Prestressed Concrete

Part 8

(Anchorage zones)

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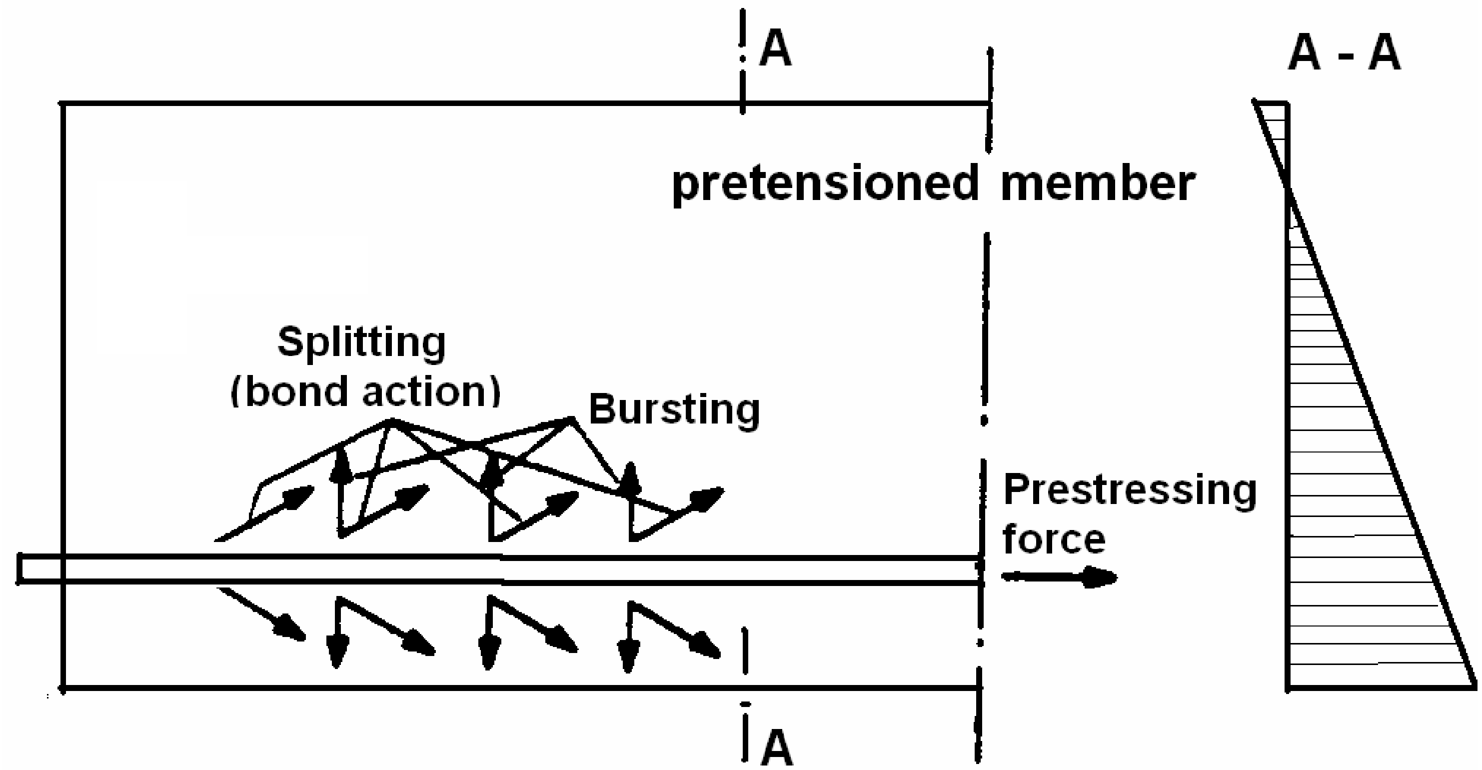
Anchorage zones - transfer of prestress

Anchorage zones - pre-tensioned members:

a) Anchorage of tendons

b) Spread of the prestressing force

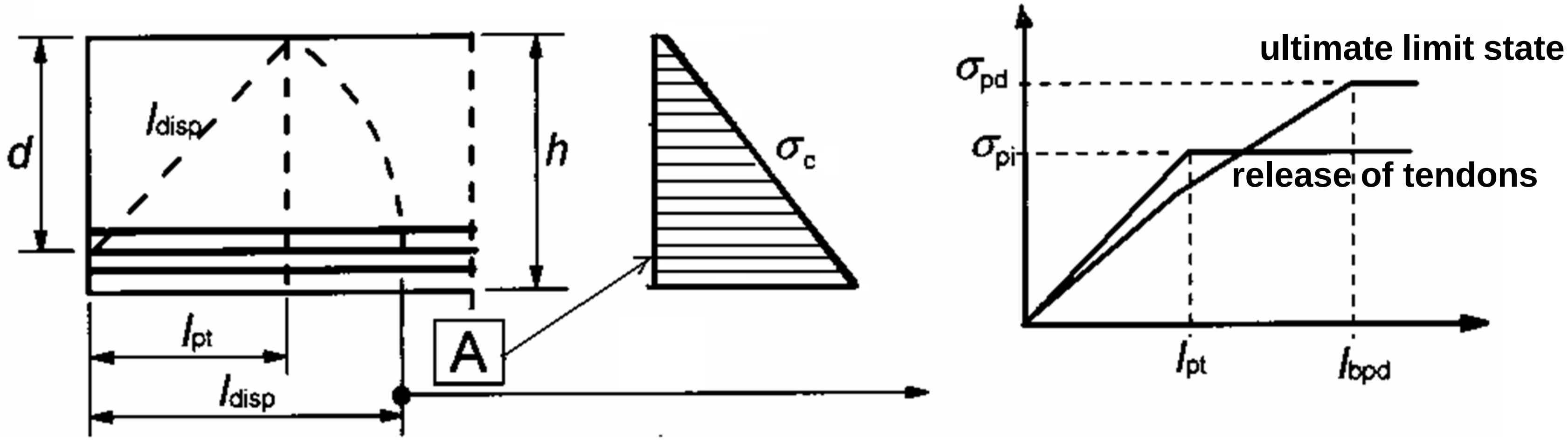


Length parameters of pre-tensioned tendons:

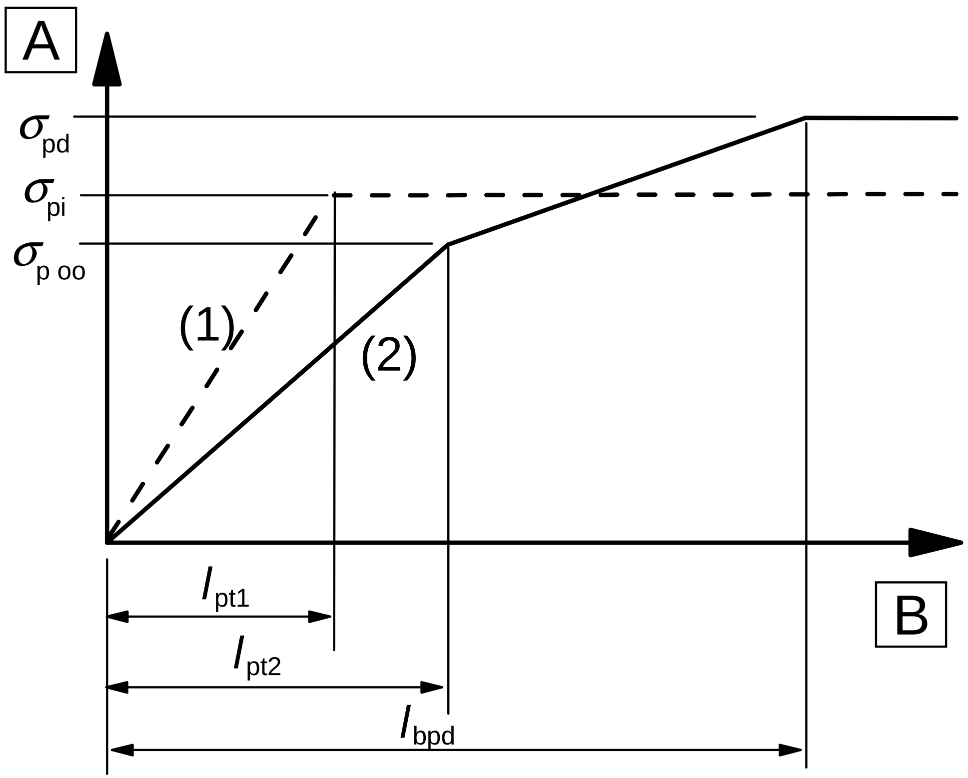
a) Transmission length, l_{pt}, over which the prestressing force ($P_0 = A_p\, \sigma_{pm0}$) is fully transmitted to the concrete;

b) Dispersion length, l_{disp} over which the concrete stresses gradually disperse to a linear distribution across the concrete section;

c) Anchorage length, l_{bpd}, over which the tendon force $F_{pd} = A_p\, \sigma_{pd}$ in the ultimate limit state is fully anchored in the concrete – check is necessary when $\sigma_{ct} > f_{ctk.0.05}$



