



MASONRY FIXINGS

Anchor Watch

Design of steel to concrete connections:

Modern fastening technology is becoming increasingly important in civil and structural engineering worldwide.

Post installed fastening systems, which are installed in hardened concrete or masonry, have found widespread use in construction practice.

Although each year millions of anchors are installed in concrete and masonry elements on construction sites around the world, the state of knowledge about this technology in practice is often very poor.

This lack of knowledge is evident with both the installer who is tasked to install the products and the designer who is tasked with selecting and specifying the products.

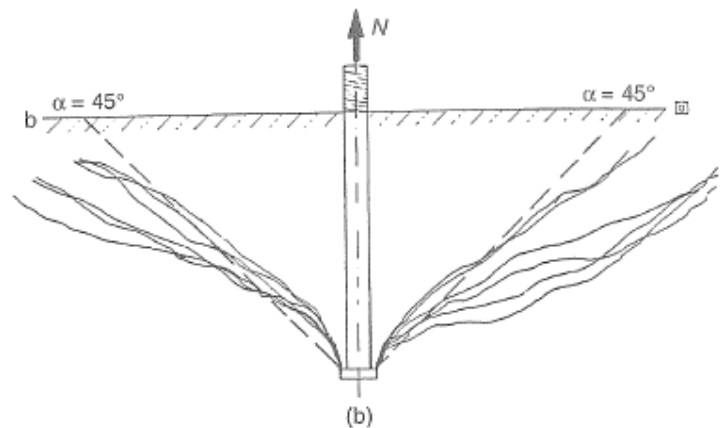
My name is Bryan Carroll and I am the managing director of Masonry Fixing Services Ltd in Dublin. During my 30 year career in the industry I have served on the technical committees for both the current Irish and British Standards for anchors and I am currently on the technical committee of the Construction Fixings Association www.fixingscfa.co.uk . In this article I am going to explain some of the fundamental changes with regard to the design of connections between steel and concrete.

Heavy duty fixing devices have been on the market since the early 1970's. In the early days the products and the design of their resistance capacities was very basic. In the years that have passed since their introduction a lot more development has taken place to enable very detailed designs to be carried out using modern sophisticated products and a very detailed design for the base material capacity. This design method is known as the concrete capacity or the CC method.

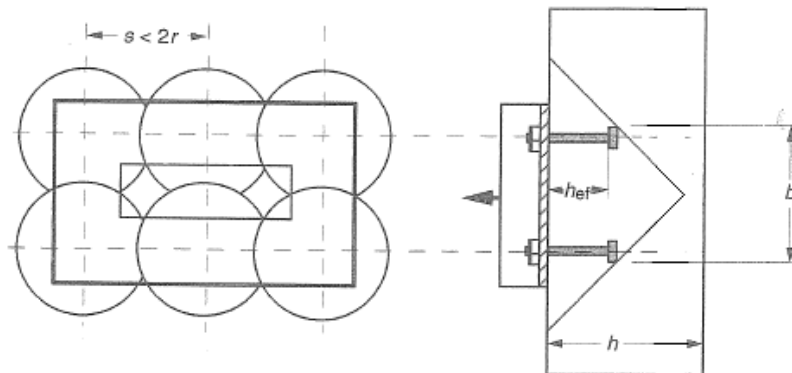
The basic design is the same since the very beginning. The resistance capacity in tension is based on the tensile strength of stress cones in the concrete. The early design method known as the "kappa" system was one where the tensile strength of the concrete was derived from the compressive strength and applied to a basic formula to determine the force required to pull



a cone out of the concrete. The size of these cones was a function of the embedment depth of the anchor. The cone was considered to breakout at circa 45 degrees. This meant that an anchor with 100 mm setting depth, for example, would develop a cone with a diameter equal to twice the embedment depth of the



anchor, or in this example 200 mm. The published design resistance was based on a fully developed cone resisting the design action N . So in order to achieve the published values for the anchor in tension the anchors needed to be equal to or greater than twice their embedment depth away from the next anchor or one times the embedment depth away from a free edge. To deal



with reduced capacities caused by anchors at closer centres the anchor producers provide simple tables which gave reduction factors that the designer employed when the actual anchor spacing or edge distance was below the published value.

In other words when the theoretical cone at the surface overlapped cones from neighbouring anchors or free edges. Consideration was also given to the concrete strength due to the fact that the tensile strength of the cone is calculated from the compressive strength of the concrete, therefore the producers also provided a factor to take into account any change between the actual compressive strength and the compressive strength that the published values were based on. The required concrete thickness was generally twice the setting depth and each anchor had a fixed embedment depth.

