



**The new German
Concrete Standards
DIN EN 206-1 and DIN EN 1045-2**

**Construções
duráveis
de Concreto**

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Notas de aula**

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**The new German concrete standards DIN EN 206-1 and DIN EN 1045-2 as
basis for the design of durable constructions**

Abstract

As a result of about 10 years' work the European concrete standard EN 206-1 was adopted in spring 2000.

This, together with the German application rules in DIN 1045-2, now forms the new German concrete standard.

The intended increase in the durability of structures is apparent not only in the bridging of the interfaces throughout the series of DIN 1045 standards but also, in particular, through the detailed specification of the exposure classes in DIN EN 206/DIN 1045-2.

The European cement standard EN 197 was adopted at almost the same time as the European concrete standard.

It contains 27 different types of cement, for which the areas of application for producing durable concrete structures and components in Germany are laid down in DIN 1045-2.

1 Introduction

In several parts of the regulations the new European concrete standard takes account of the intention, which had been under discussion in Germany for a long time, of bringing the German concrete standard up to the state of the art.

It contains a consistent design strategy – ranging from un-reinforced concrete and conventional reinforced concrete to prestressed concrete – and it also applies to structural lightweight concrete.

It also covers the specifications for the building materials, the composition and production of the concrete, the execution of the construction work and the assessment of conformity.

The classification of the technical specifications and technical goods into classes represents one of the basic principles for free trade of services and goods across all borders.

The basic design principles and the specifications for the building materials, the execution of the construction work and assessment of conformity will in future be consistent for the same classes not only in Germany but over the whole of Europe.

This will not have any adverse effect on the diversity of architectural designs and the different ways of executing the construction work.

2 Structure of the German concrete standard

The new generation of German standards contains the main elements of the old DIN 1045 in three individual standards, see Figure 1. The regulations for the dimensioning and design of concrete structures are contained in DIN 1045-1 [1].

This part of the standard was based on the European standard prEN 1992.

The European standard for the building material concrete, EN 206-1 [2], was adopted in Europe in spring 2000.

In important areas it contained only framework definitions, which meant that national supplements were possible and, for introduction of the standard in Germany by the building inspectorate, even necessary.

This is permissible as EN 206 does not yet have the legal status of a harmonized standard for the purposes of the European Building Products Directive.

The German application rules for DIN EN 206 have been published as DIN 1045-2 [3].

A composite document is to be compiled from (DIN EN 206 + DIN 1045-2) which is to be published as a DIN technical report in order to assist practical work with the interconnected regulations.

The regulations in DIN 1045-3 [4] for execution of the building work were compiled on the basis of the European draft standard EN V 13670.

One section (DIN 1045-4 [5], Monitoring Precast Concrete Elements) is still being completed in Germany, mainly so that those questions which are not dealt with internationally can be controlled nationally, as with DIN 1084-3.

The material standards for the starting materials, namely cement, aggregate, concrete additions, and in this case fly ash, silica fume and trass as well as admixtures and mixing water, are incorporated in the concrete standard (DIN EN 206-1 + DIN 1045-2).

So far only DIN EN 197 for cement has been adopted as a harmonized standard.

Further European material standards are in preparation and will replace the German regulations at the stated time.

One important innovation of the new DIN 1045 series of standards is that the sections 1 to 3 of the standard are linked more closely with one another, through appropriate references, than were the corresponding sections in the old DIN 1045. This bridging of the interfaces is indicated in Figure 1 by the inscription (S).

Right at the beginning of DIN 1045-1, for example, there is the requirement that not only the design procedures, but also the concrete technology and construction technology procedures, must be incorporated and pursued further in the planning stage.

This creates a basic initial requirement to follow a logically constructed durability strategy for the concrete structures to be produced.

3 Rules for planning durable concrete structures

3.1 Definition of durability and durability strategies

The second important innovation for European and German concrete standardization is the direct requirement for durability of the structures.

It is a constituent part of all the foundation documents of the European Building Products Directive.

In German building products law and in the state building codes durability, like stability, now has the status of a legal requirement.

Durability is a property which must be created by correct planning, design and dimensioning as well as choice of building materials and execution of the building work.

Structures are designated durable if they exhibit the required service properties under the planned service conditions over the projected service life with low maintenance costs.

All the criteria mentioned already form part of the design strategy for a structure.

The planning engineer and design engineer must specify the necessary service properties (strength, freeze-thaw resistance, etc.) on the basis of the planned service conditions (stresses, weather conditions, etc.).

A dimensioning strategy for the durability is required so that under the given effects (“attacks”) the service conditions do not lead to premature and unplanned depletion of the load bearing capacity and the service properties (the “resistance”).

A distinction is made between the “descriptive strategy” and the “performance strategy”, see **Table 1**.

