

$$f_{cm}(t) = \beta_{cc}(t) f_{cm} \quad (3.1)$$

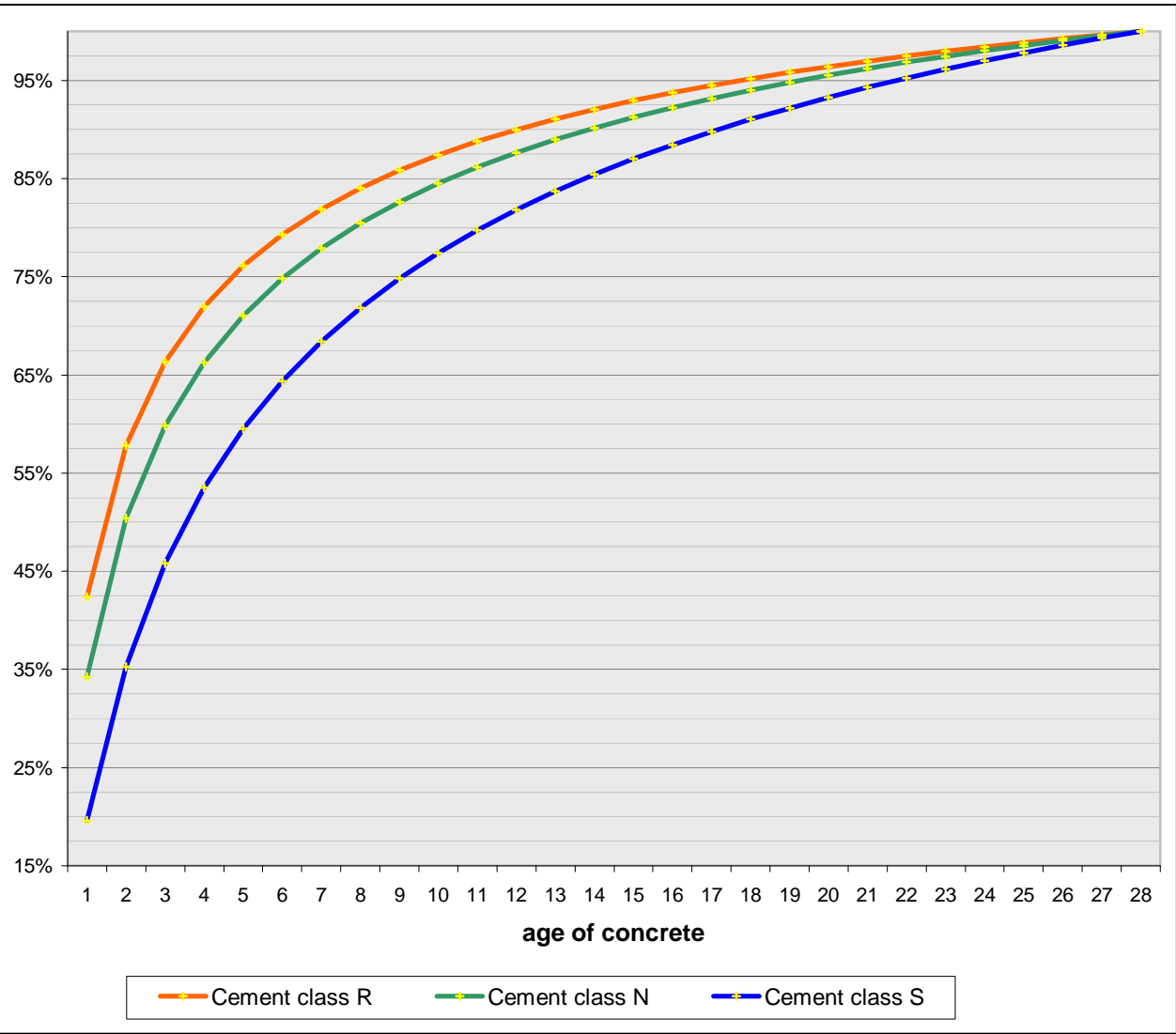
$$f_{ctm}(t) = (\beta_{cc}(t))^\alpha \cdot f_{ctm} \quad (3.4)$$

$\alpha = 1$  for  $t < 28$

$$\beta_{cc}(t) = \exp \left\{ s \left[ 1 - \left( \frac{28}{t} \right)^{1/2} \right] \right\} \quad (3.2)$$

$\beta_{cc}(t)$

Days	Cement class R	Cement class N	Cement class S
	s = 0,20	s = 0,25	s = 0,38
1	0,424	0,342	0,196
2	0,578	0,504	0,353
3	0,663	0,598	0,458
4	0,720	0,663	0,535
5	0,761	0,711	0,595
6	0,793	0,748	0,643
7	0,819	0,779	0,684
8	0,840	0,804	0,718
9	0,858	0,826	0,748
10	0,874	0,845	0,774
11	0,888	0,862	0,798
12	0,900	0,876	0,818
13	0,911	0,890	0,837
14	0,920	0,902	0,854
15	0,929	0,913	0,870
16	0,937	0,922	0,885
17	0,945	0,932	0,898
18	0,952	0,940	0,910
19	0,958	0,948	0,922
20	0,964	0,955	0,933
21	0,970	0,962	0,943
22	0,975	0,968	0,952
23	0,980	0,974	0,961
24	0,984	0,980	0,970
25	0,988	0,986	0,978
26	0,992	0,991	0,986
27	0,996	0,995	0,993
28	1,000	1,000	1,000
29	1,000	1,000	1,000
30	1,000	1,000	1,000
31	1,000	1,000	1,000



Cement class R: CEM 42,5 R ; CEM 52,5 N ; CEM 52,5 R // Cement class N: CEM 32,5 R, CEM 42,5 N // Cement class S: CEM 32,5 N

## SECTION 3 MATERIALS

### 3.1 Concrete

#### 3.1.1 General

- (1)P The following clauses give principles and rules for normal and high strength concrete.
- (2) Rules for lightweight aggregate concrete are given in Section 11.

