Social- og
Boligstyrelsen
Danish Authority of Social
Services and Housing

DS/EN 1992-1-2 DK NA:2011

National Annex to
Eurocode 2: Design of concrete structures –
Part 1-2: General rules - Structural fire design

Foreword

This national annex (NA) revises and supersedes EN 1992-1-2 DK NA:2007. This NA is valid from 2011-12-15.

This NA lays down the conditions for the implementation in Denmark of this Eurocode for construction works in conformity with the Danish Building Act or the building legislation. Other parties can put this NA into effect by referring thereto.

This NA lays down the conditions for the application of DS/EN 1992-1-2 in Denmark.

National provisions are given in the form of nationally applicable values and an option between methods as specified in the Eurocode, and complementary information.

This NA includes:

- An overview of possible national choices and complementary information;
- National choices;
- Complementary (non-contradictory) information.

Headings and numbering refer to the clauses of DS/EN 1992-1-2 where choices have been made and/or complementary information is given.

Overview of possible national choices and complementary information

The list below identifies the clauses where national choices are possible and the applicable/not applicable informative annexes. Furthermore, clauses providing complementary information are identified. Complementary information is given at the end of this document.

Clause	**Subject**	**National choice**	**Complementary information**
2.1.3(2)	Parametric fire exposure	Changed	
2.3(2)P	Design values of material properties	Unchanged	
3.2.2.1(1)P	Concrete under compression	Information added	
3.2.3(5)	Reinforcing steel	National choice and information added	
3.2.4(2)	Prestressing steel	National choice and information added	
3.3.3(1)	Thermal conductivity	Unchanged	
4.1(1)P	General	National choice	
4.2.4.3(1)	Steel	Information added	
4.5.1(2)	Explosive spalling	National choice	
5.1(3)	Scope	Information added	
5.2(3)	General design rules	National choice	
5.3.2(2)	Method A	Unchanged	
5.3.2(3)	Method A	Information added	
5.3.3(2)	Method B	Information added	
5.4.2(1)	Load-bearing solid walls		Complementary information
5.6.1(1)	General	National choice	
5.7.3(2)	Continuous solid slabs	National choice	
6.1(5)	General	Unchanged	
6.2(2)	Spalling	National choice	
6.3(1)	Thermal properties	National choice	
6.4.2.1(3)	Columns and walls	Unchanged	
6.4.2.2(2)	Beams and slabs	Unchanged	
Annex A	Temperature profiles	Applicable	Complementary information
Annex B	Simplified calculation models	National choice	
Annex C	Buckling of columns under fire conditions	Applicable	
Annex D	Calculation methods for shear, torsion and anchorage	Not applicable	
Annex E	Simplified calculation method for beams and slabs	Applicable	

NOTE - Unchanged: Recommendations in the standard are followed.

National choices

2.1.3(2) Parametric fire exposure

$\Delta\theta_1$ and $\Delta\theta_2$ are taken as $\Delta\theta_1$ = 140 K and $\Delta\theta_2$ = 180 K.

3.2.2.1(1)P Concrete under compression

For Danish concretes according to DS 2426, the reduction of the compressive strength during the heating phase and the cooling phase, respectively, is determined according to Figures 1 NA and 2 NA.

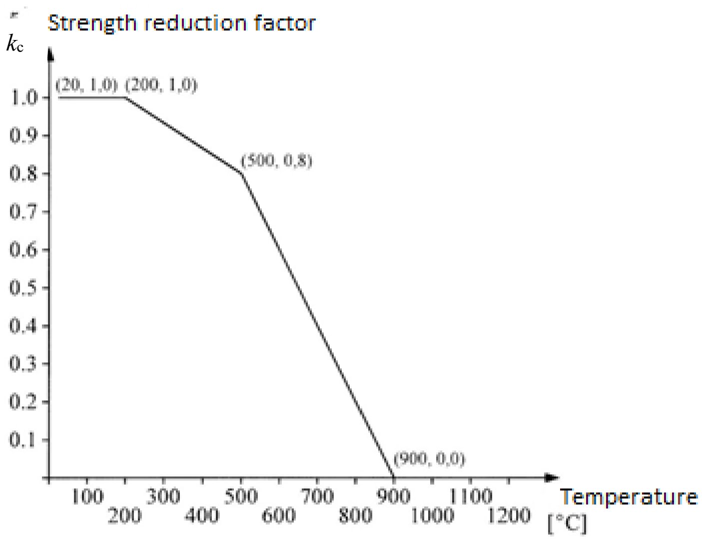

Figure 1 NA – Reduction factor k_c for the uniaxial compressive concrete strength f_{ck} during heating

