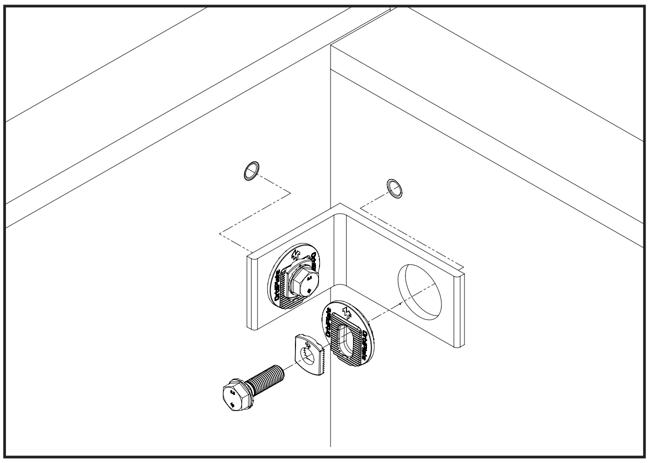
N_{us} = characteristic ultimate steel tensile capacity (kN)
N_{usr} = factored characteristic ultimate steel tensile capacity (kN)
R_u = characteristic ultimate capacity
V^* = design shear action effect (kN)
V_{sf} = nominal ultimate bolt shear capacity (kN)
V_u = ultimate shear capacity (kN)
V_{uc} = characteristic ultimate concrete edge shear capacity (kN)
V_{ur} = design ultimate shear capacity (kN)
V_{urc} = design ultimate concrete edge shear capacity (kN)
V_{us} = characteristic ultimate steel shear capacity (kN)

V_{usc} = characteristic ultimate combined concrete/steel shear capacity (kN)
$Ø$ = capacity reduction factor
$Ø_c$ = capacity reduction factor, concrete tension recommended as 0.6
$Ø_m$ = capacity reduction factor, steel bending recommended as 0.8
$Ø_n$ = capacity reduction factor, steel tension recommended as 0.8
$Ø_q$ = capacity reduction factor, concrete edge shear recommended as 0.6
$Ø_v$ = capacity reduction factor, steel shear recommended as 0.8
$Ø_p$ = capacity reduction factor, pull-through recommended as 0.65

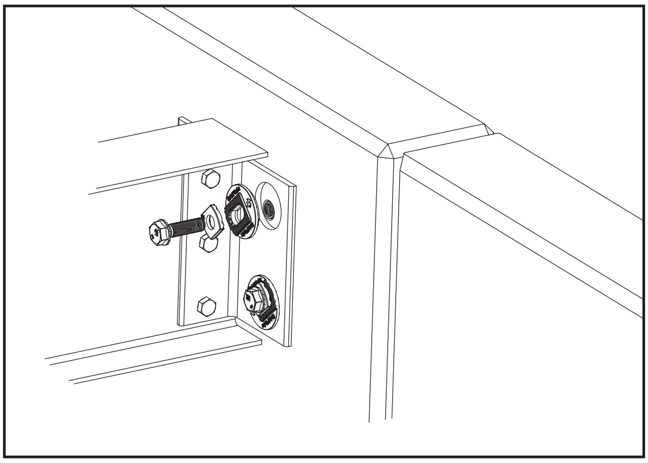
Capacity reduction factors are as per the applicable Australian Standards, i.e, AS3600:2009 for concrete factors and AS4100:1998 for steel factors.



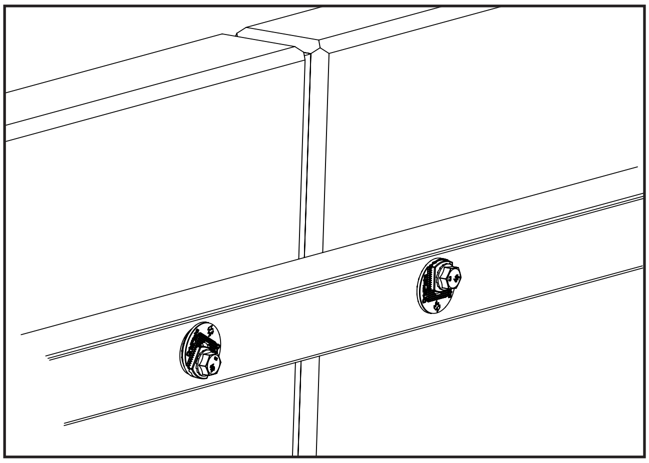
Straight panel to panel connection



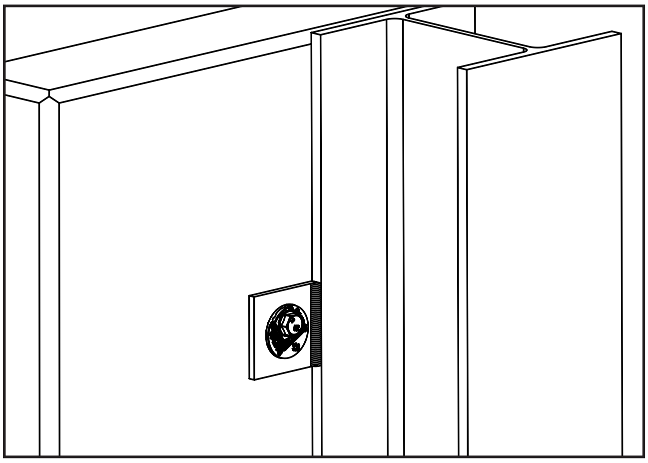
Corner panel to panel connection



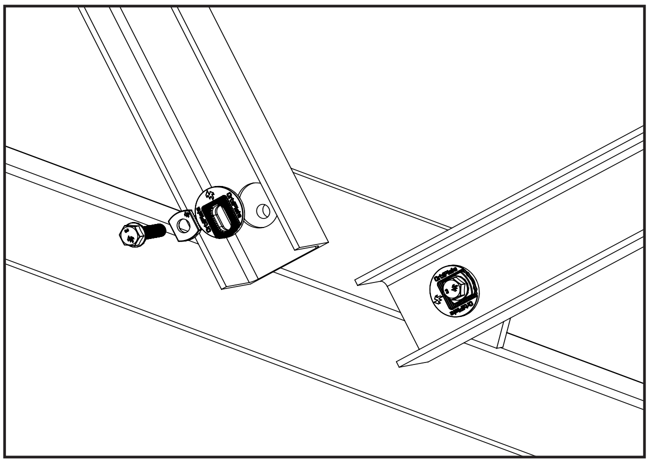
Roof beam to panel connection



Raker angle to panel connection

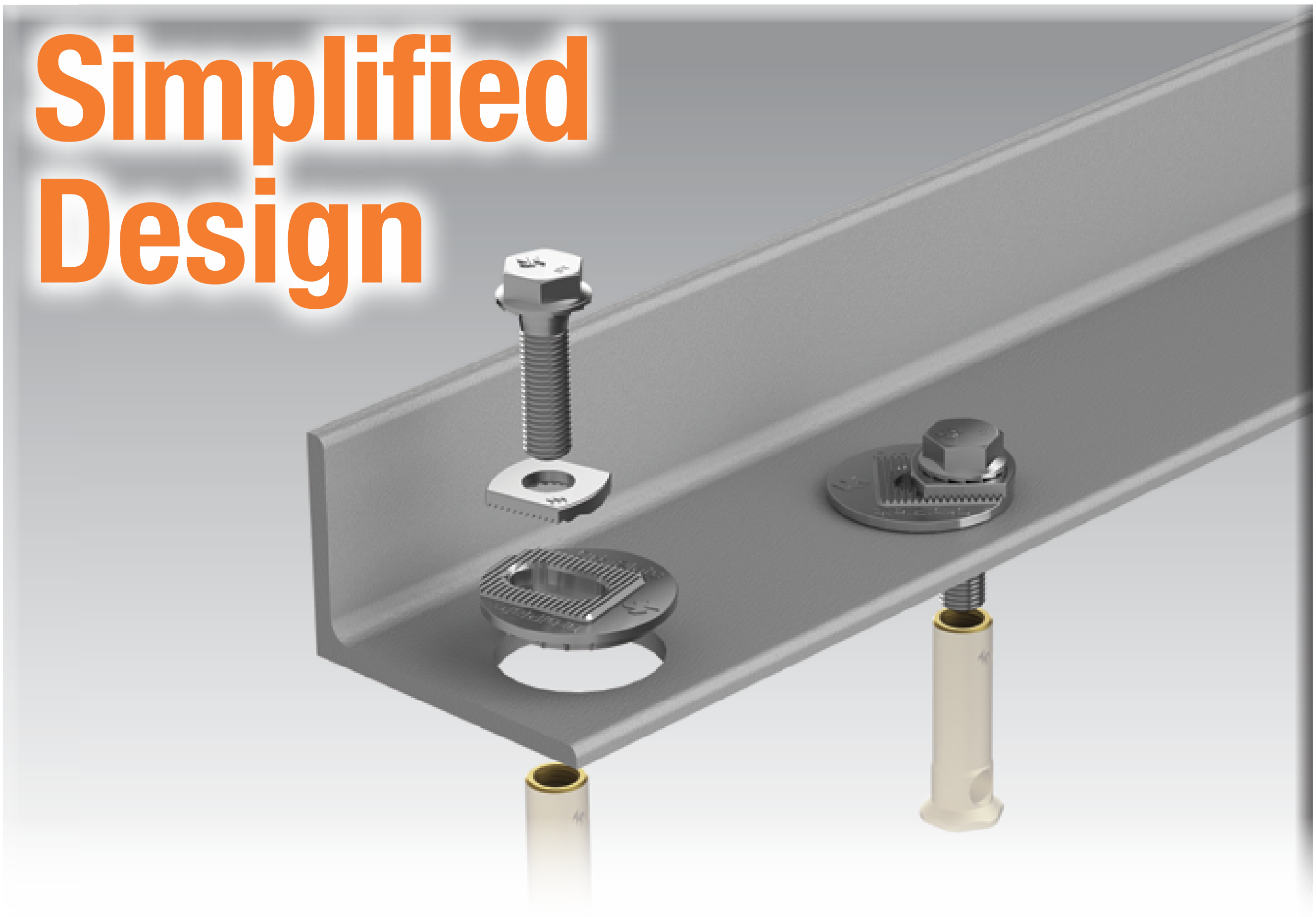


Column to panel connection



Steel to steel connection

For many more examples of OrbiPlate™ applications, visit www.reid.com.au and review the numerous case studies on the OrbiPlate™ page



This information is provided for the guidance of qualified structural engineers or other suitably skilled persons in the design of connections. It is the designer's responsibility to ensure compliance with the relevant standards, codes of practice, building regulations, workplace regulations and statutes as applicable.

