

Anchor watch – Understanding the concrete capacity design method when using anchors.

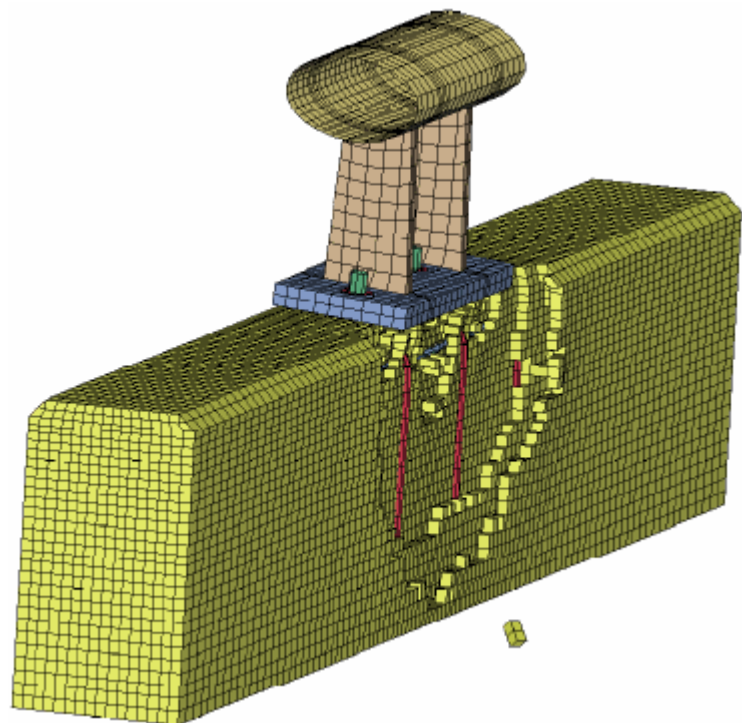
It is now generally accepted amongst designers of post installed connections that the design models for all anchor systems are based on the so called CC or “concrete capacity” design method as given in the design models of the relevant EAD and CEN EN 1992-4 used with the data from the anchors ETA

While this complex method of calculating the concrete capacity is best performed on software a lot of users of such software are completely unaware of the design models being used in the background and of their origin. Many

designers still consider that the capacity of the connection is determined by the strength of the bolt. While this might be the case for steel to steel connections it is very seldom the case for connections to concrete.

In this article I am attempting to demonstrate in very simple terms how the concrete strength, condition and thickness all influence the design resistance of the connection as do concrete edges and anchor spacing and of course the anchor itself.

As one of our daily tasks involves assisting designers with the selection of suitable anchors systems we get dozens of requests to recommend suitable anchors on a daily basis. The nature of these requests leads us to believe that there is still a great misunderstanding as to how the CC method works.



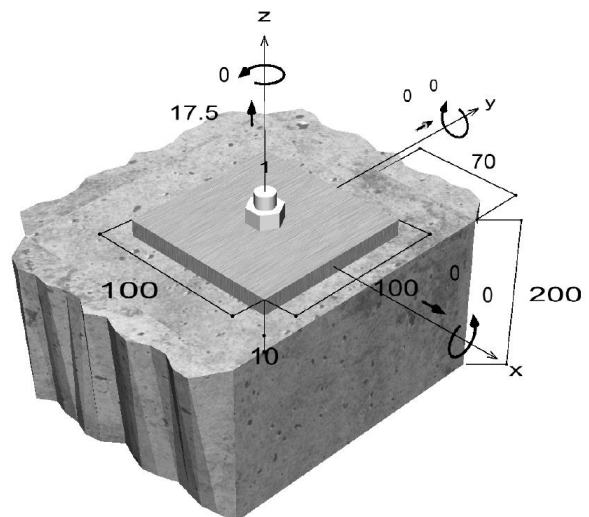
This is borne out by the fact that many of the requests we receive do not contain any information about the concrete. Designers requesting assistance may sometimes underestimate the importance of the concrete characteristics and how it is required to enable correct proof of steel to concrete connections. In 90% of connections with post installed anchors the concrete capacity is decisive and determines the design resistance of the connection.

