Working Draft

DESIGN OF POST–INSTALLED ANCHORAGE TO CONCRETE – CODE OF PRACTICE

FOREWORD

(*Formal clauses of the standard to be added later*)

Various fastening techniques are used extensively for the transfer of loads into concrete structural elements. One such technique that is, Post-installed anchors, installed in hardened structural concrete elements, has become quite common in the last two decades in India. Despite the extensive use of post-installed anchors in construction, the level of adequate knowledge regarding their behaviour is only increasing now.

Failure of connections poses risk to human life and considerable economic consequences. Hence, they should be designed, assessed and evaluated in accordance with the well-established engineering principles. Suitable guidance is therefore required for proper design of such system to ensure safety.

This standard has, therefore, been formulated to fulfill the above requirements. It addresses a variety of loading types and failure modes and takes into account the current state-of-the-art for post-installed anchorages in new concrete construction as well as for their use in the repair and strengthening of existing concrete structures. This standard would provide thus the requisite guidance regarding design and use of anchorages to concrete and would be of help to the designers, contractors and users alike.

In this standard, it has been assumed that the design of anchorages is entrusted to a qualified engineer and that the installation of anchorages to concrete is carried out under the direction of a qualified and experienced supervisor.

In the formulation of this standard, assistance has been derived from the following publications:

1. EN 1992-4 : 2018, Eurocode 2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete
2. AS 5216 : 2018 Design of post-installed and cast-in fastenings in concrete, Standards Association of Australia
3. CEB-FIP Model Code 2011, Design of anchorages in concrete

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall he rounded off in accordance with IS 2: 2022 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Working Draft

DESIGN OF POST-INSTALLED ANCHORAGE TO CONCRETE - CODE OF PRACTICE

1 SCOPE

1.1 This standard deals with the design of post-installed mechanical anchors and post installed adhesive anchorages to concrete when subjected to static, quasi-static or seismic loads. The design method in this standard is applicable only to anchors that have been tested and assessed according to CED 2(0098) WD, CED 2(0099) WD and CED 2(100) WD 1&2. The assessment report (AR) of the anchor generated based on this assessment shall be referred to for various design parameters. The concrete that forms the base material for the connection shall be of in conformity with IS 456 as may be applicable for reinforced concrete.

1.2 The design provisions in this standard do not apply to anchors in plastic hinge area.

> NOTES
>
> **1** Specialist literature may be consulted for guidance regarding fatigue or shock loads, where applicable.
> **2** Specialist literature may be consulted for guidance regarding the usage of concrete of strength higher or lower than the value recommended here.

2 REFERENCES

The standards (and documents) given in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on these standards are encouraged to investigate the possibility of applying the most recent editions of the standards given in Annex A.

3 TERMINOLOGY

For the purpose of this standard, the definition of terms given in CED 2(0125) WD shall apply.

4 SYMBOLS AND NOTATIONS

For the purpose of this standard, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at the appropriate place.

4.1 Suffixes

      a   —   Anchor

c	—	Concrete
cp	—	Concrete pry-out
cr	—	Critical
cr'	—	Cracked
d	—	Design value
g	—	Group
H	—	Horizontal
i	—	Individual
inst	—	Installation
L	—	Load
M	—	Material
m	—	Mean
mod	—	modified
p	—	Pull-out / Pull-through
red	—	Reduced
Rk	—	Characteristic value
s	—	Steel
seis	—	Seismic
sp	—	Splitting
u	—	Ultimate
uncr'	—	Uncracked
V	—	Vertical
y	—	Yield
σ^*	—	Most stressed
0	—	Basic or idealized
X	—	In direction X
Y	—	In direction Y

4.2 Symbols and Notations

|		
A	—	Area
A_s	—	Stressed cross section area of steel
E_s		Modulus of elasticity of steel
E_c	-	Modulus of elasticity of concrete
c'	—	Distance of anchor from its center to edge of concrete member
c'_1	—	Distance of anchor from its center to edge in direction 1; c'_1 is the edge distance in direction of the shear load for anchorages close to an edge loaded in shear
c'_2	—	Distance of anchor from its center to edge in direction 2; direction 2 is perpendicular to direction 1
$c'_{cr,N}$	—	Minimum edge distance of an anchor at which there is no influence of edge on its characteristic strength in tension in case of concrete cone failure
$c'_{cr,Np}$	—	Minimum edge distance of an anchor at which there is no influence of edge on its characteristic strength in tension in case of bond / pull-out failure.
$c'_{cr,sp}$	—	Minimum edge distance of an anchor at which there is no influence of edge on its characteristic strength in tension in case of splitting failure
c'_{min}	—	Minimum edge distance at which the anchor can be installed without damaging the concrete member
d_a	—	Anchor diameter of anchor bolt or thread diameter (in case of internally threaded sockets outside diameter of socket)

D	—	concrete member or base material thickness
d_{fix}	—	Diameter of clearance hole in fixture
D_{min}	—	Minimum thickness of concrete member in which the anchor can be installed without damaging the concrete member
d_{nom}	—	Outside diameter of anchor
d_0	—	Drill hole diameter
e_{N}	—	Eccentricity of the resulting tensile load acting on the tensioned anchors w.r.t center of gravity
e_{V}	—	Eccentricity of the resulting shear load acting on the anchors w.r.t center of gravity
F	—	Force
f_{ck}	—	Characteristic cube compression strength of concrete (measured on cube with side length of 150 mm)
f_{y}	—	Characteristic yield stress for steel
f_{u}	—	Ultimate tensile stress for steel
$F_{\text{k,sp}}$	—	Splitting force
h_{ef}	—	Effective anchorage/ embedment depth
I_{p}	—	Radial moment of inertia
M	—	Moment
N	—	Normal force; positive in tension, negative in compression
n	—	Number of anchors in an anchor group
$N_{\text{Ld},\sigma*}$	—	Design load on most stressed anchor of group
R	—	Strength or resistance
s'	—	Spacing of anchor in an anchor group
s'_1	—	Centre-to-center spacing of anchors in an anchor group in direction 1
s'_2	—	Centre-to-center spacing of anchors in an anchor group in direction 2
$s'_{\text{cr,N}}$	—	Minimum spacing of anchors at which there is no influence of spacing on the characteristic strength of a single anchor in tension in case of concrete cone failure
$s'_{\text{cr,Np}}$	—	Minimum spacing of anchors at which there is no influence of spacing on the characteristic strength of a single anchor in tension in case of bond pullout failure
$s'_{\text{cr,sp}}$	—	Minimum spacing of anchors at which there is no influence of spacing on the characteristic strength of a single anchor in tension in case of splitting failure
s'_{min}	—	Minimum spacing at which the anchor can be installed without damaging the base material
T	—	Torsion
V	—	Shear force
Z_{el}	—	Elastic section modulus of anchor calculated from the stressed cross section of steel ($\pi d^3 / 32$)
τ	—	Bond strength
σ_{L}	—	Stress (taken as positive, if tension) in the concrete induced by external loads, including anchors loads
σ_{R}	—	Stress (taken as positive, if tension) in the concrete due to restraint of intrinsic imposed deformations or extrinsic imposed deformations
α_{gap}	—	Reduction factor to account for inertia effects due to a gap between anchor and fixture in shear
α_{M}	—	Factor to account for degree of fixity of the anchor

α_{seis} — Reduction factor to account for the influence of large cracks and scatter of load-displacement curves under seismic conditions

α_V — Angle between shear load on anchors and a line perpendicular to the edge for which the verification for concrete edge failure is being carried out

γ_f — Partial safety factor for load

γ_c — Partial safety factor for concrete

γ_{inst} — Partial safety factor for installation

γ_M — Partial safety factor for material

γ_{Mc} — Partial safety factor for concrete failure types (cone failure, pull-out /pull-through failure, concrete pry-out failure, concrete edge failure)

γ_{Mp} — Partial safety factor for bond failure

γ_{Msp} — Partial safety factor for splitting failure

γ_{Ms} — Partial safety factor for steel failure

l — Lever arm of shear load
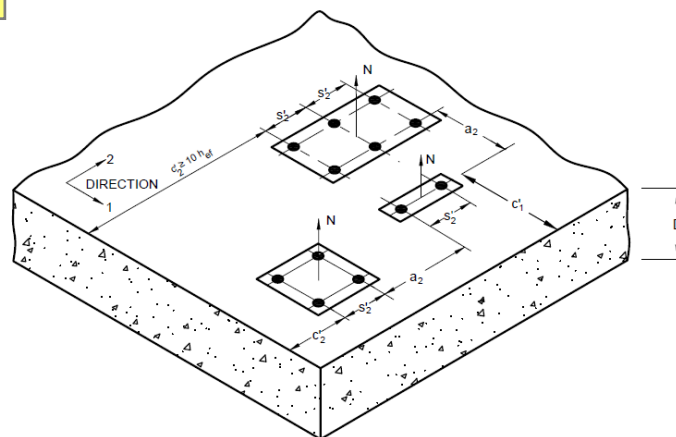
(1A) ANCHOR GROUPS SUBJECTED TO TENSILE LOAD
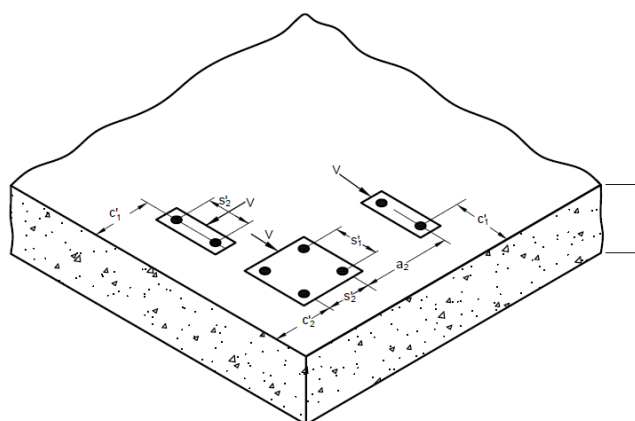
(1B) ANCHOR GROUPS SUBJECTED TO SHEAR LOAD IN CASE OF ANCHORAGE NEAR TO AN EDGE

FIG.1 NOTATIONS AND SYMBOLS

5 ANCHORS AND ANCHOR GROUP CONFIGURATIONS

The connection in a structure shall be designed so as to be consistent with the assumptions made in analysis of the structure and comply with requirements specified in this standard. The connections shall be capable of transmitting the calculated design loads in tension, shear or combined tension and shear. A suitable levelling course (non-shrink cementitious grout based) shall be provided between the concrete surface and the fixture. The thickness of the filling material shall be such that it does not create any stand-off between the base material and the plate.

5.1 Anchor

The anchors may be subjected to tension, shear, or combination of both and bending (in case of stand-off). The anchors may be made of suitable materials such as carbon steel, stainless steel or malleable cast iron. The anchors may include non-load bearing material such as plastic parts for rotation prevention.

NOTE: Undercut adhesive anchors are not covered in this standard.

5.2 Anchor Diameter and Embedment

The anchors shall have a minimum diameter of 6 mm.

5.2.1 For mechanical anchors, the embedment depth of the anchor shall be at least 6 times the anchor diameter. It shall have a minimum embedment of 40 mm. For fastening statically indeterminate non-structural elements, minimum embedment depth of anchor shall be 30 mm.

5.2.2 For adhesive anchors, the maximum embedment depth for design of the anchor shall be 20 times the anchor element diameter. Any embedment depth in excess of 20 times diameter shall be ignored in design calculation. The minimum embedment depth (h_{ef}) shall be as follows:

For
$$d_{\text{a}} \leq 10 \text{ mm}, \qquad h_{\text{ef}} = 60 \text{ mm}.$$
$$d_a = 12 \text{ mm}, \qquad h_{\text{ef}} = 70 \text{ mm};$$
$$d_a = 16 \text{ mm}, \qquad h_{\text{ef}} = 80 \text{ mm};$$
$$d_a = 20 \text{ mm}, \qquad h_{\text{ef}} = 90 \text{ mm}; \text{ and}$$
$$d_a \geq 24 \text{ mm}, \qquad h_{\text{ef}} = 4d_a .$$

5.3 Location Details of Anchors

5.3.1 *Clearance Holes in Fixtures for Anchors*

The diameter of clearance hole (d_{fix}) in the fixture shall not be larger than the values given below with the following exception that for an individual anchor or anchor groups loaded in pure tension, a larger diameter of the clearance hole is acceptable if a suitable washer is used.

For, $d < 10\ mm$ $\qquad$ $d_{\text{fix}} = d + 1$
$10 \leq d \leq 24$ mm $\qquad$ $d_{\text{fix}} = d + 2$
$d > 24$mm $\qquad$ $d_{\text{fix}} = d + 3$

$d = d_a$, if bolt bears against the fixture
$d = d_{\text{nom}}$, if sleeve bears against the fixture

5.3.2 *Permissible Anchor Group Configurations*

The anchor group configurations illustrated in Fig. 2 are valid for all loading directions and all edge distances, provided the gap between anchor and fixture is filled during installation. The gap shall be filled up by a suitable filling material of compatible strength.
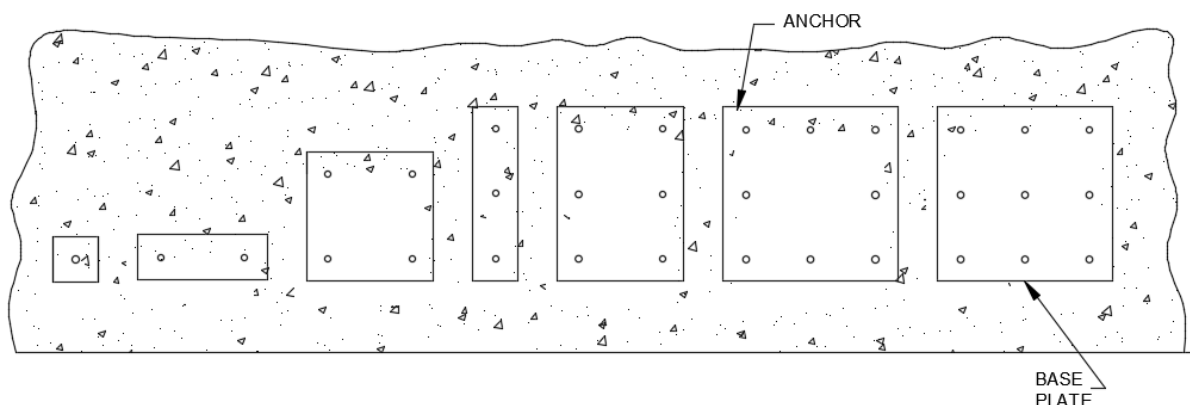
FIG. 2 ANCHOR GROUP CONFIGURATION WHEN ANNULAR GAPS ARE FILLED UP FOR ALL EDGE DISTANCE AND FOR ALL LOAD DIRECTIONS (SHEAR FORCE IS TAKEN UP BY ALL ANCHORS)

In case hole filling cannot be ensured at site, the following arrangements are allowed (*see* Fig. 3).
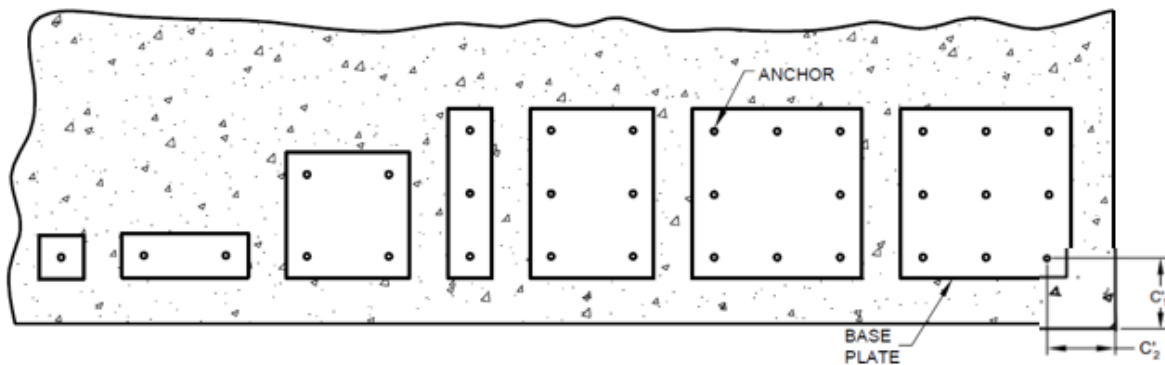
FIG. 3 ANCHORS WITH HOLE CLEARANCE ACCORDING TO 5.3.1. (WHEN ANNULAR GAPS ARE NOT FILLED UP) FOR ALL LOAD DIRECTIONS (SHEAR FORCE IS TAKEN UP BY THE FRONT ROW OF ANCHORS)

NOTE – Other anchor arrangements such as triangular or circular pattern may be allowed; however, the provisions of this standard should be applied with required engineering judgment in such cases.

