Proposal to supplement in fib design guide, drafted by Longfei Li, fib T 2.9 WP 8,

29th February 2016

4.3.1.2 Tension loads on anchors

The design value of tension loads on each anchor can be calculated from the design values of normal forces and bending moments acting on the fixture by finite element method to consider the stiffness of anchors, base plate and concrete and the compatibility of their deformations (1) or based on the assumption that the distribution of tensile strains across the fixture is linear if the fixture is sufficiently stiff and it fulfils the stiffness condition in Figure XX (2). ~~Furthermore, a linear relationship between strains and stresses is assumed.~~

If the fixture bears on the concrete (directly or through a grout layer), the compression forces are transmitted to the concrete by the fixture.

(1) The design value of tension loads on each anchor may be calculated by finite element analysis with the following basic parameters.

- The base plate is bedded elastically on concrete. The concrete bedding factor may be taken as $C_C = 15 \cdot f_{c,cube}$
- Anchor spring constant C_A may be determined by tests in uncracked concrete. Mean value should be used.

  It can be expressed with $C_A = \varphi \cdot E_s \cdot A_s / h_{ef}$

  If there are no test results available the anchor stiffness factor φ may be taken as

  $\varphi = 1.0$ for bonded anchors

  $\varphi = 0{,}5$ for mechanical anchors
- Under design actions the base plate remains elastic $\sigma_{Ed} \leq \sigma_{Rd} = f_y / \gamma_M$

  The partial factor γ_M may be taken as 1.5 derived from $\gamma_M \approx 1.35 \cdot \gamma_s$, with $\gamma_s = 1.1$ according to EC3 and the factor 1.35 to consider the scatter of the anchor stiffness.

For verifying the resistance of concrete cone failure and combined pullout and concrete cone failure of anchor groups the following modifications should be taken into account conservatively.

- For concrete cone failure

  $\Psi_{ec,N} = 1{,}0$

  $N_{Ed,\ max} \leq N_{Rd,c} / n$

- For combined pullout and concrete cone failure

  $\Psi_{ec,NP} = 1{,}0$

  $N_{Ed,\ max} \leq N_{Rd,P} / n$

$N_{Ed,\ max}$: maximum design value of anchor tension force in the anchor group

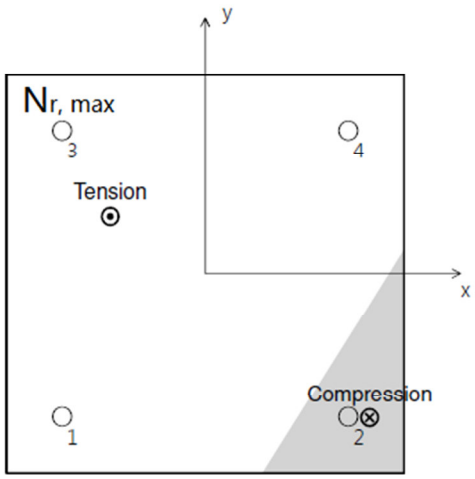
n: Number of tensioned anchors in the group

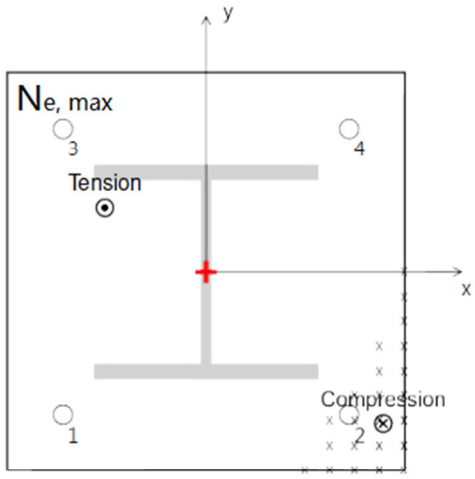
(2) If the base plate remains elastic under design actions ($\sigma_{Ed} \leq \sigma_{Rd} = f_{yk} / \gamma_M$) and it fulfils the stiffness condition in the Figure xx the design value of tension loads on each anchor may be calculated with assumed rigid baseplate as follows.

~~If the fixture bears on the concrete (directly or through a grout layer), the compression forces are transmitted to the concrete by the fixture.~~ The distribution of tension loads to the anchors may be calculated by applying the method of reinforced concrete sections using the following assumptions:

- The axial stiffness $E_s \cdot A_s$ of all anchors is equal. The cross-sectional area of the anchor, A_s, may, in general, be calculated using the nominal diameter of the anchor, d_{nom}. E_s is the modulus of elasticity of the anchor material. For threaded anchors the stressed cross section according to ISO 898-1 (ISO, 2009-1) should be taken.
- The modulus of elasticity of the concrete may be taken from relevant Standards
- In general anchors do not resist compressive forces.

For anchor groups with different levels of tension forces $N_{Sd,i}$ acting on the individual anchors of a group, the eccentricity e_N of the tension force N_{Sd}^g of the group of tensioned anchors with respect to their centre of gravity should be calculated.





x : concrete compression or prying force

Anchor tension force calculated with rigid base plate (2)
$N_{r,\,max}$ = 8.207 kN

Anchor tension force calculated with elastic base plate (1)
$N_{e,\,max}$ = 8,307 kN

(a) Stress condition $\sigma_{Ed} \leq \sigma_{Rd} = f_{yk}/\gamma_M$
(b) Stiffness condition $N_{r,\,max} / N_{e,\,max} \approx 1$, i.e. $(N_{e,\,max} - N_{r,max})/ N_{r,\,max} \leq 3\%$). The thickness of the base plate is determined by finite element analysis according to (1) so that it achieves an equivalent distribution of anchor tension forces of the rigid base plate according to (2).

Figure xx Conditions for calculating the anchor tension forces by using rigid base plate (proposal)