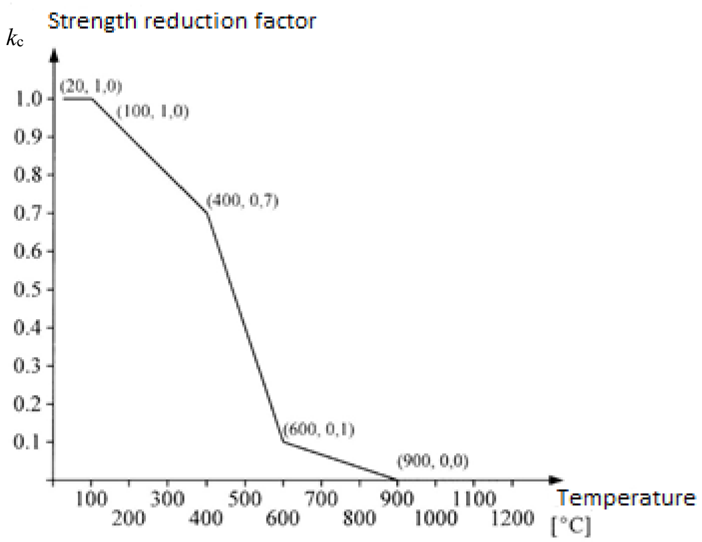

Figure 2 NA – Reduction factor k_c for the uniaxial compressive concrete strength f_{ck} during cooling as a function of the maximum temperature occurring during fire

A point (ε_c,σ_c) on the stress-strain curve corresponding to 20 °C can be mapped at a point (ε_c/ k_c, $k_c \cdot \sigma_c$) on the stress-strain curve for heating by θ °C, where k_c is the reduction factor for the compressive strength of concrete at the temperature θ °C.

The reduction factor for the modulus of elasticity of the concrete E_{cm} can be taken as k_c^2.

The ultimate strain for concrete can be taken as ε_{cu} = 0,0035/ k_c.

3.2.3(5) Reinforcing steel
Class N shall be used.

It is emphasised that the values stated for f_{sy} in DS/EN 1992-1-2 are values corresponding to a strain of 2,0 %, i.e. the ultimate stress. For a strain of 0,2 %, i.e. the strain corresponding to yielding, the values in Table 1 NA are used.

Table 1 NA - Values for the reduction of the 0,2% proof strength as a function of temperature

ºC	Hot rolled	Cold worked
20	1,00	1,00
100	0,96	0,99
200	0,88	0,95
300	0,77	0,89
400	0,65	0,78
500	0,47	0,57
600	0,27	0,30
700	0,13	0,12
800	0,05	0,05
900	0,02	0,02
1 000	0,01	0,01
1 100	0,00	0,00
1 200	0,00	0,00

For quenched and tempered steels, the values given in Table 2 NA are used.

Table 2 NA - Values for quenched and tempered steels as a function of temperature

ºC	Reduction 0,2 % proof strength	Reduction 2,0 % proof strength	Reduction Modulus of elasticity
20	1,00	1,00	1,00
100	0,98	1,00	1,00
200	0,94	1,00	1,00
300	0,89	0,99	0,99

ºC	Reduction 0,2 % proof strength	Reduction 2,0 % proof strength	Reduction Modulus of elasticity
400	0,78	0,95	0,96
500	0,55	0,79	0,79
600	0,27	0,47	0,48
700	0,10	0,17	0,21
800	0,00	0,00	0,08
900	0,00	0,00	0,03
1 000	0,00	0,00	0,01
1 100	0,00	0,00	0,01
1 200	0,00	0,00	0,00

3. 2.4(2) Prestressing steel
Class B shall be used.

It is emphasised that the values stated for f_{py} in DS/EN 1992-1-2 are values corresponding to a strain of 2,0 %, i.e. the ultimate stress. For a strain of 0,2 %, i.e. the strain corresponding to yielding, the values in Table 3 NA are used.

Table 3 NA - Values for the reduction of the 0,2% proof strength as a function of temperature

ºC	Cold worked strands	Quenched strands
20	1,00	1,00
100	0,89	0,92
200	0,71	0,84
300	0,53	0,75
400	0,33	0,52
500	0,15	0,21
600	0,05	0,06
700	0,02	0,02
800	0,01	0,01
900	0,00	0,00
1 000	0,00	0,00
1 100	0,00	0,00
1 200	0,00	0,00

4.1(1)P General
Advanced calculation methods may be applied if they are well-documented, both by theory and by experiments.

4.5.1(2) Explosive spalling
The recommended value applies if the concrete has been densified by not more than 6% of the cement mass with particles of a smaller grain size than that of the cement grains. Where this requirement is not met, testing as described in 6.2(2) should be performed.

