INTRODUCTION

Design and Safety Concept

This Design Manual uses the partial factor method according to the European EN 1990. When using the partial factor method, it shall be verified that, in all relevant design situations, no relevant limit state is exceeded when design values for actions (S_d) or effects of actions and resistances (R_d) are used in the design models.

$$S_d \leq R_d$$

For the selected design situations and the relevant limit states the individual actions for the critical load cases should be combined.
Design values should be obtained by using the characteristic, or other representative values, in combination with partial and other factors (γ_f, γ_M) as defined in EN 1991 to EN 1999, the design guides for post-installed anchors and the relevant approval of the chosen anchor.

$$S_k \cdot \gamma_f \leq \frac{R_k}{\gamma_M}$$

The respective approval number is given in the relevant chapter of the anchor's design tables. Actual design guides for post-installed anchors are published in ETAG001/Annex C, in the Technical Report TR029 and in EN1992-4. This Design Manual uses a simplification of those guides to allow manual verifications for anchorages.
The characteristic values and partial factors of the anchors are derived by assessments of the results of tests described in ETAG001. This guideline requires to meet the respective criteria of its suitability tests and tests for admissible service conditions.

The American ACI 318 / Appendix D is an equivalent design guide. Its strength design method requires service loads or related internal moments and forces to be increased by specified load factors (required strength N_{ua}) and computed nominal strengths to be reduced by specified strength reduction factors (design strength $\emptyset N_n$).

$$\emptyset N_n \geq N_{ua}$$

The assessment criteria for evaluating the nominal strength and reduction factors are published in AC193 and AC308.

Both the European and the American design guides verify in their safety concept the following modes in tension:
- steel failure,
- pull-out/pull-through failure or combined pull-out and concrete cone failure,
- concrete cone failure,
- concrete splitting failure,

and in shear:
- steel failure,
- concrete pry-out failure,
- concrete edge failure.

When both tension and shear are present interaction effects are also considered.

With above verifications it is sufficiently proven that the anchorage is able to transmit the acting loads into the concrete member.
Post-installed anchors do not always substitute e.g. falsely placed cast-in steel elements for which the load transmitting concrete member was already structurally verified. In many cases post-installed anchors are used to add attachments in order to refurbish even new construction as well as for repair and strengthening work. Therefore it is strongly recommended to verify if the concrete member is able to transmit the additional concentrated loads.

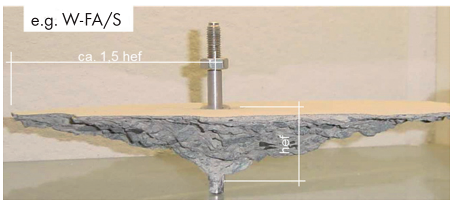
This Design Manual gives design guide for anchorages post-installed into a concrete member with a certain compressive strength. The compressive strength is an important material property for calculating the load transmitting capacity. It is e.g. in Europe denoted by concrete strength classes which relate to the characteristic (5%) cylinder strength f_{ck}, or the cube strength $f_{ck,cube}$, in accordance with EN 206.

Concrete compressive strength and compressive strength classes

Concrete strength classes (EN 206:2000)			**C12/15**	**C16/20**	**C20/25**	**C25/30**	**C30/37**	**C35/45**	**C40/50**	**C45/55**	**C50/60**
Characteristic compressive strength of concrete determined by testing cylinders of 150mm diameter by 300mm height at 28days	f_{ck}	[N/mm²]	12	16	20	25	30	35	40	45	50
Characteristic compressive strength of concrete determined by testing cubes of 150mm side length at 28days	$f_{ck,cube}$	[N/mm²]	15	20	25	30	37	45	50	55	60

Specified compressive strength of concrete (ACI 318)				**2500**		**3500**	**4500**	**5500**		**6500**	**7500**
Specified compressive strength of concrete f'_c taken from cylinders 6 by 12 in. (150x300mm) at 28days	f'_c	[psi]		2500		3500	4500	5500		6500	7500
Specified compressive strength of concrete f'_c taken from cylinders 6 by 12 in. (150x300mm) at 28days	f'_c	[N/mm²]		17.24		24.1	31.0	37.9		44.8	51.7

Concrete cone failure



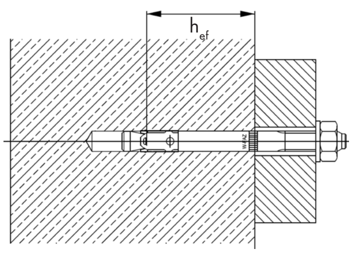
INTRODUCTION

Geometry of Anchorage

In the first instance this topic appears trivial, but at the initial phase of selecting post-installed anchors the consideration of geometrical constraints is most important. The thickness of the concrete member in which the anchor has to be post-installed later decides how deep the installer can drill a hole into the concrete, and finally the maximum effective anchorage depth of the anchor. As the anchor's pull-out resistance depends on the effective anchorage depth, the thickness of the concrete member determines the maximum load which can be transferred in almost all cases. On the other hand the projecting length of the anchor has to be selected in order to cover tolerances of the construction and the thickness of the attachment itself.

The effective anchorage depth

The effective anchorage depth h_{ef} is one of the most important dimensions as it determines the so-called concrete capacity of each anchor.