We have prepared a few examples to show the importance of the concrete in the design of a connection and how changing it can affect the result. For the purpose of demonstration we are going to use a 12 mm bolt anchor with a 70 mm anchorage depth in all cases. You should be aware that in every case the design capacity will be checked, according to the CC method, for steel capacity, pull-out capacity, concrete cone capacity, splitting capacity, pryout capacity and concrete edge capacity depending on if the design action is tension or shear. The failure mode with the least capacity becomes the decisive capacity and it is this value that will be presented in our examples.

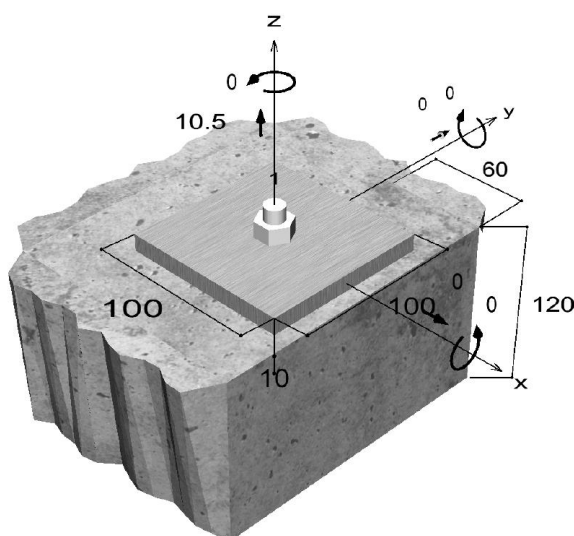
Anchors in tension:

Example 1

In this example I have used 200 mm thick C30/37 non-cracked concrete with a 70 mm edge, the anchor can resist a design action in tension of 17.5 kN. The design resistance is determined by concrete cone capacity.



$$N_{Rd,c} = \frac{N_{0Rk,c} \cdot \frac{A_{c,N}}{A_{c,N}^0} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N}}{\gamma_{Mc}} = 17.99 \text{ kN}$$



Example 2

If we simply change the concrete thickness to 120 mm the design resistance drops to 15.29 kN and is determined by splitting failure. If we also change the concrete to C25/30 cracked concrete and reduce the edge to 60 mm the design resistance drops to 10.5 kN based on concrete cone capacity.

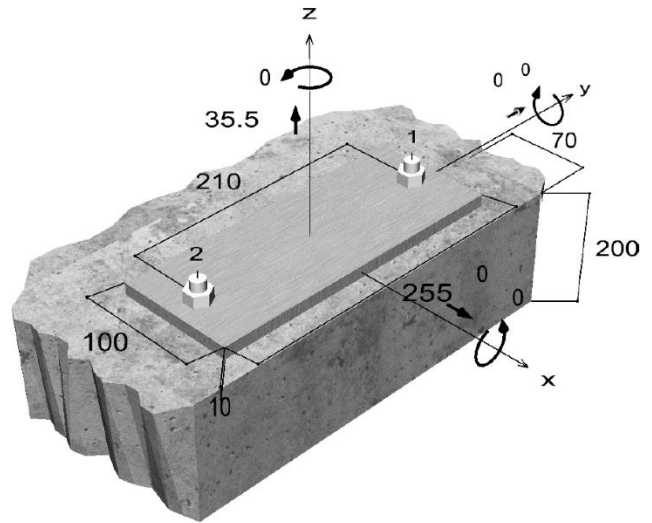
$$N_{Rd,c} = \frac{N_{0Rk,c} \cdot \frac{A_{c,N}}{A_{c,N}^0} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N}}{\gamma_{Mc}} = 10.54 \text{ kN}$$

The design resistance of the very same anchor drops by 40% just by changing the concrete conditions and geometry.

Example 3

This example uses C30/37 grade non-cracked concrete 200 mm thick with 70 mm edge and anchors at 210 mm spacing. The spacing is 3 x embedment so there is no influence for anchor spacing, the design resistance is 35.5 kN based on concrete cone failure. As expected this is twice the resistance capacity of the single anchor.