The published values for edge distance and anchor spacing, while derived from the physical size of a stress cone in tension, were generally applied to anchors in shear as well.

The safety factors used were global safety factors in the region of 4. All this resulted in simple but conservative design that led to conservative design resistance being used in somewhat restrictive conditions.

As time progressed and more research data became available, a more refined design approach was developed. The CC method now forms the backbone for all steel to concrete connection design.

Among other things designers wanted to use anchors in concrete elements where the concrete thickness was less than twice the embedment depth of the anchor and anchor manufacturers produced anchors that could be set at more than one standard embedment depth. The concept of “cracked” (tension zone) concrete was investigated and the behaviour of an anchor in a crack was researched in detail.

All of the research data was evaluated and included in the development of a single European design guide. The guidance was published by the European Organisation for Technical Approvals (a division of CEN) and presented in a European Technical Approval Guideline (ETAG 001) “Design of metal anchors for use in concrete”.

The new design approach differs greatly from the old method and includes the following additional proofs:

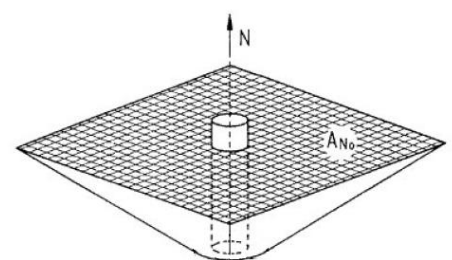
- Design for splitting.
- Design for cracked concrete.
- Design for varying embedment depths.
- Design for combined cone/bond failure of bonded anchors.
- Design for pryout in shear.
- Design for concrete edge capacity in shear.

The new design still works on the concept of stress cones in the concrete but simplifies the approach by considering prisms in place of cones. This makes it easier for the designer to determine the area of the concrete at the surface and more so the area of overlapping squares (rectangles).

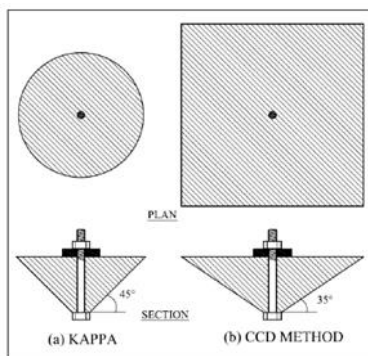
Another fundamental difference in the design is that the cones are now considered to breakout at

circa 35 degrees. This now means that an

anchor with 100 mm setting depth, for example, would develop an idealised area at the surface equal to a square with sides equal to three times the embedment depth of the anchor or 300 mm in this example (900 cm²). The resistance capacity of this prism will be different depending on if the concrete is considered cracked or non-cracked.



Idealized Concrete Cone under tensile loading



The new design approach considers all the possible failure models in both tension and shear. The design requirements are that each failure mode is checked for the particular bolted arrangement and the failure model with the least capacity becomes the decisive resistance capacity in both shear and tension. Each failure model is then subjected to a partial safety factor depending on the type of failure. This is all clearly outlined in Annex C of ETAG 001 for metal anchors and EOTA TR 029 for bonded anchors. These documents can be downloaded from the EOTA home page under publications, <http://www.eota.eu/en-GB/content/home/2/185/>

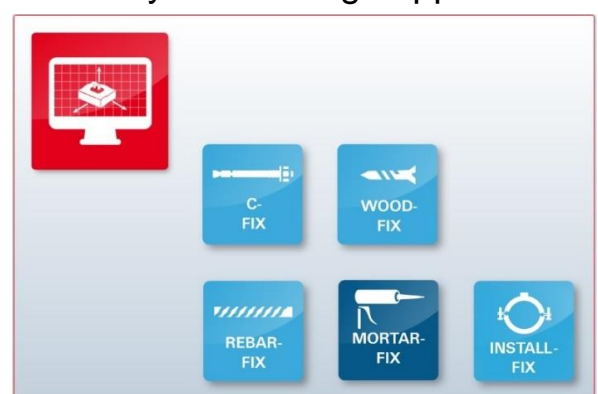
This design approach is now valid for post fixed anchor systems including metal anchors, bonded anchors and cast in systems for bolts or anchor channels. The Design guidance in the guideline is now contained within the new CEN TS 1992-4 and is in draft format for Eurocode EN 1992-4.