Advanced anchors are normally generating concrete cone failure as this failure is the limit of each post-installed fastening system. The concrete cone failure depends besides the compressive strength on the anchorage depth h_{ef}:

$$N_{Rk,c}^{0} = k_9 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$$

with $k_9 = k_{cr,N} = 7.2$ for cracked concrete and $k_9 = k_{ucr,N} = 10.1$ for verified non-cracked concrete.

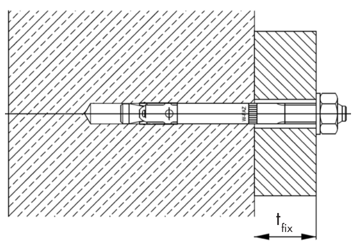
Basically the engineer is verifying if the acting tensile load is smaller than the concrete cone capacity of the anchor. From a structural design point of view the engineer has to mention the anchor's effective anchorage depth in his detailed drawings. Only this value guarantees that suppliers provide anchors with the respective performance.

The diameter of the anchor

The diameter is important for calculating the steel capacity due to shear loading, but gives also information on the required diameter d_0 of the drill hole in the concrete member and on the maximum clearance hole diameter d_f in the fixtures.

Maximum fixture thickness

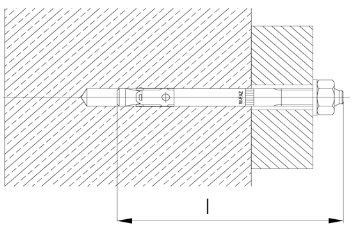
Considering the stand-off fixture below, the projecting length of the anchor rod has to cover the gap between concrete surface and anchor plate, the thickness of the anchor plate itself and in addition have to exceed the anchor plate by the thickness of washer and nut.



The maximum fixture thickness t_{fix} which represents the maximum useful length is difficult to decide during the designing stage, because the real conditions on building site differ mostly from the drawings. Most suppliers provide anchors with a wide range of useful lengths at same effective anchorage depth. This allows the installer to select a proper anchor in agreement with the responsible structural engineer.

The anchor length

The anchor length l depends on the effective anchorage depth and the useable length. In general the anchor is longer than the sum of both, because it should consider additional length for the washer and nut on the one hand. The anchor should for safety reasons project at least one pitch of the threaded bolt. On the other hand that part which exceeds the effective anchorage depth depends on the manufacturers developing ability to provide economic fastening systems.



The concrete member thickness and the drill hole depth

The drill hole depth depends on the type of anchor. Figure below shows the depth of the drill hole h_0 in case of a through fixing. This means that the anchor is installed through the bracket into the concrete.

The sufficient depth of the drill hole is important to generate the correct functioning of the anchors in order to achieve the designed performance on the one hand, but on the other hand it determines also the minimum concrete member thickness.

According to guidelines the minimum component thickness in which anchors are installed is h ≥ 100mm.

If the thickness of the concrete member is smaller than required above, then the resistance can be reduced because of a premature splitting failure or a reduction of the shear resistance for anchorages at the edge. Furthermore, the minimum values for edge distance and spacing might not be sufficient because a splitting failure can occur during installation. Therefore, a smaller thickness of the concrete member is allowed only if the above-mentioned effects are taken into account in the design and installation of the anchorage.

The minimum member thickness depends on application parameters and it is given by:

$$h = h_{ef} + \Delta h \geq 100mm$$

The following values given for Δh are valid for holes drilled with electrical hammer drilling machines and diamond core drilling machines:

a) Applicable to all anchor types: $\Delta h = h_{ef}$.

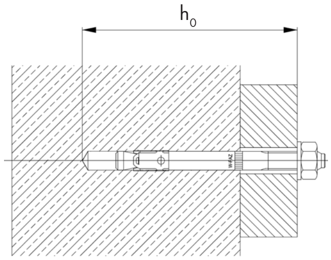
b) Applicable to all anchor types: $\Delta h \geq 2d_0 \geq 30$ mm.

c) $\Delta h \geq d_0$

This may be applied where the remote face of the concrete member is accessible and can be inspected to ensure there has been no break-through.

d) Applicable to injection type anchors: Δh = 0

This may be applied where it can be ensured that the full bonded length, h_{ef}, will be achieved, and compensation shall be made for any potential loss of bonding material.



INTRODUCTION

INTRODUCTION

The used symbols are listed below:

Symbol	Description
	Calculation with Design Software possible
	Eurpean Technical Approval Key document for the calculation. It contains design method, details of the anchor specification and performance characteristics.
	The anchor may also be used under seismic action according to ETA and /or ICC-ESR.
	International Code Council ICC Evaluation Service Inc. (ICC ES) issues evaluation reports, based on the Uniform Building CodeTM and related codes in the United States of America.
	Fire resistance classification
	Leed certificated The system looks at numerous factors that were divided into five categories, which relate to and include the health of humans and the environment.
	VOC Emissions class label In the context of analyzing the air a group of pollutants is analyzed, which can have serious health effects on humans. The term VOC (volatile organic compounds) is grouped together, a plurality of volatile organic compounds.
	NSF International The National Sanitation Foundation (NSF) is a nonprofit organization that ensures the safety of public health and environmental protection. It ensures that the materials and additives used in food, water or air are not harmful to health.
	For sprinkler systems