This manual allows the designer to determine load carrying capacities based on actual application and installation conditions, then select an appropriate connection to meet the required load case through the use of the simplified design process to arrive at recommendations in line with strength limit state design principles.

ramsetreid™ has developed this Simplified Design Approach to achieve strength limit state design, and to allow for rapid selection of a suitable connection and through systematic analysis, establish that it will meet the required design criteria under strength limit state principles. The necessary diagrams, tables etc. for each specific product are included in this publication.

We have developed this design process to provide accurate anchor performance predictions and allow appropriate design solutions in an efficient and time saving manner.

Our experience over many years of anchor design has enabled us to develop this process which enables accurate and quick solutions without the need to work laboriously from first principles each time.

Preliminary Selection

Establish the design action effects, N* and V* (Tension and Shear) acting on each anchor being examined using the appropriate load combinations detailed in the AS1170 series of Australian Standards and NZS1170 series of New Zealand Standards.

STEP 1 Select the size OrbiPlate™ to be used

Refer to table 1a, 'Indicative combined loading – Interaction Diagram', looking up N* and V* to check if the size and number of OrbiPlate™ fixings are likely to meet the design requirements.

Note that the Interaction Diagram is for a specific concrete compressive strength and does not consider edge distance and anchor spacing effects, hence is a guide only and its use should not replace a complete design process.

ACTION: Note down the anchor size selected.

Having selected an anchor size, check that the design values for edge distance and anchor spacing comply with the absolute minima detailed in table 1b. If your design values do not comply, adjust the design layout.

ACTION: Note down the edge and spacing distances.

: Note also the product part numbers referenced.

CHECK POINT 1

OrbiPlate™ and Reid™ footed ferrule combination selected ?

Absolute minima compliance achieved ?

STEP 2 Verify concrete tensile capacity - per anchorage

Referring to table 2a, determine the reduced characteristic ultimate concrete tensile capacity (ØNuc). This is the basic capacity, uninfluenced by edge distance or anchor spacing and is for the specific concrete compressive strength(s) noted.

ACTION: Note down the value for $ØN_{uc}$

Calculate the concrete compressive strength effect, tension, Xnc by referring to table 2b. This multiplier considers the influence of the actual concrete compressive strength compared to that used in table 2a above.

ACTION: Note down the value for X_{nc}

If the concrete edge distance is close enough to the anchor being evaluated, that anchors tensile performance may be reduced. Use table 2c, edge distance effect, tension, Xne to determine if the design edge distance influences the anchors tensile capacity.

ACTION: Note down the value for X_{ne}

For designs involving more than one anchor, consideration must be given to the influence of anchor spacing on tensile capacity. Use either of tables 2d or 2e to establish the anchor spacing effect, tension, Xnae or Xnai.

ACTION: Note down the value of X_{nae} or X_{nai}

CHECK POINT 2

Design reduced concrete tensile capacity, $ØN_{urc}$

$$ØN_{urc} = ØN_{uc} * X_{nc} * X_{ne} * (X_{nae} \text{ or } X_{nai}) \text{ (kN)}$$

This calculation takes into consideration the influences of concrete compressive strength, edge distance and anchor spacing to arrive at the design reduced concrete tensile capacity.

ACTION: Note down the value of $ØN_{urc}$

Simplified Design

STEP 3 Verify anchor tensile capacity - per anchorage

Having calculated the concrete tensile capacity above ($ØN_{urc}$), consideration must now be given to other tensile failure mechanisms.

Calculate the reduced characteristic ultimate steel tensile capacity ($ØN_{us}$) from table(s) 3a.

ACTION: Note down the value of $ØN_{us}$

Now that we have obtained capacity information for all tensile failure mechanisms, verify which one is controlling the design.

CHECK POINT 3

Now that we have obtained capacity information for all tensile failure mechanisms, verify which one is controlling the design.

Design reduced ultimate tensile capacity, $ØN_{ur}$

$ØN_{ur}$ = minimum of $ØN_{urc}$, $ØN_{us}$

Check $N^* / ØN_{ur} \leq 1$,

if not satisfied return to step 1

This completes the tensile design process; we now look to verify that adequate shear capacity is available.

STEP 4 Verify concrete shear capacity - per anchorage

Referring to table 4a, determine the reduced characteristic ultimate concrete edge shear capacity ($ØV_{uc}$). This is the basic capacity, uninfluenced by anchor spacings and is for the specific edge distance and concrete compressive strength(s) noted.

ACTION: Note down the value for $ØV_{uc}$

Calculate the concrete compressive strength effect, shear, X_{vc} by referring to table 4b. This multiplier considers the influence of the actual concrete compressive strength compared to the nominal value used in table 4a above.

ACTION: Note down the value for X_{vc}

The angle of incidence of the shear load acting towards an edge is considered through the factor X_{vd}, load direction effect, shear.

Use table 4c to establish its value.

ACTION: Note down the value for X_{vd}

For a row of anchors located close to an edge, the influence of the anchor spacing on the concrete edge shear capacity is considered by the factor X_{va}, anchor spacing effect, concrete edge shear.

Note that this factor deals with a row of anchors parallel to the edge and assumes that all anchors are loaded equally.

If designing for a single anchor, $X_{va} = 1.0$

ACTION: Note down the value for X_{va}

In order to distribute the concrete edge shear evenly to all anchors within a row of anchors aligned parallel to an edge, calculate the multiple anchors effect, concrete edge shear, X_{vn}.

If designing for a single anchor, $X_{vn} = 1.0$

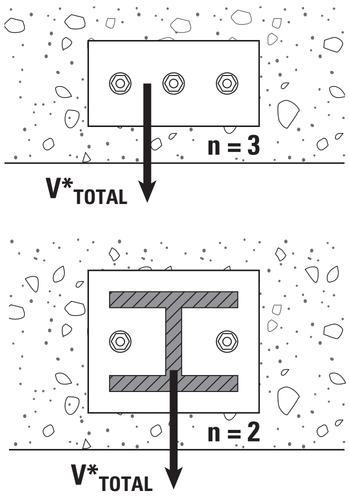
ACTION: Note down the value for X_{vn}

To allow for the combined effects of 2 concrete edges when anchoring near a corner, calculate the corner edge shear effect, shear, X_{vs}.

If designing for a single edge, $X_{vs} = 1.0$

ACTION: Note down the value for X_{vs}

Examples



CHECK POINT 4

Design reduced concrete shear capacity, $ØV_{urc}$

$$ØV_{urc} = ØV_{uc} * X_{vc} * X_{vd} * X_{va} * X_{vn} * X_{vs} \text{ (kN)}$$

This calculation takes into consideration the influences of concrete compressive strength, edge distance and anchor spacing to arrive at the design reduced concrete shear capacity.

For a design involving two or more anchors in a row parallel to an edge, this value is the average capacity of each anchor assuming each is loaded equally.

ACTION Note down the value of $ØV_{urc}$

STEP 5 Verify anchor shear capacity - per OrbiPlate™ and Reid™ footed Ferrule Combination

Having calculated the concrete shear capacity above ($ØV_{urc}$), consideration must now be given to other shear failure mechanisms.

Calculate the reduced characteristic ultimate steel shear capacity ($ØV_{usc}$) from table(s) 5a (i).

ACTION: Note down the value for $ØV_{usc}$

Calculate the concrete compressive strength effect, combined concrete/steel shear, X_{vsc} by refering to table 5a (ii). This multiplier considers the influence of the actual concrete compressive strength, compared to the nominal value in table 5a (i).

ACTION: Note down the value for X_{vsc}

Calculate $ØV_{us}$ by multiplying $ØV_{usc}$ and X_{vus}

$$ØV_{us} = ØV_{usc} * X_{vsc}$$

CHECK POINT 5

Design reduced shear capacity, $ØV_{ur}$

Now that we have obtained capacity information for all shear failure mechanisms, verify which one is controlling the design.

$ØV_{ur}$ = minimum of $ØV_{urc}$, $ØV_{us}$,

Check $V^* / ØV_{ur} \leq 1$,

if not satisfied return to step 1

This completes the shear design process, we now look to verify that adequate combined capacity is available for load cases having both shear and tensile components.

STEP 6 Combined loading and specification

For load cases having both tensile and shear components, verify that the relationship represented here is satisfied.

CHECK POINT 6

Check

$$N^*/ØN_{ur} + V^*/ØV_{ur} \leq 1.2,$$

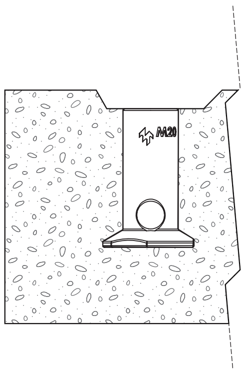
if not satisfied return to step 1

Specify the product to be used as detailed.

Note it is the Design Engineer's responsibility to ensure that the fixture plate is adequate for the design loads in accordance with AS4100-1998 / NZS 3404:1997.

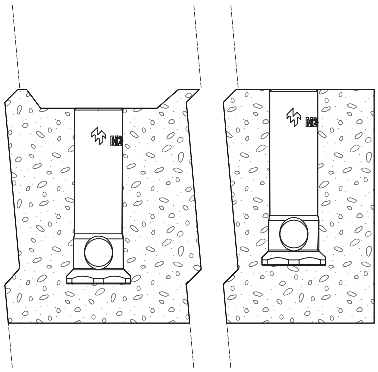
The following worked example is based on the use of OrbiPlate™ with Australian Elephant Foot™ ferrules. The same approach is used for New Zealand except for the ferrule selected.
However please note that use with Reid™ New Zealand TIM20x75G ferrules requires that a nail plate (part number NP20) be specifed so that the ferrule is positioned below the concrete surface (as shown) with a recess above the ferrule. This ensures that the M20 class 8.8 bolt does not bottom out inside the ferrule.
Reid™ Australia Elephant Foot™ ferrules can be installed either with or without nail plates as they are slightly longer, and their performance data is not affected by the use of a nail plate.