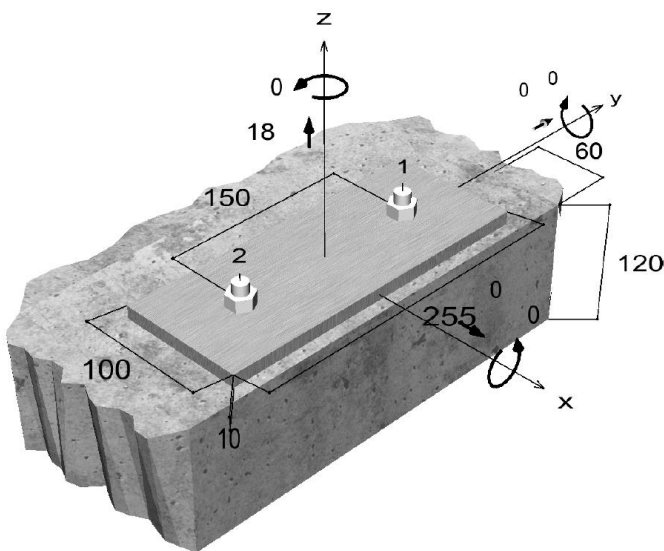
$$N_{Rd,c} = \frac{N_{0Rk,c} \cdot \frac{A_{c,N}}{A_{0c,N}} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N}}{\gamma_{Mc}} = 35.98 \text{ kN}$$



Example 4

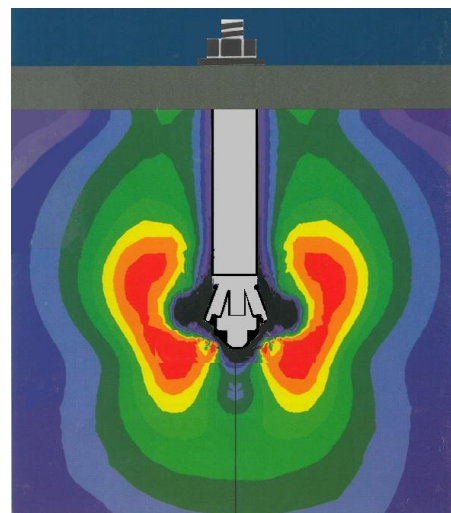
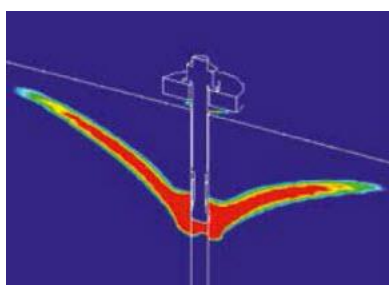
If we change the concrete thickness to 120 mm the design resistance drops to 26.76 kN and is determined by splitting failure. If we also change the concrete to C25/30 cracked concrete and reduce the edge to 60 mm and the spacing to 150 mm the design resistance drops to 18.0 kN based again on concrete cone capacity.

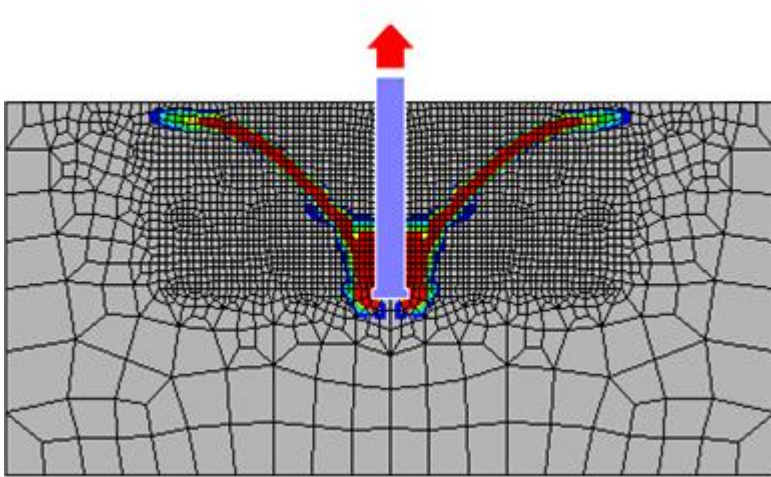
$$N_{Rd,c} = \frac{N_{0Rk,c} \cdot \frac{A_{c,N}}{A_{0c,N}} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N}}{\gamma_{Mc}} = 18.07 \text{ kN}$$



The design resistance of the very same anchor drops by 50% just by changing the concrete conditions and geometry.