Table 1: Design strategies for durability

Design strategy	Criteria
Descriptive strategy	<ul style="list-style-type: none"> – average service life is defined – effects are defined (exposure classes) – normal expenditure on maintenance – concrete composition and execution rules are laid down by the technical regulations
Performance strategy	<ul style="list-style-type: none"> – service life $t_{N(soll)}$ is chosen to suit the requirements – maintenance costs are chosen – development with time of the attack and resistance are calculated – the calculated service life $t_{N(cal)}$ is determined on the basis of the behaviour pattern of the attack and resistance and defined more accurately by failure probabilities – verification $t_{N(cal)} \geq t_{N(soll)}$

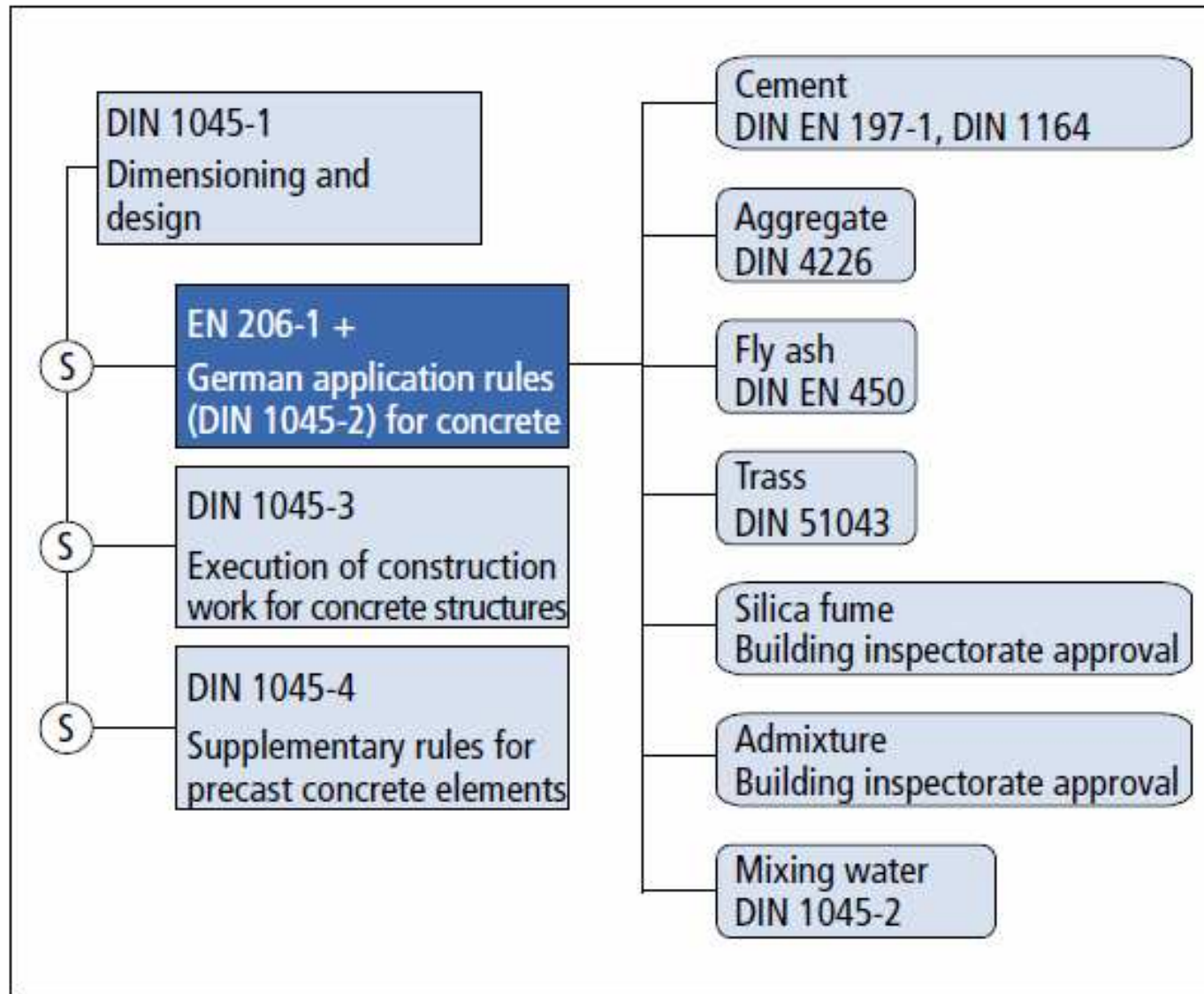


Figure 1: Overview of the German system of standards for concrete construction as at 2001 ($S \hat{=}$ "interface")

Calculated prediction of the durability on the basis of a performance strategy is currently possible for only a few effects, e.g. acid attack or chloride action and steel corrosion, and at considerable expense.

The durability dimensioning in the new European and German concrete standard is therefore carried out on the basis of the descriptive strategy.

It is based on classification of the effects (**exposure classes**) and associated measures, such as **concrete composition**, **concrete cover** on the reinforcement and **curing**.

The resistance of the concrete is characterized by the **maximum water/cement ratio**, the **minimum concrete strength class**, the **minimum cement content**, and possibly the **air void content**, the rules for taking account of concrete additions and, in individual cases, by restricting the cements which can be used.