A - Linear stress distribution of concrete in member cross-section



(1) at release of tendons

(2) at ultimate limit state

A - Tendon stress

B - Distance from end

Stresses in the anchorage zone of pre-tensioned members

Transmission length l_{pt}

At release of tendons - the prestress may be assumed to be transferred to the concrete by a constant **bond stress**

$$f_{bpt} = \eta_{p1}\ \eta_1\ f_{ctd}(t)$$

η_{p1} is a coefficient that takes into account the type of tendon and the bond situation at release

η_{p1} = 2,7 for indented wires

η_{p1} = 3,2 for 3 and 7-wire strands

η_1 = 1,0 for good bond conditions

= 0,7 otherwise

$f_{ctd}(t)$ the design tensile value of strength at time of release; $f_{ctd}(t) = \alpha_{ct} \cdot 0{,}7 \cdot f_{ctm}(t) / \gamma_c = \alpha_{ct} \cdot f_{ctk,0,05}(t) / \gamma_c$

The basic value of the transmission length

$$l_{pt} = \alpha_1 \alpha_2 \phi \sigma_{pm0} / f_{bpt}$$

α_1 = 1,0 for gradual release
= 1,25 for sudden release

α_2 = 0,25 for tendons with circular cross section
= 0,19 for 3 and 7-wire strands

ϕ the nominal diameter of tendon

σ_{pm0} the tendon stress just after release

The design value of the transmission length should be taken as the less favourable of two values, depending on the design situation:

$$l_{pt1} = 0{,}8\ l_{pt} \qquad \text{or} \qquad l_{pt2} = 1{,}2\ l_{pt}$$

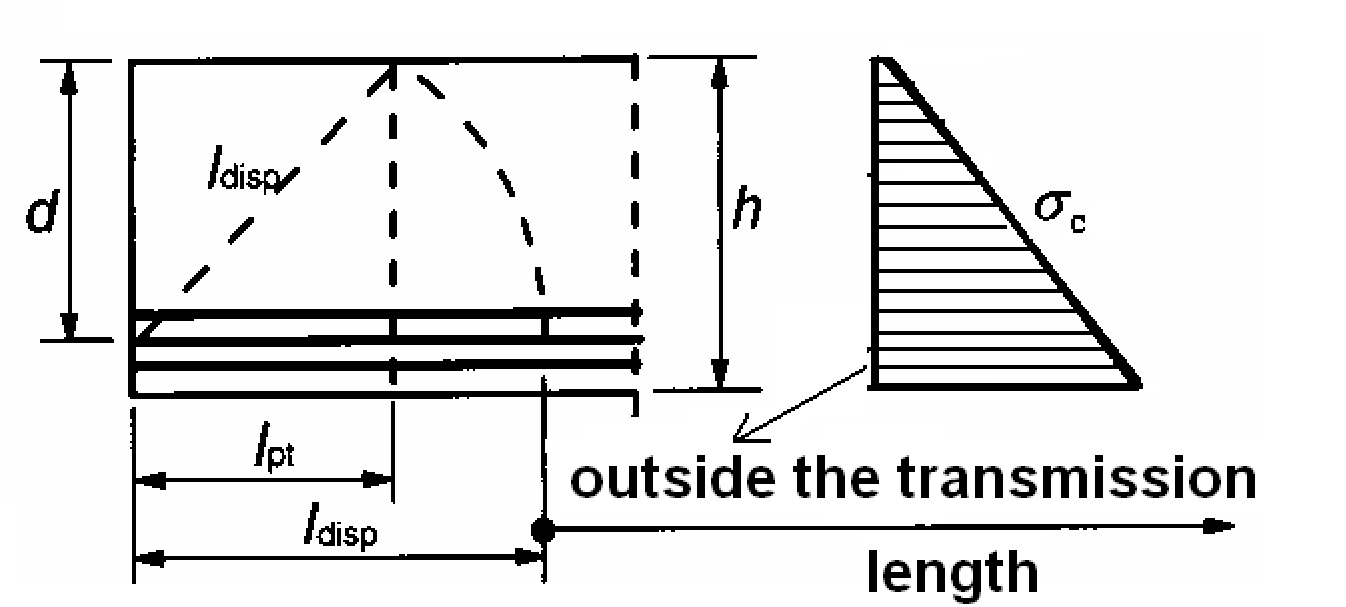
Usually: 0,8 for verifications of local stresses at release,
1,2 for ultimate limit states (shear, anchorage etc.)

Dispersion length l_{disp}

Outside the dispersion length - concrete stresses may be assumed to have a linear distribution

$$l_{\text{disp}} = \sqrt{l_{\text{pt}}^2 + d^2}$$

l_{pt} is the transmission length



Anchorage length l_{bpd}

Anchorage of tensile force for the ultimate limit state. The anchorage of tendons should be checked only in sections where the concrete tensile stress exceeds $f_{ctk,0,05}$. The tendon force should be calculated for a cracked section, including the effect of shear.

The bond strength for anchorage in the ultimate limit state:

$$f_{bpd} = \eta_{p2}\, \eta_1\, f_{ctd}$$

η_{p2} **is a coefficient that takes into account the type of tendon and the bond situation at anchorage**

= 1,4 for indented wires

= 1,2 for 7-wire strands,

η_1 **= 1,0 for good bond conditions; = 0,7 otherwise**

Due to increasing brittleness with higher concrete strength, $f_{ctk,0,05}$ should here be limited to the value for C60/75

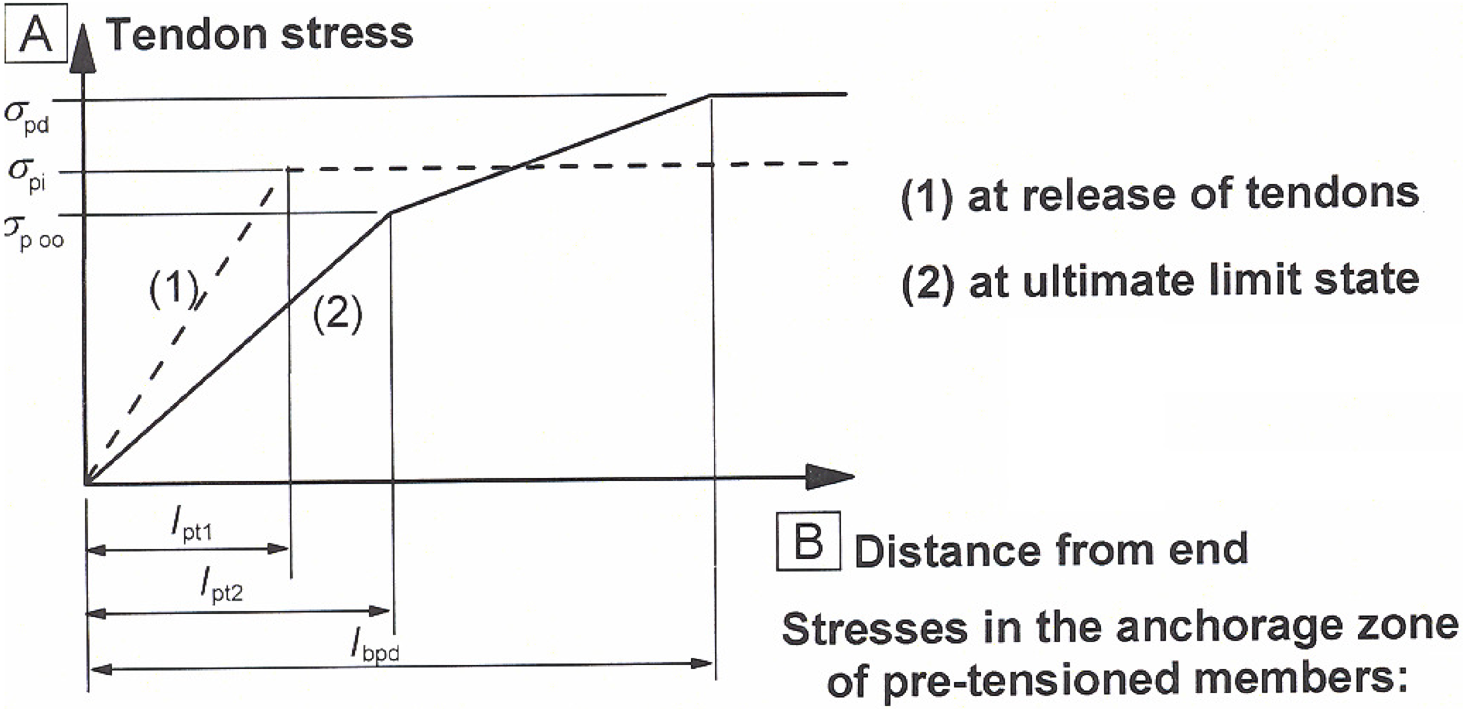
The <u>total anchorage length</u> for anchoring a tendon with stress σ_{pd} is: $l_{bpd} = l_{pt2} + \alpha_2 \phi (\sigma_{pd} - \sigma_{pm\infty})/f_{bpd}$

l_{pt2} is the upper design value of transmission length,

α_2 as defined in formula for l_{pt},

σ_{pd} the tendon stress corresponding to the force in cracked section,

$\sigma_{pm\infty}$ the prestress after all losses



Stresses in the anchorage zone of pre-tensioned members:

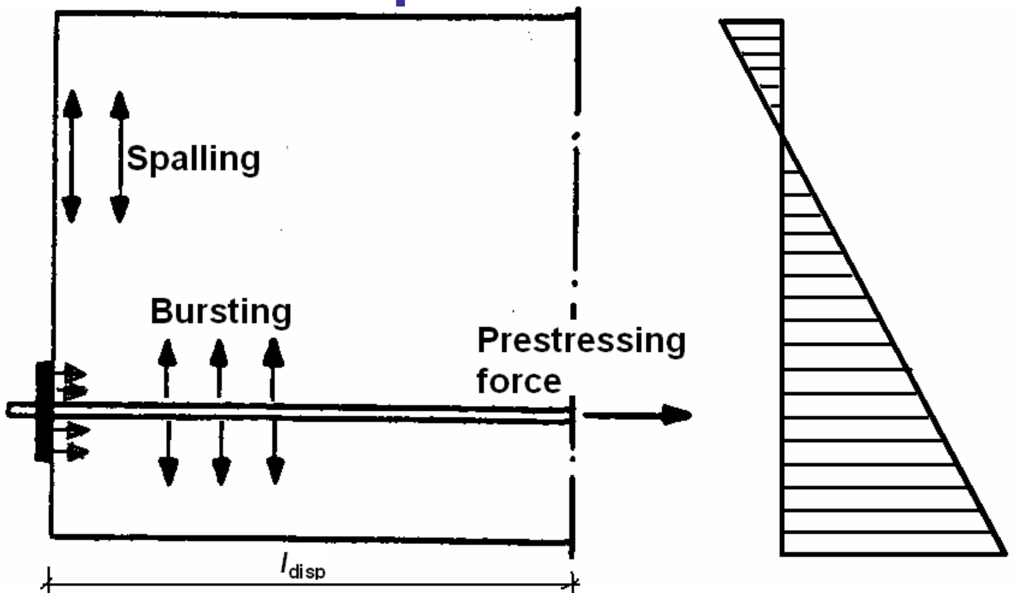
Anchorage zones – post-tensioned members

Anchorage zone – area where the concentrated prestress force spreads over the full member cross-section; attention has to be given to:

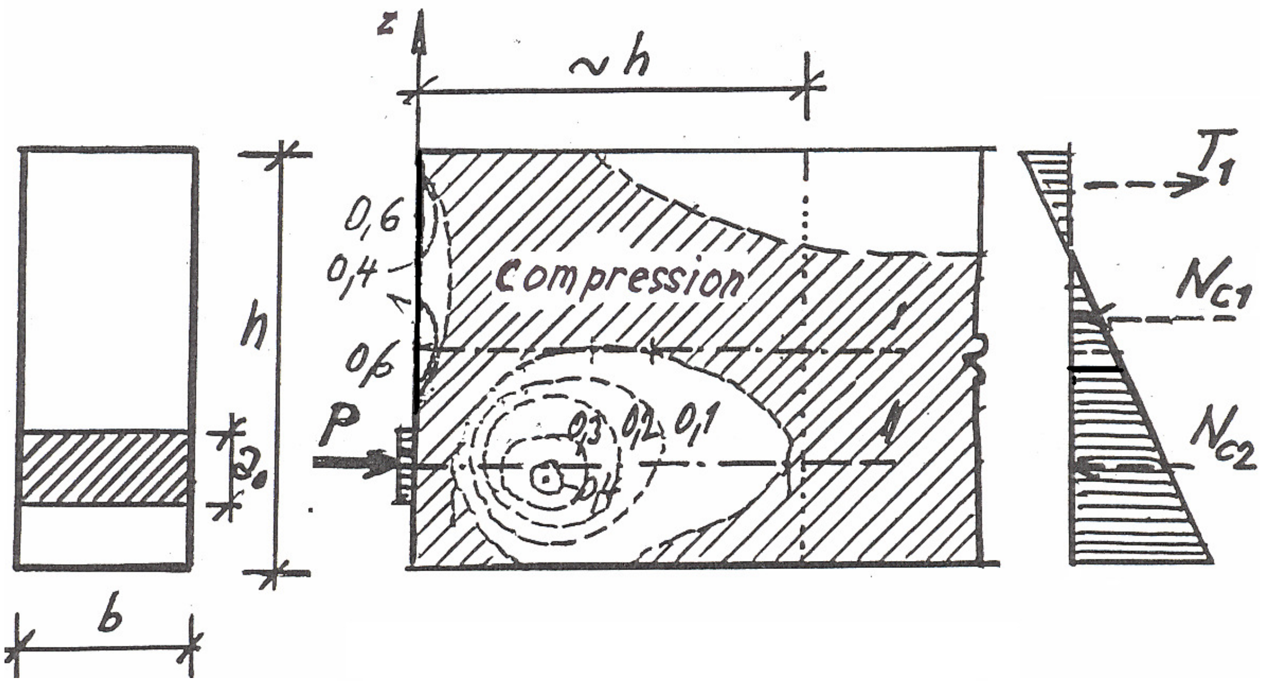
a) bearing stress - the highly stressed compression concrete in the vicinity of anchorages;

b) bursting stresses generated in the localized area of the anchorage;

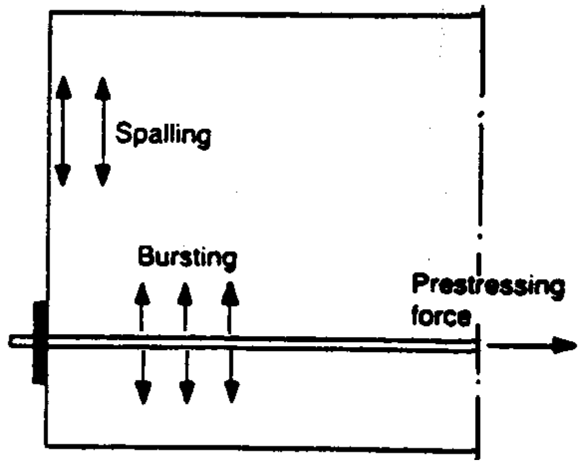
c) spalling stresses - transverse tensile forces arising from the further spread of load outside this localized area.



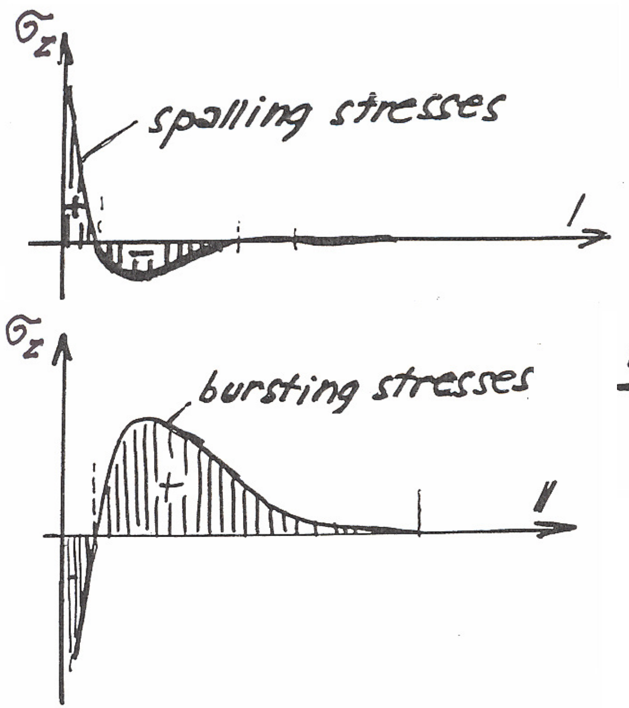
Dispersion length l_{disp} concrete stresses may be assumed to have a linear distribution



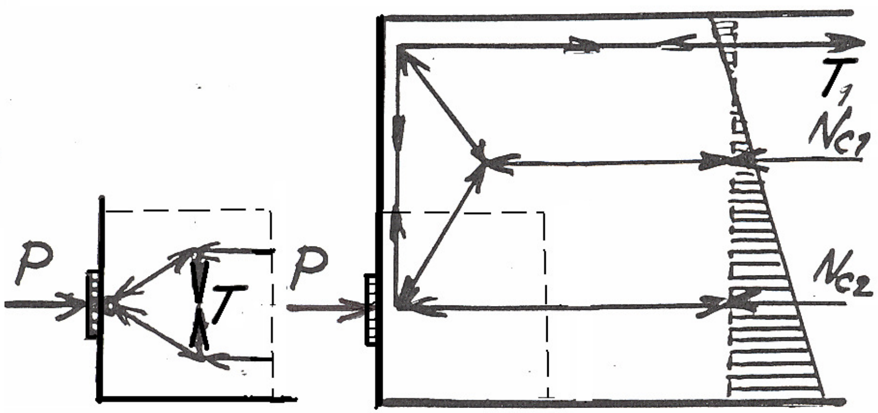
z
~h
0,6
0,4
0,6
compression
h
P
0,3
0,2
0,1
a_0
b
T_1
N_{c1}
N_{c2}



Spalling
Bursting
Prestressing
force



σ_z
spalling stresses
σ_z
bursting stresses



P
T
P
T_1
N_{c1}
N_{c2}

<u>Concentrated force on the anchorage zone</u>:

In the design is assumed:

- **The design value of the prestressing tendons should be calculated with the partial factor of prestress $\gamma_{P,unfav} = 1,2$.**
- **The lower characteristic tensile strength of the concrete should be used.**
- **Tensile forces due to concentrated forces should be assessed by a strut and tie model.**
- **Reinforcement should be detailed assuming that it acts at its design strength. If the stress in this reinforcement is limited to 300 MPa no check of crack widths is necessary.**

Partially loaded areas: - local crushing

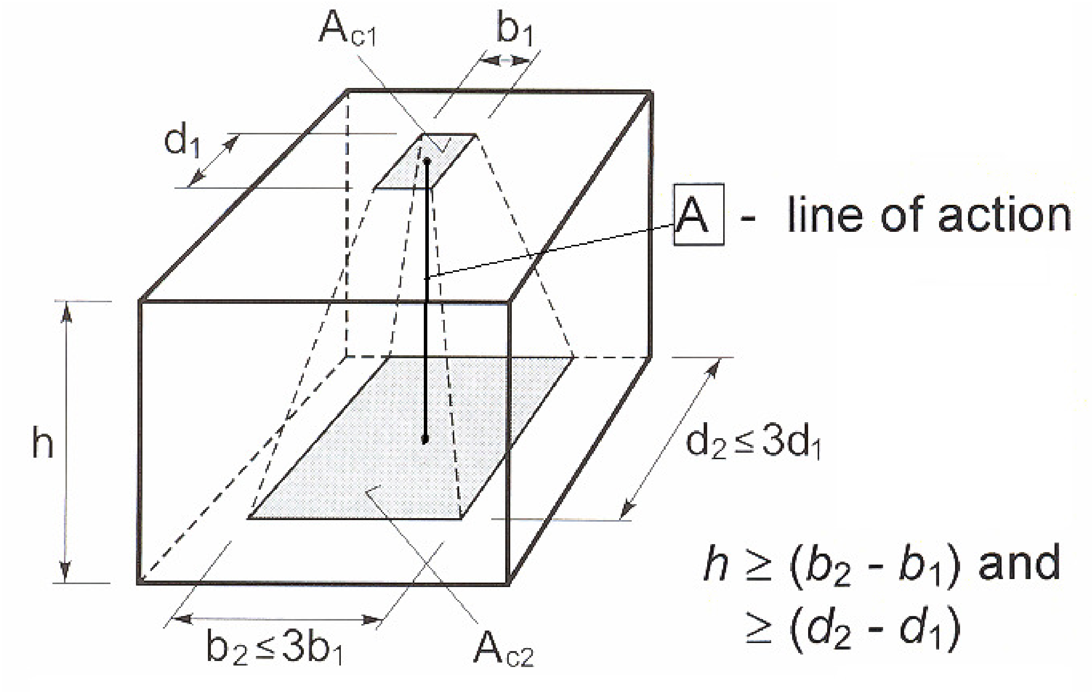
- transverse tension forces

The concentrated resistance force

$$F_{Rdu} = A_{c0} \cdot f_{cd} \cdot \sqrt{A_{c1} / A_{c0}} \leq 3{,}0 \cdot f_{cd} \cdot A_{c0}$$

A_{c0} is the loaded area,

A_{c1} the maximum design distribution area with a similar shape to A_{c0}



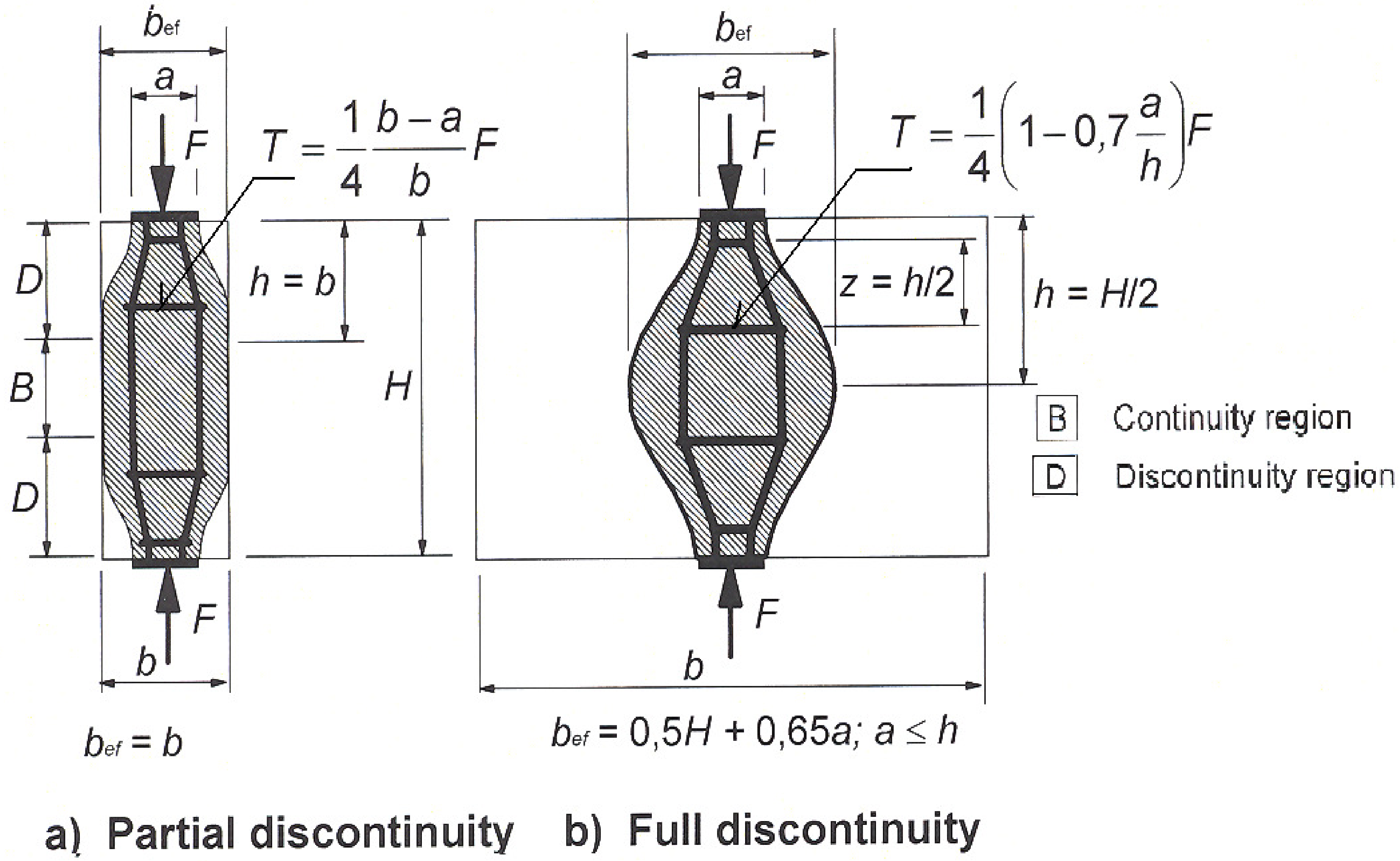
The design distribution area A_{c1} required for the resistance force F_{Rdu} should correspond to the following conditions:

- **the height h for the load distribution in the load direction should correspond to the conditions**

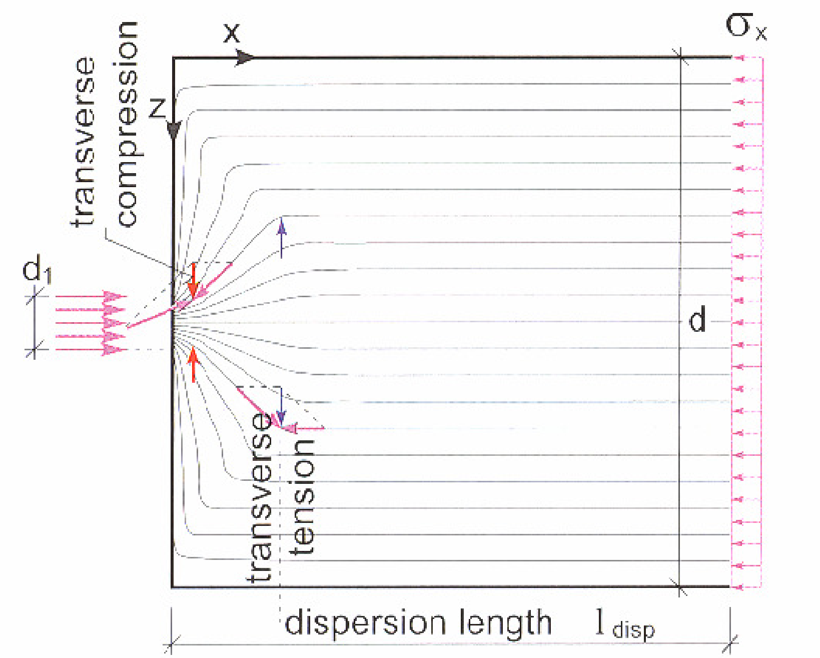
  $h \geq (b_2 - b_1)$

  $\geq (d_2 - d_1)$

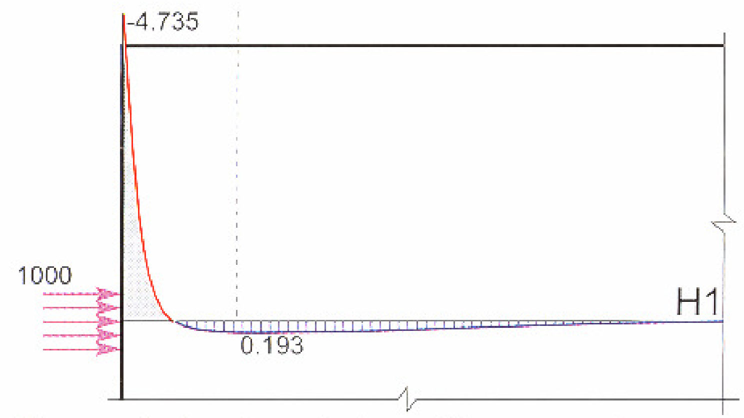
- **the centre of the design distribution area A_{c1} should be on the line of action passing through the centre of the load area A**
- **if there is more than one compression force acting on the concrete cross section, the designed distribution areas should not overlap.**