The reason for this is because the actions in the anchor are transferred into the concrete base and unlike steel to steel connections the base is brittle and generally fails in the area surrounding the anchoring zone before the steel fails.



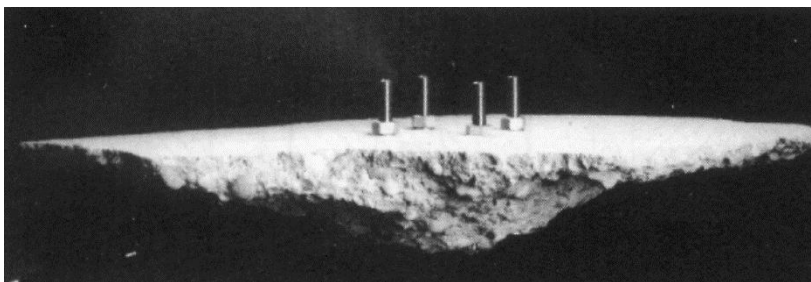


As the cone gets bigger or smaller the design resistance will increase or decrease proportionally irrespective of the anchor diameter.

The size of the cone and therefore the concrete cone resistance is a function of the embedment depth and compressive strength of the concrete, and **NOT the anchor diameter**

The result of concrete failure from anchor groups can be seen below.

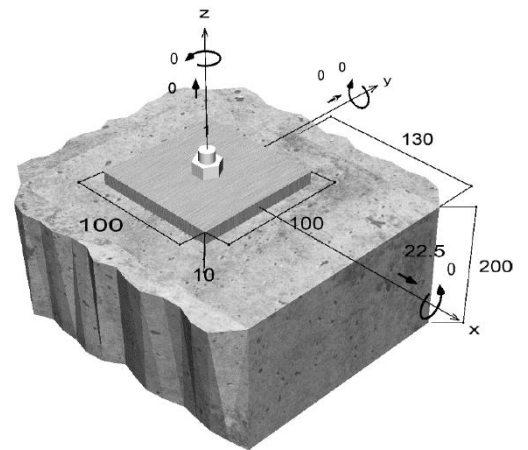
If the anchor spacings are large the failure may result in Individual cones failing and if the anchor spacings are smaller a combined anchor cone failure can be expected.



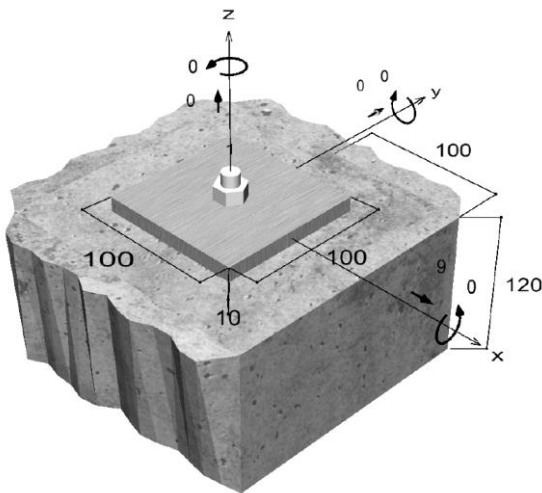
Anchors in shear:

Example 5

In this example I have used 200 mm thick C30/37 non-cracked concrete with a 130 mm edge and the anchor can resist a design action in shear of 22.5 kN towards the edge. The design resistance is determined by concrete edge capacity.



$$V_{Rd,c} = \frac{V^{0Rk,c} \cdot \frac{A_{c,V}}{A^{0c,V}} \cdot \Psi_{s,V} \cdot \Psi_{h,V} \cdot \Psi_{\alpha,V} \cdot \Psi_{ec,V} \cdot \Psi_{re,V}}{\gamma_{Mc}} = 22.54 \text{ kN}$$