There are vast publications available on the concrete capacity design method and the design can be found in:

- Annex C of ETAG 001
<http://www.eota.eu/en-GB/content/etags-used-as-ead/26/>
- EOTA TR 029
<http://www.eota.eu/en-GB/content/technical-reports/28/>
- CEN TS 1992-4
<http://shop.bsigroup.com/ProductDetail/?pid=000000000030180298>
- FIB bulletin 58
<http://www.fib-international.org/design-of-anchorage-in-concrete>

All of the design models in these various publications require information on the specific anchor being considered. This information is contained within the particular anchors ETA. When designs are performed using the design models in the above publications and the data from the ETA the design is compliant with all the national and international standards. Any other design approach is not.

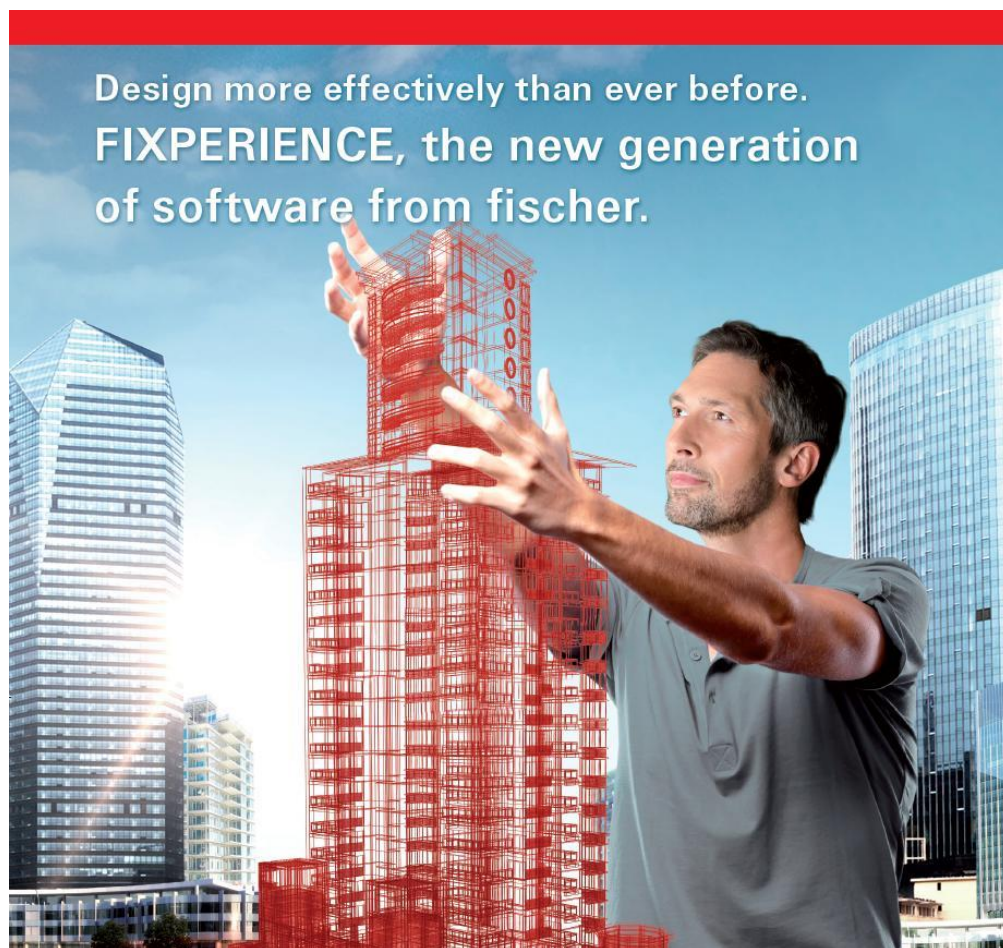
As the design procedure has become more sophisticated it is no longer possible for the anchor producers to offer tables that can deal accurately with all the possible parameters facing them. At *Masonry Fixings* we are partners with [fischer fixings](#) and offer the best suite of design software available to enable you



to design steel to concrete connections in accordance with all current standards. The fischer [fixperience](#) software is available to download or as a CD by request from technical@masonryfixings.ie

If you don't have knowledge of the concrete capacity design method then I encourage you to research it as it is the background to all concrete connections irrespective of product or brand.

Masonry Fixings are serving the Construction Industry in Ireland since 1977 and have been associated with most major construction projects during that period. If you have used our products and services in the past we would like to thank you, if you have not I would encourage you to check out what we can offer.



Should you have any questions on any of the content please feel free to call for advice on Dublin (01) 6426700.