5.4 Concrete Base Material

The concrete thicknesses required for post-installed mechanical anchors shall be at least $2h_{ef}$, but not less than 120 mm. The concrete thicknesses required for post-installed adhesive anchors shall be at least equal to $(h_{ef} + \Delta D)$, but not less than 100 mm, ΔD shall be taken as $2d_0$ or 30 mm whichever is larger. Concrete shall be assumed to be cracked for design purpose.

NOTE – In some cases, uncracked concrete may be assumed if under service conditions the anchor with its entire anchorage depth is located in compression zone. This will be satisfied if the following equation is observed.

$\sigma_L + \sigma_R \leq 0$

where, σ_L = Stress (taken as positive, if tension) in the concrete induced by external loads, including anchors loads.

σ_R = Stress (taken as positive, if tension) in the concrete due to restraint of intrinsic imposed deformations or extrinsic imposed deformations such as displacement of support and temperature variations. (*see* **IS 456**).

6 STRUCTURAL ANALYSIS

Loads and moments acting on the anchorage shall be determined using general principles of structural analysis (elastic) taking into account partial safety factors.

6.1 Tension Load – The direct tension forces and bending moments acting on the fixture shall be resolved into tension load acting on each anchor and shall be calculated according to the theory of elasticity using the following assumptions:

a) The anchor plate shall not deform under the design loads.

NOTE – For this assumption to be valid, the anchor plate shall be sufficiently stiff. Guidance may be taken from IS 800 on steel plate design.

b) The axial stiffness ($E_s A_s$) of all anchors shall be equal, where E_s shall be taken as per structural properties of material of the anchor.

c) The anchors shall not be considered to contribute in the transmission of normal forces in the zone of compression under the fixture. The compression forces shall be assumed to be transferred to concrete by fixture.

d) The modulus of elasticity of concrete (E_c) shall be considered as per IS 456.

If the magnitude of tension force acting on individual anchors ($N_{L,i}$) of an anchor group is different, then the eccentricity e_N of the total tension force acting on the anchor group ($N_{L,g}$) shall be calculated to enable accurate assessment of strength of the anchor group (*see* Fig. 4).

NOTE – Prying forces may occur due to deformation of fixtures and displacement of anchors, and shall be taken into account. Prying forces are avoided using rigid fixtures.

$$N_{L,g} = \Sigma N_{L,i}$$
$$N_{L1} = N_{L,\sigma}{}^*$$
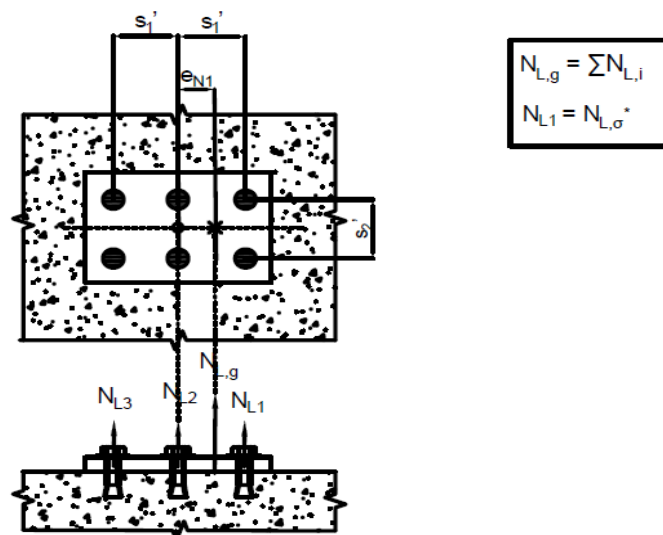
(4A) ECCENTRICITY IN ONE DIRECTION WHEN ALL ANCHORS ARE IN TENSION

$$N_{L,g} = \sum N_{L,i}$$
$$N_{L1} = N_{L,\sigma}^*$$
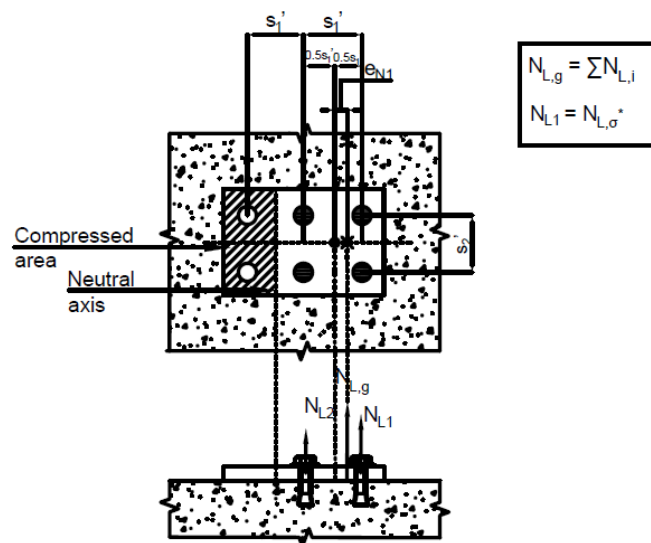
(4B) ECCENTRICITY IN ONE DIRECTION WHEN ONLY SOME OF THE ANCHORS OF AN ANCHOR GROUP ARE LOADED IN TENSION
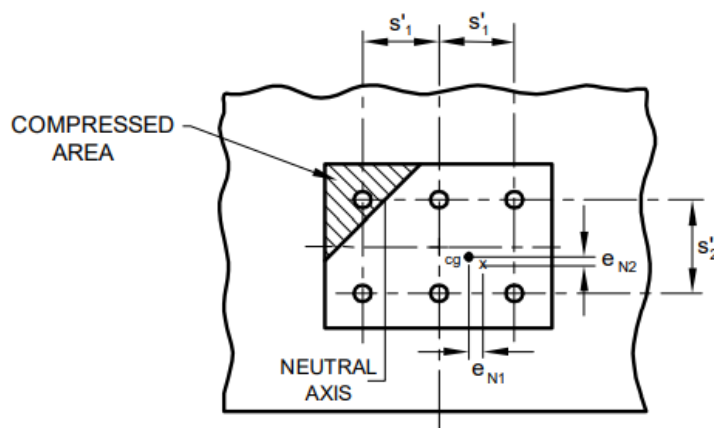
(4C) ECCENTRICITY IN TWO DIRECTIONS WHEN ONLY SOME OF THE ANCHORS OF AN ANCHOR GROUP ARE LOADED IN TENSION

10
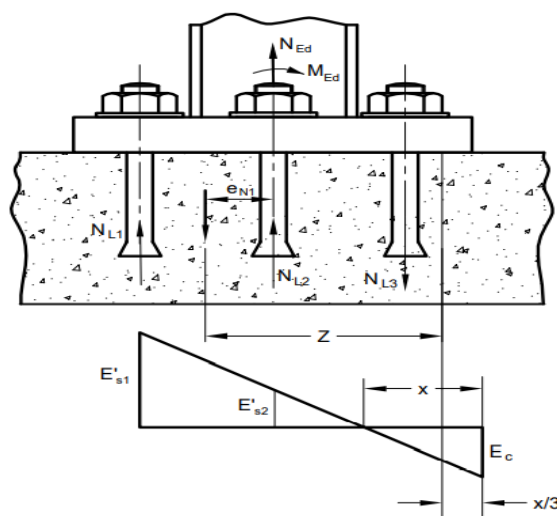
4D ANCHORAGE LOADED BY A BENDING MOMENT AND TENSION FORCE

Key:

⬤   Tensioned anchors

⊕   Center of gravity of anchors in tension

x   Point of resulting tensile force of tensioned anchors

FIG. 4 TYPICAL ANCHOR GROUPS SUBJECTED TO ECCENTRIC LOAD

6.2 Shear Load

6.2.1 *Distribution of Shear Loads*

The distribution of shear loads is dependent on the effectiveness of the anchors to resist shear loads which is influenced by the hole clearance and the edge distance.

a) In case of steel failure and concrete pry-out failure, it shall be assumed that all anchors of an anchor group will take up shear load (*see* Fig. 5).
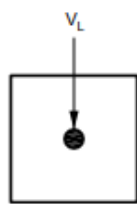
(5A) ANCHOR TAKING SHEAR LOAD
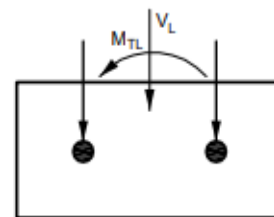
(5 B) TWO ANCHORS SUBJECTED TO SHEAR SUBJECTED TO SHEAR AND MOMENT
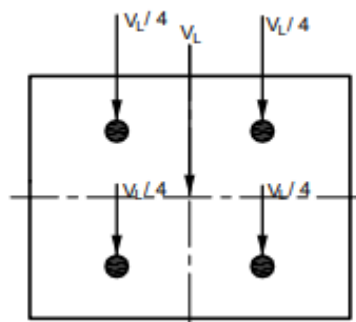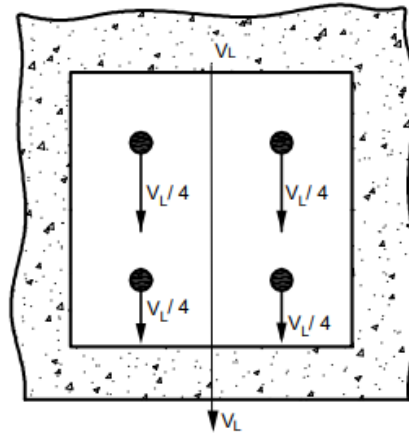

(5C) MULTIPLE ANCHORS SUBJECTED TO SHEAR

FIG. 5 EXAMPLE OF LOAD DISTRIBUTION FOR CASES WHEN ALL ANCHORS TAKE UP SHEAR LOAD

b) In case of concrete edge failure and filled clearance holes between the anchor and the fixture, it shall be assumed that all anchors take up shear forces perpendicular and parallel to the edge (*see* Fig. 6).
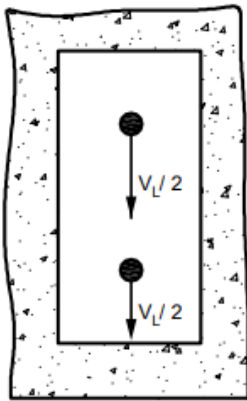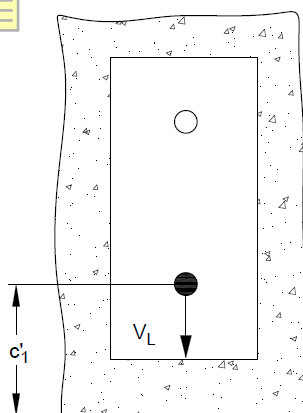

(6A) TWO ANCHOR GROUP   (6B) FOUR ANCHOR GROUP

FIG. 1 EXAMPLE OF DISTRIBUTION OF SHEAR LOAD - ANCHOR LOCATED NEAR THE EDGE (WHEN GAP BETWEEN THE ANCHOR AND THE FIXTURE IS FILLED UP)

c) In case of concrete edge failure with an unfilled clearance hole according to 5.3.1, it shall be assumed that only the most unfavourable anchor (first row of anchor) will take up shear loads acting perpendicular towards the edge (see Fig. 7). In case the shear is acting parallel to the edge then all anchors shall be assumed to take up shear load

NOTE — The slotted holes in fixtures in the direction of shear load prevent anchors from taking up shear loads and may be used in case of fastenings close to an edge (see Fig. 8). In this case, the anchors near to the edge would not take shear but other anchors can be designed for their full capacity.

For, eccentrically loaded connections, shear load transfer shall follow similar principles as above and load distribution shall be in accordance with Fig. 9.
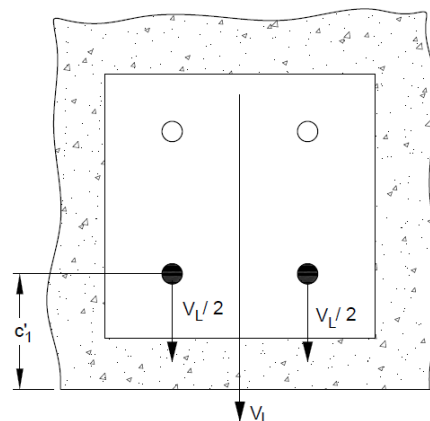
(7A)   (7B)

FIG. 2 EXAMPLE OF DISTRIBUTION OF SHEAR LOAD - ANCHOR LOCATED NEAR THE EDGE (WHEN GAP BETWEEN THE ANCHOR AND THE FIXTURE IS NOT FILLED UP
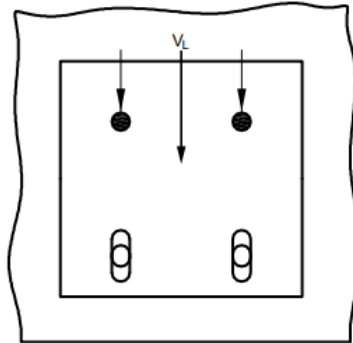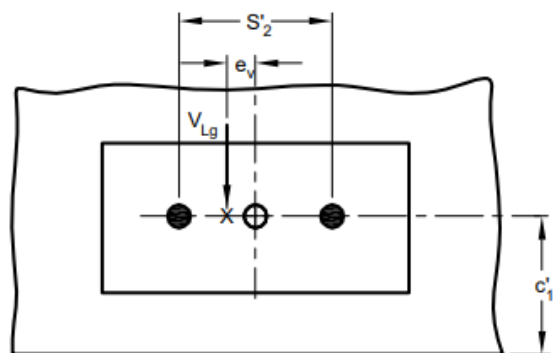

FIG. 3 EXAMPLE OF LOAD DISTRIBUTION FOR ANCHORAGE WITH SLOTTED HOLES

⊕   CENTER OF GRAVITY OF ANCHORES IN TENSION

X   POINT OF RESULTING TENSILE FORCE OF
    TENSIONED ANCHORS

FIG. 4 EXAMPLE OF ANCHORAGE SUBJECTED TO ECCENTRIC SHEAR LOAD
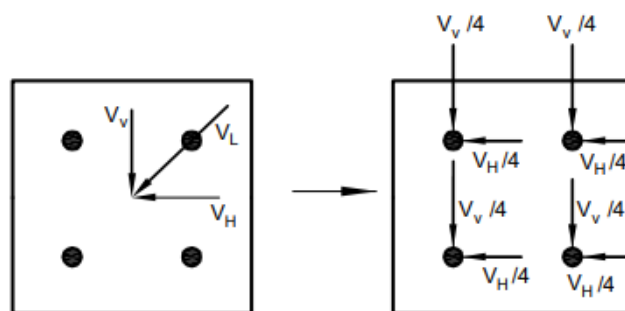
6.2.2 *Determination of Shear Loads*