Table 1 shows that the descriptive dimensioning strategy for durability is based on acceptance of the anticipated average service life. This is estimated numerically for the first time in the new European and German concrete standard and amounts to 50 years.

The figure has nothing to do with the warranty.

However, it does provide a reference value on which the requirements for planning, design, concrete technology and execution of the construction work are based in the new generation of standards.

4 Rules for designing durable concrete structures

4.1 Exposure classes

In order to be able to plan the durability of structures successfully it is necessary to think ahead.

Assumptions about the expected environmental effects or “attacks” have to be made when the structure is being designed.

They are listed in the “exposure classes” in (**DIN EN 206-1 + DIN 1045-2**).

In order to give the planner and designer a rapidly usable basis which is comparable throughout Europe the concrete standard offers them seven exposure classes, each sub-divided into up to four intensity stages corresponding to the “descriptive strategy”, see **Figure 2**.

These stresses resulting from the exposure classes have to be taken into account in the same way as the stresses caused by external loads.

Three of the exposure classes relate to the durability of the reinforcement in the concrete, and four relate to the durability of the concrete itself.

Special applications are regulated in these tables by an abundance of footnotes, e.g. the use of highly sulfate resisting cements.

The minimum cement contents to be observed in accordance with (**DIN EN 206-1 + DIN 1045-2**) are independent of the type of cement used.

Coal fly ash complying with DIN EN 450 and other fly ash with appropriate building inspectorate approval and silica fume with building inspectorate approval may be added to the concrete as concrete additions regardless of the type of cement

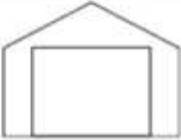
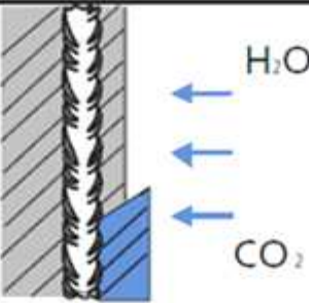
Exposure classes (environmental effects, "attacks")			Concrete technology measures ("resistances")		
class designation	effect and stress		max. w/c	min. c	fck Cilindro/cubo
X0	 no attack	no concrete attack	no requirement	no requirement	C8/10 C8/10
XC		1 dry	0,75	240	C16/20
		2 constantly wet	0,75	240	C16/20
		3 moderately moist	0,65	260	C20/25
		4 carbonation wet / dry	0,60	280	C25/30

Figure 2 Exposure classes (environmental effects, "attacks") and concrete technology measures.

- X0** This exposure class relates to the concrete for un-reinforced components in interior spaces or in the earth without exposure to frost. Ex : Interior de Edifícios
- XC1** relates to the corrosion-promoting action for reinforcing steel in dry interior spaces, Ex. : Fundações em solos não agressivos.
- XC2** in components in non-corrosive water,
- XC3** in moist spaces like indoor swimming pools and

XC4 in external components directly exposed to rain.

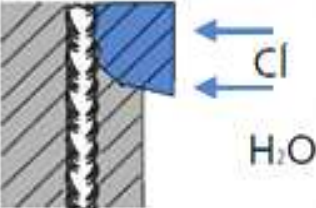

Exposure classes (environmental effects, "attacks")			Concrete technology measures ("resistances")		
class designation	effect and stress		max. w/c	min. c	fck Cilindro/cubo
XD/ XS	1		0,55	300	C30/37
	2		0,50	320	C35/45
	3	chloride wet / dry	0,45	320	C35/45

Figure 2 cont. Exposure classes (environmental effects, "attacks") and concrete technology measures.

Components in the XD and XS exposure classes are exposed to the action of chloride through de-icing salt (XD) or seawater (XS),

- specifically from spray (XD1 / XS1),
- in continuous contact with salt-containing water (XD2 / XS2) Exemplo XD2: Piscina
- and alternating contact with salt solution and drying out (XD3 / XS3).

Exemplo XS1 : ESTRUTURAS AO AR LIVRE NA ORLA OCEÂNICA

Exemplo XS2 : FUNDAÇÃO DE PORTO NO MAR

Exemplo XS3 : ESTACAS DE PORTOS NO MAR, BLOCOS DE FUNDAÇÃO DE PORTOS

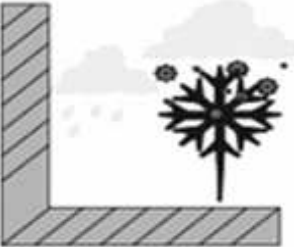
Exposure classes (environmental effects, "attacks")			Concrete technology measures ("resistances")				
class designation	effect and stress		max. w/c	min. c	fck Cilindro/cubo		
XF		1	moderate water saturation (sem sal)	0,60	280	C25/30	
		2	moderate water saturation (com sal)	0,55	+ LP	300	C25/30
				0,50		320	C35/45
		3	high water saturation (sem sal)	0,55	+ LP	300	C25/30
				0,50		320	C35/45
4	high water saturation (com sal)	0,50	+ LP	320	C30/37		

Figure 2 cont. Exposure classes (environmental effects, "attacks") and concrete technology measures.

