NCI re 6.8.4 (1)

If a simplified analysis as described in 6.8.5 or 6.8.6 is not possible, verification of the structural adequacy as in 6.8.4 (2) shall be performed.

NDP re 6.8.4, Table 6.3N

Table 6.3DE instead of Table 6.3N applies.

Table 6.3DE — Parameters of stress-number diagrams for reinforcement

Type of reinforcement	Number of cycles N^*	Stress exponent k_1	Stress exponent k_2	$\Delta\sigma_{Rsk}$ at N^* cycles N/mm^2
Straight and bent-up bars[a]	10^6	5	9[c]	175
Welded bars and wire mesh[b]	10^6	4	5	85

[a] For values of $D < 25\,\phi$, $\Delta\sigma_{Rsk}$ shall be multiplied by a reduction factor, ξ_1, equal to 0,35 + 0,026 D/ϕ, where ϕ is the bar diameter and D is the mandrel diameter. For bars with $\phi > 28$ mm, $\Delta\sigma_{Rsk}$ = 145 N/mm² (applies only to highly ductile steel).

[b] Unless other stress-number diagrams are specified in German national technical approvals or by permission on a case-by-case basis.

[c] In the case of corrosive environments (of types XC2, XC3, XC4, XS and XD), further considerations regarding the stress-number diagram may have to be made. In the absence of any experience, k_2 may be taken to be $5 \leq k_2 < 9$.

NCI re 6.8.4, Table 6.3N

Mechanical connections are subject to technical approval.

Values for welded bars include those with tack welds and butt joints.

The use of bars with diameters exceeding 40 mm is subject to technical approval.

Factor ζ_1 need not be used for shear reinforcement with 90°-bends for bar diameters not greater than 16 mm, with lengths of bend not less than 600 mm.

NDP re 6.8.4, Table 6.4N

Table 6.4DE applies instead of Table 6.4N.

Table 6.4DE — Parameters of stress-number diagrams for prestressing steel

Type of prestressing steel[a]	Number of cycles N^*	Stress exponent		$\Delta\sigma_{Rsk}$ at N^* cycles[b] N/mm²	
		k_1	k_2	Category 1	Category 2
Pre-tensioned	10^6	5	9	185	120
Post-tensioned					
— Single strands in plastic ducts	10^6	5	9	185	120
— Straight tendons; bent tendons in plastic ducts	10^6	5	9	150	95
— Bent tendons in steel ducts	10^6	3	7	120	75

[a] Unless other stress-number diagrams for the steel elements as installed are specified in technical approvals or by permission on a case-by-case basis.

[b] Values apply to steel elements as installed. Prestressing steel is classified into two categories, category 1 being subject to technical approval in the form of a German national technical approval. Parameters regarding the anchorage zone of tendons shall always be obtained from German national technical approvals.

NCI re 6.8.4, Table 6.4N

Mechanical couplers are always dealt with in technical approvals covering the prestressing method.

The use of bars of diameter greater than 40 mm is covered in technical approvals.

NDP re 6.8.4 (5)

The recommended value k_2 = 5 applies.

NDP re 6.8.6 (1)

k_1 = 70 N/mm² and k_2 = 0 apply.

NDP re 6.8.6 (3)

k_3 = 0,75 applies.

NDP re 6.8.7 (1)

$N = 10^6$ cycles and k_1 = 1,0 apply.

NCI re 6.8.7 (3)

In this case, $f_{cd,fat}$ may generally be multiplied by the reduction factor ν_1 as in NDP re 6.2.3 (2) above.

NCI re 7.1

(NA.3) Non-prestressed conventional buildings designed as specified in Section 6 do not usually require stress analyses as specified in 7.2 if both of the following conditions apply:

— the action-effects are determined by elastic theory and are redistributed by not more than 15 % at the ultimate limit state;

— detailing is as specified in Section 9, and the requirements for minimum reinforcement are complied with.

NDP re 7.2 (2)

The recommended value k_1 = 0,6 applies.

NOTE A characteristic combination of loads is understood as being a rare combination of loads.

NDP re 7.2 (3)

The recommended value k_2 = 0,45 applies.