The direct shear forces and torsion acting on the fixture shall be resolved into shear load acting on each anchor and shall be calculated according to the theory of elasticity assuming equal stiffness for all anchors in an anchor group. Equilibrium shall be satisfied. Some examples are illustrated in Fig. 10.
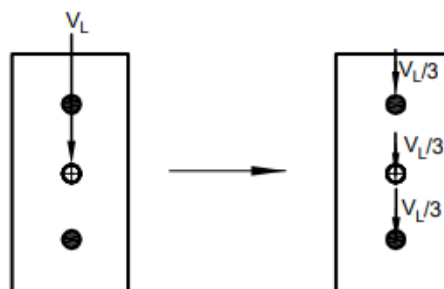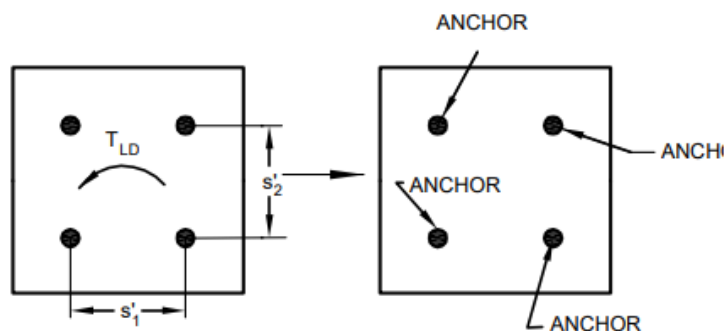
(10A) GROUP OF THREE ANCHORS SUBJECTED TO SHEAR
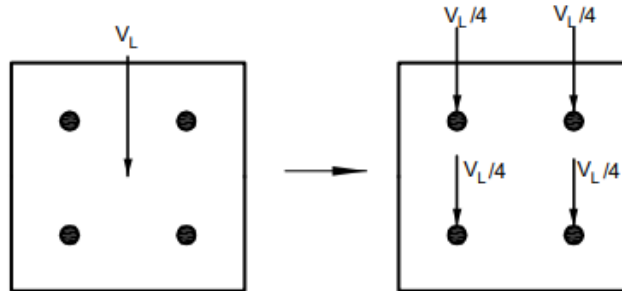
(10B) GROUP OF FOUR ANCHORS SUBJECTED TO SHEAR

$$V_{anchor} = \frac{T_{Sd}}{I_p} \cdot \left[(s_1/2)^2 + (s_2/2)^2 \right]^{0.5}$$

I_p = radial moment of inertia

(here: $I_p = s_1^2 + s_2^2$)

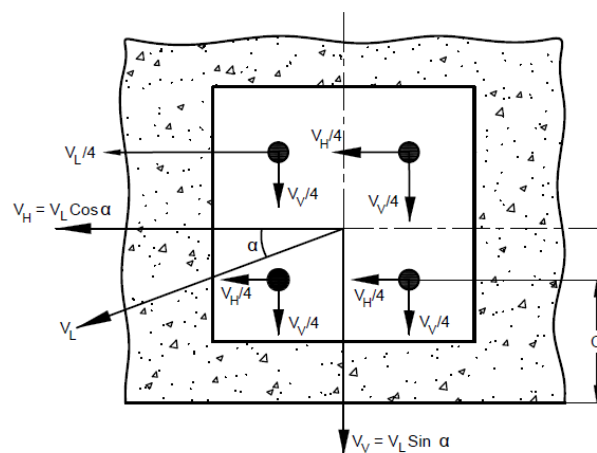(10C) GROUP OF FOUR ANCHORS SUBJECTED TO INCLINED SHEAR

(10D) GROUP OF FOUR ANCHORS SUBJECTED TO TORSION MOMENT

FIG. 5 DETERMINATION OF SHEAR LOADS FOR CASES WHEN LOAD IS TAKEN UP BY ALL ANCHORS, IN CASE OF STEEL AND CONCRETE PRY-OUT FAILURE

In case of anticipated concrete edge failure (that is, when anchors are located close to edge), it shall be assumed that all anchors take up shear forces perpendicular and parallel to the edge, given that the gap between the anchor and fixture is filled up (*see* Fig. 11). In case the shear is acting parallel to the edge then all anchors shall be assumed to take up shear load.
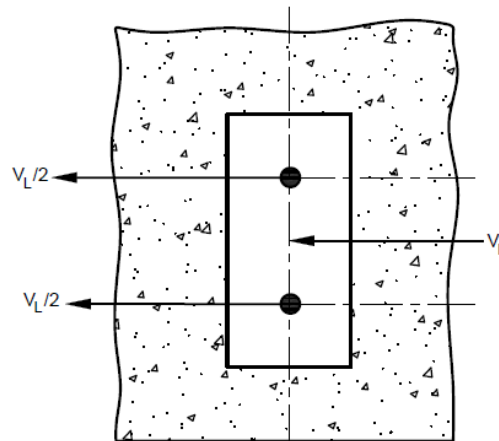
(11A) GROUP OF TWO ANCHORS WHEN LOADED IN SHEAR PARALLEL TO THE EDGE

(11B) GROUP OF FOUR ANCHORS WHEN LOADED BY INCLINED SHEAR LOAD
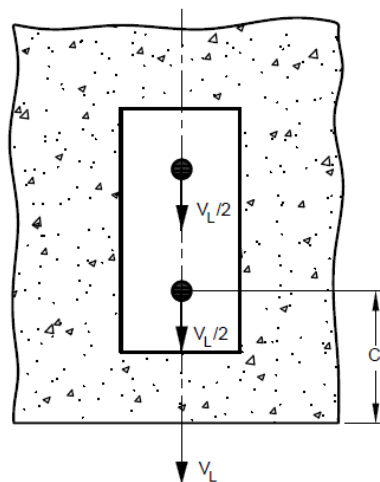
(11C) GROUP OF TWO ANCHORS WHEN LOADED IN SHEAR PERPENDICULAR
TO THE EDGE

FIG. 6 DETERMINATION OF SHEAR LOADS FOR CASES WHEN LOAD IS
TAKEN UP BY ALL ANCHORS (THAT IS, GAP BETWEENT THE ANCHOR AND
THE FIXTURE IS FILLED UP)

In special cases where the gap between the fixture and the anchor cannot be filled up
or in case of seismic shear loading, the anchors located in most unfavorable position
(that is anchors located closest to the edge) in case of concrete edge failure shall take
up load. In case the shear load is acting parallel to the edge then all anchors shall be
assumed to take up shear load. In case of concrete edge failure, if the anchor group
is subjected to inclined shear, then the load components acting perpendicular to the
edge shall be taken up by the most unfavorable anchors, while the load components
acting parallel to the edge shall be equally distributed to all anchors of the group (*see*
Fig. 12).
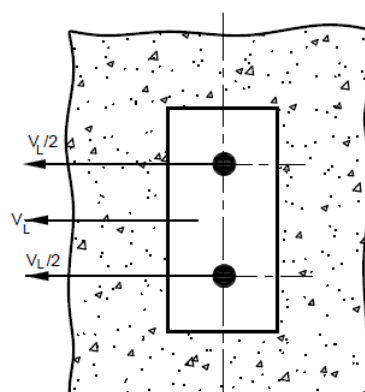
(12A) GROUP OF TWO ANCHORS WHEN LOADED IN SHEAR PARALLEL TO
THE EDGE

16

(12B) GROUP OF FOUR ANCHORS WHEN LOADED BY INCLINED SHEAR LOAD

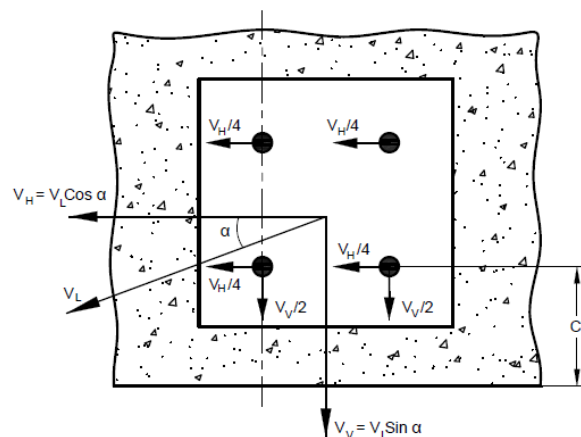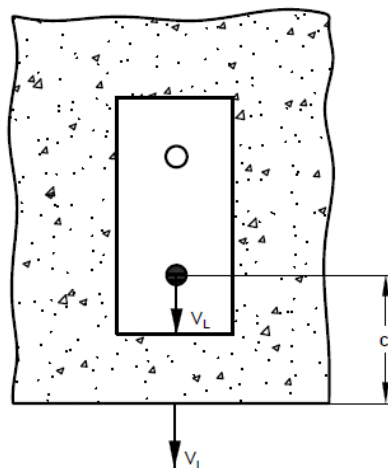(12C) GROUP OF TWO ANCHORS WHEN LOADED IN SHEAR PERPENDICULAR TO THE EDGE

FIG. 7 DETERMINATION OF SHEAR LOADS FOR CASES WHEN LOAD IS TAKEN UP BY EDGE ANCHORS (THAT IS, GAP BETWEEN THE ANCHOR AND THE FIXTURE IS NOT FILLED UP)

6.2.2.1 If the following conditions are met then it shall be assumed that anchors are subjected to shear loads without lever arm:

a) The fixture is made of metal. In the area of the anchorage, the fixture is fixed directly to the concrete either without an intermediate layer or with a leveling layer of mortar with compression strength of at least 30 N/mm^2 and thickness $\leq d_a/2$.

b) The fixture is in contact with the anchor over its entire thickness.

6.2.2.2 If the conditions given in **6.2.2.1** are not fulfilled then lever arm of shear load (l) shall be calculated according to the following equation (*see* Fig. 13).

$$l = a_3 + e_1$$

where,

$a_3 = 0.5d_a$ [exception: if a washer and a nut is directly clamped to the concrete surface (*see* Fig. 13B), then $a_3 = 0$]

e_1 = Distance between shear load and concrete surface
(*see* Fig.13A and 13B)

d_a = Anchor diameter; in case sleeve bears against the fixture use sleeve diameter (d_{nom}) (*see* Fig. 13A).
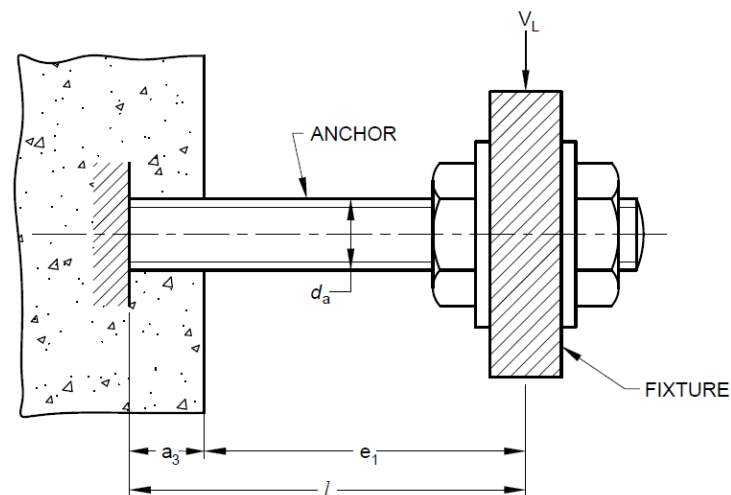
(13A) FOR ANCHORS DRILLED AND GROUTED
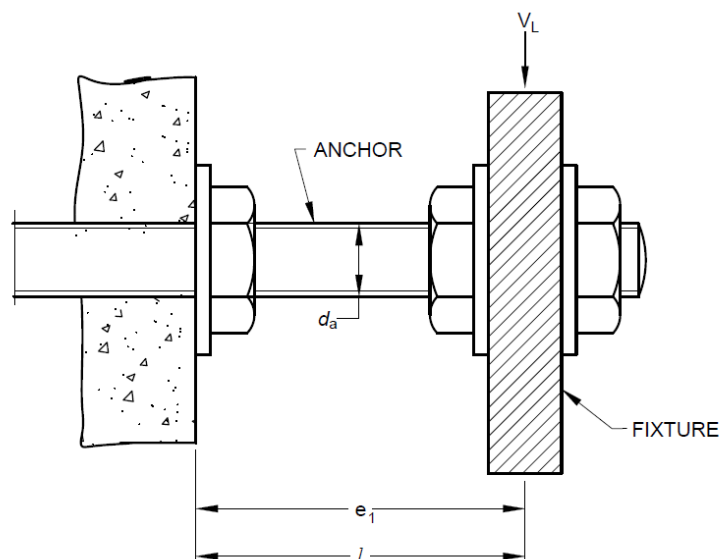
(13B) FOR ANCHORS BOLTED ON THE SURFACE

FIG. 13 DETERMINATION OF LEVER ARM

6.2.2.3 The design moment acting on the anchor due to shear load with lever arm shall be calculated according to the following equation:

18

$$M_{\text{Ld}} = V_{\text{Ld}}(l/\alpha_{\text{M}})$$

The value α_{M} in this equation depends on the degree of fixity of the anchor at the side of the fixture of the application in question. It shall be judged according to sound engineering practice.

If the fixture can rotate freely (*see* Fig. 14A), then no fixity (α_{M} = 1.0) shall be assumed.

If the fixture is not free to rotate (*see* Fig. 14B), then full fixity (α_{M} = 2.0) shall be assumed.

The fixture shall be able to take up the fixing moment in case restraint of the anchor is assumed.
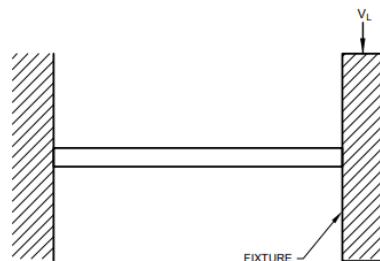
(14A) FIXTURE WITHOUT ROTATIONAL RESTRAINT (α_{M}= 1.0)
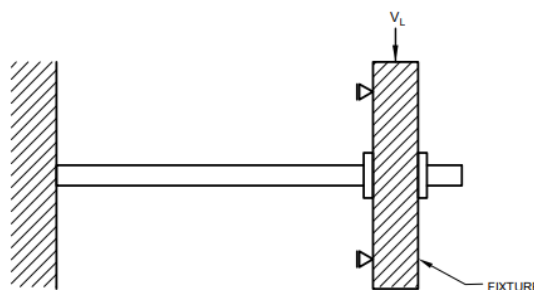
(14B) FIXTURE WITH ROTATIONAL RESTRAINT (α_{M}= 2.0)

FIG. 14 FIXTURE RESTRAINT CONDITIONS

7 DESIGN OF POST-INSTALLED ANCHORING SYSTEMS FOR STATIC OR QUASI-STATIC CONDITIONS

7.1 General

The characteristic values of the anchor to be used for the calculation of anchor strength and parameters like spacing, edge distance, minimum thickness of concrete member, etc. shall be taken from the assessment report (AR) of the anchor.

7.1.1 *Limit State Design*

The design of anchorages shall be done using limit state design method. It shall be established that the value of the design load, L_d does not exceed the value of the design strength, R_d.

$$L_d \leq R_d$$

where,

L_d	=	$\gamma_f L_e$
L_e	=	Unfactored loads shall be obtained from IS 875 (all Parts)
γ_f	=	Partial safety factor for loads (as per IS 456)
R_d	=	R_k / γ_m
R_k	=	Characteristic strength of a single anchor or an anchor group
γ_M	=	Partial safety factor for material.

7.1.2 *Limit State of Strength*

The limit state of strength are those associated with failures, under the action of most critical combination of loads on the anchorages using the appropriate partial safety factors, which may endanger the safety of life and property.

7.1.3 *Limit State of Serviceability*

In the serviceability limit state, it shall be ensured that the displacements of anchors occurring under the design loads are not larger than the admissible displacement as may be decided by the structural engineer.

NOTE — The admissible displacement depends on the application in question and shall be decided by the structural designer.

7.1.3.1 *Displacements*

The characteristic displacement of the anchor under defined tension and shear loads shall be taken from the Assessment Report. The displacements shall be assumed as a linear function of the applied load. In the case of combined tension and shear load, the displacements for the tension and the displacement for the shear component of the resultant load shall be geometrically added. The influence of the hole clearance in the fixture on the expected displacement of the whole anchorage system shall be taken into account in case of shear loads.