Further effects on the concrete itself relate to components exposed to freeze-thaw

XF1 – with moderate water saturation without de-icing salt (sem sal)– Ex: Estruturas ao ar livre.

XF2 – with moderate water saturation with de-icing salt (com sal)

XF3 – with high water saturation and without de-icing salt (sem sal) – Ex: Reservatório de água doce.

XF4 – with high water saturation and with de-icing salt (com sal) .



Exposure classes (environmental effects, "attacks")				Concrete technology measures ("resistances")			
class designation	effect and stress			max. w/c	min. c	fck Cilindro/cubo	
XA	1		weakly corrosive	0,60	280	C25/30	
	2		moderately corrosive	0,50	320	C35/45	
	3	chemical attack	strongly corrosive	0,45	320	C35/45	

Figure 2 cont. Exposure classes (environmental effects, "attacks") and concrete technology measures.

The grade of attack during concrete corrosion by chemical attack (**XA1 – XA2 – XA3**) is classified in accordance with the definitions in DIN 4030.

Exemplo XA1 : Reservatórios de estação de tratamento de água

Exemplos XA2 : Solos fortemente agressivos . Ver tabela na próxima página.

Água do mar.

Exemplo XA3 : Esgoto fortemente agressivo

Classes de Exposição - Ataque Químico ao Concreto pela Água do Solo

Química	Unidade	XA 1	XA 2	XA3
Sulfat SO_4^{2-}	mg/l	200 ... 600	>600 ... 3000	> 3000 ... 6000
pH-Wert	---	6,5 ... 5,5	<5,5 ... 4,5	<4,5 ...4,0
CO2 capaz de dissolver a cal, CaO, do concreto	mg/l	15 ... 40	>40 ...100	>100 até a saturação
Ammonium NH_4^+	mg/l	15 ... 30	>30 ... 60	>60 ... 100
Magnesium Mg^{2+}	mg/l	300 ... 1000	>1000 ... 3000	>3000 até a saturação

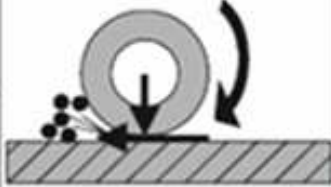
Exposure classes (environmental effects, "attacks")			Concrete technology measures ("resistances")		
class designation	effect	and stress	max. w/c	min. c	fck Cilindro/cubo
XM	1		0,55	300	C30/37
	2		0,45	320	C35/45
	3	wear	0,45	320	C35/45

Figure 2 cont. Exposure classes (environmental effects, "attacks") and concrete technology measures.

In Germany there is also the wear exposure class which regulates loading and wearing of load-bearing pavements and of stiffening industrial floors.

- XM1 moderate (rodovias para veículos leves)
- XM2 strong (rodovias com caminhões pesados)
- XM3 very strong (rodovias com caminhões pesados incluindo veículos com "correntes" nas rodas)

Producing concrete components with a planned resistance is the same as dimensioning them with respect to durability.

This dimensioning is carried out in the new European standard as a function of the above-mentioned different stages of the exposure classes, essentially by fulfilling three requirements (see Figure 2).

They relate to :

- the maximum water/cement ratio,
- the minimum cement content, and
- the minimum compressive strength class of the concrete.(fck cilindro / fck cubo)

It is the task of the designer to take account of that exposure class in each component which requires the greatest resistance in the form of the “lowest water/cement” ratio coupled with the “highest minimum cement content” and the “highest concrete strength” class.

This is shown in **Figure 3** by different exposure classes for individual components.

The determining effect is shown in **black**, and the other effects are shown in **light-blue**.

The designer also has to choose the “concrete cover” for the reinforcement to suit the exposure class in accordance with DIN 1045-1.