Reid™ New Zealand TIM footed ferrule



Install with NP20 nail plate

Reid™ Australia Elephant Foot™ ferrule



May be Installed with or without nail plate

Verify capacity of the anchors detailed below:

Concrete compressive strength	f'_c	40 MPa
Design tensile action effect	N^*_{TOTAL}	45 kN
Design shear action effect	V^*_{TOTAL}	75 kN
Edge distance	e	100 mm
Anchor spacing	a	150 mm
Fixture plate	t	12 mm
No. of anchors in shear	n	3

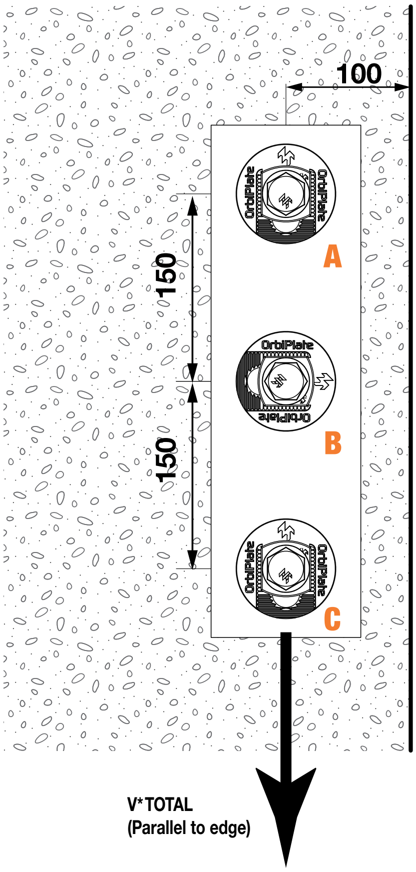
As the design process considers design action effects PER anchor, distribute the total load case to each anchor as is deemed appropriate.

In this case, equal load distribution is considered appropriate hence,

Design tensile action effect (per anchor)	N*	15 kN
Design shear action effect (per anchor)	V*	25 kN

Given that the 'interior' anchor is influenced by two adjacent anchors, verify capacity for anchor 'B' in this case.

Having completed the preliminary selection component of the design process, commence the Strength Limit State Design process.



Select anchor to be evaluated

Refer to table 1a, 'Indicative combined loading – interaction diagram' on page 20. Applying both the N* value and V* value to the interaction, it can be seen that the intersection of the two values falls within the M16 & M20 bands.

ACTION: M20 anchor size selected.

Confirm that absolute minima requirements are met.

From table 1b (page 20) for M20, it is required that edge distance, $e > 60$ mm. and that anchor spacing, $a > 80$ mm.

The design values of $e = 100$ mm and $a = 150$ mm comply with these minima, hence continue to step 1c.

Anchor size selected ?	M20
Absolute minimum compliance achieved ?	Yes

STEP 2 Verify concrete tensile capacity - per anchor

Referring to table 2a, consider the value obtained for an M20 OrbiPlate.

ACTION: $ØN_{uc} = 48.0$ kN

Verify the concrete compressive strength effect, tension, X_{nc} value from table 2b.

ACTION: $X_{nc} = 1.12$

Verify the edge distance effect, tension, X_{ne} value from table 2c.

ACTION: $X_{ne} = 0.81$

As we are considering anchor 'B' for this example, use table 2e on page 21 to verify the anchor spacing effect, internal to a row, tension, X_{nai} value. If we were inspecting anchors 'A' or 'C' we would use table 2d for anchors at the end of a row.

ACTION: $X_{nai} = 0.55$

CHECK POINT 2

Design reduced concrete tensile capacity, $ØN_{urc}$

$$ØN_{urc} = ØN_{uc} * X_{nc} * X_{ne} * X_{nai} \quad \text{(kN)}$$
$$= 48.0 * 1.12 * 0.81 * 0.55$$
$$= 23.9 \text{ kN}$$

ACTION: $ØN_{urc} = 23.9$ kN

STEP 3 Verify anchor tensile capacity - per anchor

From table 3a, verify the reduced characteristic ultimate steel tensile capacity, $ØN_{us}$.
For an M20 OrbiPlate™ & FE20095 Ferrule $ØN_{us}$ = 96.8 kN.

ACTION: $ØN_{us}$ = 96.8 kN

CHECK POINT 3

$ØN_{ur}$ = minimum of $ØN_{urc}$, $ØN_{us}$

In this case $ØN_{ur}$ = 23.9 kN (governed by concrete capacity).

Check $N^* / ØN_{ur} \leq 1$,

15 / 23.9 = 0.63 ≤ 1 Tensile design criteria satisfied, proceed to Step 4.

STEP 4 Verify concrete shear capacity - per anchor

Referring to table 4a, consider the value obtained for an M20 anchor at e = 100 mm.

ACTION: $ØV_{uc}$ = 26.6 kN

Verify the concrete compressive strength effect, tension, X_{vc} value from table 4b.

ACTION: X_{vc} = 1.12

Verify the load direction effect, concrete edge shear, X_{vd} value using table 4c.

ACTION: X_{vd} = 2.00 for angle of 90 degrees to normal.

Verify the anchor spacing effect, concrete edge shear, X_{va} value using table 4d.

ACTION: X_{va} = 0.80

In order to distribute the shear load evenly to all anchors in the group, the multiple anchors effect, concrete edge shear, X_{vn} value is retrieved from table 4e.

The ratio of (a / e) for this design case is 150 / 100 = 1.5.

ACTION: $X_{vn} = \frac{0.91 + 0.93}{2} = 0.92$

Verify anchor at a corner effect, concrete edge shear, X_{vs}

ACTION: X_{vs} = 1.00

CHECK POINT 4

Design reduced concrete shear capacity, $ØV_{urc}$

$$ØV_{urc} = ØV_{uc} * X_{vc} * X_{vd} * X_{va} * X_{vn} * X_{vs} \text{ (kN)}$$
$$= 26.6 * 1.12 * 2.0 * 0.80 * 0.92 * 1.00$$
$$= 43.8 \text{ kN}$$

ACTION: $ØV_{urc}$ = 43.8 kN

Worked Example

STEP 5 Verify anchor shear capacity - per anchor

From table 5a, (i) verify the reduced characteristic ultimate steel shear capacity, $ØV_{usc}$ M20 & t = 12mm

ACTION: $ØV_{usc}$ = 38.3 kN

From table 5a, (ii) verify the concrete compressive strength effect, shear, X_{vsc}

ACTION X_{vsc} = 1.08

$$ØV_{us} = ØV_{USC} \times X_{vsc}$$
$$= 38.3 \times 1.08$$
$$= 41.4 \text{ kN}$$

CHECK POINT 5

$ØV_{ur}$ = minimum of $ØV_{urc}$, $ØV_{us}$

In this case $ØV_{ur}$ = 41.4 kN (governed by Steel capacity).

Check $V^* / ØV_{ur} \leq 1$,

$25 / 41.4 = 0.60 \leq 1$

Shear design criteria satisfied, proceed to Step 6.

STEP 6 Combined loading and specification

CHECK POINT 6

Check that the combined loading relationship is satisfied:

$N^*/ØN_{ur} + V^*/ØV_{ur} \leq 1.2$,

15.0 / 23.9 + 25 / 41.5 = 1.23 > 1.2

Combined loading criteria FAILED.

Review the design process and examine the critical factors influencing the overall anchor capacity.

For tension (governed by concrete failure),

$ØN_{uc}$ = 48.0 kN
X_{nc} = 1.12
X_{ne} = 0.81
X_{nai} = 0.55

It can be seen from the above values that whilst the concrete compressive strength effect, X_{nc} improves the design ultimate tensile capacity, the anchor spacing effect, X_{nai} significantly reduces design ultimate tensile capacity.

Possible solution: Increase anchor spacing to raise the value of X_{nai}.

For shear (governed by concrete failure),

$ØV_{uc}$ = 26.6 kN
X_{vc} = 1.12
X_{vd} = 2.0
X_{va} = 0.8
X_{vn} = 0.92
X_{vs} = 1.00

Again, the concrete compressive strength effect, X_{vc} improves the design ultimate shear capacity. Anchor spacing effect, X_{va} reduces the design ultimate shear capacity.

Possible solution: Increase anchor spacing to raise the value of X_{va}.

Note that increasing the anchor spacing for this design will improve X_{nai}, X_{va} and X_{vn}.

Re-consider the design using the adjusted values with anchor spacing, "a" set at 200 mm.

$ØN_{uc}$ = 48.0 kN
X_{nc} = 1.12
X_{ne} = 0.81
X_{nai} = 0.73

Hence $ØN_{urc}$ = 31.8 kN (at a = 200 mm).

$ØV_{uc}$ = 26.6 kN
X_{vc} = 1.12
X_{vd} = 2.0
X_{va} = 0.9
X_{vn} = 0.96 (at a = 200 mm, hence a / e = 2.0)
X_{vs} = 1.00

Hence $ØV_{urc}$ = 41.5 kN (still limited by steel shear).

Now,

$N^*/ØN_{ur} + V^*/ØV_{ur} \leq 1.2$,

15 / 31.8 + 25/41.5 = 1.07 < 1.2

Combined loading criteria PASSES.

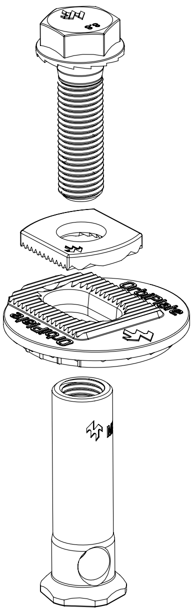
Specify

Reid™ OrbiPlate™
M20 HDG (ORB2020BGH)

Reid™ Elephant Foot™ Ferrules
M20 x 95 HDG (FE20095GH)

Note it is the Design Engineer's responsibility to ensure that the fixture plate is adequate for the design loads in accordance with AS4100-1998.

OrbiPlate™ & Reid™ Footed Ferrule Combination



OrbiPlate™ & Reid™ Elephant Foot™ Ferrule (Aust)

GENERAL INFORMATION

Product

OrbiPlate™ overcomes the main headache that comes with bolted connections, getting the holes to line up!

Features

- A large washer with an elongated slot surrounded by teeth that lock the smaller washer in place, positioning the main structural bolt in alignment with the ferrule even with up to 20mm misalignment

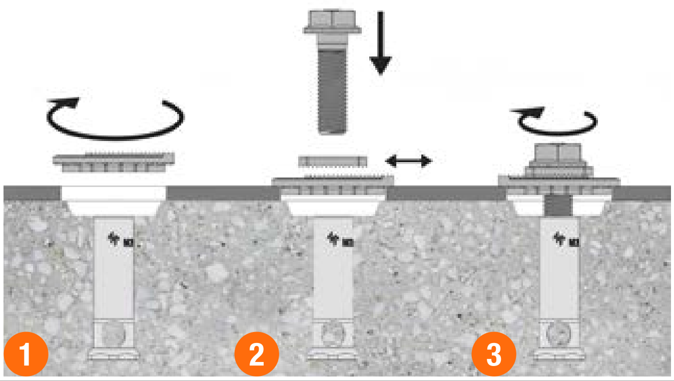
Advantage

- Provides 20mm positional tolerance.
- Fine positional adjustment
- No rotation under shear load.