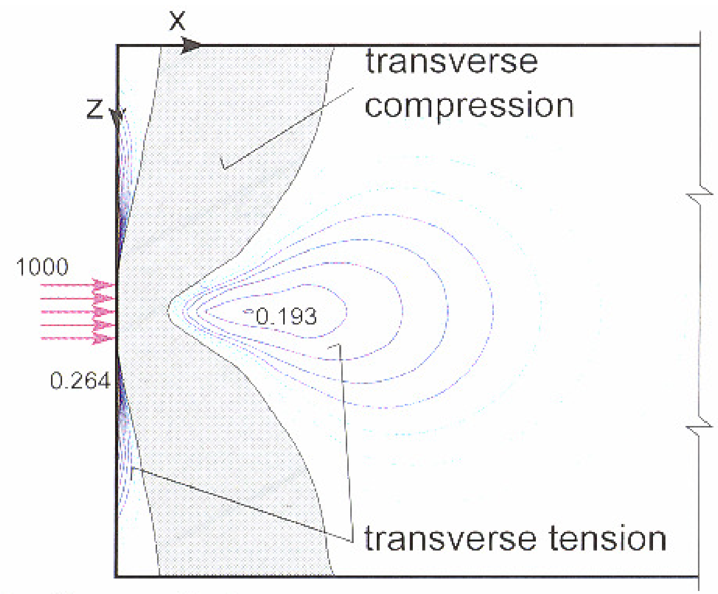
Reinforcement for the tensile force due to the effect of the action



(a) Principal stress trajectories in compression σ_2



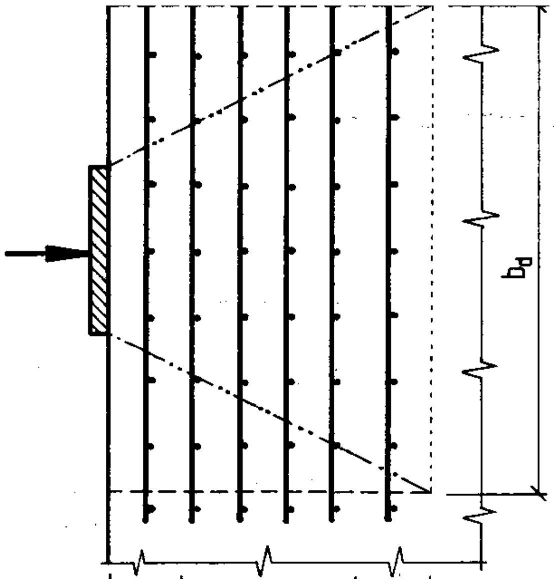
(b) Stress in horizontal section $\sigma_1 = \sigma_z$