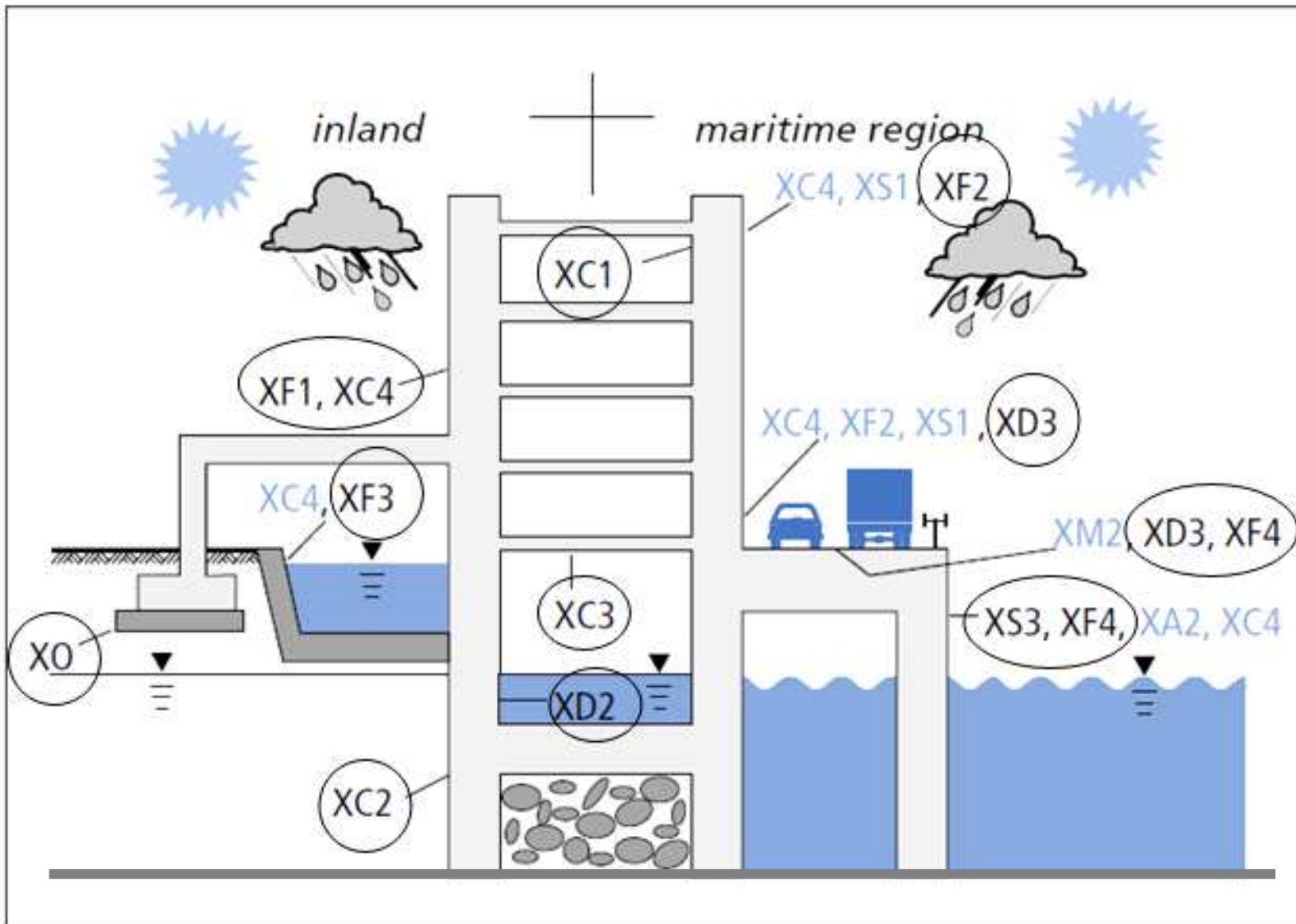


Figure 3: Examples of exposure classes acting jointly on typical components
 obs: **black type** indicates determining factor for durability design

X0

For X0 there are no requirements for the w/c ratio or the minimum cement content, see Figure 2. The minimum compressive strength class is C8/10. The first figure is the minimum cylinder compressive strength and the second one is the minimum cube compressive strength at 28 days.

XC

A maximum water/cement ratio between 0.75 and 0.60 is required for XC, with a minimum cement content between 240 kg/m³ and 280 kg/m³ and strength classes between C16/20 and C25/30.

An increased value *c* for the concrete cover on the reinforcement is naturally also required here to avoid corrosion of the reinforcement.

XD and XS

Even denser concretes are required to protect the reinforcement from corrosion for the two exposure classes XD and XS with exposure to chloride.

This is achieved by water/cement ratios between 0.55 and 0.45, cement contents between 300 kg/m³ and 320 kg/m³ and strength classes between C30/37 and C35/45.

XF, XA and XM

Corresponding requirements also applied to exposure classes XF, XA and XM to ensure the durability either of the concrete alone or of the reinforcement in the concrete.

Conhecendo-se as classes de exposição e de ataque, a norma DIN 1045 indica quais os cobrimentos a usar na estrutura.

	Cobrimentos segundo a DIN 1045												
Tipo de ataque →	Corrosão induzida por carbonatação				Corrosão induzida por cloretos			Corrosão induzida por cloretos da água do mar			Pavimentos com desgaste por abrasão e com armaduras		
Classe de exposição →	XC1	XC2	XC3	XC4	XD1	XD2	XD3	XS1	XS2	XS3	XM1	XM2	XM3
Concreto Armado	20	35	35	40	55	55	55	55	55	55	45	50	55
Concreto Protendido	30	45	45	50	65	65	65	65	65	65	55	60	65