NDP re 7.2 (5)

The k_3, k_4 and k_5 values shall be the following:

k_3 = 0,8

k_4 = 1,0

k_5 = 0,65 for quasi-permanent combinations of actions after deduction of the losses in prestressing force according to 5.10.5.2 and 5.10.6 and using the mean prestressing force.

NOTE A characteristic combination of loads is understood as being a rare combination of loads.

NCI re 7.2

(NA.6) The mean prestressing force immediately after release of the pressure on the anchorages or after release of the anchorages under a rare combination of loads shall at no point be more than 0,9 $f_{p0,1k}$ or 0,8 f_{pk}, whichever is less.

(NA.7) At anchorages and bearings, the analyses as in paragraphs (2) and (3) are not required if the specifications of 8.10.3 and Section 9 are complied with.

NDP re 7.3.1 (5)

Table 7.1DE applies instead of Table 7.1N.

Table 7.1DE — Theoretical maximum design crack width w_{max}

<table>
<tr><th rowspan="4">Exposure class</th><th colspan="4">Maximum design crack width w_{max}
mm</th></tr>
<tr><th>Reinforced members and prestressed members with unbonded tendons</th><th>Post-tensioned members</th><th colspan="2">Pre-tensioned members</th></tr>
<tr><th colspan="4">subjected to a</th></tr>
<tr><th>quasi-permanent</th><th>frequent</th><th>frequent</th><th>rare</th></tr>
<tr><th></th><th colspan="4">combination of loads</th></tr>
<tr><td>X0 and XC1</td><td>0,4[a]</td><td>0,2</td><td>0,2</td><td rowspan="2">—</td></tr>
<tr><td>XC2 to XC4</td><td rowspan="2">0,3</td><td rowspan="2">0,2[b, c]</td><td>0,2[b]</td></tr>
<tr><td>XS1 to XS3
XD1 to XD3[d]</td><td>Decompression</td><td>0,2</td></tr>
<tr><td colspan="5">[a] For X0 and XC1 exposure classes, the crack width has no influence on durability and this limit is set to ensure an acceptable appearance. In the absence of appearance requirements, a higher value may be specified.
[b] For these exposure classes, in addition, decompression shall be checked under a quasi-permanent combination of loads.
[c] If corrosion protection is ensured by other means (see technical approval for prestressing method), decompression need not be checked.
[d] See 7.3.1 (7).</td></tr>
</table>

NCI re 7.3.1 (5)

In order to keep within the decompression limit, it is required that the concrete surrounding the tendon is in compression over a width of 100 mm or 1/10 of the depth of section (whichever is greater). Stresses are to be checked in state II.

The note to Table 7.1N is dropped.

NCI re 7.3.1 (8)

Tensile forces may also occur in places not requiring reinforcement according to the strut-and-tie model. Such tensile forces may need to be accommodated by suitable detailing of the structural reinforcement (e.g. for deep beams as specified in 9.7).

NCI re 7.3.1

(NA.10) If reinforcing fabric with a cross section $a_s \geq 6$ cm^2/m is two-layered (see 8.7.5.1), limitation of crack width shall be checked at the joint, assuming a 25 % increase in steel stress.

NCI re 7.3.2 (2)

This reinforcement is mainly to be located at the edge of the section in tension, although a suitable percentage shall be distributed over the tension zone to prevent cracks converging to form wider cracks.

The minimum reinforcement may be of reduced cross section if the imposed deformation is sufficiently minor for it to be unlikely to cause cracking. In such cases, it may be designed by considering the cross section subjected to the imposed deformation, taking into account the requirements relating to the limitation of crack width.