7.2 Design Method

The design strength shall be calculated according to limit state method of design for all load directions, namely tension, shear individually or combined as well as for all

applicable failure modes. The minimum strength shall govern after verification of interaction of tension and shear forces for the load case.

7.2.1 *Partial Safety Factors*

a) Partial safety factor for concrete failure

These could be cone failure (γ_{Mc}), pull-out / pull-through failure (γ_{Mp}), concrete pry-out failure (γ_{Mc}), concrete edge failure (γ_{Mc}), splitting failure (γ_{Msp}) and bond failure (γ_{Mp}).
$$\gamma_{Mc} = \gamma_{Msp} = \gamma_{Mp} = \gamma_c \cdot \gamma_{inst}$$

γ_c = Partial safety factor for concrete (as per IS 456) = 1.5
γ_{inst} = Installation safety factor of an anchor system in tension shall be taken from AR of the anchor. Installation safety factor of an anchor system in shear shall be taken as 1.0.

b) Partial safety factor for Steel failure (γ_{Ms})

For tension loading: $\gamma_{Ms} = 1.2/(f_y/f_u) \geq 1.4$
For shear loading of the anchor with and without lever arm:

$$\gamma_{Ms} = 1.0/(f_y/f_u) \geq 1.25 \quad \text{(for } f_u \leq 800 \text{ N/mm}^2 \text{ and } f_y/f_u \leq 0.8)$$
$$\gamma_{Ms} = 1.5 \quad\quad\quad\quad\quad\quad \text{(for } f_u > 800 \text{ N/mm}^2 \text{ or } f_y/f_u > 0.8)$$

7.2.2 *Design Strength in Tension*

The design strength in tension shall be calculated and checked according to limit state of design for all applicable failure modes as per Table 1, and the minimum strength shall govern.

Table 1 Design Strength Checks in Tension
(*Clause* 7.2.2)

SI No (1)	Strength to Resist Expected Failure Types (2)	Checks for Single Anchor (3)	Checks for Anchor Group (4)
i)	Steel strength	$N_{Ld} \leq N_{Rk,s}/\gamma_{Ms}$	$N_{Ld,\sigma*} \leq N_{Rk,s}/\gamma_{Ms}$
ii)	Concrete cone strength	$N_{Ld} \leq N_{Rk,c}/\gamma_{Mc}$	$N_{Ld,g} \leq N_{Rk,c}/\gamma_{Mc}$
iii)	Pull-out strength of mechanical anchor/ bonded expansion anchor	$N_{Ld} \leq N_{Rk,p}/\gamma_{Mp}$	$N_{Ld,\sigma*} \leq N_{Rk,p}/\gamma_{Mp}$
iv)	Pull-out strength of adhesive anchor	$N_{Ld} \leq N_{Rk,p}/\gamma_{Mp}$	$N_{Ld,g} \leq N_{Rk,p}/\gamma_{Mp}$
v)	Splitting strength	$N_{Ld} \leq N_{Rk,sp}/\gamma_{Msp}$	$N_{Ld,g} \leq N_{Rk,sp}/\gamma_{Msp}$

7.2.2.1 *Determination of steel strength*

The characteristic steel strength ($N_{\text{Rk},s}$) of an anchor shall be taken from the AR of the anchor and the steel strength check in tension shall be performed according to Table 1.

NOTE – If the value of characteristic steel strength is not available in the AR or then it may be calculated using the following equation, $N_{\text{Rk},s} = A_s f_u$

7.2.2.2 *Determination of concrete cone strength*

The characteristic concrete cone strength of an individual anchor or an anchor group, respectively, shall be determined according to the following equation:

$$N_{\text{Rk},c} = N_{\text{Rk},c}^0 \left(A_{c,N}/A_{c,N}^0\right)\Psi_{s,N}\Psi_{re,N}\Psi_{ec,N}\,\Psi_{M,N}$$

where

$N_{\text{Rk},c}^0$ = The characteristic strength of a single anchor placed in cracked or uncracked concrete in tension not influenced by adjacent fasteners or edges of the concrete member

$N_{\text{Rk},c}^0 = 7.2\sqrt{f_{ck}}h_{ef}^{1.5}$ (for applications in cracked concrete)
$N_{\text{Rk},c}^0 = 10.1\sqrt{f_{ck}}h_{ef}^{1.5}$ (for applications in uncracked concrete)
$s'_{cr,N} = 3h_{ef} = 2c'_{cr,N}$

$\Psi_{s,N}$ = Factor to account for discontinuities in the symmetric stress distribution in the concrete due to edges of the concrete member. The smallest edge distance shall be used as c in the following equation.
$\Psi_{s,N} = 0.7 + 0.3\left(c'/c'_{cr,N}\right) \le 1.0$

$\Psi_{re,N}$ = Factor to account for the effect of dense reinforcement between which the fastener is installed.

$\Psi_{re,N} = 0.5 + (h_{ef}/200) \le 1.0$

NOTE – If in the area of the anchorage there is reinforcement with a spacing $\ge$ 150 mm (any diameter) or with a diameter $\le$ 10 mm and a spacing $\ge$ 100 mm then the factor $\Psi_{re,N}$ shall be taken as 1.0.

$\Psi_{ec,N}$ = Factor to account for group effect when different tension loads are acting on the individual anchors of an anchor group. Where there is an eccentricity in two directions, $\Psi_{ec,N}$ shall be determined separately for each direction and the product of both factors shall be inserted the above equation for determining $N_{\text{Rk},c}$.
$\Psi_{ec,N} = \dfrac{1}{\left[1+\left(2e_N/s'_{cr,N}\right)\right]} \le 1$

$A_{c,N}^0$ = Idealized projected concrete cone area of an individual anchor with no influence of edge and spacing on the concrete cone strength of the anchor. It shall be calculated

by idealizing the concrete cone as a pyramid with a height equal to h_{ef} and a base length equal to $s'_{cr,N}$ (*see* Fig. 15), $A^0_{c,N} = s'_{cr,N} \cdot s'_{cr,N}$

$A_{c,N}$ = Actual projected concrete cone area of the anchorage at the concrete surface. It is limited by overlapping concrete cones of adjoining anchors as well as by edges of the concrete member when edge and spacing are less than the critical values. (*see* Fig. 16).

$\Psi_{M,N}$ = Factor to account for the influence of a compression force between the fixture and the concrete on the tensile strength of the anchor. The value shall be considered as 1 if either of the following criteria are met:

a) The anchor is located close to the edge $c' < 1.5\ h_{ef}$
b) Anchors which are located away from the edge ($c' > 1.5\ h_{ef}$) and loaded by bending moment as well as tension force, satisfy the equation $\dfrac{N''_c}{N_{Ld}} < 0.8$

c) $\dfrac{z}{h_{ef}} > 1.5$

For all other applications, it should be taken as $\left(2 - \dfrac{z}{h_{ef}}\right) \geq 1$

(z = lever arm and N''_c is the resultant compression force between the fixture and the concrete)

For direct tension forces the factor $\Psi_{M,N}$ shall be considered as 1.

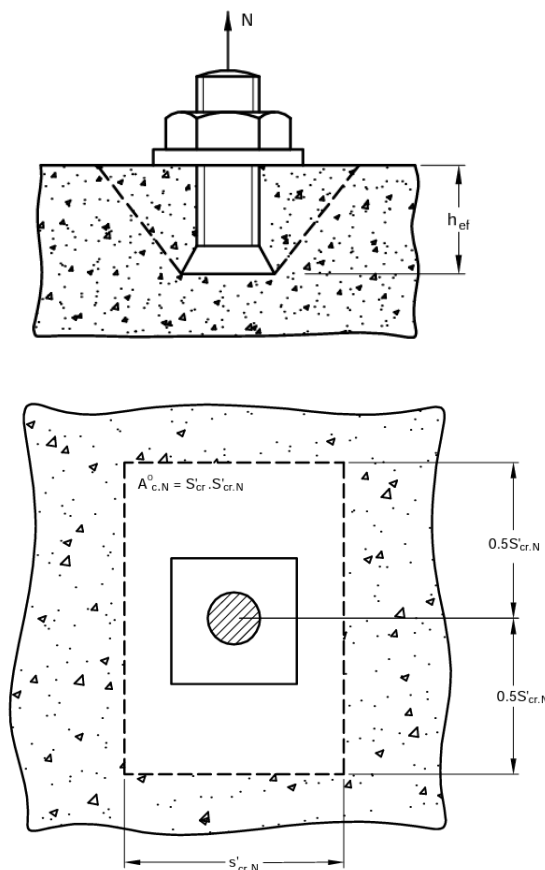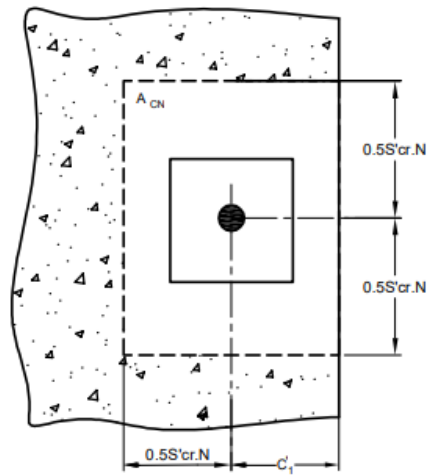FIG. 8 IDEALIZED PROJECTED CONCRETE CONE AREA OF AN INDIVIDUAL ANCHOR
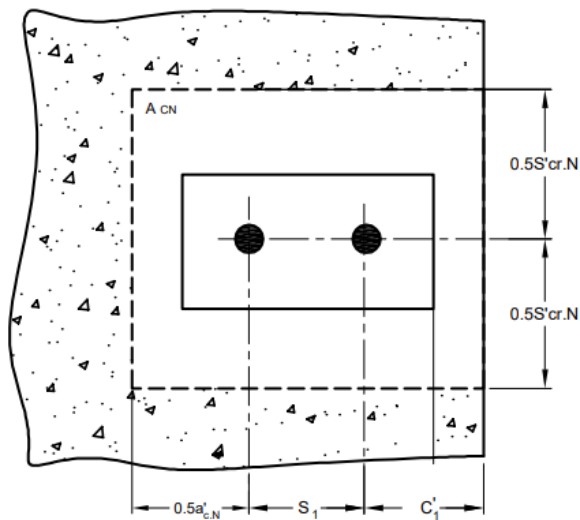

$$A_{c,N} = (c'_1 + 0.5s'_{cr,N}) * s'_{cr,N}$$
where
$$c'_1 \leq c'_{cr,N}$$

(16A) INDIVIDUAL ANCHOR LOCATED CLOSE TO THE EDGE OF CONCRETE MEMBER

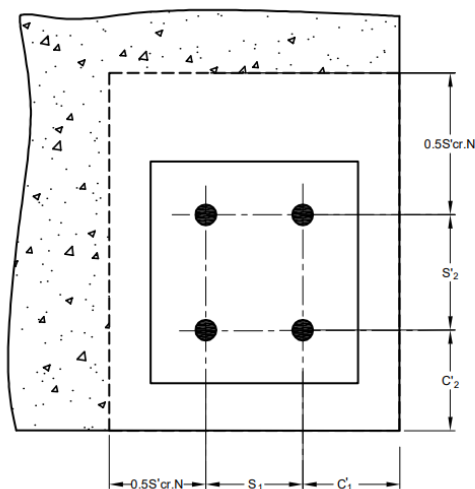$$A_{c,N} = (c'_1 + s'_1 + 0.5s'_{cr,N}) * s'_{cr,N}$$
where
$$c'_1 \leq c'_{cr,N}$$
$$s'_1 \leq s'_{cr,N}$$

(16B) GROUP OF TWO ANCHORS LOCATED CLOSE TO THE EDGE OF CONCRETE MEMBER

$A_{c,N} = (c'_1 + s'_1 + 0.5s'_{cr,N})*$
$\quad (c'_2 + s'_2 + 0.5s'_{cr,N})$
where
c'_1 & $c'_2 \leq c'_{cr,N}$
s'_1 & $s'_2 \leq s'_{cr,N}$

(16C) GROUP OF FOUR ANCHORS LOCATED AT A CORNER OF CONCRETE MEMBER

FIG. 9 EXAMPLES OF ACTUAL PROJECTED CONCRETE CONE AREA FOR DIFFERENT ANCHOR CONFIGURATIONS

7.2.2.2.1 *Special Case*

For anchorages with three or more edges with the largest edge distance less than the critical edge distance for concrete cone in tension (*see* Fig. 17), the calculation of strength as above may lead to very conservative values. For such cases, the embedment depth, h_{ef}, spacing, $s'_{cr,N}$ and edge distance, $c'_{cr,N}$ shall be substituted with their modified values as indicated below for determining the characteristic concrete cone strength, $N_{Rk,c}$ according to **7.2.2.2**. However, $\Psi_{re,N}$ shall be calculated with h_{ef} only.

$$h_{ef,mod} = \max\left[(c'_{max}/c'_{cr,N})h_{ef}, (s'_{max}/s'_{cr,N})h_{ef}\right]$$
$$s'_{cr,N,mod} = (h_{ef,mod}/h_{ef})s'_{cr,N}$$
$$c'_{cr,N,mod} = (h_{ef,mod}/h_{ef})c'_{cr,N}$$

where c'_{max} is the maximum distance from the center of the anchor to the edge of concrete member $(< c'_{cr,N})$, and

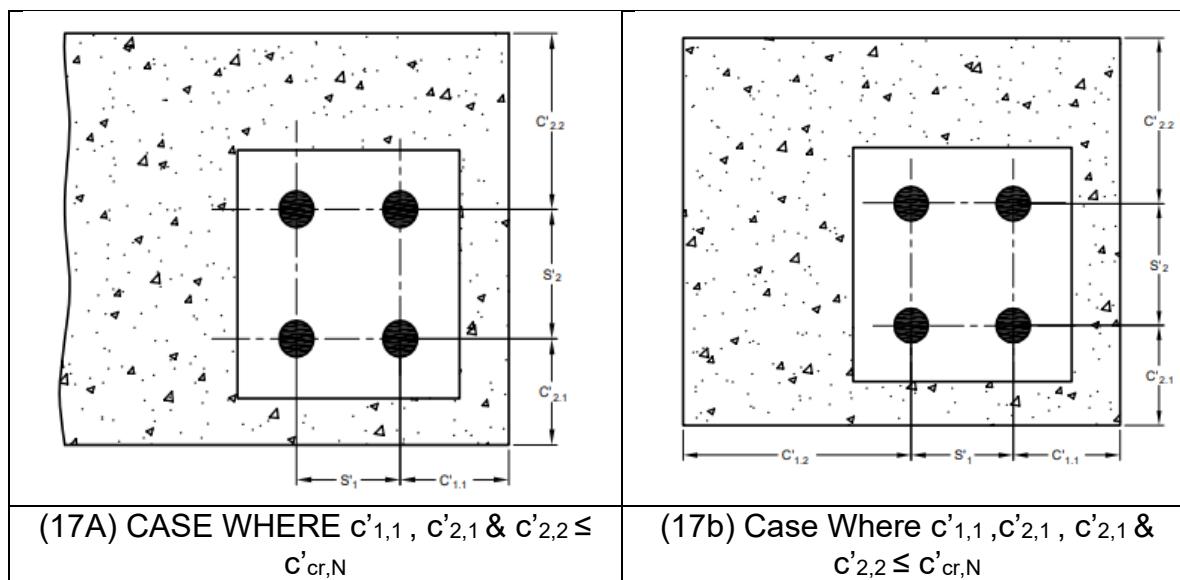s'_{max} is the maximum center to center distance between anchors $(< s'_{cr,N})$

| (17A) CASE WHERE c'$_{1,1}$, c'$_{2,1}$ & c'$_{2,2} \le$ c'$_{cr,N}$ | (17b) Case Where c'$_{1,1}$,c'$_{2,1}$, c'$_{2,1}$ & c'$_{2,2} \le$ c'$_{cr,N}$ |

FIG. 10 EXAMPLES OF SPECIAL CASES

7.2.2.3 *Pull-out strength of mechanical anchors*

The characteristic pull-out strength shall be taken from the AR of the anchor, depending on the concrete strength and the state of concrete (cracked or uncracked) assumed for design. The pullout strength shall be checked for anchor that is most stressed due to load.