Cimentos segundo a EN 206-1

Hauptzementarten	Bezeichnung (Normalbezeichnung)	BR_CPI	Hauptbestandteile											Nebenbestandteile	
			Portlandzementklinker K	Hütten sand S	Silica- staub D ²⁾	Pazzolane		Flugasche		Ge- brannter Schiefer T	Kalkstein				
						nattlich P	nattel. getempert Q	kiesel- säurereich V	kalk- reich W		L	LL			
CEM I	Portlandzement	CEM I	95-100	-	-	-	-	-	-	-	-	-	-	-	0-5
	Portlandhöfenzement	CEM II/A-S	80-94	6-20	-	-	-	-	-	-	-	-	-	-	0-5
CEM II	Portlandsilicastaubzement	CEM II/B-S	65-79	21-35	-	-	-	-	-	-	-	-	-	-	0-5
		CEM II/A-D	90-94	-	6-10	-	-	-	-	-	-	-	-	-	0-5
		CEM II/A-P	80-94	-	-	6-20	-	-	-	-	-	-	-	-	0-5
	Portlandpuzzolan- zement	CEM II/B-P	65-79	-	-	21-35	-	-	-	-	-	-	-	-	0-5
		CEM II/A-Q	80-94	-	-	-	6-20	-	-	-	-	-	-	-	0-5
		CEM II/B-Q	65-79	-	-	-	21-35	-	-	-	-	-	-	-	0-5
		CEM II/A-V	80-94	-	-	-	-	6-20	-	-	-	-	-	-	0-5
	Portlandflugasche- zement	CEM II/B-V	65-79	-	-	-	-	21-35	-	-	-	-	-	-	0-5
		CEM II/A-W	80-94	-	-	-	-	-	6-20	-	-	-	-	-	0-5
		CEM II/B-W	65-79	-	-	-	-	-	21-35	-	-	-	-	-	0-5
	Portlandschiefer- zement	CEM II/A-T	80-94	-	-	-	-	-	6-20	-	-	-	-	-	0-5
		CEM II/B-T	65-79	-	-	-	-	-	21-35	-	-	-	-	-	0-5
	Portlandkalkstein- zement	CEM II/A-L	80-94	-	-	-	-	-	-	-	6-20	-	-	-	0-5
		CEM II/B-L	65-79	-	-	-	-	-	-	-	21-35	-	-	-	0-5
CEM II/A-LL		80-94	-	-	-	-	-	-	-	-	6-20	-	-	0-5	
CEM II/B-LL		65-79	-	-	-	-	-	-	-	-	21-35	-	-	0-5	
Portlandkomposit- zement ³⁾	CEM II/A-M	80-94	-	-	-	-	-	6-20	-	-	-	-	-	0-5	
	CEM II/B-M	65-79	-	-	-	-	-	21-35	-	-	-	-	-	0-5	
CEM III	Hochofenzement	CEM III/A	35-64	36-65	-	-	-	-	-	-	-	-	-	-	0-5
		CEM III/B	20-34	66-80	-	-	-	-	-	-	-	-	-	-	0-5
		CEM III/C	5-19	81-95	-	-	-	-	-	-	-	-	-	-	0-5
CEM IV	Puzzolanzement ³⁾	CEM IV/A	65-89	-	-	-	11-35	-	-	-	-	-	-	0-5	
		CEM IV/B	45-64	-	-	-	36-55	-	-	-	-	-	-	0-5	
CEM V	Kompositzement ³⁾	CEM V/A	40-64	18-30	-	-	18-30	-	-	-	-	-	-	0-5	
		CEM V/B	20-38	31-50	-	-	31-50	-	-	-	-	-	-	0-5	

Table 2: Application rules for cements conforming to DIN EN 197-1 and DIN 1164

BR - CPII E

BR - CPIII

X / valid area of application ● / cannot be used in accordance with DIN 1045-2		/ cements complying with DIN EN 197-1 and DIN 1164								
		CEM I	CEM II				CEM III		CEM IV	CEM V
component / structure	exposure classes relevant to the design		S T D A-LL	V ⁹⁾ A-L ⁶⁾ P/Q	B-LL B-L A-M A-W	B-M B-W	A/B	C ²⁾	A/B	A/B
unreinforced concrete	X0	✖	✖	✖	✖	✖	✖	✖	✖	✖
components protected from frost (interior or in water)	XC1-XC4	✖	✖	✖	✖	● 1)	✖	● 1)	● 1)	● 1)
exterior components, hydraulic engineering structures	XC, XF1, XF3	✖	✖	✖	●	●	✖	●	●	●
exterior components exposed to de-icing agents	XC, XD, XF2, XF4	✖	✖	●	●	●	✖ 3), 4)	●	●	●
maritime structures	XC, XS, XF2, XF4	✖	✖	●	●	●	✖ 3), 4)	●	●	●
chemical attack ⁷⁾	XA	✖	✖	✖	●	●	✖	●	●	●
traffic surfaces	XF4, XM	✖ 9)	✖ 8) 9)		●	●	✖ 3) 4) 8) 9)	●	●	●
wear without frost	XM	✖	✖	✖	●	●	✖	●	●	●

- 1) Use for exposure class XC2 permitted
- 2) Use for exposure classes XD2 and XS2 permitted
- 3) For exposure class XF4 (obras marinhas) : only CEM III/A (36% a 65% de Escória) of the strength classes $\geq 42,5$ or $\geq 32,5$ R containing ≤ 50 % by mass blastfurnace slag may be used.
- 4) For exposure class XF4 (obras marinhas): CEM III/B (66% a 80% de Escória) may only be used for the following applications:
 - a) Sea water components: $w/c \leq 0.45$; minimum strength class C35/45 and $c \geq 340$ kg/m³
 - b) Track for motor scraper bridge, $w/c \leq 0.35$; minimum strength class C40/50 and $c \geq 360$ kg/m³; note DIN 19569