Benefits

- High structural capacity
- Allows fine positional adjustment
- Avoids misalignment delays and call outs.
- No hot work required on site.

Installation



Step 1 (TWIST IT)
Place the large washer in the 70mm fixture hole and rotate until the slot lines up with the ferrule.

Step 2 (SLIDE IT)
Move small washer along slot until it aligns with ferrule.

Step 3. (FIX IT)
Insert the bolt and tighten to specified torque.

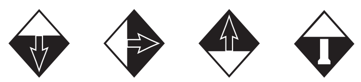
Principal Applications

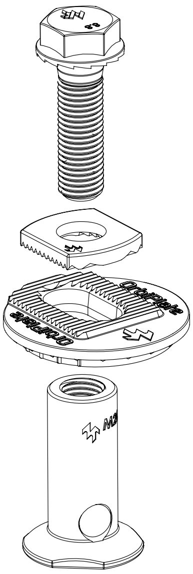
- **Panel to panel fixing**
- **Raker Angles**
- **Roof beams to walls**
- **Panels to steel columns**

Performance Related

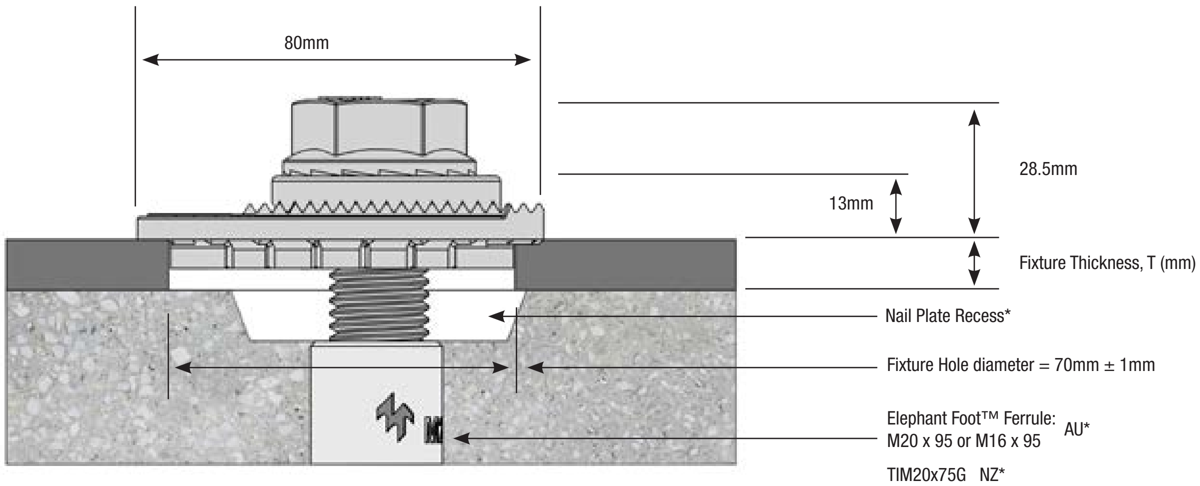
Material

Installation Related





OrbiPlate™ & Reid™ TIM Footed Ferrule (NZ) installed with a nail plate, NP20



** Note that use with Reid™ New Zealand TIM20x75G ferrules requires that a nail plate (part number NP20) be specifed so that the ferrule is positioned below the concrete surface (as shown) with a recess above the ferrule. This ensures that the M20 class 8.8 bolt does not bottom out inside the ferrule.*

Reid™ Australia FE Ferrules can be installed either with or without nail plates as they are slightly longer, and their performance data is not affected by the use of a nail plate.

OrbiPlate™ & Reid™ Footed Ferrule Combination

The following design information is for the OrbiPlate™ when used in combination with Reid™ Ferrules. This design information is not applicable if OrbiPlate™ is used with other ferrules as a reduction in capacity can be expected.

Installation and Performance Details

Country	Anchor Size (mm)	OrbiPlate™ Part Number	Ferrrule Part Number	Fixture hole dia (mm)	Tightening Torue, T (Nm)	Optimum dimensions *		Fixture thickness (mm)	Reduced Characteristic Capacity					
									Shear, $ØV_{usc}$ (kN)			Tension , $ØN_{uc}$ (kN) **		
						Edge Distance, e_c (mm)	Anchor spacing, a_c (mm)		Concrete compressive strength, f'_c			Concrete compressive strength, f'_c		
									20 MPa	32 MPa	40 MPa	20 MPa	32 MPa	40 MPa
Australia	M16	ORB2016BGH	FE16095GH	70 ± 1	94	135	270	6	33.2	39.0	42.1	33.9	42.9	48.0
								8	29.8	35.1	37.9			
								10	28.2	33.2	35.9			
								12	26.5	31.2	33.7			
	M20	ORB2020BGH	FE20095GH	70 ± 1	180	135	270	6	34.8	40.9	44.2	37.9	48	53.8
								10	33.7	39.6	42.8			
								12	32.6	38.3	41.4			
								16	31.5	37.0	40			
New Zealand	M20	ORB2020BGH	TIM20x75G with nail plate	70 ± 1	144	105	210	10 - 16mm	36.8	36.8	36.8	33.0	41.6	41.6

* Note: For shear loads acting towards an edge or where these optimal distances are not achievable, please use the simplified strength limit state design process to verify capacity.

** Note: Reduced characteristic ultimate tenbsile capacity = $ØN_{UC}$ where Ø = 0.6 and N_{UC} = Characteristic ultimate concrete tensile capacity.

DESCRIPTION AND PART NUMBERS

OrbiPlate™

Ferrule size, d_b	Washer OD (mm)	Fixture Hole ø (mm)	Bolt	Hex Head AF (mm)	Part No.
					Gal
M16	80	70 ± 1	M16 x 50	30	ORB2016BGH
M20	80	70 ± 1	M20 x 60	30	ORB2020BGH

Ferrules

Country	Ferrule size, d_b	Ferrule OD (mm)	Ferrule length, L (mm)	Effective depth, h (mm)	Thread length, L_t (mm)	Cross hole to suit	Part No.
							Gal
Australia	M16	22	95	91	32	N12	FE16095GH
	M20	26	95	91	38	N12	FE20095GH
New Zealand	M20	30	75	70	32	N12	TIM20x75G

Effective depth, h (mm). Read value from "Description and Part Numbers" table.

ENGINEERING PROPERTIES

OrbiPlate™

Size	Bolt Stress area (mm^2)	Yield Strength, f_y (MPa)	Ult Strength, f_U (MPa)	Hex Head A/F (mm)	Section Modulus, Z (mm^3)
M16	157	664	830	30	277.5
M20	245	664	830	30	540.9

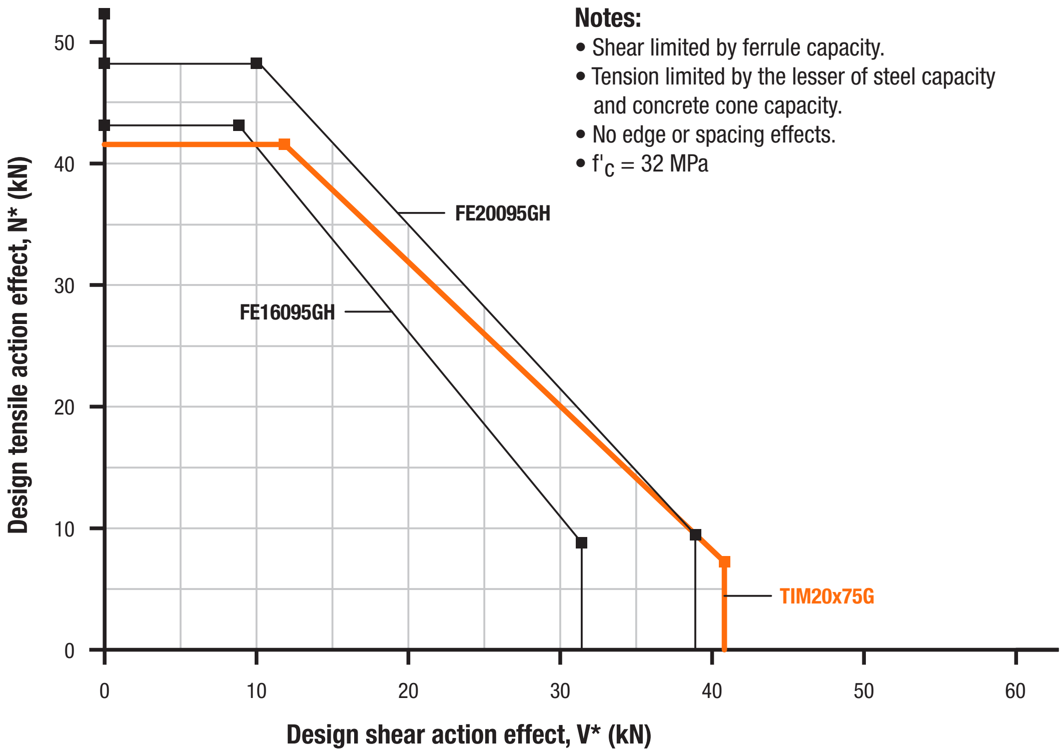
Reid™ Footed Ferrules

Country	Part Number	Ferrule size, d_b	Stress area threaded section, A_s (mm^2)	Carbon Steel		Section modulus, Z (mm^3)
				Yield strength, f_y (MPa)	Ult Strength f_u (MPa)	
Australia	FE16095GH	M16	158.0	400	500	692.8
	FE20095GH	M20	242.0	400	500	1034.0
New Zealand	TIM20x75G	M20	263.4	240	400	3174.0

Strength Limit State Design / OrbiPlate™ & Reid™ Footed Ferrules

STEP 1 Select anchor to be evaluated

Table 1a - Indicative combined loading – interaction diagram



Notes:
- Shear limited by ferrule capacity.
- Tension limited by the lesser of steel capacity and concrete cone capacity.
- No edge or spacing effects.
- f'_C = 32 MPa

Table 1b - Absolute minimum edge distance and anchor spacing values, e_m and a_m (mm)

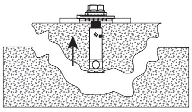
Ferrule size, d_b	M16	M20
e_m	48	60
a_m	90	90

CHECK POINT 1 Anchor size determined, absolute minima compliance achieved.