Example 6

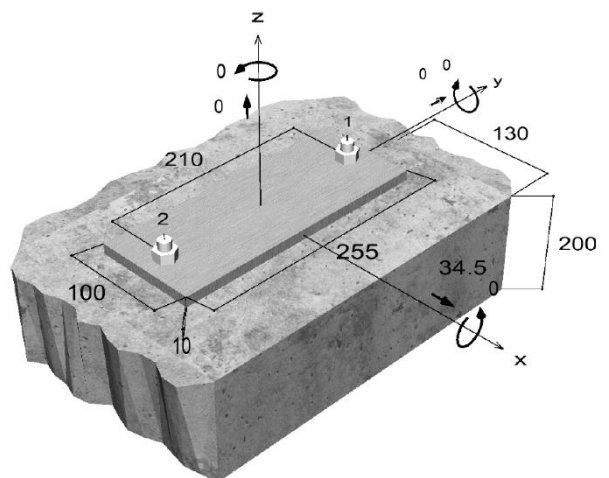
If we simply change the concrete thickness to 120 mm the design resistance towards the edge drops to 17.68 kN and is determined by edge capacity. If we also change the concrete to C25/30 cracked concrete and reduce the edge to 100 mm the design resistance towards the edge drops to 9.03 kN based on concrete edge capacity.

$$V_{Rd,c} = \frac{V^{0Rk,c} \cdot \frac{A_{c,V}}{A^{0c,V}} \cdot \Psi_{s,V} \cdot \Psi_{h,V} \cdot \Psi_{\alpha,V} \cdot \Psi_{ec,V} \cdot \Psi_{re,V}}{\gamma_{Mc}} = 9.03 \text{ kN}$$

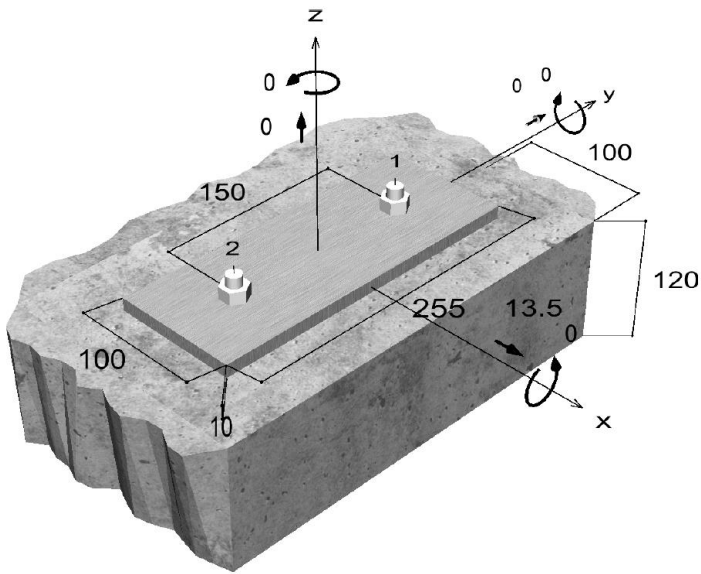
The design resistance of the very same anchor drops by 60% just by changing the concrete conditions and geometry.

Example 7

This example uses C30/37 grade non-cracked concrete 200 mm thick with 130 mm edge and anchors at 210 mm spacing. The design resistance in shear towards the edge is 34.5 kN based on concrete edge capacity. This is less than twice a single anchor as the anchor spacing is no longer related to embedment depth. Instead it is related to edge distance. If the spacing was 3 x edge = 390 mm the resistance capacity would be double that of a single anchor.



$$V_{Rd,c} = \frac{V^{0Rk,c} \cdot \frac{A_{c,V}}{A^{0c,V}} \cdot \Psi_{s,V} \cdot \Psi_{h,V} \cdot \Psi_{\alpha,V} \cdot \Psi_{ec,V} \cdot \Psi_{re,V}}{\gamma_{Mc}} = 34.67 \text{ kN}$$