Air voids can be dispensed with in both cases.
- 5) CEM II/B-V not permitted for use with exposure class XF3
- 6) Use not permitted for exposure classes XF1 and XF3
- 7) For chemical attack by sulfate (except in sea water) highly sulfate resisting cement must be used above exposure class XA 1. A mixture of cement and fly ash may be used instead of highly sulfate resisting cement for producing sulfate resisting concrete where the corrosive water has a sulfate content of $SO_4^{2-} \leq 1500$ mg/l
- 8) For concrete highways pavements XM , complying with ZTV Beton-StB with the agreement of the client (only CEM III/A blastfurnace cement at least of 42,5 strength class)
- 9) For concrete highways pavements XM , complying with ZTV Beton-StB, total alkali content Na_2O -equivalent ≤ 1.0 % by mass used. The minimum cement content required in DIN 1045-2 shall only be

reduced to the specified lower values if CEM I Portland cements, CEM II/S, CEM II/T and CEM II/A-L Portland compo-site cements or CEM III/A or CEM III/B blastfurnace cements are used.

For the CEM III/B blastfurnace cements this only applies for a proven blastfurnace slag content of up to 70 % by mass.

The rules for calculating the allowance to be made for fly ash and silica fume in the effective water/cement ratio apply regardless of the type of cement used.

With simultaneous use of fly ash and silica fume as concrete additions the maximum quantity of fly ash permissible in the concrete composition for Portland composite(CEM II) and blastfurnace cements (CEM III) must, according to DIN 1045-2, be more severely limited than in Portland cements (CEM I).

Simultaneous use of fly ash and silica fume is not permissible in Portland composite cements containing fly ash (CEM II/V or CEM II/SV), in Portland pozzolanic cements (CEM II/P) or in blastfurnace cements (CEM III/B).

Table 3: Application rules for CEM II, CEM IV and CEM V cements with up to three main constituents complying with DIN EN 197-1

* gültiger Anwendungsbereich / valid area of application ○ nach DIN 1045-2 nicht anwendbar / cannot be used in accordance with DIN 1045-2		Zemente nach / cements complying with DIN EN 197-1 und / and DIN 1164									
		CEM II-M						CEM IV	CEM V		
component / structure	exposure classes relevant to the design	A	S-D S-T S-LL D-T D-LL T-LL	A	S-P S-V D-P D-V P-V P-T P-LL V-T V-LL	B	S-V D-V P-V V-T	B	S-LL D-LL P-LL V-LL T-LL	B-P ²⁾	A/B -(S-P) ⁴⁾
		B	S-D S-T D-T	B	S-P D-P P-T						
unreinforced concrete	X0	*	*	*	*	*	*	*	*	*	*
components protected from frost (interior or in water)	XC1-XC4	*	*	*	*	*	*	*	*	*	*
exterior components, hydraulic engineering structures	XC, XF1, XF3	*	*	*	○ ¹⁾	○	○	○	○	*	○
exterior components exposed to de-icing agents	XC, XD, XF2, XF4	*	○	○	○	○	○	○	○	○	○
maritime structures	XC, XS, XF2, XF4	*	*	*	○	○	○	○	○	○	○
chemical attack ²⁾	XA	*	*	*	*	*	*	○	○	*	○
traffic surfaces	XF4, XM	* ³⁾	○	○	○	○	○	○	○	○	○
wear without frost	XM	*	*	*	*	*	*	○	○	○ ⁴⁾	○

- 1) Use for exposure class XF 1 permitted
- 2) For chemical attack by sulfate (except in sea water) highly sulfate resisting cement must be used above exposure class XA1. A mixture of cement and fly ash may be used instead of highly sulfate resisting cement for producing sulfate resisting concrete where the corrosive water has a sulfate content of $\text{SO}_4^{(2-)} \leq 1500 \text{ mg/l}$
- 3) Not permitted for concrete carriageway surfaces complying with ZTV Beton- StB
- 4) Use for exposure class XM 1 permitted
- 5) Only applies for trass complying with DIN 51043 as a main constituent up to a maximum of 40 % by mass
- 6) Only applies for trass complying with DIN 51043 as a main constituent.

4.2 Application rules for cements complying with DIN EN 197-1 and DIN 1164

In general, all cements complying with DIN EN 197-1 and DIN 1164 are suitable for producing concrete complying with DIN EN 206-1 and the German application rules DIN 1045-2.

However, it is necessary under some circumstances and depending on the area of application to pay attention to differences caused by the type of cement with respect to the durability of the concretes produced with these cements.

These regulations are given in DIN 1045-2 as a function of the exposure classes to which a component is assigned.

Due to the high basic capabilities of all the types of cements so far standardized in DIN 1164 hardly any restrictions had to be made for these cements in practical building application.

The few restrictions relate only to concretes which are exposed to freeze-thaw attack with de-icing agents.