Strength Limit State Design / OrbiPlate™ & Reid™ Footed Ferrules

STEP 2 Verify concrete tensile capacity - per anchor

Table 2a - Reduced characteristic ultimate concrete tensile capacity, $ØN_{uc}$ (kN), $Ø_c$ = 0.6, f'_c = 32 MPa

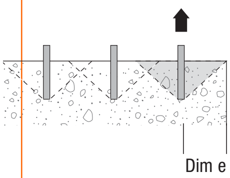


		h (mm)	e_c (mm)	M16	M20
Australia	FE**095GH	91	136.5	42.9	48
New Zealand	TIM20x75G	70	105		41.6

Table 2b - Concrete compressive strength effect, tension, X_{nc}

f'_c (MPa)	15	20	25	32	40	50
X_{nc}	0.68	0.79	0.88	1.00	1.12	1.25

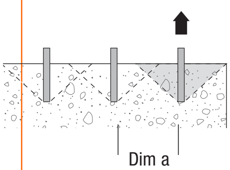
Table 2c - Edge distance effect, tension, X_{ne}



		h_{EF}	e_c	60	65	70	75	80	90	100	120	140
Australia	FE**095GH	91	136.5		0.63	0.66	0.68	0.71	0.76	0.81	0.92	1.02
New Zealand	TIM20x75G	70	105	0.70	0.73	0.77	0.8	0.83	0.9	0.97	1.00	1.00

Table 2d - Anchor spacing effect, end of a row, tension, X_{nae}

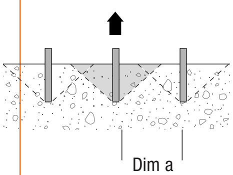
Note: For single anchor designs, X_{nae} = 1.0



		h	a_c	60	70	85	100	125	150	200	250	300
Australia	FE**095GH	91	273	0.61	0.63	0.66	0.68	0.73	0.77	0.87	0.96	1
New Zealand	TIM20x75G	70	210	0.64	0.67	0.7	0.74	0.8	0.86	1	1	1

Table 2e - Anchor spacing effect, internal to a row, tension, X_{nai}

Note: for single anchor designs, X_{nai} = 1.0



		h	a_c	60	70	85	100	125	150	200	250	300
Australia	FE**095GH	91	273	0.22	0.26	0.31	0.37	0.46	0.55	0.73	0.92	1
New Zealand	TIM20x75G	70	210	0.29	0.33	0.4	0.48	0.6	0.71	0.95	1	1

CHECK POINT 2

Design reduced ultimate concrete tensile capacity, $ØN_{urc}$

$$ØN_{urc} = ØN_{uc} * X_{nc} * X_{ne} * (X_{nae} \text{ or } X_{nai})$$

Strength Limit State Design / OrbiPlate™ & Elephant Foot™ Ferrules

STEP 3 Verify anchor tensile capacity - per anchor

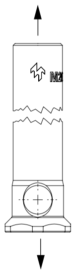


Table 3a - Reduced characteristic ultimate steel tensile capacity, $\emptyset N_{us}$ (kN), $\emptyset_n = 0.8$

		M16	M20
Australia	FE**095GH	63.2	96.8
New Zealand	TIM20x75G		84.3

Note: The Reid™ OrbiPlate™ bolts exceed the steel strength of the ferrule, hence need not be considered.

CHECK POINT 3

Design reduced ultimate tensile capacity, $\emptyset N_{ur}$

$\emptyset N_{ur}$ = minimum of $\emptyset N_{urc}$, $\emptyset N_{us}$,

Check $N^* / \emptyset N_{ur} \leq 1$,

if not satisfied return to step 1

Strength Limit State Design / OrbiPlate™ & Elephant Foot™ Ferrules

STEP 4 Verify concrete shear capacity - per anchor

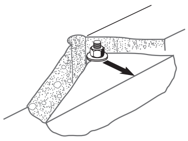
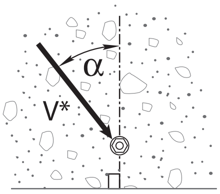


Table 4a - Reduced characteristic ultimate concrete edge shear capacity, $ØV_{uc}$ (kN), $Ø_q = 0.6$, $f'_c = 32$ MPa

Ferrule size, d_b	M16	M20
Edge distance, e (mm)		
50	8.7	
60	11.3	12.3
70	14.4	15.6
100	24.4	26.6
200	69.2	75.2
300	127.1	138.2
400	195.8	212.8
500		297.5

Table 4b - Concrete compressive strength effect, concrete edge shear, X_{vc}

f'_c (MPa)	15	20	25	32	40	50
X_{vc}	0.68	0.79	0.88	1.00	1.12	1.25



Load direction effect, conc. edge shear, X_{vd}

Table 4c - Load direction effect, concrete edge shear, X_{vd}

Angle, α°	0	10	20	30	40	50	60	70	80	90 - 180
X_{vd}	1.00	1.04	1.16	1.32	1.50	1.66	1.80	1.91	1.98	2.00

Table 4d - Anchor spacing effect, concrete edge shear, X_{va}

Note: For single anchor designs, $X_{va} = 1.0$

Edge distance, e (mm)	50	60	70	100	200	300	400	500	600
Anchor spacing, a (mm)									
90	0.86	0.80	0.76	0.68	0.59	0.56	0.55	0.54	0.53
100	0.90	0.83	0.79	0.70	0.60	0.57	0.55	0.54	0.53
125	1.00	0.92	0.86	0.75	0.63	0.58	0.56	0.55	0.54
150		1.00	0.93	0.80	0.65	0.60	0.58	0.56	0.55
200			1.00	0.90	0.70	0.63	0.60	0.58	0.57
300				1.00	0.80	0.70	0.65	0.62	0.60
450					0.95	0.80	0.73	0.68	0.65
600					1.00	0.90	0.80	0.74	0.70
750						1.00	0.88	0.80	0.75
1000							1.00	0.90	0.83
1250								1.00	0.92
1500									1.00

Strength Limit State Design / OrbiPlate™ & Reid™ Footed Ferrules

STEP 4
continued

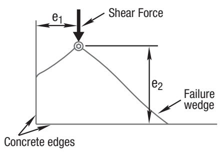
Table 4e - Multiple anchors effect, concrete edge shear, X_{vn}

Note: For single anchor designs, X_{vn} = 1.0

Anchor spacing / Edge distance, a / e	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.25	2.50
Number of anchors, n												
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	0.72	0.76	0.80	0.83	0.86	0.88	0.91	0.93	0.95	0.96	0.98	1.00
4	0.57	0.64	0.69	0.74	0.79	0.82	0.86	0.89	0.92	0.94	0.97	1.00
5	0.49	0.57	0.63	0.69	0.74	0.79	0.83	0.87	0.90	0.93	0.97	1.00
6	0.43	0.52	0.59	0.66	0.71	0.77	0.81	0.85	0.89	0.93	0.96	1.00
7	0.39	0.48	0.56	0.63	0.69	0.75	0.80	0.84	0.88	0.92	0.96	1.00
8	0.36	0.46	0.54	0.61	0.68	0.74	0.79	0.84	0.88	0.92	0.96	1.00
9	0.34	0.44	0.52	0.60	0.67	0.73	0.78	0.83	0.87	0.91	0.96	1.00
10	0.32	0.42	0.51	0.59	0.66	0.72	0.77	0.82	0.87	0.91	0.96	1.00
15	0.26	0.37	0.47	0.55	0.63	0.70	0.76	0.81	0.86	0.90	0.95	1.00
20	0.23	0.35	0.45	0.54	0.61	0.68	0.75	0.80	0.85	0.90	0.95	1.00

Table 4f - Anchor at a corner effect, concrete edge shear, X_{vs}

Note: For $e_1/e_2 > 1.25$, X_{vs} = 1.0



Edge distance, e_2 (mm)	50	60	75	125	200	300	400	600	900
Edge distance, e_1 (mm)									
50	0.86	0.77	0.67	0.52	0.44	0.39	0.37	0.35	0.33
60	0.97	0.86	0.75	0.57	0.47	0.41	0.38	0.36	0.34
75	1.00	1.00	0.86	0.64	0.51	0.44	0.41	0.37	0.35
125	1.00	1.00	1.00	0.86	0.65	0.53	0.48	0.42	0.38
200	1.00	1.00	1.00	1.00	0.86	0.67	0.58	0.49	0.42
300	1.00	1.00	1.00	1.00	1.00	0.86	0.72	0.58	0.49
400	1.00	1.00	1.00	1.00	1.00	1.00	0.86	0.67	0.55
500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.77	0.61
600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.86	0.67
900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.86

CHECK POINT 4

Design reduced ultimate concrete edge shear capacity, $ØV_{urc}$

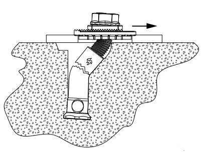
$$ØV_{urc} = ØV_{uc} * X_{vc} * X_{vd} * X_{va} * X_{vn} * X_{vs}$$

STEP 5

Verify anchor shear capacity - per anchor

Table 5a - Reduced characteristic ultimate steel shear capacity, $ØV_{us}$ (kN), $Ø_v$ = 0.6, f'_c = 32 MPa

(i) $ØV_{usc}$ Reduced characteristic ultimate combined concrete/steel shear capacity



Ferrule	OrbiPlate™	Fixture Thickness			
		6	8	12	16
FE16095GH	ORB2016BGH	39.0	35.1	31.2	
FE20095GH	ORB2020BGH	40.9	39.6	38.3	37.0
TIM20x75G	ORB2020BGH	56.0	50.0	42.0	37.0

(ii) X_{vsc} Concrete compressive strength effect, combined concrete/steel shear

f'_c (MPa)	15	20	25	32	40	50
X_{vsc}	0.77	0.85	0.92	1.00	1.08	1.16

$$ØV_{us} = ØV_{usc} * X_{vsc}$$

Strength Limit State Design / OrbiPlate™ & Reid™ Footed Ferrules

CHECK POINT 5

Design reduced ultimate shear capacity, $ØV_{ur}$

$ØV_{ur}$ = minimum of $ØV_{urc}$, $ØV_{us}$,

Check $V^* / ØV_{ur} \leq 1$,

if not satisfied return to step 1

STEP 6 Combined loading and specification

CHECK POINT 6

Check

$N^*/ØN_{ur} + V^*/ØV_{ur} \leq 1.2$,

if not satisfied return to step 1

HOW TO SPECIFY

Reid™ OrbiPlate™
(Thread size & Finish (Part Number))

Reid™ Elephant Foot™ Ferrule (AU), or Reid™ TIM Ferrule (NZ)
(Ferrule Size x Length) (Part Number)

EXAMPLE

Reid™ OrbiPlate™
M20 HDG (ORB2020BGH)

Australia
Reid™ Elephant Foot™ Ferrule, Gal
M20 x 95 (FE20095GH).