7.2.2.4 *Pull-out (bond) strength of adhesive anchors*

The characteristic pull-out strength of an individual anchor or an anchor group, shall be determined according to the following equation:

$$N_{\mathrm{Rk,p}} = N_{\mathrm{Rk,p}}^0 \left(A_{\mathrm{p,N}}/A_{\mathrm{p,N}}^0\right)\Psi_{\mathrm{s,Np}}\Psi_{\mathrm{re,Np}}\Psi_{\mathrm{ec,Np}}\Psi_{g,\mathrm{Np}}$$

where,

$N_{\mathrm{Rk,p}}^0$ = The characteristic pull-out strength of an adhesive anchor placed in cracked or uncracked concrete and not influenced by adjacent fasteners or edges of the concrete member .

$$N_{\mathrm{Rk,p}}^0 = \Psi_{\mathrm{sus}}\pi d_a h_{\mathrm{ef}}\tau_{\mathrm{Rk,cr}'} \text{ (for applications in cracked concrete)}$$
$$N_{\mathrm{Rk,p}}^0 = \Psi_{\mathrm{sus}}\pi d_a h_{\mathrm{ef}}\tau_{\mathrm{Rk,uncr}'} \text{ (for applications in uncracked concrete)}$$

The values of $\tau_{\mathrm{Rk,cr}'}$ & $\tau_{\mathrm{Rk,uncr}'}$ are to be taken from AR.

$$\Psi_{\mathrm{sus}} = 1 \; for \; a_{\mathrm{sus}} \le \; \Psi_{\mathrm{sus}}^0$$

$$\Psi_{\mathrm{sus}} = \; \Psi_{\mathrm{sus}}^0 + 1 - \; a_{\mathrm{sus}} \; for \; a_{\mathrm{sus}} > \Psi_{\mathrm{sus}}^0$$

where Ψ_{sus}^0 is the product depending factor accounting for the effect of sustained loading on the bond strength of chemical anchor. It shall be taken from the AR of the chemical anchor, and it shall be taken as 0.6 if no value is given.

a_{sus} is the ratio between the value of sustained action (permanent action + permanent component of variable action) and the value of total action considered at limit state

$s'_{\text{cr,Np}} =$ Critical spacing for pull-out. In the following equation, $\tau_{\text{Rk,uncr}}$ shall correspond to M25 grade concrete,

$$= 7.3 d_{\text{a}} \left(\Psi_{\text{sus}} \tau_{\text{Rk,uncr}} \right)^{0.5} \leq 3 h_{\text{ef}}$$

$c'_{\text{cr,Np}} =$ Critical edge distance for pull-out

$$= 0.5 s'_{\text{cr,Np}}$$

$\Psi_{s,\text{Np}} =$ Factor to account for discontinuities in the symmetrical stress distribution in the concrete due to edges of the concrete member.

$$= 0.7 + 0.3 \left(c' / c'_{\text{cr,Np}} \right) \leq 1.0$$

$\Psi_{\text{re,Np}} =$ Factor to account for the negative effect of orthogonal reinforcement (that is, with orientation perpendicular to the direction of the force) in the area of the concrete cone.

$$= 0.5 + (h_{\text{ef}}/200) \leq 1.0$$

NOTE — If in the area of the anchorage there is reinforcement with a spacing $\geq$ 150 mm (any diameter) or with a diameter $\leq$ 10 mm and a spacing $\geq$ 100 mm then the factor $\Psi_{\text{re,Np}}$ shall be taken as 1.0.

$\Psi_{\text{ec,Np}} =$ Factor to account for group effect when different tension loads are acting on the individual anchors of an anchor group.

$$= \frac{1}{[1+(2 e_{\text{N}}/s'_{\text{cr,Np}})]} \leq 1$$

$\Psi_{\text{g,Np}} =$ Factor to account for the effect of failure surface for the anchor group. For individual anchor, this factor shall be taken as 1.0. The characteristic bond value τ_{Rk} shall correspond to the strength and the state of concrete assumed for design (cracked or uncracked).

$$= \Psi^0_{\text{g,Np}} - \left(s'/s'_{\text{cr,Np}} \right)^{0..5} \left(\Psi^0_{\text{g,Np}} - 1 \right) \geq 1.0$$

$$\Psi^0_{\text{g,Np}} = \sqrt{n} - \left(\sqrt{n} - 1 \right) \left[\frac{d_a \tau_{\text{Rk}}}{\varphi \sqrt{h_{\text{ef}}} \sqrt{f_{\text{ck}}}} \right]^{1.5} \geq 1.0$$

$n =$ No. of anchors in a group

$$\varphi = 2.3 \text{ for cracked concrete}$$
$$= 3.2 \text{ for uncracked concrete}$$

$A^0_{\text{c,Np}} =$ Idealized projected concrete cone area of an individual anchor with no influence of edge and spacing on the pull-out strength of the anchor. It shall be calculated by idealizing the concrete cone as a pyramid with a height equal to h_{ef} and a base length equal to $s'_{\text{cr,Np}}$ (*see* Fig. 15).

$A^0_{\text{c,Np}} = s'_{\text{cr,Np}} \cdot s'_{\text{cr,Np}}$

$A_{c,Np} =$ Actual projected concrete cone area of the anchorage at the concrete surface. It is limited by overlapping concrete cones of adjoining anchors as well as by edges of

the concrete member when edge and spacing are less than the critical values. $A_{c,Np}$ shall be calculated in a manner similar to $A_{c,N}$ as shown in Fig. 16 but using the critical edge distance ($c'_{cr,Np}$) and spacing ($s'_{cr,Np}$) values that correspond to pull-out.

7.2.2.5.1 *Special Case*

For anchorages with three or more edges with the largest edge distance less than the critical edge distance for pullout in tension, the calculation of strength as above may lead to very conservative values. For such cases, the embedment depth, h_{ef}, spacing, $s'_{cr,N}$ and edge distance, $c'_{cr,N}$ shall be substituted with their modified values as indicated below for determining the characteristic pull out strength $N_{Rk,p}$ according to

7.2.2.4. However, $\Psi_{re,N}$ shall be calculated with h_{ef} only.

$$h_{ef,mod} = \max\left[(c'_{max}/c'_{cr,Np})h_{ef}, (s'_{max}/s_{cr,Np})h_{ef}\right]$$
$$s'_{cr,Np,mod} = (h_{ef,mod}/h_{ef})s'_{cr,Np}$$
$$c'_{cr,Np,mod} = (h_{ef,mod}/h_{ef})c'_{cr,Np}$$

7.2.2.5 *Determination of splitting strength*

The characteristic splitting strength of an individual anchor or an anchor group, shall be determined using the following equation:

$$N_{Rk,sp} = N^0_{Rk,sp}(A_{c,N}/A^0_{c,N})\Psi_{s,N}\Psi_{re,N}\Psi_{ec,N}\Psi_{h,sp}$$

where,

$N^0_{Rk,sp}$ shall be taken as minimum of $N_{Rk,c}$ and $N_{Rk,p}$. The factors $N_{Rk,c}$, $A_{c,N}$, $A^0_{c,N}$, $\Psi_{s,N}$, $\Psi_{ec,N}$, $\Psi_{re,N}$ shall be determined according to **7.2.2.2** but using the critical edge distance ($c'_{cr,sp}$) and spacing ($s'_{cr,sp}$) values that correspond to splitting, taken from the AR of the anchor.

$\Psi_{h,sp}$ = Factor to account for the influence of the actual base material depth (D) on the splitting strength. In the following equation, D_{min} corresponding to splitting failure shall be used.

$$\Psi_{h,sp} = (D/D_{min})^{\frac{2}{3}} \le \max[1, (h_{ef} + 1.5\, c'/D_{min})^{\frac{2}{3}}] \le 2$$

NOTE – This check may be omitted if either of the following conditions are fulfilled:

a) The edge distance in all directions is greater than or equal to $1.2c'_{cr,sp}$ and the base material is greater than or equal to $2h_{ef}$.

b) For anchors suitable for use in cracked concrete:

    1) Reinforcement is present to limit crack width to 0.3 mm, taking into account the splitting forces according to section 9.3

    2) The characteristic strength for concrete cone failure and pull-out failure is calculated for cracked concrete

    c) If the edge distance of an anchor is smaller than the value $c_{cr,sp}$ then the presence of longitudinal reinforcement between anchor and edge should be ensured.

 7.2.2.6 *Special case*

The special case for anchorages with three or more edges as defined under **7.2.2.2** shall also apply to splitting failure due to loading. The modified value of embedment, spacing and edge distance as recommended under **7.2.2.2** shall be calculated using critical edge and spacing values corresponding to splitting failure. However, the range for $\Psi_{h,sp}$ for adhesive anchors shall be calculated using the actual value embedment, h_{ef}.

7.2.3 *Design Strength in Shear*

The design strength in shear shall be calculated and checked according to limit state of design for all applicable failure modes as per Table 2. The minimum strength shall govern.

Table 2 Design Strength Checks in Shear

(*Clause* 7.2.3)

SI No (1)	Strength to Resist Expected Failure Types (2)	Checks for Single Anchor (3)	Checks for Anchor Gruop (4)
i)	Steel strength (for shear load without lever arm)	$V_{Ld} \leq V_{Rk,s}/\gamma_{Ms}$	$V_{Ld,\sigma*} \leq V_{Rk,s}/\gamma_{Ms}$
ii)	Steel strength (for shear load with lever arm)	$V_{Ld} \leq V_{Rk,s}/\gamma_{Ms}$	$V_{Ld,\sigma*} \leq V_{Rk,s}/\gamma_{Ms}$
iii)	Concrete pry-out strength	$V_{Ld} \leq V_{Rk,cp}/\gamma_{Mc}$	$V_{Ld,g} \leq V_{Rk,cp}/\gamma_{Mc}$
iv)	Concrete edge strength	$V_{Ld} \leq V_{Rk,c}/\gamma_{Mc}$	$V_{Ld,g} \leq V_{Rk,c}/\gamma_{Mc}$

7.2.3.1 *steel strength for shear load without lever arm*

The characteristic steel strength, $V_{Rk,s}^0$ of an anchor subjected to shear load without lever arm shall be taken from the AR of the anchor.

The characteristic resistance of a fastener ($V_{Rk,s}$) accounting for ductility of the fastener in a group is given by

$$V_{Rk,s} = k_1 V_{Rk,s}^0$$

k_1 is product dependent factor and shall be taken from the AR.

NOTE – If the value of characteristic steel strength is not available in the AR then it may be calculated using the following equation for anchors having uniform cross section along its length.

$V_{Rk,s}^0 = 0.5 A_s f_u$ [This is applicable only for $f_u \leq 1\ 000$ N/mm^2]

7.2.3.2 *steel strength for shear load with lever arm*

The characteristic steel strength, $V_{\mathrm{Rk,s}}$ of an anchor subjected to shear load with lever arm shall be calculated using the following equation. The characteristic bending strength $M_{\mathrm{Rk,s}}^0$, characteristic steel strength $N_{\mathrm{Rk,s}}$ and the material safety factor γ_{Ms} shall be taken from AR of the anchor.

$$V_{\mathrm{Rk,s}} = \left(\alpha_{\mathrm{M}} M_{\mathrm{Rk,s}}\right)\Big/ l$$

where,

α_{M} = Factor to account for degree of fixity of the anchor at the side of the fixture (*see* **6.2.2.3**)

ℓ = Lever arm (*see* 6.2.2.2)

$M_{\mathrm{Rk,s}} = M_{\mathrm{Rk,s}}^0 [1 - N_{\mathrm{Ld}}/(N_{\mathrm{Rk,s}}/\gamma_{\mathrm{Ms}})]$

NOTE – If the value of characteristic bending strength is not available in the AR then it may be calculated using the following equation for anchors having uniform cross section along its length.

$$M_{\mathrm{Rk,s}}^0 = 1.2 Z_{el} f_{\mathrm{u}}$$

7.2.3.3 *Determination of concrete pry-out strength*

The characteristic concrete pry-out strength (*see* Fig. 18) of an individual anchor or an anchor group, shall be determined according to the following equations.

For mechanical anchors, $V_{\mathrm{Rk,cp}} = \mathrm{k}_{\mathrm{cp}} \, N_{\mathrm{Rk,c}}$

For adhesive anchors: $V_{\mathrm{Rk,cp}} = \min\left(\mathrm{k}_{\mathrm{cp}} N_{\mathrm{Rk,p}}, \mathrm{k}_{\mathrm{cp}} N_{\mathrm{Rk,c}}\right)$

The factor k_{cp} shall be taken from the relevant assessment report.

NOTE – In cases where the anchor group is loaded by shear loads and/or external torsion moments, the direction of the individual shear loads may change. Figure 19 demonstrates this for a group of two anchors loaded by a torsion moment. The above equations are not suitable for this application. The shear loads acting on the individual anchors neutralize each other and the shear load acting on the entire group (V_{Ld}) is 0.
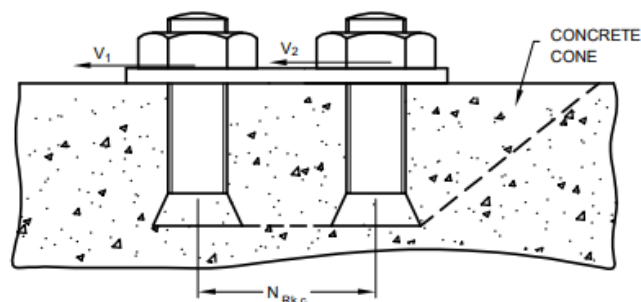

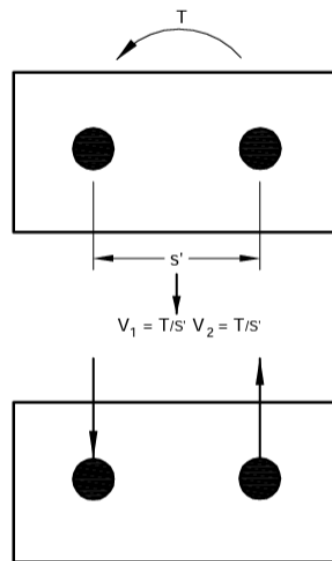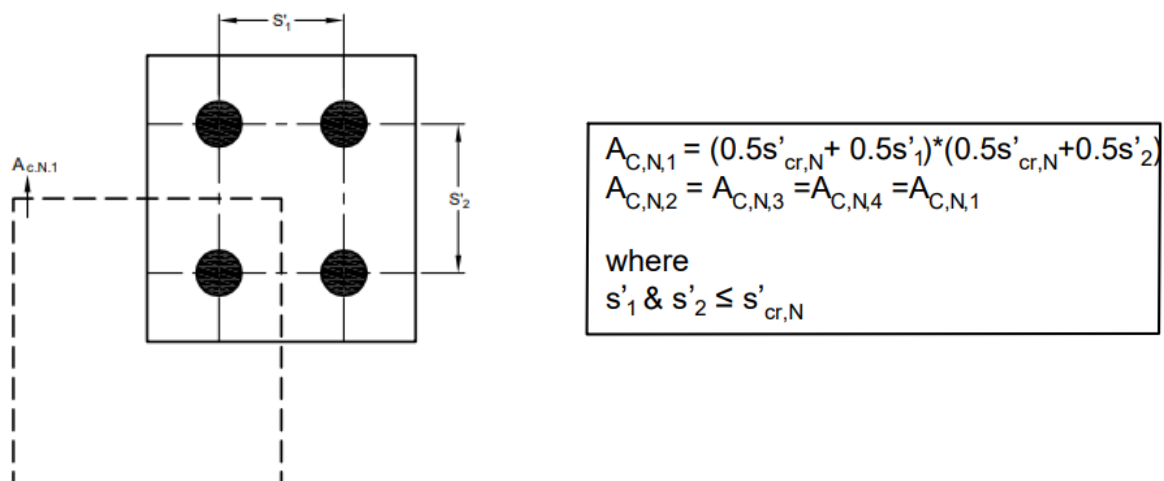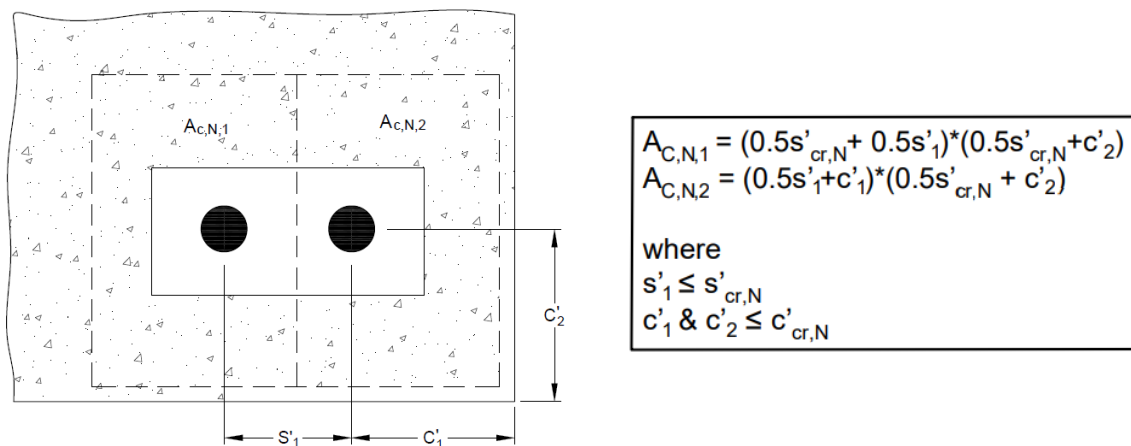FIG. 11 TYPICAL CONCRETE PRY-OUT FAILURE