The definitions of $f_{ct,eff}$, σ_c and factor k are to be modified as follows:

$f_{ct,eff}$ is the axial tensile strength of the concrete, at time t, in which cracking is to be expected (the mean tensile strength of the concrete, $f_{ctm}(t)$, in this verification). In many cases (e.g. if restraint is due to early thermal contraction), the concrete can crack during the first three to five days after placing, depending on the environmental conditions, the shape of the member and the type of formwork; in such cases, unless a more detailed analysis is required, $f_{ct,eff}$ shall be set at 50 % of the mean tensile strength f_{ctm} after 28 days (i.e. $f_{ct,eff}$ = 0,5 $f_{ctm}(28d)$). This is to be indicated in the drawings and specification of works so as to give the person undertaking the work adequate notification to permit him to specify the concrete accordingly. If it cannot be assumed that cracking will occur within the first 28 days, a tensile strength of at least 3 N/mm^2 should be assumed;

k is a factor taking into account non-uniformly distributed tensile stresses in the concrete and other effects counteracting cracking; its value depends on the type of tensile stress to which it is assigned, as follows:

a) where tensile stresses are the result of restraint due to internal stresses (e.g. caused by early thermal contraction due to loss of heat of hydration), k may be taken as equal to 0,8, using as h the depth or width of the section or subsection, whichever is smaller;

b) where tensile stresses are the result of restraint due to imposed deformations (e.g. caused by settlement of supports, with the section being free of non-uniformly distributed internal stresses and not subjected to other effects counteracting cracking): k = 1,0;

σ_c is the stress in the concrete at the level of the centroidal axis of the section or subsection in the uncracked condition under the combination of actions resulting in initial cracking of the overall cross section.

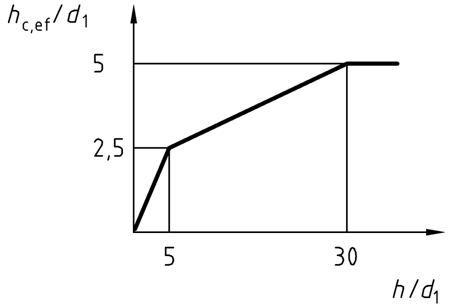
NCI re 7.3.2 (3)

NOTE The approach taking the effective area of concrete in tension $A_{c,eff}$ as equal to 2,5 $(h - d)$ is adequately accurate only if for concentrations of reinforcement and for thin members, i.e. where $h/(h - d) \leq 10$ for members in flexure and $h/(h - d) \leq 5$ where there is axial restraint. For deeper members, the effective area may reach a value up to 5 $(h - d)$ (see Figure 7.1 d)).

Where the reinforcement is not located within a zone of depth equal to $(h - x)/3$, the depth should be enlarged to become $(h - x)/2$, with x in state I.

NCI re 7.3.2, Figure 7.1

Figure 7.1 is supplemented by the following graph:



$d_1 = (h - d)$

Figure NA.7.1d) — Depth of effective tension area $h_{c,ef}$ as a function of member depth h/d_1

NDP re 7.3.2 (4)

The following is substituted for this paragraph:

In pre-tensioned bonded members, the minimum reinforcement required to ensure controlled cracking is not required in concrete subjected to a rare combination of actions and pre-tensioning as expressed by the relevant characteristic values, if compressive stresses $\sigma_{ct,p}$ greater than 1,0 N/mm^2 occur in the concrete at the edge of the section. Otherwise, minimum reinforcement is required.

NOTE A characteristic combination of loads is understood as being a rare combination of loads.

NCI re 7.3.2 (minimum reinforcement for crack control)

(NA.5) For members of greater depth, the minimum area of reinforcement when subjected to axial restraint, required to limit crack width on each side of the member, taking into account an effective boundary zone, $A_{c,eff}$, may be calculated as follows:

$$A_{s,min} = f_{ct,eff} \cdot A_{c,eff}/\sigma_s \geq k \cdot f_{ct,eff} \cdot A_{ct}/f_{yk} \quad \text{(NA.7.5.1)}$$

where

$A_{c,eff}$ is the effective tension area (as in Figure 7.1: $A_{c,eff} = h_{c,ef} \cdot b$);

A_{ct} is the area of the concrete compressive zone on each side of the member (equal to $0,5h \cdot b$).

The maximum bar diameter ϕ_s for determining the stress in the steel for Equation (NA.7.5.1) shall be adjusted as a function of $f_{ct,eff}$, as follows:

$$\phi = \phi_s^* \cdot f_{ct,eff}/2,9 \quad \text{(NA.7.5.2)}$$

However, no more minimum reinforcement needs to be provided than is required in accordance with Equations (7.1) and (7.7DE) or in accordance with 7.3.4.