EN 197, which now applies throughout Europe, contains 27 different types of cement compared with the 12 types of cement in the old DIN 1164.

The expansion relates almost entirely to Portland composite cements with higher proportions of pozzolanic or inert main constituents, or to pozzolanic and composite cements with lower proportions of clinker

EN 197 therefore contains a number of types of cement for which there is no experience in Germany with respect to the durability of the concretes produced with them.

In these cases it was therefore necessary to specify new application rules.

Table 2 shows the German application rules for the entire range of the 27 types of cement in EN 197 for the usual components and structures used in building construction and civil engineering.

The rules used to apply for the cements already standardized in the previous standard DIN 1164 have been updated.

Table 2 shows that there are restrictions on the usability of the cements, especially for composite cements CEM V, pozzolanic cements CEM IV and blastfurnace cements CEM III-C.

The same applies to almost all the CEM II-M cements which were not previously covered by the standards.

The restrictions relate in particular to use for components exposed to freeze-thaw and chloride attack.

For CEM II-M Portland composite cements with three main components it was possible to specify extended possible applications for certain combinations of the main constituents (Table 3).

This affects cements with main constituents which were already standardized in DIN 1164.

These are limestone meal below 20 % by mass, granulated blastfurnace slag, silica fume, burnt shale, siliceous fly ash and natural pozzolans as the second or third main constituents.

For composite and pozzolanic cements with trass complying with DIN 51043 as a main constituent the areas of application previously specified in building inspectorate approvals have been adopted in the standard.

4.3 Curing

Specifications for the construction of load-bearing structures made of concrete, reinforced concrete and prestressed concrete will in future be laid down in DIN 1045-3. The regulations will, for example, cover specifications for documentation of the construction, for scaffolding and formwork, reinforcement, prestressing, concreting, building with precast elements and for tolerances and monitoring.

Adequate curing is an essential measure for achieving the planned durability of a component by protecting the freshly placed concrete from drying out, freezing etc.

DIN 1045-3 will, among other things, replace the earlier DAfStB “Guidelines for curing of concrete” by a European regulation. The basic principle of the European draft is that curing must be at least long enough for the component to reach 50 % of its characteristic strength f_{ck} .

The concrete producer is required to provide information on the strength development of the particular concrete for planning and specifying the necessary length of curing on the building site.

The information is based on the ratio of the average 2 day to 28 day compressive strengths at 20 °C, and leads to classification into the ranges of rapid, average, slow and very slow strength development.

The minimum duration of curing which is specified in DIN 1045-3 is directed towards these ranges of strength development.

The minimum curing time is listed in Table 4 as a function of the strength development of the concrete and of the surface temperature.

The strength development and the requisite curing time derived from it therefore also become characteristics of the type designation of ready-mixed concretes.

In individual cases DIN 1045-3 also expressly permits accurate verification of the strength development.

As a rule this is applied if, due to the mode of construction or the construction completion cycle, it is necessary or logical to use values lower than those specified for the minimum curing time.

Table 4: Minimum curing time for concrete complying with DIN 1045-3 for all exposure classes with the exception of X0 and X1

Strength development of the concrete ¹⁾	<i>rapid</i>	<i>average</i>	<i>slow</i>	<i>very slow</i>
$r = f_{cm2} / f_{cm28}$ ²⁾	$r \geq 0,50$	$r \geq 0,30$	$r \geq 0,15$	$r \leq 0,15$
surface temperature ϑ in °C	minimum curing time in days ³⁾			
$\vartheta \geq 25$	1	2	2	3
$25 > \vartheta \geq 15$	1	2	4	5
$15 > \vartheta \geq 10$	2	4	7	10
$10 > \vartheta \geq 5$ ⁴⁾	3	6	10	15

5 Summary

- The new concrete standard DIN 1045 consists of four parts
 - **Design** (DIN 1045-1)
 - **Concrete** (DIN EN 206 + DIN 1045-2)
 - **Execution** (DIN 1045-3)
 - **Conformity** control of precast concrete elements (DIN 1045-4)
- To improve the durability the different parts of the standard contain references for bridging the interfaces between design, building materials and execution of the construction work.

The design relating to durability has been given the same status as the design relating to loadbearing capacity.

The strategy for durability-related design in the standard is a descriptive one.

The effects are defined by 7 exposure classes which are each sub-divided into up to 4 stages of intensity.

The effects on the concrete and on the reinforcing steel are evaluated separately.

The durability of the concrete is essentially described by the following criteria: **maximum water/cement ratio, minimum cement content and minimum compressive strength class.**

The new cement standard DIN EN 197 covers types of cement for which no practical experience exists in Germany as yet regarding their durability in concrete. It was therefore necessary to specify application rules for cements in DIN 1045-2.

Application restrictions for cements refer mainly to CEM V composite cements, CEM IV pozzolanic cements, CEM III-C blastfurnace cements and CEM II-M cements not previously covered by the standards.

These restrictions refer usually to structures exposed to freez-thaw or chloride.

A new curing regulation in DIN 1045-3 should ensure that the properties obtained through the concrete mix design are also achieved in the parts of the component close to the surface.