FIG.19 GROUP OF ANCHORS LOADED BY TORSION MOMENT

When the horizontal or vertical components of the shear loads on the anchors change direction within a group (for example, torsion or inclined shear), the verification of pry-out failure for the entire group shall be substituted by the verification of pry-out failure for the most unfavorably positioned and loaded anchor of the group. When calculating the strength of the most unfavorable anchor, the influences of both edge distances as well as anchor spacing shall be considered. This shall be done by using the $A_{c,N}$ for the most unfavorably loaded anchor in N_{Rk} calculation for determining concrete pryout strength using above equation. Examples for the calculation of $A_{c,N}$ for individual anchors of an anchor group are illustrated in Fig. 20.

$$A_{C,N,1} = (0.5s'_{cr,N} + 0.5s'_1)*(0.5s'_{cr,N} + 0.5s'_2)$$
$$A_{C,N,2} = A_{C,N,3} = A_{C,N,4} = A_{C,N,1}$$

where
$$s'_1 \,\&\, s'_2 \leq s'_{cr,N}$$

(20A) GROUP OF FOUR ANCHORS WITHOUT EDGE INFLUENCE

$$A_{C,N,1} = (0.5s'_{cr,N} + 0.5s'_1)*(0.5s'_{cr,N} + c'_2)$$
$$A_{C,N,2} = (0.5s'_1 + c'_1)*(0.5s'_{cr,N} + c'_2)$$

where
$$s'_1 \leq s'_{cr,N}$$
$$c'_1 \ \& \ c'_2 \leq c'_{cr,N}$$

(20B) GROUP OF TWO ANCHORS IN A CORNER

FIG. 20 EXAMPLES OF ACTUAL PROJECTED CONCRETE CONE AREA ($A_{C,N}$) FOR INDIVIDUAL ANCHORS IN A GROUP

7.2.3.4 *Concrete edge strength*

The characteristic concrete edge strength of an individual anchor or an anchor group, shall be determined according to the following equation. For anchorages placed at a corner, the strengths for both edges shall be calculated, and the smallest value shall govern.

$$V_{\text{Rk,c}} = V^0_{\text{Rk,c}}\left(A_{c,V}/A^0_{c,V}\right)\Psi_{s,V}\Psi_{re,V}\Psi_{ec,V}\Psi_{h,V}\Psi_{\alpha,V}$$

In case of an anchor group with filled clearance holes and more than one row in direction of the shear load each crack plane "i" shall be considered separately.

$$V_{Rk,c,i} = \frac{n}{n_i} \cdot V^0_{\text{Rk,c}}\left(A_{c,V}/A^0_{c,V}\right)\Psi_{s,V}\Psi_{re,V}\Psi_{ec,V}\Psi_{h,V}\Psi_{\alpha,V}$$

Where
$V_{\text{Rkc,i}}$ is the shear capacity associated with the break-out body of the crack plane i.
n = total number of anchors in the group
n_i = number of anchors located within the breakout body of the crack plane i

The minimum strength out of the above shall govern the design for concrete edge break-out.

$$V_{Rk,c} = MIN(V_{Rk,c,1}; \ldots ; V_{Rk,c,i})$$

This has been elaborated in Fig 23.

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In case the hole filling cannot be conformed at site, only the capacity of the front row anchors shall be considered for concrete edge break-out verification.

$V_{\mathrm{Rk,c}}^0$ = The characteristic strength of a single anchor placed in cracked or uncracked concrete, loaded perpendicular to the edge in shear and not influenced by adjacent fasteners or edges of the concrete member

$$= 1.7d^{\alpha}h_{\mathrm{ef}}^{\beta}\sqrt{f_{\mathrm{ck}}}c_1'^{1.5} \text{ (for applications in cracked concrete)}$$

$$= 2.4d_{\mathrm{a}}^{\alpha}h_{\mathrm{ef}}^{\beta}\sqrt{f_{\mathrm{ck}}}c_1'^{1.5} \text{ (for applications in uncracked concrete)}$$

$\alpha = 0.1(h_{\mathrm{ef}}/c_1')^{0.5}$

$\beta = 0.1(d_{\mathrm{a}}/c_1')^{0.2}$

$s'_{\mathrm{cr,V}} = 3c_1' = 2c'_{\mathrm{cr,V}}$

$\Psi_{s,\mathrm{V}}$ =Factor to account for discontinuities in the symmetrical stress distribution in the concrete due to edges of the concrete member on shear strength.

For anchorages with the edges parallel to the direction of load (for example in a narrow concrete member), the smallest edge distance shall be used as c_2' in the following equation.

$$\Psi_{s,\mathrm{V}} = 0.7 + 0.3(c_2'/1.5c_1') \leq 1.0$$

$\Psi_{\mathrm{re,V}}$ = Factor to account for effect of reinforcement in cracked concrete.

$\quad$ = 1.0 (For anchorage in uncracked concrete and anchorage in cracked concrete without edge reinforcement)

$\quad$ = 1.4 (For anchorage in cracked concrete with edge reinforcement and closely spaced stirrups (spaced at less than or equal to 100 mm)

$\Psi_{\mathrm{ec,V}}$ = Factor to account for group effect when different shear loads are acting on the individual anchors of an anchor group.

$$= \frac{1}{[1+(2e_{\mathrm{V}}/s'_{\mathrm{cr,V}})]} \leq 1$$

$\Psi_{\mathrm{h,V}}$ = Factor to account for member thickness

$$= (1.5c_1'/D)^{0.5} \geq 1$$

$\Psi_{\alpha,\mathrm{V}}$ = Factor to account for the angle α_V between the load applied, V_{Ld}, and the direction perpendicular to the free edge of the concrete member ($\alpha_v \leq 90°$).

$$= \sqrt{\frac{1}{(\cos\alpha_V)^2+(0.5\sin\alpha_V)^2}} \geq 1.0$$

NOTE – In case $\alpha_V > 90°$ it shall be assumed that only the component of the shear load parallel to the edge is acting on the anchor. The component acting away from the edge may be neglected for checking concrete edge failure.

$A_{c,V}^0$ = Idealized projected concrete cone area of an individual anchor at the lateral concrete surface with no influence of edge, spacing and member thickness on the concrete edge strength of the anchor. It shall be calculated by idealizing the concrete edge cone as half pyramid with height equal to $1.5c_1$ and a base length equal to $3c'_1$ (*see* Fig. 21).

$$A_{c,N}^0 = 4.5c'^2_1$$

$A_{c,V}$ = Actual projected concrete cone area of the anchorage at the lateral concrete surface. It is limited by overlapping concrete cones of adjoining anchors, member thickness as well as by edges of the concrete member parallel to the assumed load direction (*see* Fig. 22).
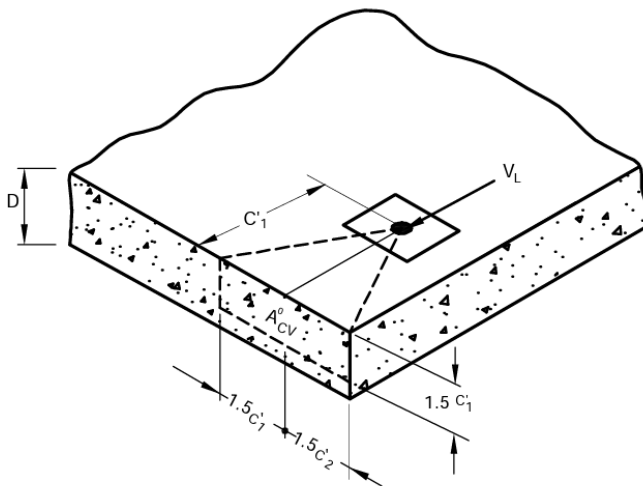
NOTE – For the calculation of $A_{c,N}^0$ and $A_{c,V}$ it is assumed that the shear loads are applied perpendicular to the edge of the concrete member.
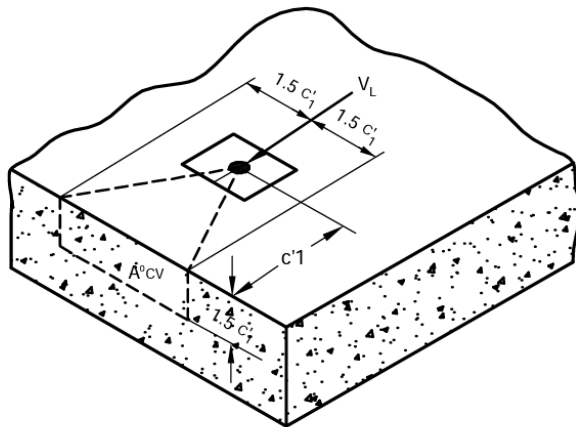
$$A_{c,v}^0 = (1.5c'_1 + 1.5c'_1)*1.5c'_1 = 4.5c'_1$$
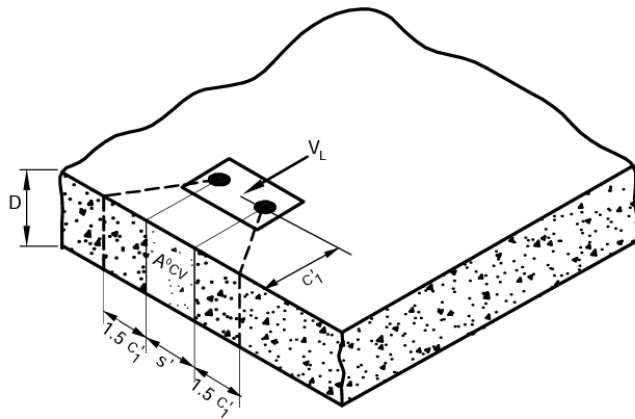
where
$$D > 1.5c'_1$$

FIG. 21 IDEALIZED PROJECTED CONCRETE CONE AREA, $A_{c,V}^0$ OF AN INDIVIDUAL ANCHOR

$$A_{c,v} = (1.5c'_1 + c'_2)*1.5c'_1$$

where
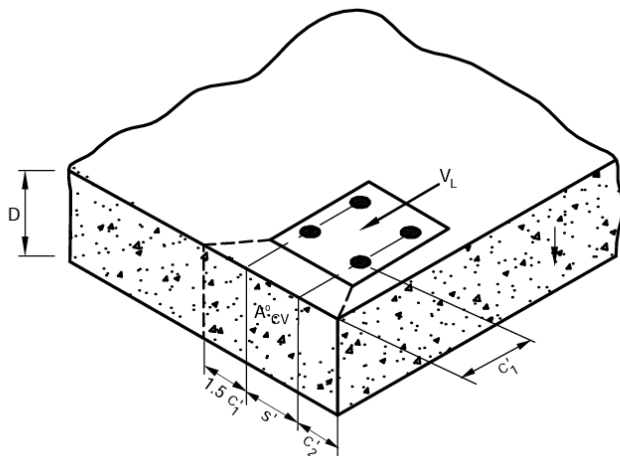$$D > 1.5c'_1$$
$$c'_2 \le 1.5c'_1$$

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(22A) SINGLE ANCHOR AT A CORNER

$$A_{c,v} = (1.5c'_1 + s'_2 + 1.5c'_1)*D$$

where
$$D \leq 1.5c'_1$$
$$s'_2 \leq 3c'_1$$

(22B) GROUP OF ANCHORS AT AN EDGE IN A THIN CONCRETE MEMBER

$$A_{c,v} = (1.5c'_1 + s'_2 + c'_2)*D$$

where
$$D \leq 1.5c'_1$$
$$s'_2 \leq 3c'_1$$
$$c'_2 \leq 1.5c'_1$$

(22C) GROUP OF ANCHORS AT CORNER IN A THIN CONCRETE MEMBER with unfilled clearance holes (front anchor take the shear load perpendicular to the edge)

FIG. 12 EXAMPLES OF ACTUAL PROJECTED CONCRETE CONE AREA FOR DIFFERENT ANCHOR CONFIGURATIONS SUBJECTED TO SHEAR LOAD
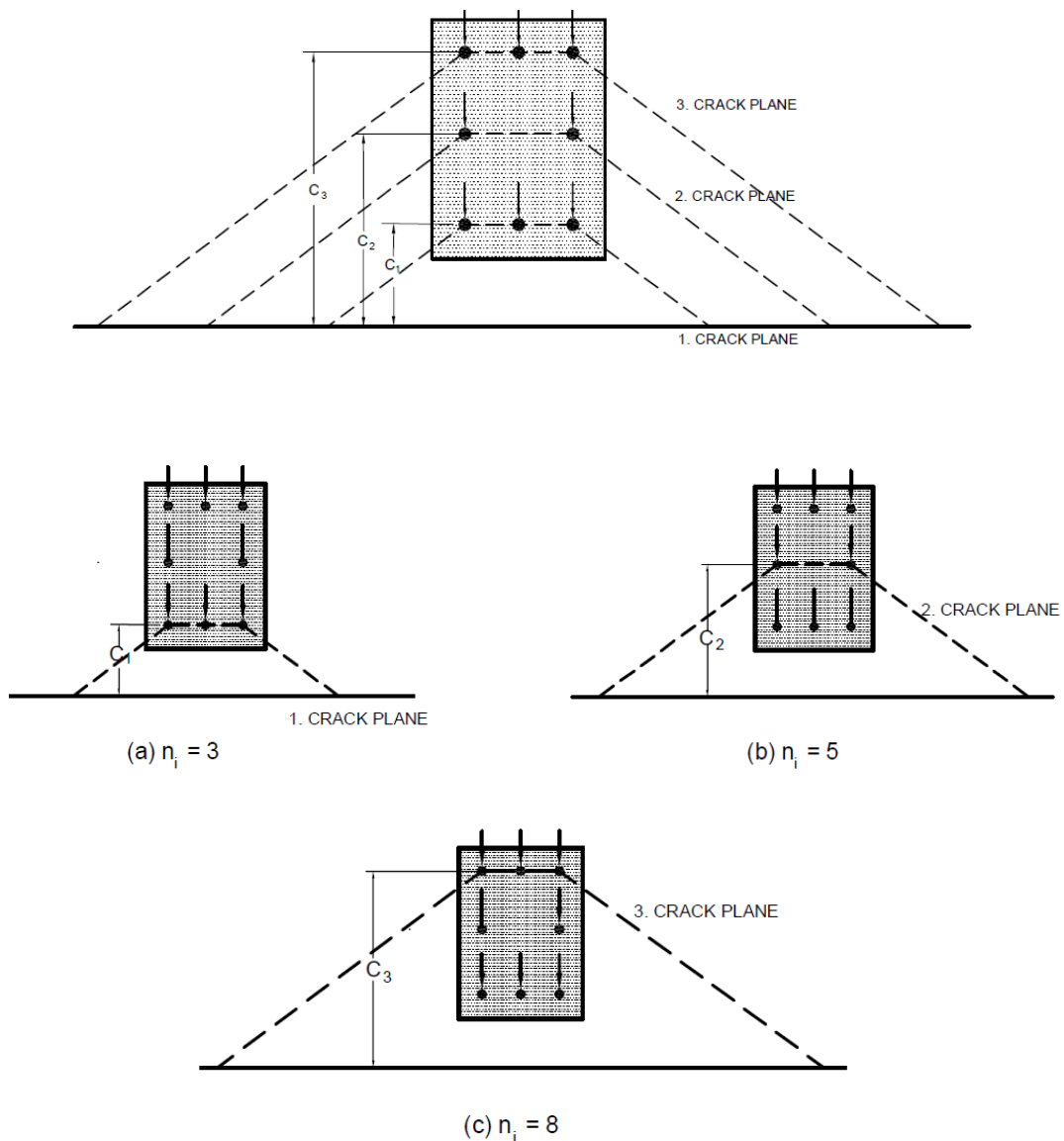
FIG. 23 CRACK PLANES WITH A GROUP OF 8 ANCHORS WITH A SHEAR LOAD PERPENDICULAR TO THE EDGE, NUMBER OF ANCHORS N_I WITHIN THE RESPECTIVE CRACK PLANE