(NA.6) Where slowly hardening concrete with $r \leq 0,3$ is used (which normally is the case where members are deeper), the minimum reinforcement may be multiplied by a factor of 0,85. Relevant detailing requirements relating to a reduction in reinforcement are then to be specified in the documentation.

NOTE See DIN EN 206-1 for the ratio f_{cm2}/f_{cm28} characterizing the strength development of concrete ($r = f_{cm2}/f_{cm28}$).

NCI re 7.3.3 (1)

The specification applies only to slabs coming under exposure class XC1.

NDP re 7.3.3 (2)

The note is supplemented as follows:

Tables 7.2DE (instead of Table 7.2N) and 7.3N apply.

Stress in the reinforcement, σ_s, of pre-tensioned bonded members shall be obtained for the relevant combination of actions by means of Equation (NA.7.5.3), taking into account the difference in bonding behaviour between the reinforcing steel and prestressing steel.

$$\sigma_s = \sigma_{s2} + 0{,}4 \cdot f_{ct,eff} \left(\frac{1}{\rho_{p,eff}} - \frac{1}{\rho_{tot}} \right) \qquad \text{(NA.7.5.3)}$$

where

σ_{s2} is the stress in the reinforcing steel or the increase in stress in the prestressing steel in state II for the combination of actions considered, assuming a rigid bond;

$\rho_{p,eff}$ is the effective reinforcement ratio, taking into account the variation in bond strength, to be calculated using Equation (7.10);

ρ_{tot} is the geometric reinforcement ratio, calculated as follows:

$$\rho_{tot} = (A_s + A_p)/A_{c,eff} \qquad \text{(NA.7.5.4)}$$

with

A_s (sectional) area of the reinforcement (cf. key to Equation (7.1));

A_p (sectional) area of the tendons located in the zone of the concrete section in which reinforcement is effective, $A_{c,eff}$;

$A_{c,eff}$ effective tension area (cf. Figure 7.1) (normally assuming $h_{c,eff}$ to be equal to 2,5d_1, constant).

$f_{ct,eff}$ is the effective tensile strength of the concrete (cf. NCI re 7.3.2 (2) above).

Table 7.2DE — Maximum bar diameter

Steel stress σ_s [b] N/mm^2	**Maximum bar diameter** ϕ_s**[a], in** mm, **for a crack width** w_k **of**		
	0,4 mm	**0,3** mm	**0,2** mm
160	54	41	27
200	35	26	17
240	24	18	12
280	18	13	9
320	14	10	7
360	11	8	5
400	9	7	4
450	7	5	3

[a] The above values are based on the following assumptions:

The limit values obtained from Equations (7.9) and (7.11), taking $f_{ct,eff}$ as 2,9 N/mm^2 and E_s as 200 000 N/mm^2, are calculated as follows:

$$\sigma_s = \sqrt{w_k \frac{3{,}48 \cdot 10^6}{\phi_s^*}}$$

[b] Assuming the relevant combination of loads.

The maximum bar diameter shall be as follows:

Minimum reinforcement to control cracking (cf. 7.3.2):

$$\phi_s = \phi_s^* \cdot \frac{k_c \cdot k \cdot h_{cr}}{4\,(h-d)} \cdot \frac{f_{ct,eff}}{2{,}9} \geq \phi_s^* \cdot \frac{f_{ct,eff}}{2{,}9} \tag{7.6DE}$$

Minimum tensile reinforcement (cf. 7.3.2):

$$\phi_s = \phi_s^* \cdot \frac{k_c \cdot k \cdot h_{cr}}{8\,(h-d)} \cdot \frac{f_{ct,eff}}{2{,}9} \geq \phi_s^* \cdot \frac{f_{ct,eff}}{2{,}9} \tag{7.7DE}$$

Reinforcement subjected to direct loading:

$$\phi_s = \phi_s^* \cdot \frac{\sigma_s \cdot A_s}{4\,(h-d) \cdot b \cdot 2{,}9} \geq \phi_s^* \cdot \frac{f_{ct,eff}}{2{,}9} \tag{7.7.1DE}$$

where

σ_s is the steel stress in state II (for bonded tension members to be calculated using Equation (NA.7.5.3).