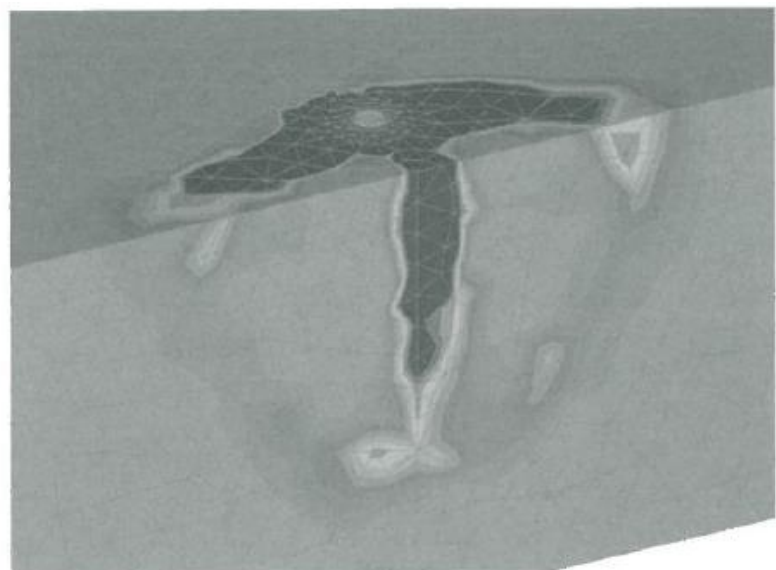
Example 8

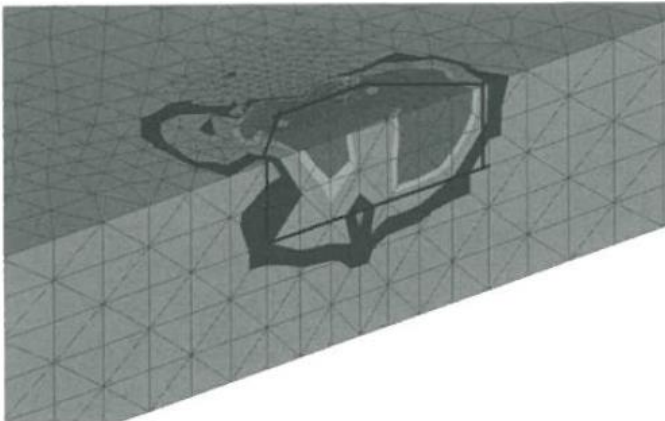
If we change the concrete thickness to 120 mm the design resistance towards the edge drops to 15.00 kN. If we also change the concrete to C25/30 cracked concrete and reduce the edge to 100 mm and the spacing to 150 mm the design resistance towards the edge drops to 13.5 kN based on concrete edge capacity.

$$V_{Rd,c} = \frac{V_{Rk,c}^0 \cdot \frac{A_{c,v}}{A_{c,v}^0} \cdot \Psi_{s,v} \cdot \Psi_{h,v} \cdot \Psi_{\alpha,v} \cdot \Psi_{ec,v} \cdot \Psi_{re,v}}{\gamma_{Mc}} = 13.54 \text{ kN}$$

The design resistance of the very same anchor drops by 60% just by changing the concrete conditions and geometry.

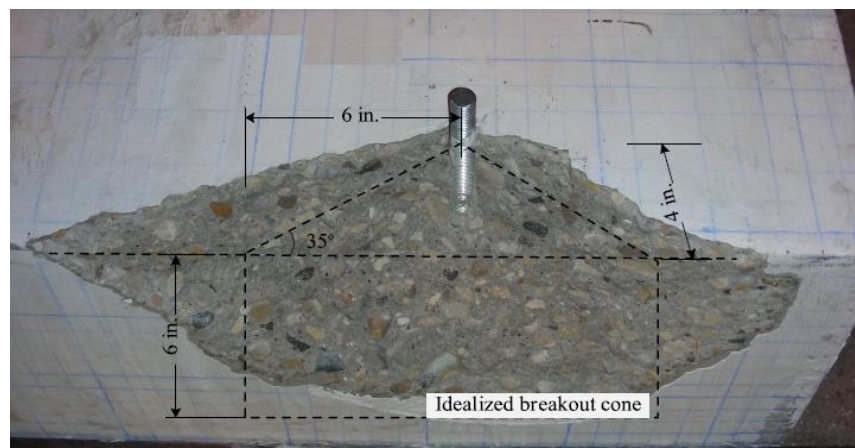
The reason for this is because the actions in the anchor are transferred into the concrete on the lateral face and unlike steel to steel connections the base is brittle and generally fails in the area surrounding the anchoring zone before the steel fails.