New Zealand
Reid™ TIM Ferrule, Gal
M20 x 75 (TIM20x75G)
installed with a nail plate, (NP20)

Please refer to Reid™ product guides for the range of accessories, (nailing plates, antenna caps, chairing solutions. etc.) that are available.

Note it is the Design Engineer's responsibility to ensure that the fixture plate is adequate for the design loads in accordance with AS4100-1998 / NZS3404:1997.

OrbiPlate™

GENERAL INFORMATION

Product

The patented OrbiPlate™ system is used when connecting steel to steel elements and delivers connection tolerances of up to 20mm where the ability to achieve fine locational accuracy when positioning each steel member is required.

Features

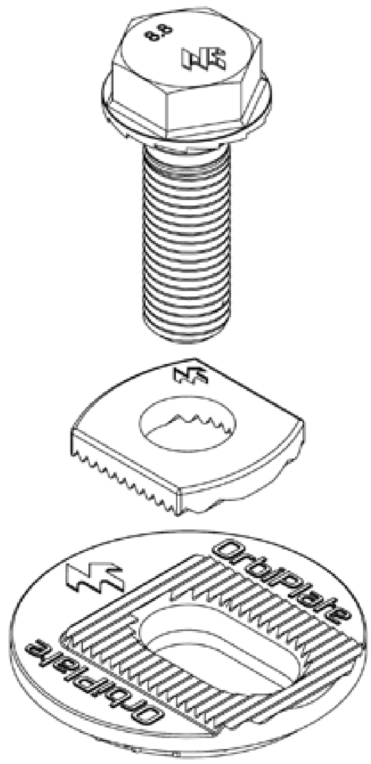
- A large washer with an elongated slot surrounded by teeth that locks the smaller washer in place, allowing positioning of the main structural bolt even with up to 20mm of misalignment.

Advantage

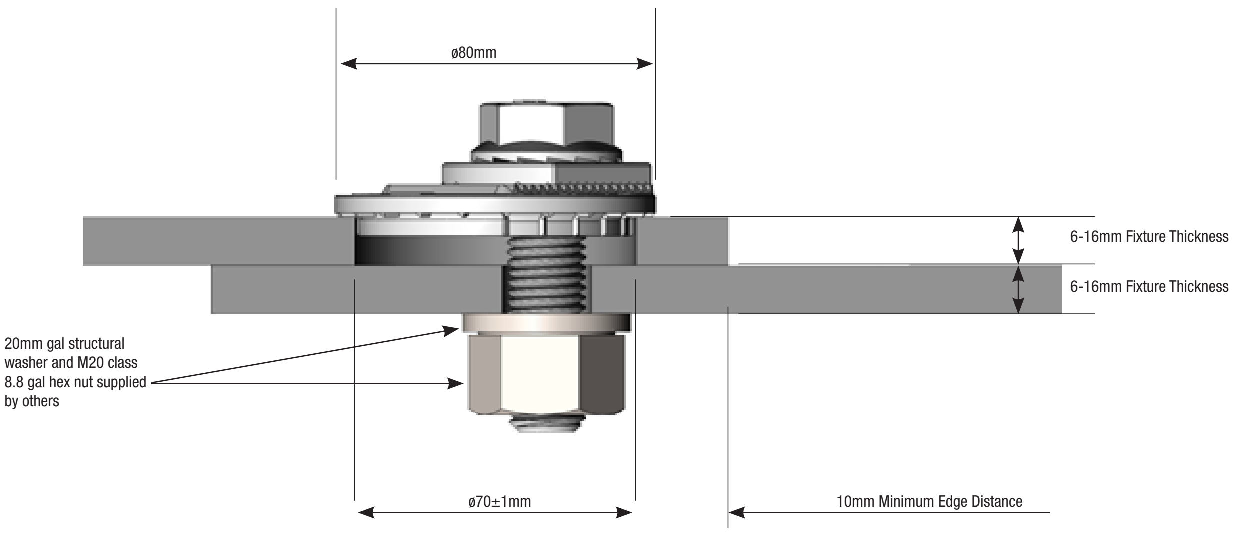
- Provides 20mm positional tolerance.
- Fine positional adjustment
- No rotation under shear load.

Benefits

- High structural capacity
- Allows fine positional adjustment
- Avoids misalignment delays and call outs.
- No hot work required on site.



Principal Applications
• Connecting steel elements where joint positional tolerance or adjustment is required without hot work such as complex facades



Strength Limit State Design / Steel to Steel Connection (through bolted)

STEP 1 Select anchor to be evaluated

Table 1a - Indicative combined loading – interaction diagram

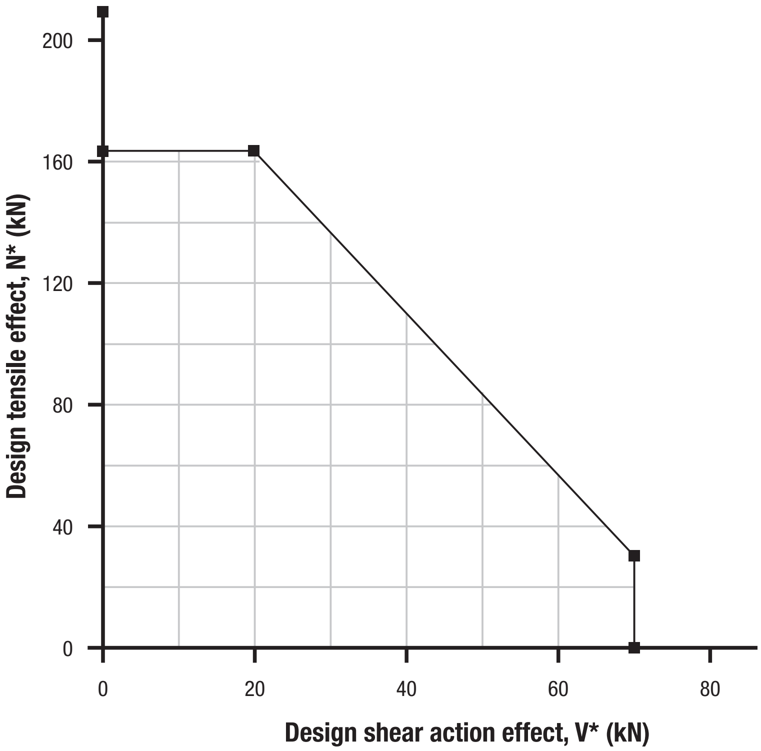


Table 1b - $ØN_{US}$ (kN), Reduced characteristic ultimate OrbiPlate steel tensile capacity, $ØN_{US}$ (kN), $Ø_N$ = 0.8

OrbiPlate	
ORB2020BGH	162.7

Step 1c - $ØV_{US}$ (kN), Reduced characteristic ultimate steel shear capacity, $ØV_{US}$ (kN), $Ø_V$ = 0.8

OrbiPlate	Fixture Thickness, T (mm)
	6 - 16
ORB2020BGH	70.0

CHECK POINT 1

Check $N^* / ØN_{US} \leq 1$, if not satisfied return to step 1

Check $V^* / ØV_{US} \leq 1$, if not satisfied return to step 1

Check $N^* / ØN_{US} + V^* / ØV_{US} \leq 1.0$,

Note it is the Design Engineer's responsibility to ensure that the fixture plate is adequate for the design loads in accordance with AS4100-1998 / NZS 3404:1997

DERIVATION OF CAPACITY

Internationally, design standards are becoming more probabilistic in nature and require sound Engineering assessment of both load case information and component capacity data to ensure safety as well as economy.

Published capacity data for Reid™ anchoring products are derived from Characteristic Ultimate Capacities.

From a series of controlled performance tests, Ultimate Failure Loads are established for a product.

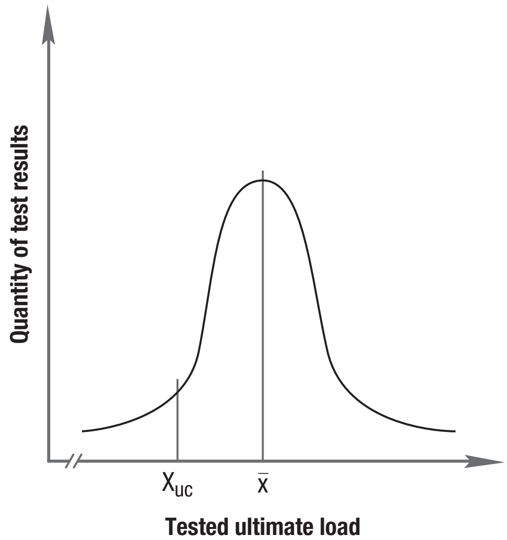
Obviously, the value obtained in each test will vary slightly, and after obtaining a sufficient quantity of test samples, the Ultimate Failure Loads are able to be plotted on a chart.

Test values will typically centre about a mean value.

Once the mean Failure Load is established, a statistically sound derivation is carried out to establish the Characteristic Ultimate Capacity which allows for the variance in results as well as mean values.

The Characteristic Value chosen is that which ensures that a 90% confidence is obtained that 95% of all test results will fall above this value.

From this value, and dependent on local design requirements, the design professional may then undertake either a strength limit state or working load design assessment of the application at hand, confident that they are working with state of the art capacity information.



$\bar{x}$ = Mean Ultimate Capacity
X_{uc} = Characteristic Ultimate Capacity

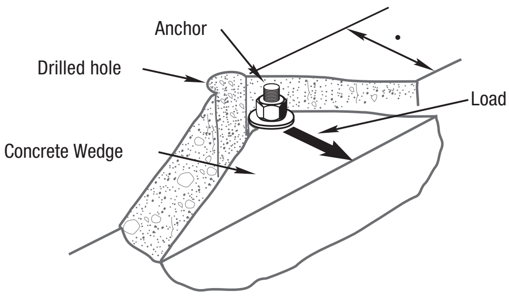
GENERAL

Reid™ footed ferrules are high quality, precision made fixings designed to give optimal performance.
Resistance to tensile loads is provided by engagement of the foot of the ferrule, deep in the concrete.