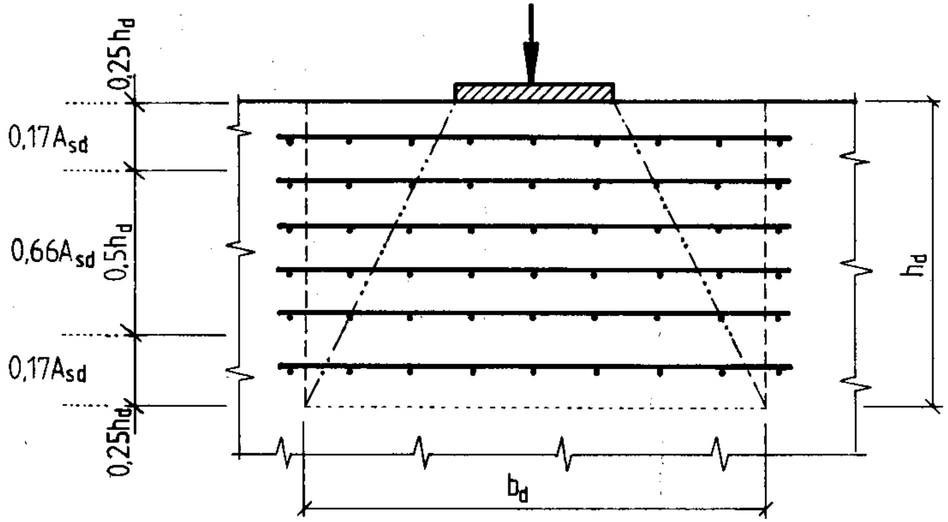


(c) Isolines of stress σ_z

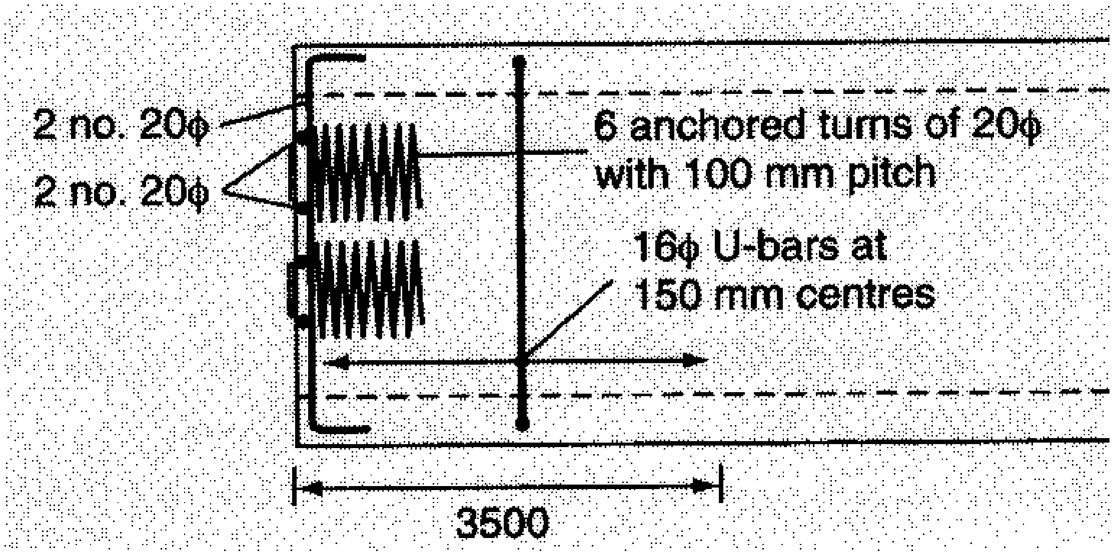
State of stress in anchorage zone

Reinforcement

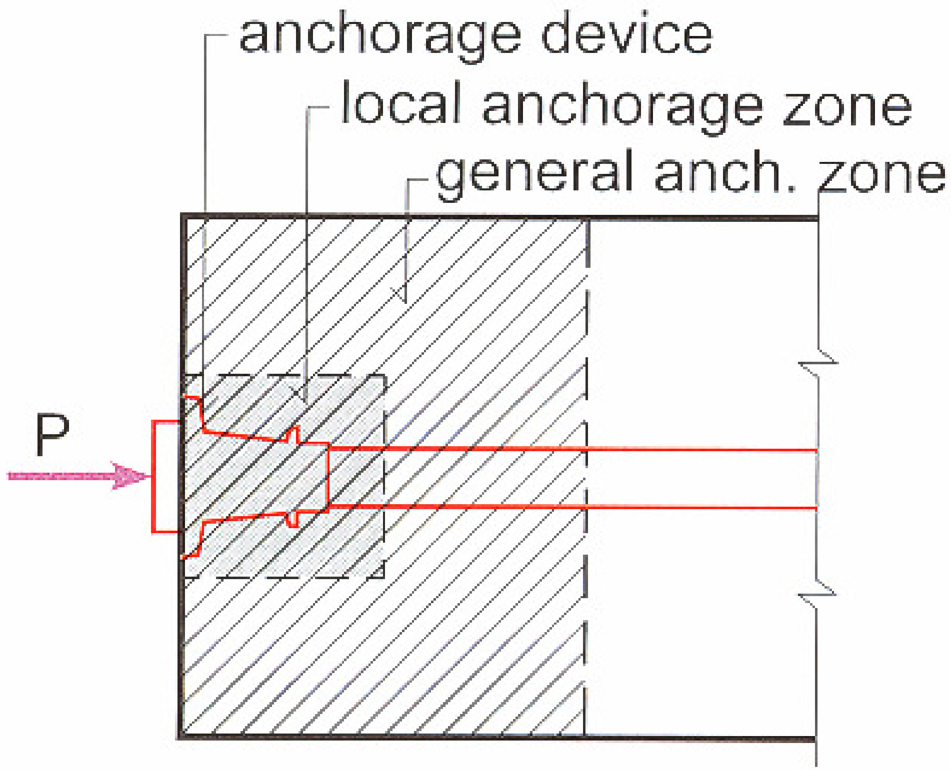




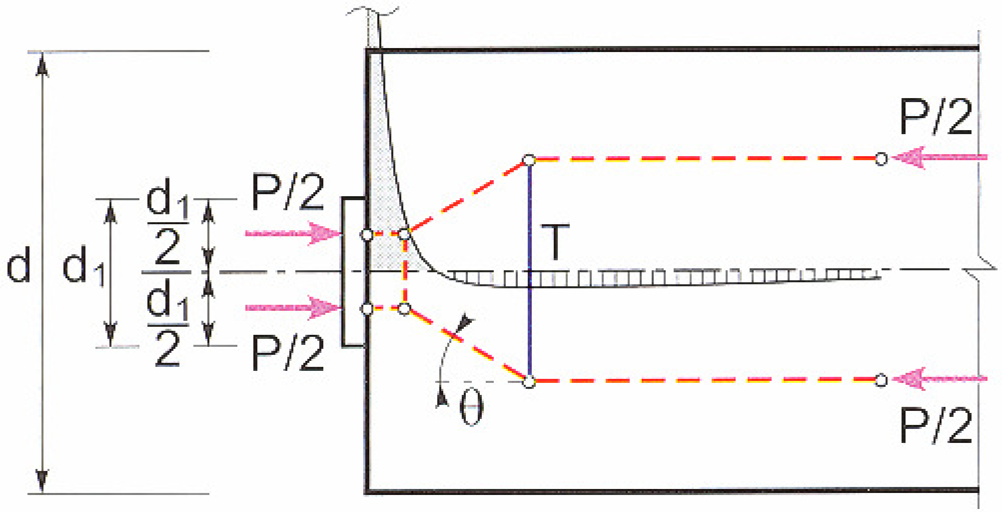
high labour input



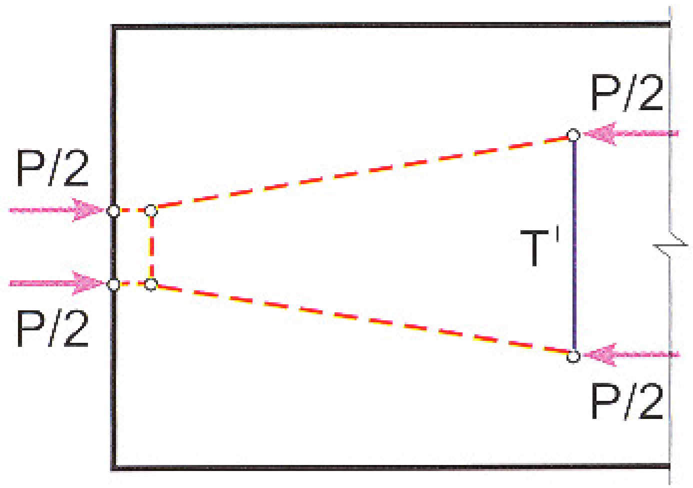
usually used



Anchorage zone

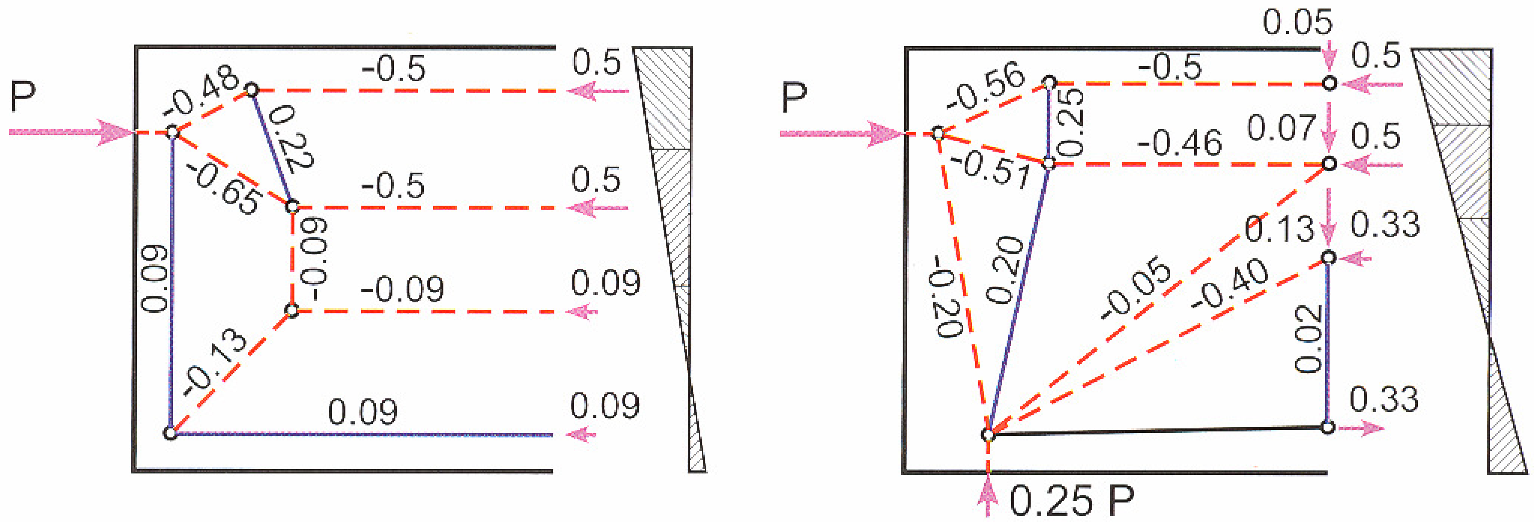


(a) Likely force flow



(b) Incorrect model

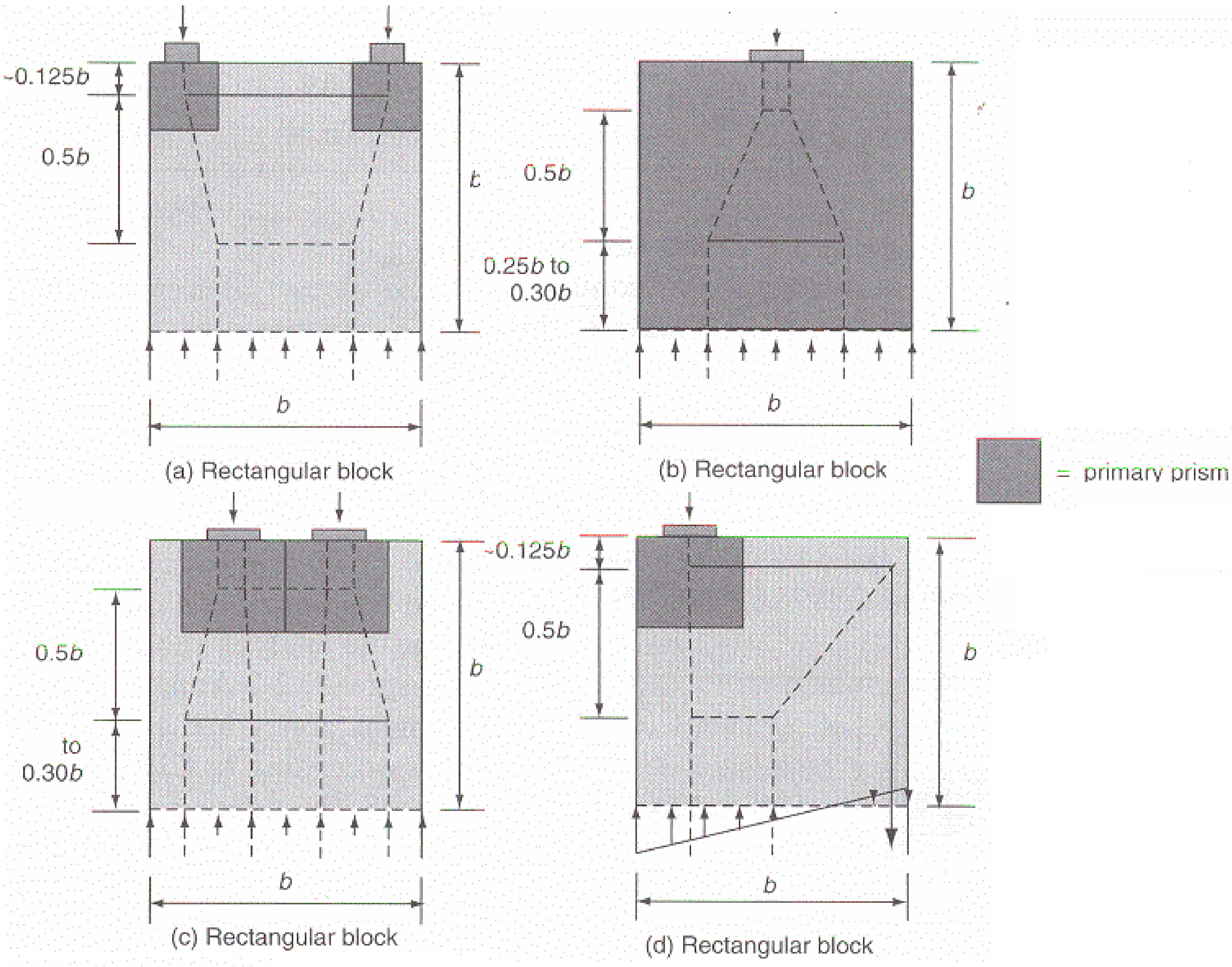