5.1(3) Scope
In order to consider the shear and torsion capacity in the fire situation, shear reinforcement in the form of stirrups should be arranged so that the axis distances of the stirrups at least correspond to the required shear capacity under fire conditions in accordance with Figure 3 NA. The axis distance of the stirrups is determined as the minimum distance from the central axis of the stirrups to the nearest concrete surface.

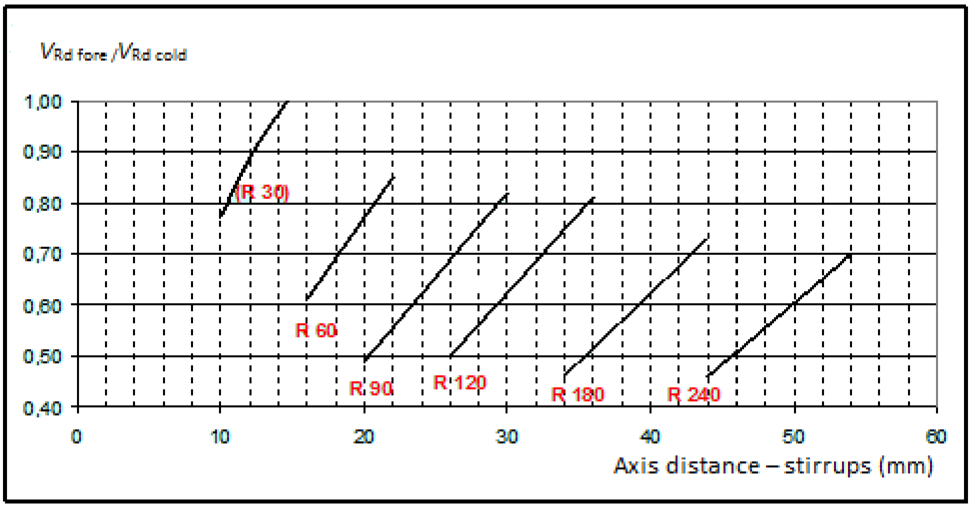

Figure 3 NA – Requirement for distance from centre stirrup reinforcement to the nearest concrete surface as a function of exposure and fire resistance

5.2(3) General design rules
The load parameter η_{fi} is determined by $\eta_{fi} = E_{d,fi}/(k_\eta \cdot E_d)$. For k_η the following value is applied $k_\eta = [1,35 - 0,13\ (Q_{k,1}/G_k)]$.

5.3.2(3) Method A
The parameter μ_{fi} is determined by $\mu_{fi} = 0,90\ (N_{Ed,fi}/N_{Rd})$.

5.3.3(2) Method B
The parameter n is determined by $n = 0,90\ N_{0Ed,fi}/[0,7\ (A_c f_{cd} + A_s f_{yd})]$.

5.6.1(1) General
Class WA shall be used.

5.7.3(2) Continuous solid slabs
Reference is made to the National Annex to DS/EN 1992-1-1.

6.2(2) Spalling
Method B and method C are applicable.

6.3(1) Thermal properties
The rules given in 3.3.3 (1) apply.

Annex B Simplified calculation methods
Annex B may be used with the limitations given below.

Method B1 is not applicable. Method B2 may be used for both normal concretes and for high strength concretes, if measures have been taken to avoid the risk of explosive spalling, cf. the relevant provisions in DS/EN 1992-1-2.

Calculations are based on the yield strength of the reinforcement, i.e. the 0,2 % proof strength, cf. the relevant values in this National Annex.

For the reinforcement, the 2,0% proof strength may be applied only if available documentation demonstrates that deformations of the structural members do not influence the load-bearing capacity of the structural member, nor e.g. affect fasteners and the integrity of the fire protection material, or result in compression or destruction of underlying fire separating walls etc.

For the purpose of calculation, the concrete compressive strength and modulus of elasticity are taken as 0 in the damaged boundary zone and as

$$f_{cd}(\theta_M) = k_c(\theta_M) \cdot f_{cd}$$

$$E_{cd}(\theta_M) = (k_c(\theta_M))^2 \cdot E_{cd}$$

in the reduced cross section.

Complementary (non-conflicting) information

5.4.2(1) Load-bearing solid walls

For braced building structures in the form of walls where the required standard fire exposure is higher than 30 min., the effective length $l_{0,fi}$ may be taken as 0,5l for intermediate floors and 0,5$l \leq l_{0,fi} \leq$ 0,7l for the upper floor, where l is the actual length of the column (centre to centre), provided that the first order eccentricity under fire conditions is a maximum of 0,25b, but no more than 100 mm.

Annex A Temperature profiles

The following approximate method of calculation can be used for the standard fire exposure to calculate the temperature distribution in rectangular cross sections or cross sections composed of rectangular parts. The method allows for the influence of moisture movement on the temperature near the surfaces of the cross section.