Generally, shear load resistance mechanisms are more uniform amongst anchors, and comprise these elements:

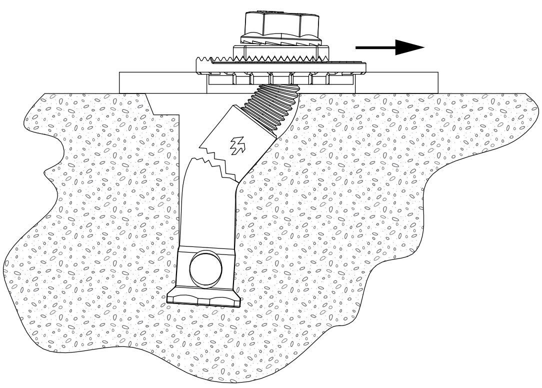
- the bolt or stud, and the body of the ferrule.
- the ability of the ferrule to resist the bending moment induced by the shear force.
- the compressive strength of the concrete.
- the shear and tensile strength of the concrete at the surface of the potential concrete failure wedge.

When loaded to failure in concrete shear, an anchor located near an edge breaks a triangular wedge away from the concrete.



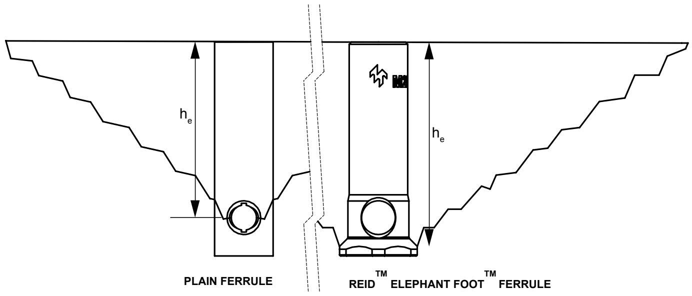
CONCRETE WEDGE FAILURE MODE

When loaded to failure in concrete shear, a cast in anchor located away from an edge in normal strength concrete often fails below the surface of the concrete in a concrete /steel failure.



FOOTED FERRULES VS PLAIN FERRULES

Reid™ footed ferrules offer the design Engineer far superior performance and features over a conventual plain ferrule.



PERFORMANCE FEATURES

- The patented integral footed design yields the maximum effective depth, hence optimizes concrete cone capacity of the ferrule.
- A cross bar is not required to achieve their capacity. (The cross hole is provided to enable the ferrule to used with a cross bar tied to the reinforcing mesh to hold it in position during casting).
- Premium grade, carbon steel gives the highest possible steel capacity while maintaining good ductility and toughness.

Because Reid™ footed ferrules offer such significant advantages over plain ferrules, Reid™ only recommend them for use in combination with OrbiPlate™.

Base Materials

SUITABILITY

Reid™ cast-in ferrules can be used in plain or in reinforced concrete. It is recommended that the cutting of reinforcement be avoided. The specified characteristic compressive strength "f'_c" will not automatically be appropriate at the particular location of the anchor. The designer should assess the strength of the concrete at the location of the anchor making due allowance for degree of compaction, age of the concrete, and curing conditions.

Particular care should be taken in assessing strength near edges and corners, because of the increased risk of poor compaction and curing. Where the anchor is to be placed effectively in the cover zone of closely spaced reinforcement, the designer should take account of the risk of separation under load of the cover concrete from the reinforcement.

Concrete strength "f'_c" determined by standard cylinders, is used directly in the equations. Where strength is expressed in concrete cubes, a conversion is given in the following table:

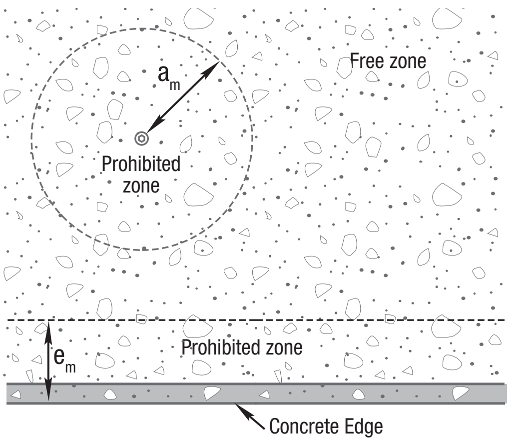
Cube Strength β (N/mm^2)	20	30	40	50	60
Cylinder Strength f'_c (MPa)	15	24	33	42	51

The design engineer is responsible for the overall design and dimensioning of the structural element to resist the service loads applied to it by the anchor.

ABSOLUTE MINIMUM DIMENSIONS

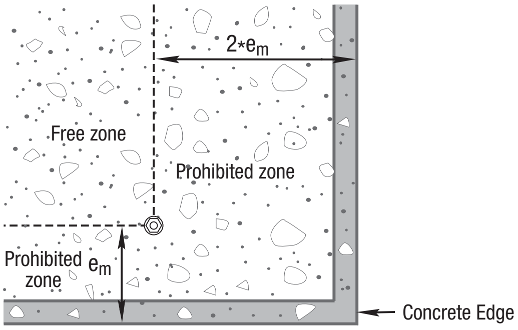
Spacings, edge distances, and concrete thicknesses are limited to absolute minima, in order to avoid risks of splitting or spalling of the concrete cast-in anchors are defined on the basis of notional limits, which take account of the practicalities of anchor placement.

Absolute minimum spacing "a_m" and absolute minimum edge distance "e_m", define prohibited zones where no anchor should be placed. The prohibited spacing zone around an anchor has a radius equal to the absolute minimum spacing. The prohibited zone at an edge has a width equal to the absolute minimum edge distance.



PROHIBITED ZONES FOR SPACINGS AND EDGES

Where an Cast-in anchors is placed at a corner, there is less resistance to splitting, because of the smaller bulk of concrete around the anchor. In order to protect the concrete, the minimum distance from one of the edges is increased to twice the absolute minimum.



PROHIBITED ZONES AT CORNER FOR CAST-IN ANCHORS

STRENGTH LIMIT STATE DESIGN

Designers are advised to adopt the limit state design approach which takes account of stability, strength, serviceability, durability, fire resistance, and any other requirements, in determining the suitability of the fixing. Explanations of this approach are found in the design standards for structural steel and concrete. When designing for strength the anchor is to comply with the following:

$ØR_u \geq S^*$

where:

$Ø$ = capacity reduction factor

R_u = characteristic ultimate load carrying capacity

S^* = design action effect

$ØR_u$ = design strength

Design action effects are the forces, moments, and other effects, produced by agents such as loads, which act on a structure. They include axial forces (N*), shear forces (V*), and moments (M*), which are established from the appropriate combinations of factored loads as detailed in the **AS-NZS 1170.0 : 2002** "Minimum Design Load on Structures" series of Australian/New Zealand Standards.

Capacity reduction factors are given below, these typically comply with those detailed in **AS 4100:1998 & NZS 3404.1: 1997** - "Steel Structures" and **AS 3600:2009 & NZS 3101.1:2006** - "Concrete Structures". The following capacity reduction factors are considered typical:

$Ø_c$ = capacity reduction factor, concrete tension
= 0.6

$Ø_q$ = capacity reduction factor, concrete shear
= 0.6

$Ø_n$ = capacity reduction factor, steel tension
= 0.8

$Ø_v$ = capacity reduction factor, steel shear
= 0.8

$Ø_m$ = capacity reduction factor, steel bending
= 0.8

Whilst these values are used throughout this document, other values may be used by making the adjustment for Ø as required.

NZ3101 Capacity reduction factors

For designing in New Zealand, the capacity reduction factors used in this guide will result in slightly conservative capacities than using those prescribed in NZS 3101.1:2006.
The steel tension reduction factor of 0.8 is the only non conservative exception, however the cast in ferrules specified within this guide are not limited by steel capacity up to the concrete strengths in the design tables.

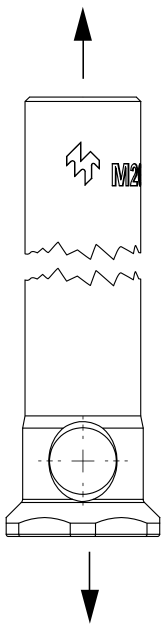
STEEL TENSION

The characteristic ultimate tensile capacity for the steel of an anchor is obtained from:

$N_{us} = A_s f_u$

where:

N_{us}	=	characteristic ultimate steel tensile capacity	(N)
A_s	=	tensile area	(mm^2)
	=	stress area for threaded sections	(mm^2)
f_u	=	characteristic ultimate tensile strength	(MPa)



Note that the strength of the OrbiPlate™ washers and class 8.8 bolt exceed the steel strength of the ferrule

CONCRETE CONE

Characteristic ultimate tensile capacities for cast-in anchors vary in a predictable manner with the relationship between:

- effective depth (h), and
- concrete compressive strength (f'_c)

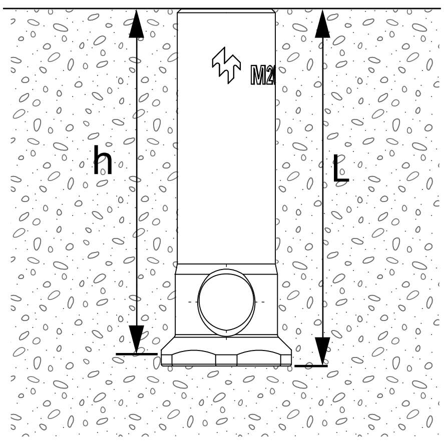
within a limited range of effective depths, h.

This is typically expressed by a formula such as:

$N_{uc} = \text{factor} * d_b^{\text{factor}} * h^{1.5} * \sqrt{f'_c}$

Anchors may have constraints that apply to the effective depth of the anchor or the maximum or minimum concrete strength applicable.

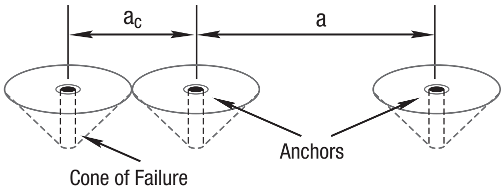
Anchor effective depth (h) is taken from the surface of the substrate to the point where the concrete cone is generated.



The appropriate concrete compressive strength "f'_c" is the actual strength at the location of the anchor, making due allowance for site conditions, such as degree of compaction, age of concrete, and curing method.

CRITICAL SPACING

In a group of Cast-in anchors loaded in tension, the spacing at which the cone shaped zones of concrete failure just begin to overlap at the surface of the concrete, is termed the critical spacing, a_c.

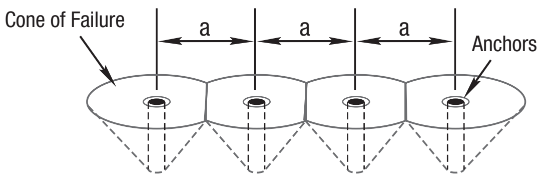


At the critical spacing, the capacity of one anchor is on the point of being reduced by the zone of influence of the other anchor. **Reid™** Cast-in anchors placed at or greater than critical spacings are able to develop their full tensile capacity, as limited by concrete cone bond capacity. Anchors at spacings less than critical are subject to reduction in allowable concrete tensile capacity.