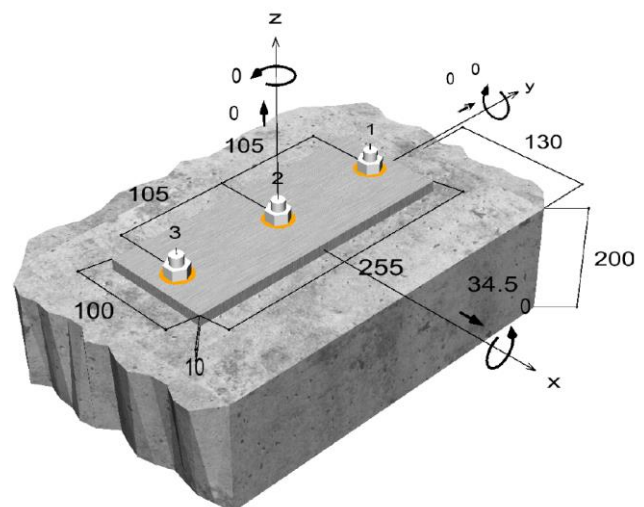
When we employ the use of more anchors the area on the lateral face increases. As the anchor spacing increases (up to 3 x edge distance) the design resistance increases and similarly as the anchor spacing decreases the design resistance for concrete edge also decreases. If the concrete thickness is less than 1.5 x edge distance, concrete edge resistance shall be reduced proportionally.

The result of concrete edge failure from a single anchor can be seen below.



Example 9

It should therefore come as no surprise that when 3 anchors are used as shown here the design resistance is identical to that for the 2 anchors in example 7 above because concrete edge resistance is decisive and both examples are using the very same area of concrete on the lateral face to resist the design actions.



$$V_{Rd,c} = \frac{V^{0}_{Rk,c} \cdot \frac{A_{c,V}}{A^{0}_{c,V}} \cdot \Psi_{s,V} \cdot \Psi_{h,V} \cdot \Psi_{\alpha,V} \cdot \Psi_{ec,V} \cdot \Psi_{re,V}}{\gamma_{Mc}} = 34.67 \text{ kN}$$



It should be noted however that while the resistance capacity can be the same for different anchor types when concrete capacity is decisive, the anchor used must have a relevant ETA and the data from the ETA must be used in the various design checks to determine the decisive design resistance.

Different anchor types may have different pull-out capacities and different setting depths. It may well be that while one anchor type exhibits cone failure a different anchor type may exhibit pull-out failure at a lower value. For this reason good change management should always be carried out when deciding to use alternative anchors to ensure the proposed alternative is also suitable.

As you can see from the examples given, the anchorage resistance capacity varies greatly depending on the environment in which the anchor is used. Obviously the bolt properties don't change, the properties of the substrate change. At Masonry Fixing Services we offer a high degree of technical support to assist the project engineers when it comes to selecting suitable anchor on their project. The software offered by fischer uses the design models of the EAD and CEN 1992-4 in conjunction with the anchors from the full fischer anchor product range.

Once the project engineer has determined all the parameters such as the design actions using the relevant codes, engineered the fixture or selected it from a proprietary system, determined the concrete conditions and thickness he can submit all this information to us and we will gladly assist in the selection of a suitable anchor from the fischer range.

The project engineer should ensure that in the event of the installer wanting to use an alternative anchor someone should carry out correct change management in accordance with BS 8539 to show that the alternative anchor is also suitable in the prevailing conditions. The project engineer should also ensure that the actual concrete conditions are as assumed and that the anchors are installed in accordance with the manufactures instructions.

The technical support offered by Masonry Fixing Services is free of charge and is of the highest possible standard. It should not be misinterpreted as being part of any consultancy offering for which there would normally be professional fees.

If you have any questions on any of the above please contact us at technical@masonryfixings.ie



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