Calculation of the temperature distribution is in principle carried out by solving the thermal conductivity equation. The influence of the reinforcement on the temperature distribution may be disregarded.

Cross sections exposed on one side

For a cross section exposed on one side, the temperature at the time t at a depth x from the exposed surface may be taken as:

$$\theta_1(x,t) = 312 \cdot \log_{10}(8 \cdot t + 1) e^{-1.9k(t) \cdot x} \cdot \sin\left(\frac{\pi}{2} - k(t) \cdot x\right)$$

where

$$k(t) = \sqrt{\frac{\pi \cdot \rho \cdot c_p}{750 \cdot \lambda \cdot t}}$$

θ_1 is the temperature in °C, which may not be taken as less than 20 ºC
x is the distance from the surface in m
t is the time in minutes
λ is the thermal conductivity in W/m°C
ρ is the density in kg/m^3
c_p is the specific heat in J/kg°C, formally taken as c_p = 1000 J/kg°C.

The thermal conductivity λ for concretes made in accordance with DS 2426 may approximately be taken as a constant λ = 0,75 W/m °C, corresponding to the value for the temperature 500 °C.

The temperature θ_1 may not be taken as less than 20 ºC.

Cross sections exposed on two sides

For a cross section of thickness 2w exposed on two sides, the temperature θ_2, which cannot be less than 20 °C, can be approximately determined by superimposing two curves for one-sided exposure from either side. Thus, the temperature is determined by:

$$\theta_2(x,t) = \left(\theta_1(x,t) + \theta_1(2w-x,t)\right) \cdot \frac{\theta_1(0,t)}{\theta_1(0,t) + \theta_1(2w,t)}$$

For θ_1, the expression stated for cross sections exposed on one side is used, although θ_1, however, is only used for all x values higher than the lowest x value giving $\theta_1 = 0$.

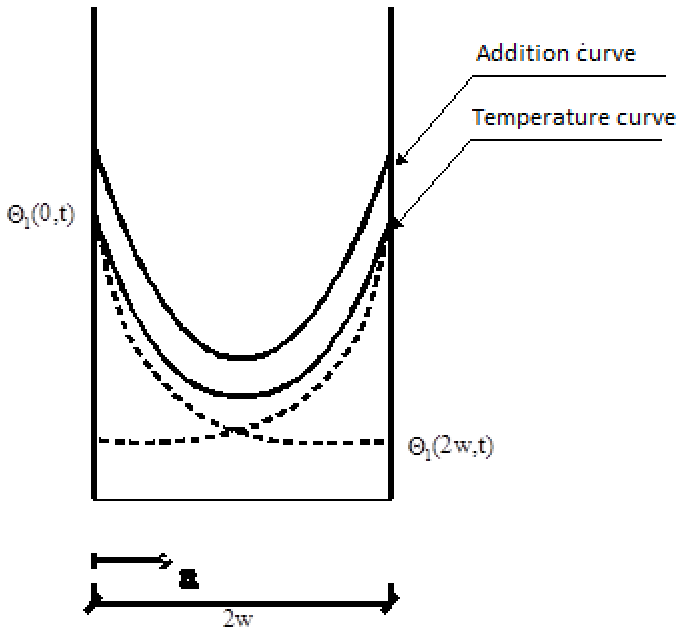

Figure 2 NA - Temperature conditions in a cross section exposed on two sides

Cross sections exposed on three sides

For a cross section of thickness 2w exposed on three sides, the temperature θ_3, which cannot be less than 20 °C, at a point (x,y) is determined by :

$$\theta_3(x,y,t) = \theta_2(x,t) + \theta_1(y,t) - \frac{\theta_2(x,t) \cdot \theta_1(y,t)}{\theta_1(0,t)}$$

where the principles stated above for the determination of θ_1 apply to θ_1 as well as θ_2.

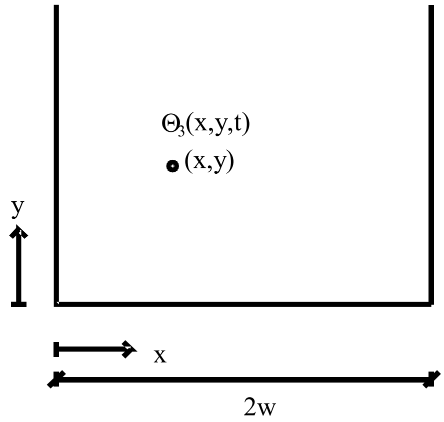

Figure 5 NA - Definition of coordinates for the calculation of temperature in a cross section exposed on three or four sides

<u>Cross sections exposed on four sides</u>
For a cross section exposed on four sides, the temperature is determined by superimposing the temperature curves for cross sections exposed on two sides.