Both ultimate and working loads on anchors spaced between the critical and the absolute minimum, are subject to a reduction factor "X_{na}", the value of which depends upon the position of the anchor within the row:

$$N_{ucr} = X_{na} * N_{uc}$$

for strength limit state design.



ANCHORS IN A ROW

For anchors influenced by the cones of two other anchors, as a result for example, of location internal to a row:

$$X_{na} = a / a_c \leq 1$$

Unequal distances ("a_1" and "a_2", both $< a_c$) from two adjacent anchors, are averaged for an anchor internal to a row:

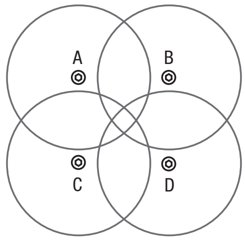
$$X_{na} = 0.5 (a_1 + a_2) / a_c$$

If the anchors are at the ends of a row, each influenced by the cone of only one other anchor:

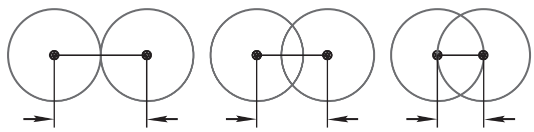
$$X_{na} = 0.5 (1 + a/a_c) \leq 1$$

The cone of anchor A is influenced by the cones of anchors B and C, but not additionally by the cone of anchor D. "X_{na}" is the appropriate reduction factor as a conservative solution.

Critical spacing (a_c) defines a critical zone around a given anchor, for the placement of further anchors. The critical spacing zone has a radius equal to the critical spacing. The concrete tensile strengths of anchors falling within the critical zone are reduced. For clarity, the figure includes the prohibited zone as well as the critical zone.



ANCHOR GROUP INTERACTION



CRITICAL	REDUCTION	PROHIBITED
$a \geq a_c$	$a_c > a > a_m$	$a < a_m$
No influence.	Interaction occurs between failure cones. Capacity reduction necessary.	Risk of cracking.

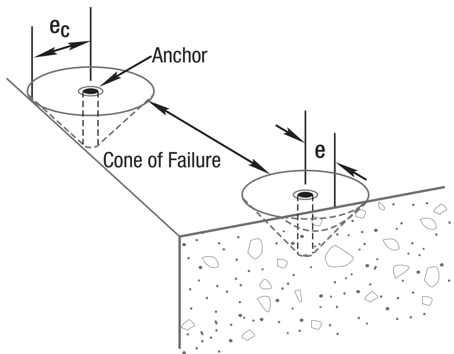
CRITICAL EDGE DISTANCE

At the critical edge distance for anchors loaded in tension, reduction in tensile capacity just commences, due to interference of the edge with the zone of influence of the anchor.

Cast-in Anchors

The critical edge distance (e_c) for cast-in anchors is taken as one and a half times effective depth:

$$e_c = 1.5 * h$$

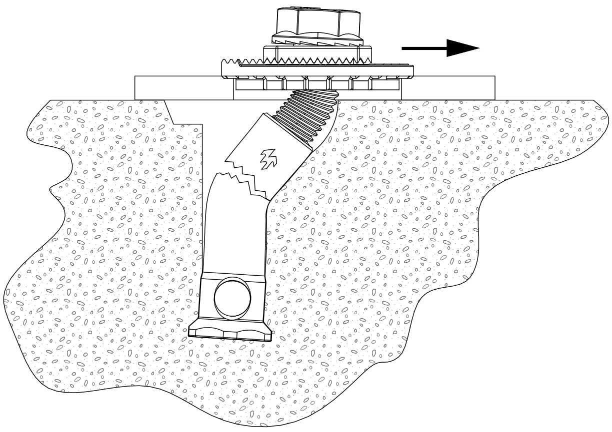


INTERFERENCE OF EDGE WITH CONCRETE CONES

CAST-IN ANCHOR STEEL SHEAR

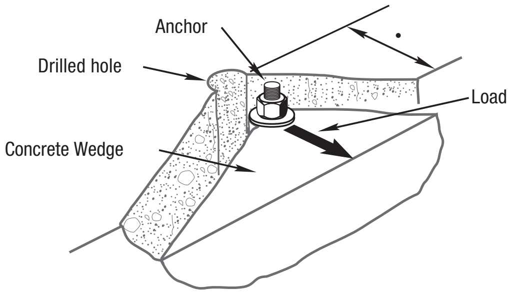
For an anchor not located close to another anchor nor to a free concrete edge, the ultimate shear load will be determined by the steel shear strength of the anchor:

Elephant Foot™ Ferrule



CONCRETE EDGE SHEAR

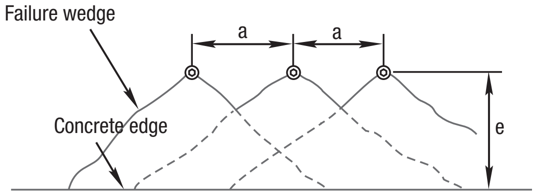
Where load is directed either towards or parallel to an edge, and the anchor is located in the proximity of the edge, failure may occur in the concrete.



CONCRETE WEDGE FAILURE MODE

SPACING UNDER CONCRETE SHEAR

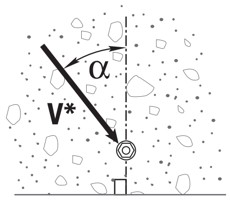
At a spacing of at least 2.5 times edge distance, there is no interference between adjacent failure wedges. Where anchor spacing is less than 2.5 times edge distance, the shear load capacities in the concrete are subject to a reduction factor "X_{va}".



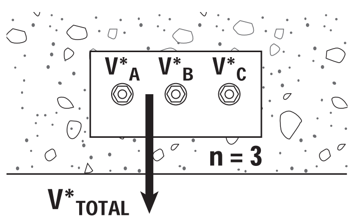
INTERFERENCE BETWEEN SHEAR WEDGES

$$X_{va} = 0.5\,(1 + a / (2.5 * e)) \leq 1$$

The direction of the shear load towards an edge will influence the concrete edge shear capacity. This is accounted for with the factor X_{vd}.



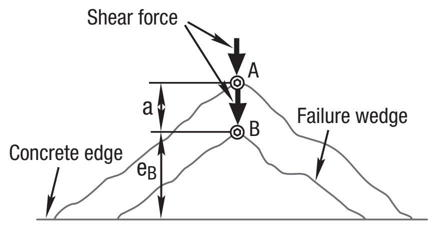
When a row of anchors is subject to a shear load acting towards an edge, the distribution of each anchor's capacity in the anchor group is derived by using the factor X_{vn}.



$$V^*_A = V^*_B = V^*_C$$

$$ØV_{ur} \geq V^*_A, V^*_B, V^*_C$$

Two anchors installed on a line normal to the edge, and loaded in shear towards the edge, are treated as a special case. Where the anchors are loaded simultaneously by the same fixture, the ultimate or the concrete edge shear capacity for each anchor will be influenced by the other anchor. Where the spacing "a" between anchors A and B is less than or equal to "e_B" the edge distance of anchor B, the ultimate edge shear for anchor A is equal to anchor B, despite the longer edge distance of anchor A:



ANCHORS IN LINE TOWARDS AN EDGE

For an anchor located at a corner and where the second edge is parallel to the applied shear, interference by the second edge upon the shear wedge is taken into account by the following reduction factor:

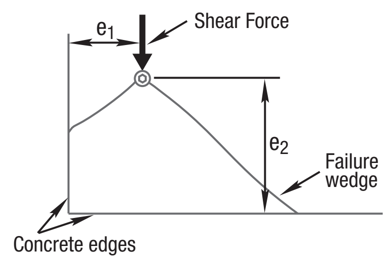
$$X_{vs} = 0.30 + 0.56 * e_1 / e_2 \leq 1$$

An anchor is considered to be at a corner if the ratio of the edge distance parallel to the direction of shear to the edge distance in the direction of shear is less than 1.25.

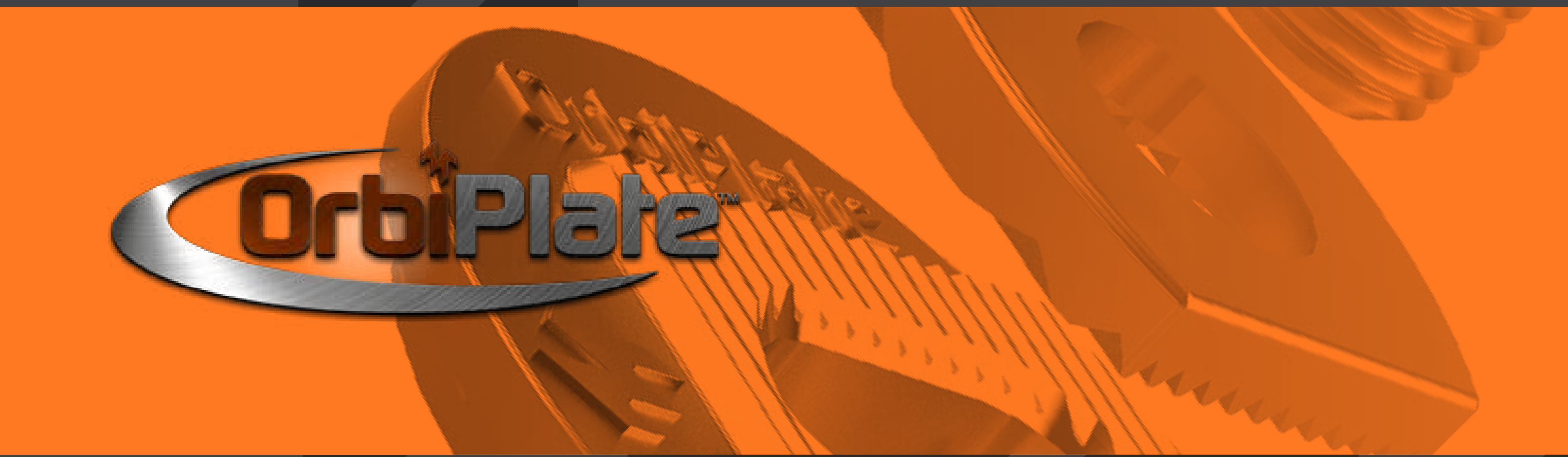
If:

$\frac{e_1}{e_2} < 1.25$ then apply reduction factor X_{vs} shown above

$\frac{e_1}{e_2} > 1.25$ acceptable $X_{vs} = 1.00$



ANCHOR AT A CORNER



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