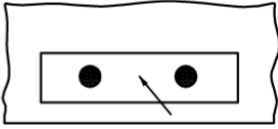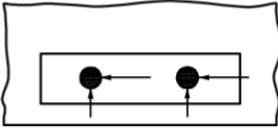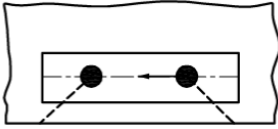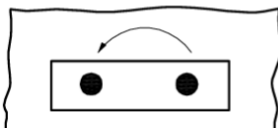|	Loads directed away from the edge, hence no proof for concrete edge failure needed.
(24A) GROUP OF ANCHORS AT AN EDGE LOADED BY V_{ld} With An Angle $\alpha_v = 180°$	

Total Load Action		
Load on each anchor		Load components directed away from the edge are neglected
Load on anchor group for calculations		

(24B) GROUP OF ANCHORS AT AN EDGE LOADED BY v_{ld} With An Angle 90 °< α_v < 180°
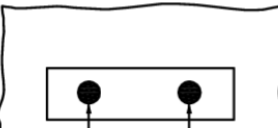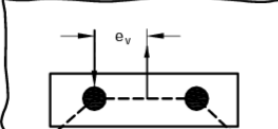
Total load Action		
Load on each anchor		Load components directed away from the edge are neglected
Load on anchor group for calculations		

(24C) GROUP OF ANCHORS AT THE EDGE LOADED BY A TORSION MOMENT

FIG. 24 EXAMPLES OF ANCHOR GROUP AT EDGE LOADED BY SHEAR FORCE OR TORSION
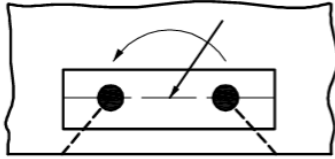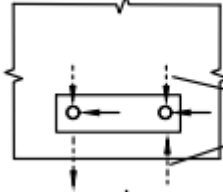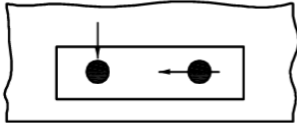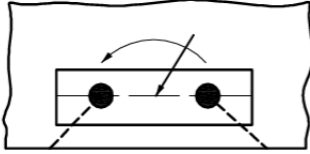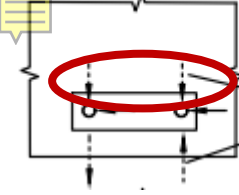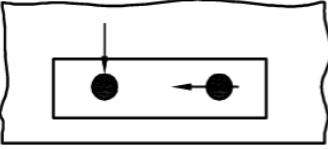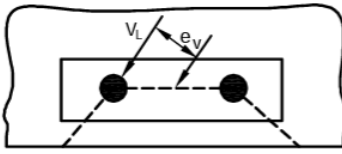
Action		
Load on each anchor	Loads neglected because sum of components is directed away from the edge	
Load on anchor group		
Load on anchor group for calculations		
Action		
Load on each anchor	Loads neglected because sum of components is directed away from the edge	
Load on anchor group		
Load on anchor group for calculations		

FIG. 25 EXAMPLES OF ANCHOR GROUP AT EDGE LOADED BY SHEAR FORCE AND TORSION

7.2.3.4.1 *Special Case*
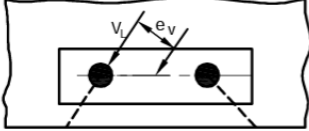
For anchorages in a narrow or thin member ($D < 1.5c'_1$) with the largest edge distance less than the critical edge distance of $1.5c'_1$ in shear, the calculation of strength according to **7.2.3.4** may lead to very conservative values. For such cases, the edge distance c_1 shall be substituted with modified value c'_1 as indicated below in all equations in 7.2.3.4.

For single anchor

$$c'_1 = \max(c'_{2\max}/1.5, D/1.5)$$

For group of anchors,

$$c'_1 = \max(c'_{2\max}/1.5, D/1.5, s'_{2\max}/3)$$

Where s'_{2max} is the maximum spacing between the anchors in the orthogonal directions
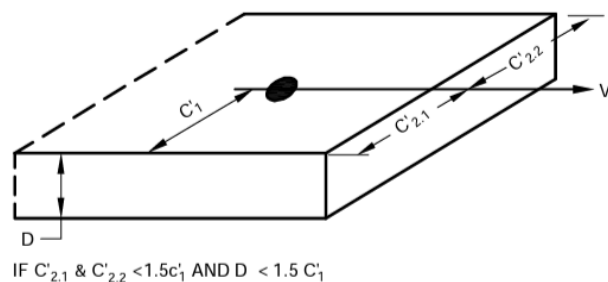
FIG. 26 EXAMPLES OF ANCHORAGE IN A THIN NARROW MEMBER

7.2.4 *Check for Combined Tension and Shear*

The following equations shall be satisfied for combined tension and shear loads (see Figure 27).

$$\beta_N \leq 1$$
$$\beta_V \leq 1$$
$$(\beta_N) + (\beta_V) \leq 1.2 \quad \text{(for failure mode other than steel)}$$

Or

$$(\beta_N)^\alpha + (\beta_V)^\alpha \leq 1$$

where,

α = 2.0, if N_{Ld} and V_{Rd} are governed by steel failure, and

α = 1.5, for all other failure modes

β_N and β_V =   Ratio between design load and design strength for tension and shear loading, respectively. The largest value of β_N and β_V for the different failure modes shall be taken.
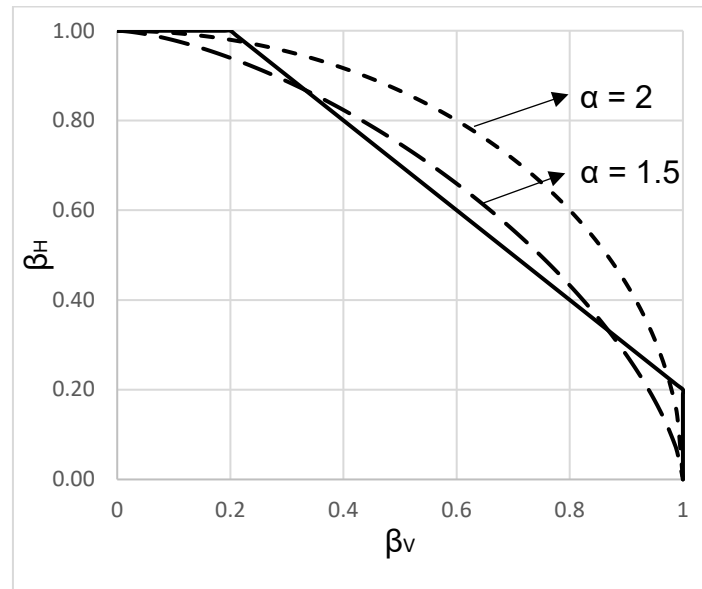
FIG. 27 INTERACTION DIAGRAM FOR COMBINED TENSION AND SHEAR LOADS

8 DESIGN OF POST-INSTALLED ANCHORING SYSTEMS FOR SEISMIC EFFECTS

8.1 General

The basic design requirement and provisions for static conditions shall also apply to design of anchor for seismic conditions. The partial safety factors recommended for static conditions are applicable for seismic design as well. In addition, the requirements of this section shall be fulfilled.

8.1.1 Anchors

As a prerequisite for seismic design, the anchors shall be tested and evaluated as per seismic test provisions in addition to cracked assessment requirements. Appropriate measures shall be adopted to avoid loosening of nut during seismic event (for example, double nut). Further, it shall be assumed that anchors do not dissipate energy by means of ductile hysteretic behavior and do not contribute to the overall ductile behavior of the structure. Stand-off fastening or other configurations where anchors may be subjected to shear load with lever arm shall not be permitted under seismic conditions. Fixtures with grout layer shall not be permitted under seismic conditions.

8.1.2 Location of Anchors

The gap between the fixture clearance hole and the anchor should be avoided in seismic conditions. If it is not possible to avoid this gap, then the factor α_{gap} shall be applied to account for the effect of this gap on behavior of the anchor. However, the clearance diameter d_f shall be limited to the values given in **5.3.1**.

8.1.3 *Applicability of Seismic Design Provisions*

For all seismicity levels defined as per IS 1893, anchor shall be designed for seismic conditions. The design seismic force acting on the fixture shall be determined according to IS 1893 (Part 1) and other relevant standards.

NOTE

1 When the seismic tension component of the design force at the ultimate limit state applied to an individual anchor or an anchor group is equal to or less than 20 per cent of the total design tensile force, then seismic provisions in **8.2** need not apply for the verification of the tension component acting on a single anchor or a group of anchors.

2 When the seismic shear component of the design force at the ultimate limit state applied to an individual anchor or an anchor group is equal to or less than 20 per cent of the total design shear force, provisions in **8.2** need not apply for the verification of the shear component acting on a single anchor or a group of anchors.

3 The seismic forces may be considered for non-structural components also. Specialist literature may be consulted for understanding on how to derive seismic forces on anchor and how to account for amplification of seismic forces. Reference to IS 1893 or IS 16700 may be made in this regard for calculation of seismic force on non-structural elements.

8.2 Design Options

The anchor shall be designed for seismic condition as per **8.2.1** or **8.2.2** or **8.2.3**.

8.2.1 *Capacity Design*

As per this method, an individual anchor or an anchor group shall be designed for the maximum tension and/or shear load that can be transmitted to the anchor based on either the development of a ductile yield mechanism in the attached element (*see* Fig. 28A) or the fixture (*see* Fig. 28B) taking into account strain hardening and the capacity of a non-yielding attached element (or structural element) (*see* Fig. 28C).

NOTE – The assumption of a plastic hinge in the fixture (*see* Fig. 28B) requires to take into account aspects like the redistribution of loads to the individual anchors of a group, the redistribution of the loads in the structure, the fatigue behavior of the fixture, etc.

28A YIELDING IN ATTACHED ELEMENT	28B YIELDING IN FIXTURE	28C CAPACITY OF ATTACHED ELEMENT
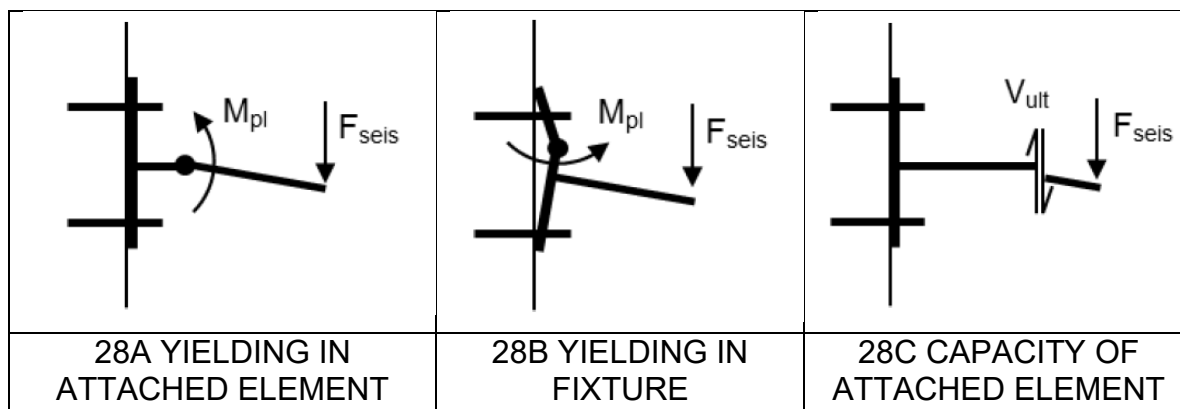
FIG. 28 SEISMIC DESIGN BY PROTECTION OF ANCHOR (*see* **8.2.1**)

8.2.2 *Elastic Design*

As per this method, an individual anchor or an anchor group shall be designed for the maximum load obtained from the design load combinations (including seismic) corresponding to the limit state (*refer* IS 1893 Part 1) assuming an elastic behavior of the anchorage and of the structure. Furthermore, uncertainties in the model to derive seismic forces on the anchorage shall be taken into account.

8.2.3 *Design with Requirements on the Ductility of the Anchors*

This method shall not be used for anchor connections of primary seismic members. This method may be used only for secondary/tertiary seismic member.As per this method, an individual anchor or an anchor group shall be designed for the maximum load obtained from the design load combinations (including seismic) corresponding to the limit state (refer IS 1893). The tension steel capacity of the anchor or anchor group shall be smaller than the tension capacity in concrete related failure modes. Elongation capacity of the anchors shall be such that it accommodates the deformation according to the seismic analysis of the connection.

8.2.3.1 For this design method, the following requirements shall apply:

a) The anchor shall have technical assessment report (AR) that includes qualification for seismic performance.
b) To ensure steel failure mechanism, following shall be satisfied:

For single anchor in tension: $N_{\mathrm{Rk,s,seis}} \leq 0.7\, N_{\mathrm{Rk,c,seis}}/\gamma_{\mathrm{inst}}$

For anchor group in tension: $\dfrac{N_{\mathrm{Rk,s,seis}}}{N_{\mathrm{Ld},\sigma*}} \leq 0.7\, N_{\mathrm{Rk,c,seis}}/(N_{\mathrm{Ld,g}} \cdot \gamma_{\mathrm{inst}})$

In addition to the above requirement, the following shall apply to the highest loaded anchor for group of mechanical anchor in tension:

$$N_{\mathrm{Rk,s,seis}} \le 0.7\, N_{\mathrm{Rk,p,seis}}/\gamma_{\mathrm{inst}}$$

where,

$N_{\mathrm{Rk,s,seis}}$ = Characteristic seismic steel strength

$N_{\mathrm{Rk,c,seis}}$ = Characteristic seismic strength for all non-steel failure types like concrete cone, blowout and splitting failure.

$N_{\mathrm{Rk,p,seis}}$ = Characteristic seismic pullout strength

γ_{inst} = Partial safety factor for installation safety.