#### 3.1.2 Strength

(1)P The compressive strength of concrete is denoted by concrete strength classes which relate to the characteristic (5%) cylinder strength  $f_{ck}$ , or the cube strength  $f_{ck,cube}$ , in accordance with EN 206-1.

(2)P The strength classes in this code are based on the characteristic cylinder strength  $f_{ck}$  determined at 28 days with a maximum value of  $C_{max}$ .

**Note:** The value of  $C_{max}$  for use in a Country may be found in its National Annex. The recommended value is C90/105.

(3) The characteristic strengths for  $f_{ck}$  and the corresponding mechanical characteristics necessary for design, are given in Table 3.1.

(4) In certain situations (e.g. prestressing) it may be appropriate to assess the compressive strength for concrete before or after 28 days, on the basis of test specimens stored under other conditions than prescribed in EN 12390.

If the concrete strength is determined at an age  $t > 28$  days the values  $\alpha_{cc}$  and  $\alpha_{ct}$  defined in 3.1.6 (1)P and 3.1.6 (2)P should be reduced by a factor  $k_t$ .

**Note:** The value of  $k_t$  for use in a Country may be found in its National Annex. The recommended value is 0,85.

(5) It may be required to specify the concrete compressive strength,  $f_{ck}(t)$ , at time  $t$  for a number of stages (e.g. demoulding, transfer of prestress), where

$$\begin{aligned} f_{ck}(t) &= f_{cm}(t) - 8 \text{ (MPa)} && \text{for } 3 < t < 28 \text{ days.} \\ f_{ck}(t) &= f_{ck} && \text{for } t \geq 28 \text{ days} \end{aligned}$$

More precise values should be based on tests especially for  $t \leq 3$  days

(6) The compressive strength of concrete at an age  $t$  depends on the type of cement, temperature and curing conditions. For a mean temperature of 20°C and curing in accordance with EN 12390 the compressive strength of concrete at various ages  $f_{cm}(t)$  may be estimated from Expressions (3.1) and (3.2).

$$f_{cm}(t) = \beta_{cc}(t) f_{cm} \quad (3.1)$$

with

$$\beta_{cc}(t) = \exp \left\{ s \left[ 1 - \left( \frac{28}{t} \right)^{1/2} \right] \right\} \quad (3.2)$$

where:

$f_{cm}(t)$  is the mean concrete compressive strength at an age of  $t$  days

- $f_{cm}$  is the mean compressive strength at 28 days according to Table 3.1  
 $\beta_{cc}(t)$  is a coefficient which depends on the age of the concrete  $t$   
 $t$  is the age of the concrete in days  
 $s$  is a coefficient which depends on the type of cement:  
 = 0,20 for cement of strength Classes CEM 42,5 R, CEM 52,5 N and CEM 52,5 R (Class R)  
 = 0,25 for cement of strength Classes CEM 32,5 R, CEM 42,5 N (Class N)  
 = 0,38 for cement of strength Classes CEM 32,5 N (Class S)

**Note:**  $\exp\{ \}$  has the same meaning as  $e^{( )}$

Where the concrete does not conform with the specification for compressive strength at 28 days the use of Expressions (3.1) and (3.2) is not appropriate.

This clause should not be used retrospectively to justify a non conforming reference strength by a later increase of the strength.

For situations where heat curing is applied to the member see 10.3.1.1 (3).

(7)P The tensile strength refers to the highest stress reached under concentric tensile loading. For the flexural tensile strength reference should be made to 3.1.8 (1).

(8) Where the tensile strength is determined as the splitting tensile strength,  $f_{ct,sp}$ , an approximate value of the axial tensile strength,  $f_{ct}$ , may be taken as:

$$f_{ct} = 0,9f_{ct,sp} \quad (3.3)$$

(9) The development of tensile strength with time is strongly influenced by curing and drying conditions as well as by the dimensions of the structural members. As a first approximation it may be assumed that the tensile strength  $f_{ctm}(t)$  is equal to:

$$f_{ctm}(t) = (\beta_{cc}(t))^\alpha \cdot f_{ctm} \quad (3.4)$$

where  $\beta_{cc}(t)$  follows from Expression (3.2) and

$$\alpha = 1 \text{ for } t < 28$$

$$\alpha = 2/3 \text{ for } t \geq 28. \text{ The values for } f_{ctm} \text{ are given in Table 3.1.}$$

**Note:** Where the development of the tensile strength with time is important it is recommended that tests are carried out taking into account the exposure conditions and the dimensions of the structural member.

### 3.1.3 Elastic deformation

(1) The elastic deformations of concrete largely depend on its composition (especially the aggregates). The values given in this Standard should be regarded as indicative for general applications. However, they should be specifically assessed if the structure is likely to be sensitive to deviations from these general values.

(2) The modulus of elasticity of a concrete is controlled by the moduli of elasticity of its components. Approximate values for the modulus of elasticity  $E_{cm}$ , secant value between  $\sigma_c = 0$  and  $0,4f_{cm}$ , for concretes with quartzite aggregates, are given in Table 3.1. For limestone and sandstone aggregates the value should be reduced by 10% and 30% respectively. For basalt aggregates the value should be increased by 20%.

**Note:** A Country's National Annex may refer to non-contradictory complementary information.