# **Design of the anchor bolts and base plate**

The following section contains details on how the anchor bolt and base plate will be determined following the book,Guide on Design of post-installed anchor bolt systems in Hong Kong by Dr. S.S.H Cho and Ir Prof. SL Chan Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University.

## **Anchor bolts**

Types of anchor bolts

To suit different needs and the conditions of the base materials, there are many types of anchor bolts as shown in Figure 2.1 such as:

1. Torque-controlled expansion anchor (sleeve type and wedge type)
2. Deformation-controlled expansion anchor
3. Undercut anchor
4. Concrete screw
5. Chemical anchor
6. Expansion chemical anchor

For the purposes of this project two types of bolts are candidates for usage which include the undercut anchor bolt and the concrete screw.

Undercut anchors develop mechanical interlock between anchor and base material. The undercutting can be achieved by a special drilling tool or by the anchor itself during installation. Then the expansion “sleeve” will fill the undercut hole and develop a tensile resistance.

Concrete screws are screwed into pre-drilled holes by a special screwdriver. The threads will cut into the concrete and create mechanical interlock between screw and concrete.

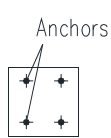
## Bolt configurations

When designing anchor bolt joints it is important to recognize that they are several recommended (ETAG 001, Annex C [1]) and widely used configurations.

Equally important is the special considerations to be made if the anchor bolt is too close to the edge. as this renders the joint susceptible to concrete edge failure. Therefore, in ETAG 001, Annex C [1], TR029 [5] and CEN/TS 1992-4 [2], bolt configurations for bolts close to edge will have a more stringent requirement.

The design proposed by the author ensures that the anchor bolts are far from the concrete edge and thus the above suggested measures may not be taken.

Configuration chosen is shown below:



## Minimum bolt spacing and edge distance requirements

Design engineers shall refer to manufacturer design manual for minimum bolt spacing requirement and minimum edge distance requirement which are normally determined by tests and mentioned in the relevant approval documents.

## Base Materials.

The concrete structures shall be of normal weight concrete with grades ranging from C25 to C60 (i.e. characteristic cube strength of concrete ranging from 25N/mm2 to 60N/mm2.

As a conservative approach, cracked concrete shall be assumed for anchor bolt design if the condition of concrete is not known.

## Static analysis of anchor bolts

### General

A fastening can be subject to tension, compression, shear forces, moments, torsion, or the combination of above.

These forces are resolved into shear and tension of individual bolts. Therefore, an anchor bolt can be subject to the following loading conditions:

1. Tension force only
2. Shear force only
3. Combined tension and shear

In general, elastic analysis may be used for calculating the loads on individual anchor bolts both at ultimate and serviceability limit states.

Tension force per anchor bolt According to the theory of elasticity a linear distribution of strains across the base plate and a linear relationship between strains and stresses exists (Figure 3.1). This assumption is valid only if the base plate is rigid and does not deform significantly. The base plate should remain elastic under design forces and its deformation should be compatible with the displacement of the anchor bolts.

For the determination of forces of the anchor bolts the following assumptions may be used:

1. The axial stiffness of all fasteners is equal. The anchor bolt threaded area shall follow the manufacturer specifications and the modulus of elasticity of steel shall follow the Code of Practice for the Structural Use of Steel [6] and is taken as 205 000 N/mm2.
2. The modulus of elasticity of the concrete depends on the concrete grade and shall follow the Code of Practice for Structural Use of Concrete [7].
3. Anchor bolts in the zone of the base plate under compression do not take forces. The compression force is taken by the base plate and transferred to base concrete.

The compressive stress in the concrete and the tension force in the anchor bolts can be solved by finding the neutral axis of the base plate under axial force and moments. The neutral axis can be found by solving a cubic equation by numbers of iteration. Therefore, it is best to use design software to obtain the tension force in the anchor bolts. However, under some simple loading conditions as in the following sections, the tension forces of individual anchor bolts can be solved by simple hand calculation.

### General

The failure modes of mechanical anchors under tension forces include:

1. Steel failure
2. Pull-out failure
3. Concrete cone failure
4. Splitting failure

The failure modes of mechanical anchor under shear forces include:

1. Steel failure
2. Concrete edge failure
3. Concrete pry-out failure

It is almost impossible to predict the failure mode of an anchor bolt or a bolt group which governs the resistance as it depends on a couple of factors such as the magnitude and direction of forces, anchor bolt grade, concrete condition and grade, embedment depth, edge distance, bolt spacing, etc. Therefore, it is necessary to calculate the resistance of each failure mode. In fact, manufacturers will provide all the values of design resistance under different failure modes of a single anchor bolt and design guidelines in a design manual. Design engineers only need to follow the design manual to calculate the ultimate design resistance of an anchor bolt group (Chan).

Steel failure

Steel failure is the most straightforward failure mode. It is observed by fracture in the shaft or the thread area as shown in Figure 4.1. The design tensile resistance of anchor bolt can be found in manufacturer design manual; otherwise the characteristic value of bolt resistance, to tension of an anchor bolt can be calculated directly by;

Where;

As = threaded area of an anchor bolt and given in manufacturer specifications.

Fuk = the ultimate tensile stress of the bolt.

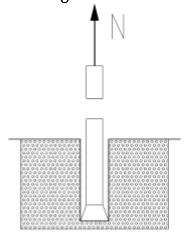


Figure 2-tensile failure in steel

Also recall that, the design resistance check requirements for mechanical anchor bolts in tension for this kind of failure are that:

Where;

Nsd = design tension for a single anchor bolt.

= factor of safety

**Pull-out failure**

Pull-out failure is a failure mode where the complete anchor bolt is pulled out of the hole as shown in Figure 4.2. The pull-out resistance, is determined by repetitive laboratory tests fulfilling the requirements in ETAG 001 [1] and engineers shall refer to manufacturer specifications for design values. However, in some cases, pull-out failure may not occur as the anchor bolts is failed by other failure mode such as concrete cone failure or steel failure. In this case, check against pull-out failure is not required.

**Concrete cone failure**

Concrete cone failure occurs when a cone-shaped break-out body is separated from the base concrete.

The characteristic cone resistance in ideal conditions can be got from the formula;

Where;

=factor specified by the manufacturer and dependent on the condition of the concrete

= concrete characteristic cube strength in N/mm2

= embedment depth of the anchor in mm.

The values of commonly range from 7.0 to 7.2 for cracked concrete and 9.8 to 10.1 for non-cracked concrete. The actual value is given in the relevant approval documents (Chan).