NCI re 7.3.3

The clause shall be supplemented as follows:

(NA.6)P Where there are bundles of bars, their equivalent diameter ϕ_n shall be used instead of the bar diameter of individual bars, as follows: $\phi_n = \phi \cdot \sqrt{n},$ where n is the number of bars.

(NA.7) If bars of different diameters are used in a section, a mean bar diameter, ϕ_m, equal to $\Sigma\phi_i^2/\Sigma\phi_i$ shall be assumed.

(NA.8) In the case of welded fabric with double bars, the diameter of a single bar may be used in calculations.

(NA.9) The limitation of shear cracking may be assumed satisfactory with no further verification being necessary if the specifications relating to reinforcement as in 8.5 and the detailing provisions given in 9.2.2 and 9.2.3 are complied with.

NCI re 7.3.4 (1)

Where crack widths are to be calculated for design situations in which tension is due to a combination of restraint and loading, the equations in this clause may be used but the strain due to loading, calculated on the basis of a cracked section, should be increased by the strain due to restraint.

NCI re 7.3.4 (2)

If the strain due to restraint in the cracked condition is not more than 0,8 ‰, it will generally suffice to base calculations of crack width on the stress due to either restraint or loading, whichever is greater.

The effective tensile strength of the concrete $f_{ct,eff}$ as specified in Equation (7.9) is identical to $f_{ct,eff}$ as in NCI re 7.3.2 (2) above, except that no minimum tensile strength is specified here.

As a rule, slip of tendons is to be allowed for and k_t taken to be 0,4.

For pretensioned bonded members, σ_s shall be that defined in (NCI) re 7.3.3 (2) above.

NDP re 7.3.4 (3)

The following k factors apply:

$k_1 \cdot k_2 = 1$; $k_3 = 0$ and $k_4 = 1/3{,}6$

$s_{r,max}$ as in Equation (7.11) shall satisfy the following condition:

$$s_{r,max} \leq \frac{\sigma_s \cdot \phi}{3{,}6 \cdot f_{ct,eff}},$$

but not exceed a value equal to twice the mesh width in the case of reinforcing fabric.

NCI re 7.3.4 (5)

Where cracking is to be checked for these walls, an upper limit should be set for the crack width on a case-by-case basis, assuming the maximum crack spacing to be twice the height of the wall.

NCI re 7.4.1 (3)

NOTE This paragraph only deals with deformations occurring in vertical direction in members in bending, with a distinction made between the following:

— sag (i.e. vertical deformation of a member relative to the shortest line connecting the points of support);

— deflection (i.e. vertical deformation of a member relative to the system line of the member (e.g. relative to the precamber if upward deflection is incorporated in the formwork)).

NCI re 7.4.1 (4)

The span of cantilevers may be assumed to be 2,5 times their length, i.e. their sag does not exceed 1/100 of their length. However, the maximum sag should be no more than that of the adjacent span.

This value may be increased in cases where the sag has no effect on serviceability and no special requirements need to be met regarding the appearance of the structure.

NOTE Even when the span-to-depth ratio criteria are applied, and despite careful analyses, the limits of deformation can sometimes be slightly exceeded.

NDP re 7.4.2 (2)

Table 7.4N applies as recommended.

NCI re 7.4.2 (2)

The span-to-depth ratio l/d calculated in accordance with Equation (7.16) should normally not exceed a value of $K \cdot 35$ (i.e. $l/d \leq K \cdot 35$) or, where members are liable to affect the performance of finishing, partitions, fixings, etc. susceptible to deformation, a value of $K^2 \cdot 150/l$ (i.e. $l/d \leq K^2 \cdot 150/l$).

NCI re 7.4.3 (2)P

NOTE Further information regarding calculation of the deflection of steel members can be found in the specialist literature (cf. *DAfStb-Heft* 600).

NCI re 8.1 (1)P

The detailing arrangements for reinforcement and tendons also cover the accidental action “vehicle impact”.

NDP re 8.2 (2)

The k_1 and k_2 factors shall be as follows:

$k_1 = 1$

$k_2 = 0$ for $d_g \leq 16$ mm

$k_2 = 5$ for $d_g > 16$ mm