Truss model of anchorage zone

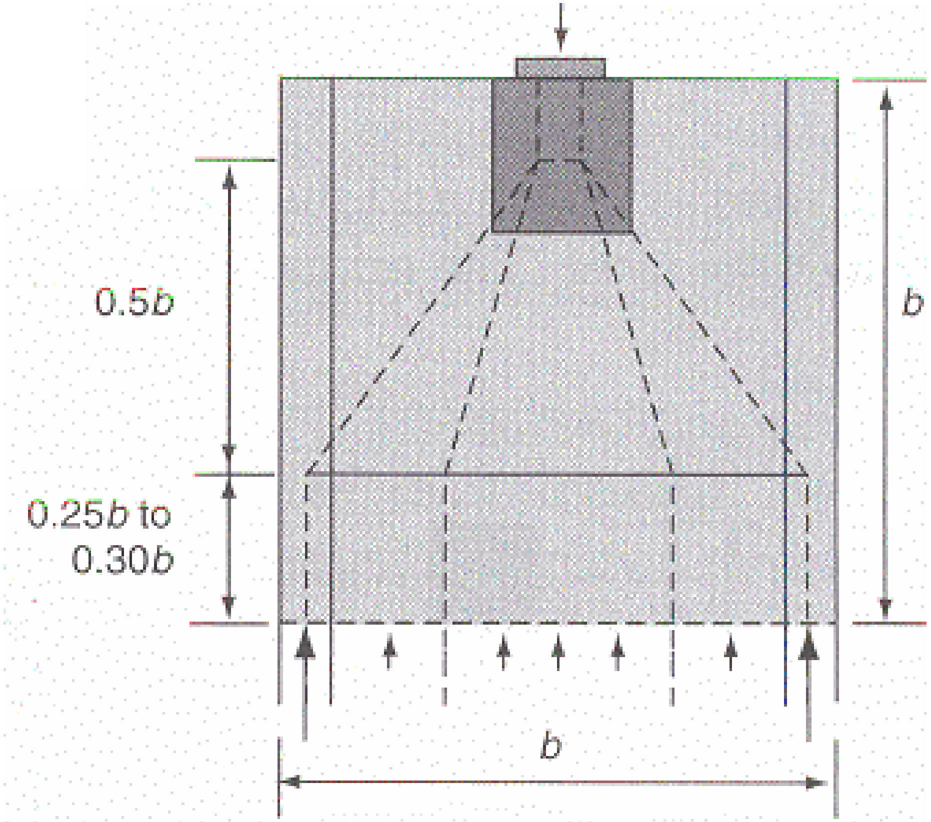


(a) Unsymmetrical position of prestressing force

(b) Influence of support reaction on truss model

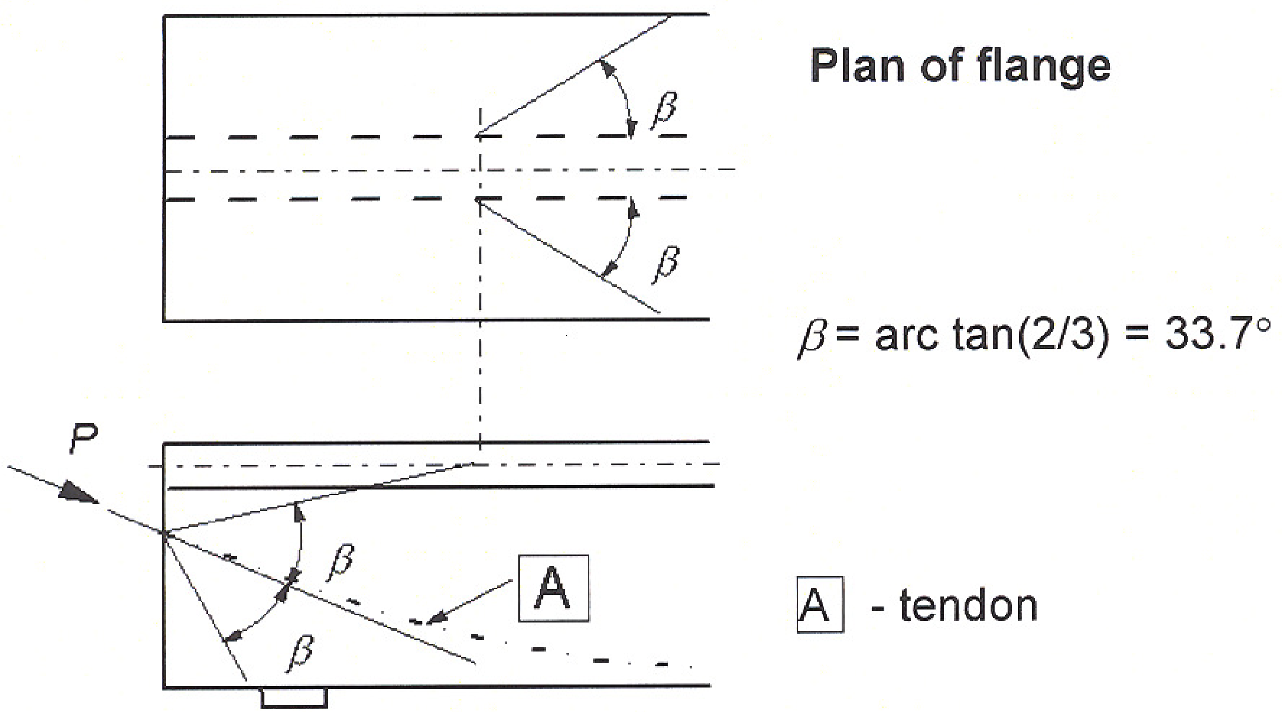
Impact of support reaction on truss model of anchorage zone


~0.125b
0.5b
b
b
(a) Rectangular block
0.5b
0.25b to
0.30b
b
b
(b) Rectangular block
= primary prism
0.5b
to
0.30b
b
b
(c) Rectangular block
~0.125b
0.5b
b
b
(d) Rectangular block