$N_{\mathrm{Ld,\sigma*}}$ = Design load on the most stressed anchor of an anchor group and

$N_{\mathrm{Ld,g}}$ = Design load on the tensioned anchors of an anchor group.

c) Anchors for tension load shall be ductile and shall have a stretch length of at least $8d_{\mathrm{a}}$ (*see* Fig. 29) or more as per the analysis requirement.

Key
1   stretch length
2   anchor chair
3   sleeve or debonded length
4   anchor
5   base plate
6   column
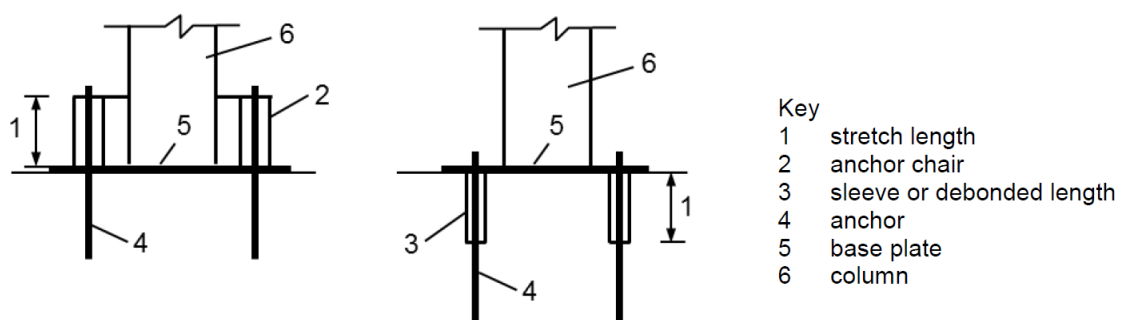
FIG. 29 SEISMIC DESIGN BY YIELDING OF A DUCTILE ANCHOR – ILLUSTRATION OF STRETCH LENGTH

d) An anchor shall be considered as ductile if the nominal steel yield strength $((f_y)$ of the load transferring section does not exceed 650 MPa, the ratio of nominal yield strength (f_y) to nominal ultimate strength (f_u) does not exceed 0.8, and the rupture elongation (measured over a length of $5d_{\mathrm{a}}$) is at least 12 percent.

e) The characteristic steel strength (resistance) of the anchors that incorporate a reduced section over a length smaller than $8d_{\mathrm{a,red}}$ ($d_{\mathrm{a,red}}$ = anchor diameter of reduced section) shall be greater than 1.3 times the characteristic yield capacity (resistance) of the unreduced section as per AR.

8.3 Design Method

The design strength shall be calculated according to limit state of design for all load directions namely, tension, shear individually or combined as well as for all applicable failure modes. The minimum strength shall govern for each load direction.

8.3.1 *Partial Safety Factors*

Partial safety factor of material for static design (*see* **7.2.1**) shall also be applicable for seismic design.

8.3.2 *Design Check in Tension and Shear*

The design strength in tension and shear shall be calculated and checked according to limit state of design for all applicable failure modes as per Table 3. The minimum strength shall govern for each load direction.

Table 3 Design Strength Checks in Tension and Shear for Seismic Design

(Clause 8.3.2)

SI No.	Parameter	Checks for Anchor
(1)	(2)	(3)
	Strength to resists expected failure types in tension	
a)	Steel strength	$N_{\mathrm{Ld,seis}} \leq N_{\mathrm{Rk,s,seis}}/\gamma_{\mathrm{Ms}}$
b)	Concrete cone strength	$N_{\mathrm{Ld,seis}} \leq N_{\mathrm{Rk,c,seis}}/\gamma_{\mathrm{Mc}}$
c)	Pull-out strength (MA) (*see* Note 1)	$N_{\mathrm{Ld,seis}} \leq N_{\mathrm{Rk,p,seis}}/\gamma_{\mathrm{Mp}}$
d)	Pull-out strength (AA) (*see* Note 1)	$N_{\mathrm{Ld,seis}} \leq N_{\mathrm{Rk,p,seis}}/\gamma_{\mathrm{Mp}}$
e)	Splitting strength (*see* Note 3)	$N_{\mathrm{Ld,seis}} \leq N_{\mathrm{Rk,sp,seis}}/\gamma_{\mathrm{Msp}}$
ii)	**Strength to resists expected failure types in shear**	
a)	Steel strength (For shear load without lever arm) (*see* Note 2)	$V_{\mathrm{Ld,seis}} \leq V_{\mathrm{Rk,s,seis}}/\gamma_{\mathrm{Ms}}$
b)	Concrete pry-out strength	$V_{\mathrm{Ld,seis}} \leq V_{\mathrm{Rk,cp,seis}}/\gamma_{\mathrm{Mc}}$
c)	Concrete edge strength	$V_{\mathrm{Ld,seis}} \leq V_{\mathrm{Rk,c,seis}}/\gamma_{\mathrm{Mc}}$

NOTES

1 MA – Mechanical anchor and AA – Adhesive anchor.

2 Steel failure for shear load with lever arm is not covered in this standard.

3 Check for splitting failure shall not be required if cracked concrete is assumed and reinforcement is available in base material (that is concrete) to resist splitting forces.

8.3.2.1 *Determination of characteristic strength*

The characteristic strength for an anchor or an anchor group shall be determined for each failure type as follows:

$$R_{\mathrm{Rk,seis}} = \alpha_{\mathrm{gap}}\alpha_{\mathrm{seis}}R^0_{\mathrm{Rk,seis}}$$

where

α_{gap} = Reduction factor to account for inertia effects due to an gap between anchor and fixture in shear; as given in the relevant AR.

NOTE – If α_{gap} value is not available in AR then α_{gap} may be assumed to be 1.0 in case of no hole clearance between anchor and fixture and 0.5 in case of connections with hole clearance (d_{fix}) as given in **5.3.1**.

α_{seis} = Reduction factor to account for the influence of large cracks and scatter of load-displacement curves (see Table 4)

$R^0_{\mathrm{Rk,seis}}$ = Characteristic seismic resistance of a single anchor for a given failure mode and not influenced by adjacent fasteners or edges of the concrete member determined as per Table 5

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Table 4 Reduction Factor for Seismic Design α_{seis}
(*Clause* 8.3.2.1)

SI No.	Parameter	For Single Anchor	For Anchor Group
(1)	(2)	(3)	(4)
1)	Failure type in tension		
a)	Steel failure	1	1
b)	Concrete cone failure		
	i) Undercut anchor	1	0.85
	ii) All other anchors	0.85	0.75
c)	Pull-out failure for mechanical anchor	1	0.85
d)	Pull-out failure adhesive anchor	1	0.85
e)	Splitting failure	1	0.85
2)	Failure type in shear		
a)	Steel failure (For shear load without lever arm	1	0.85
b)	Concrete pry-out failure		
	i)Undercut anchor	1	0.85
	ii) All other anchors	0.85	0.75
c)	Concrete edge failure	1	0.85

Table 5 Determination of $R^0_{\text{Rk,seis}}$

(*Clause* 8.3.2.1)

SI No.	Parameter	Method of Determination of Characteristic Seismic Resistance $R^0_{\text{Rk,seis}}$
(1)	(2)	(3)
i)	**Strength to resists expected failure types in tension**	
a)	Steel strength	As per AR of the anchor
b)	Concrete cone strength	Same as that for static condition (See 7.2)
c)	Pull-out strength for mechanical anchor	As per AR of the anchor
d)	Pull-out strength for Adhesive Anchor	As per **7.2.2.4** using the characteristic bond resistance for seismic $\tau_{\text{Rk,seis}}$ as per AR shall be used
e)	Splitting strength	Same as that for static condition (*see* **7.2**)
ii)	**Strength to resists expected failure types in shear**	
a)	Steel strength (For shear load without lever arm)	As per AR of the anchor
b)	Concrete pry-out strength	Same as that for static condition (*see* **7.2**)
c)	Concrete edge strength	Only first row of anchor to be considered. (*see* **7.2**)

Note – The design of fastenings under seismic loading for seismic zones III and above and for important building classes (as per NBC 2016 and IS 1893) shall be based on an assessment under pulsating tension, crack cycling under constant tension load and alternating shear in cracked concrete at a crack width of 0.8 mm.

8.3.3 *Check for Combined Tension and Shear*

The following equations shall be satisfied for combined tension and shear loads:

$$N_{\text{Ld,seis}} / N_{\text{Rd,seis}} \leq 1$$

$$V_{\text{Ld,seis}} / V_{\text{Rd,seis}} \leq 1$$

$$\left(N_{\text{Ld,seis}} / N_{\text{Rd,seis}} \right) + \left(V_{\text{Ld,seis}} / V_{\text{Rd,seis}} \right) \leq 1$$

where the largest ratio for $N_{\text{Ld,seis}}/N_{\text{Rd,seis}}$ and $V_{\text{Ld,seis}}/V_{\text{Rd,seis}}$ for different failure types shall be inserted in the above equations. The interaction checks shall be separately performed for steel and concrete failures.

8.3.4 *Displacements*

The anchor displacement under tensile and shear load at limit state of displacement shall be limited to $\delta_{N,req(DLS)}$ and $\delta_{V,req(DLS)}$ value of the application to meet requirements regarding functionality and assumed support conditions. If anchor and attached elements are expected to be operational after an earthquake then relevant anchor displacements shall be taken into account. If the anchor displacements $\delta_{N,seis(DLS)}$ under tension loading and/or $\delta_{V,seis(DLS)}$ under shear load provided in the relevant AR are higher than the corresponding required values $\delta_{N,req(DLS)}$ and/or $\delta_{V,req(DLS)}$, the design resistance may be reduced according to the following equations:

$$N_{Rd,seis,red} = N_{Rd,seis}\ \delta_{N,req(DLS)}\big/\delta_{N,seis(DLS)}$$

$$V_{Rd,seis,red} = V_{Rd,seis}\ \delta_{V,req(DLS)}\big/\delta_{V,seis(DLS)}$$

NOTE – When a rigid support is assumed in the analysis the designer shall establish the limiting displacement compatible to the requirement for the structural behavior. The acceptable displacement associated to a rigid support condition is considered to be 3 mm.

If the connection such as façade element is designed to accommodate deformations (that is displacements or rotations) then it shall be demonstrated that the anchor can accommodate these deformations. The rotation of a connection θ (*see* Fig. 30) is given by

$$\theta = \delta_{N,seis}/s'_{max}$$

where,

$\delta_{N,seis}$ = Displacement of the anchor (limited to 3mm) when subjected to seismic load

s'_{max} = Distance between the outermost row of anchors and the opposite edge of the fixture

KEY

1. SLEEVE OR DEBONDING LENGTH
2. ANCHOR
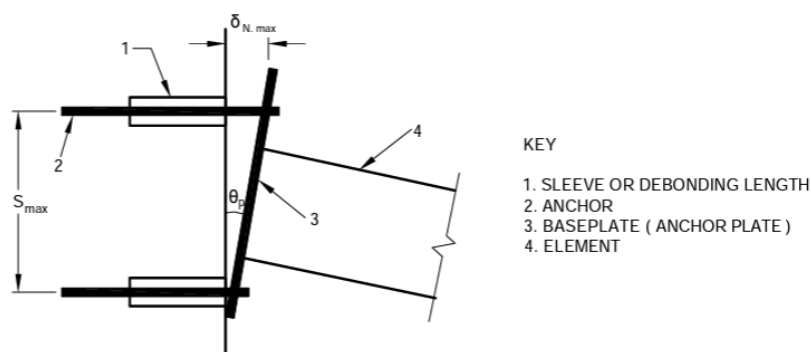3. BASEPLATE (ANCHOR PLATE)
4. ELEMENT

FIG. 30 EXAMPLE OF ROTATION AND DISPLACEMENT OF A CONNECTION

9 ADDITIONAL CHECKS AND REQUIREMENTS

9.1 General

To establish the transmission of the anchor loads to the supports of the concrete member, basic checks shall be carried out with due consideration of the loads introduced by the anchors along with additional provisions given in this section.

NOTE – In the case of slabs and beams made out of prefabricated units and added cast-in-situ concrete, anchor loads may be transmitted into the prefabricated concrete only if the precast concrete is connected with the cast-in-situ concrete by shear reinforcement. If this shear reinforcement between precast and cast-in-situ concrete is not present, the anchors shall be designed as per the provisions of this standard.

9.2 Shear Strength of Concrete Member

The shear forces V_{Lda} caused by anchor loads shall not exceed the value $0.4V_{Rd1}$; where V_{Rd1} is design shear strength of concrete according to IS 456. When calculating V_{Lda} the anchor loads shall be assumed as point loads with a width of load application $t_1 = s'_{t1} + 2h_{ef}$ and $t_2 = s'_{t2} + 2h_{ef}$, where s'_{t1} and s'_{t2} is spacing between the outer anchors of a group in direction 1 and 2, respectively.

9.3 Resistance of Concrete Member to Splitting

The splitting forces generated by anchors shall be taken into account while designing the concrete member. This requirement may be neglected if one of the following conditions is met:

   a) The load transfer area that is the embedment length along which load is transferred) of anchor is in the compression zone of the concrete member.
   b) The tension component of the characteristic loads acting on the single anchor or anchor group is less than 10 kN.

If tension component of the characteristic loads is greater than 10 kN but less than 30 kN, the splitting check may still be neglected
   a) if the area of the transverse reinforcement is at least 60 percent of the longitudinal reinforcement required for the loads due to anchor loads.
   b) For fastenings in slabs and walls wherever reinforcement in both directions is present as per IS 456 in the region of the anchorage.

If the tension component of the characteristic loads acting on the anchorage is greater than or equal to 30 kN and the anchors are located in the tension zone of the concrete member then the splitting forces shall be taken up by reinforcement. The ratio between splitting force $F_{Rk,sp}$ and the tension component of the characteristic loads $N_{L,Rk}$ shall be taken as:

$$F_{Rk,sp} = 0.5\ N_{L,Rk}\text{ , for adhesive anchors}$$
$$F_{Rk,sp} = 1.5\ N_{L,Rk}\text{, for torque controlled expansion anchors}$$
$$F_{Rk,sp} = 1.0\ N_{L,Rk}\text{ , for undercut (mechanical) anchors}$$
$$F_{Rk,sp} = 2.0\ N_{L,Rk}\text{ , for deformation controlled expansion anchors}$$

ANNEX A

LIST OF CROSS REFERRED INDIAN STANDARDS

IS No.	Title
CED 2 WD(0125)	Glossary of terms relating to anchors in concrete
CED 2(0099)WD	Assessment of performance of post-installed mechanical Anchoring Systems.(*under development*)
CED 2(0098)WD	Assessment of performance of Post-installed adhesive anchoring systems(*under development*)
CED 2(0100)WD-1	Testing of Post-installed mechanical anchoring systems (*under development*)
CED 2(0100)WD-2	Testing of Post-Installed adhesive anchoring systems (*under development*)
1608 (Part 1)	Mechanical testing of metals - Tensile testing
1893 (Part1):2016	Criteria for earthquake resistant design of structures (*sixth revision*)
456 :2000	Plain and reinforced concrete - Code of practice (fourth *revision*)
875 (Part 1) : 1987	Code of practice for design loads (Other Than Earthquake) for buildings and structures: Part 1 dead loads - Unit weights of building materials and stored materials (*second revision*)
875 (Part 2) : 1987	Code of practice for design loads (Other Than Earthquake) for buildings and structures: Part 2 imposed loads. (*second revision*)
875 (Part 3) : 2015	Design Loads (Other than Earthquake) for Buildings and Structures - Code of Practice Part 3 Wind Loads (*third revision*)
875 (Part 4) : 2021	Code of practice for design loads other than earthquake for Buildings and Structures Part 4 Snow Loads
875 (Part 5) : 1987	Code of practice for design loads (Other Than Earthquake) for buildings and structures: Part 5 special loads and load combinations (*second revision*)
16700 : 2017	Criteria for structural safety of tall concrete buildings

Annex B

(Committee composition will be added after finalization)

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