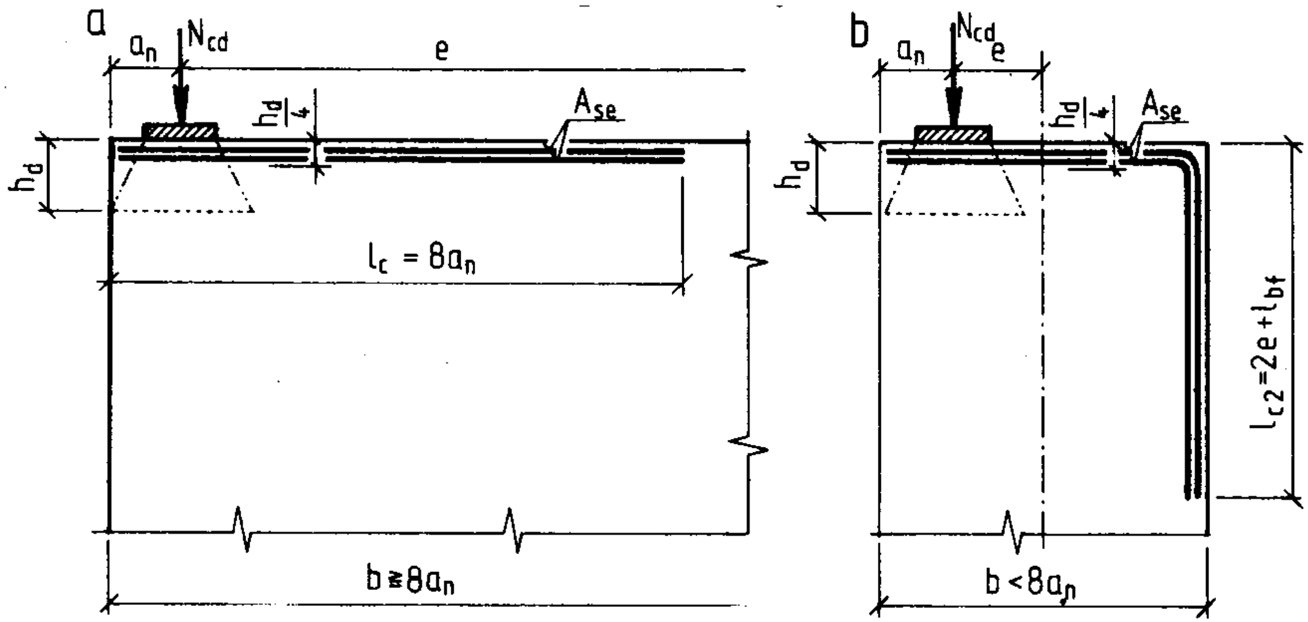
(e) Flanged beam

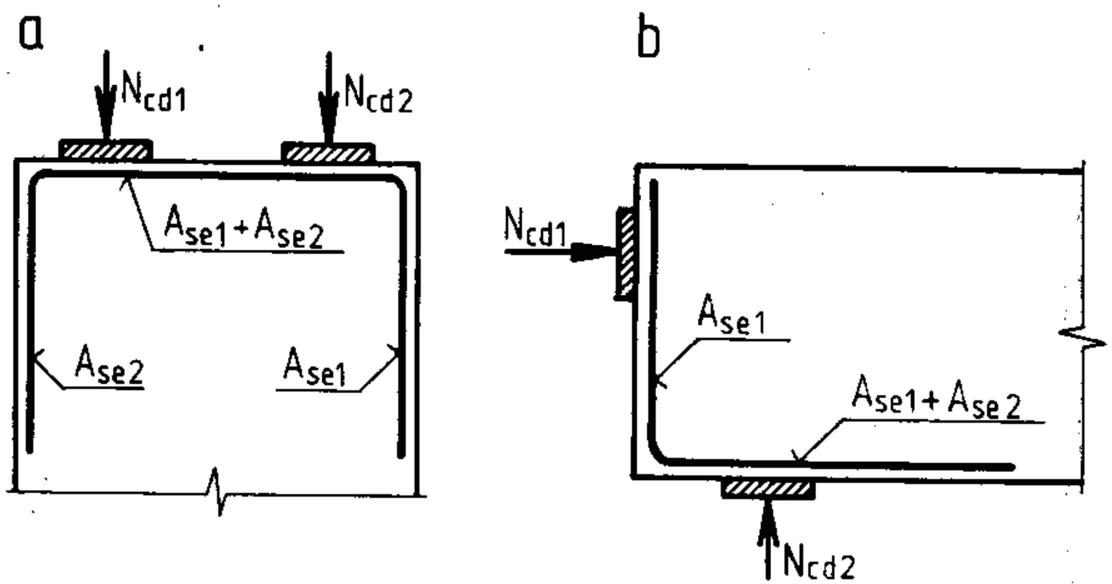
As a simplification the prestressing force may be assumed to disperse at an angle of spread 2β, starting at the end of the anchorage device, where β may be assumed to be arc tan 2/3.

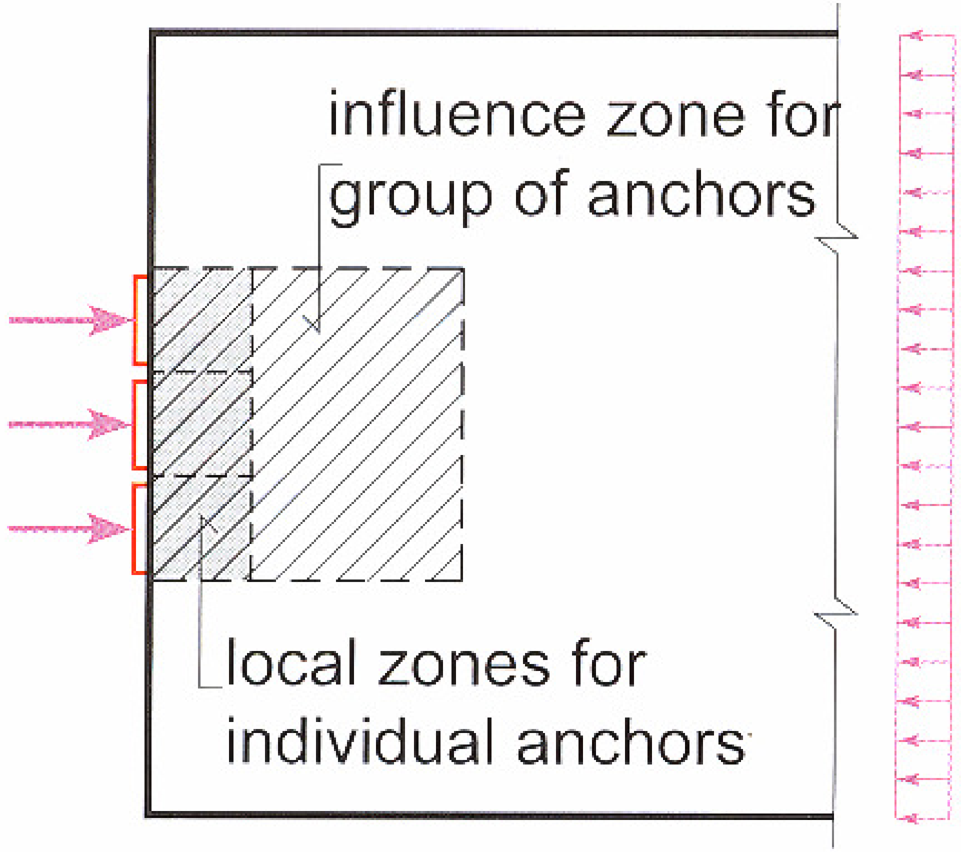


Dispersion of prestress

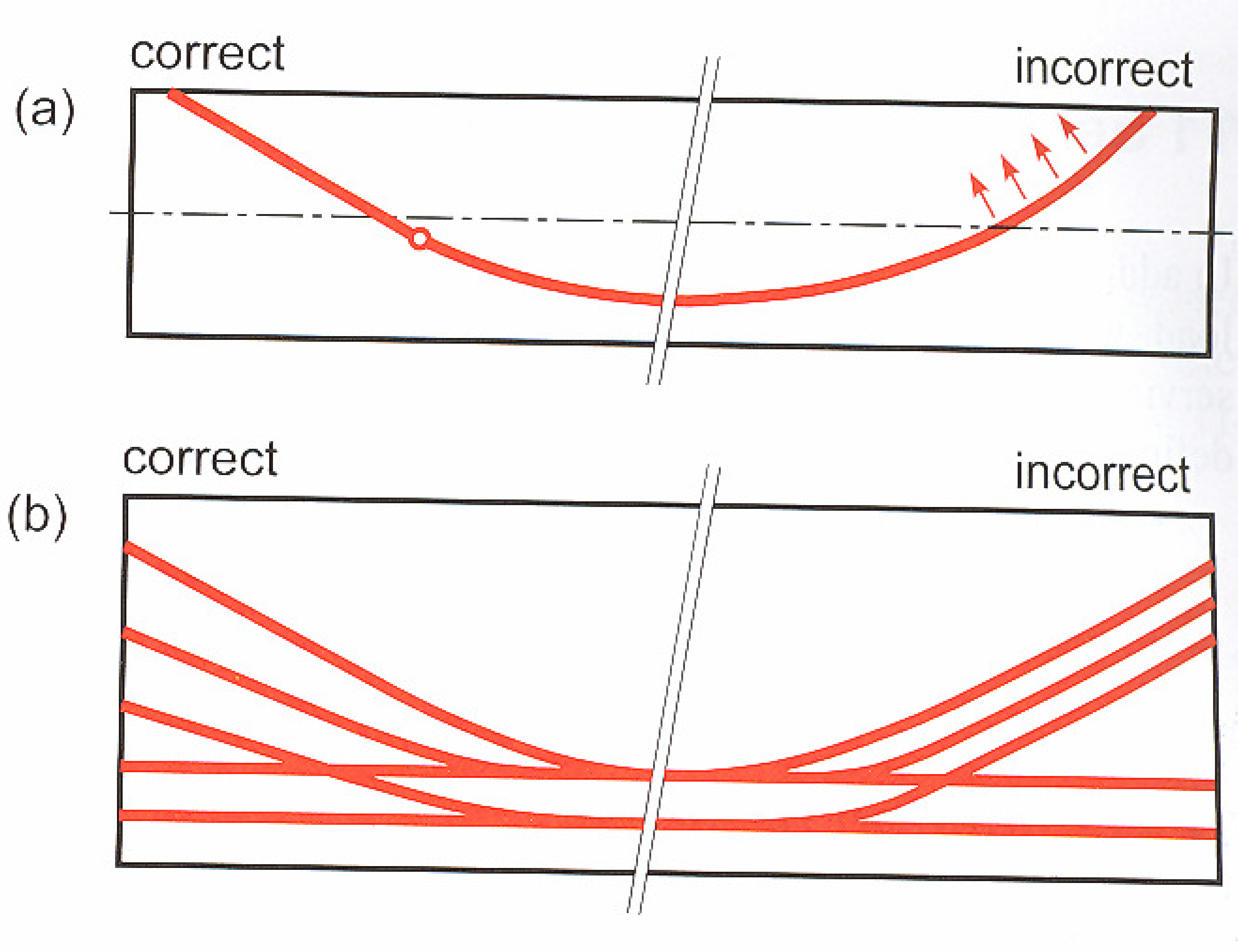
Reinforcement







Multiple end anchorages



Recommendations for tendon profiles