

6 CONCRETE WORKS. SPECIFICATIONS

6.1 Concrete classification

6.1.1 Concrete compressive strength class

Concrete type is defined by the characteristic compressive strength. This is based on cylinder strength samples testing rather than cube strength ones, specified according to BS 8500: Concrete - Complementary British Standard to BS 206-1.

Strength class	20/25	25/30	28/35 ^a	30/37	32/40 ^a	35/45	40/50	45/55	50/60
Cylinder strength (MPa)	20	25	28	30	32	35	40	45	50
Cube strength (MPa)	25	30	35	37	40	45	50	55	60
Modulus of elasticity (GPa)	30	31	32	33	34	34	35	36	37
Tensile strength (MPa)	2.2	2.6	2.8	2.9	3.0	3.2	3.5	3.8	4.1
a) Concrete class not cited in Table 3.1, Eurocode 2, Part 1-1									

Table 1. From table 3.1, Eurocode 2, Part 1-1. Strength class and selected concrete properties.

The classification system describes: Table 2

- Concrete type normal (C) or lightweight (LC). If reinforced, then it is RC.
- Minimum characteristic cylinder strength
- Minimum characteristic cube strength.

Using the example of compressive strength class C40/50:

C — normal weight concrete

40 — cylinder strength of 40N/mm² (or MPa)

50 — cube strength of 50N/mm² (or MPa)

A standard cylinder is 150mm diameter by 300mm high and a standard cube is 150mm size.

6.1.2 Exposure conditions

It is also very important to determine the exposure conditions. According to it, the design of concrete elements is going to be different.

Class designation	Class description	Informative examples applicable in the United Kingdom
No risk of corrosion or attack (X0 class)		
X0	For concrete without reinforcement or embedded metal: all exposures except where there is freeze-thaw, abrasion or chemical attack	Unreinforced concrete surfaces inside structures Unreinforced concrete completely buried in soil classed as AC-1 and with a hydraulic gradient not greater than 5 Unreinforced concrete permanently submerged in non-

	For concrete with reinforcement or embedded metal: very dry	aggressive water Unreinforced concrete surfaces in cyclic wet and dry conditions not subject to abrasion, freezing or chemical attack Reinforced concrete surfaces exposed to very dry conditions
Corrosion induced by carbonation (XC classes) ^{a)} (where concrete containing reinforcement or other embedded metal is exposed to air and moisture)		
XC1	Dry or permanently wet	Reinforced and prestressed concrete surfaces inside enclosed structures except areas of structures with high humidity Reinforced and prestressed concrete surfaces permanently submerged in non-aggressive water
XC2	Wet, rarely dry	Reinforced and prestressed concrete completely buried in soil classed as AC-1 and with a hydraulic gradient not greater than 5 ^{b)}
XC3 and XC4	Moderate humidity or cyclic wet and dry	External reinforced and prestressed concrete surfaces sheltered from, or exposed to, direct rain Reinforced and prestressed concrete surfaces subject to high humidity (e.g. poorly ventilated bathrooms, kitchens) Reinforced and prestressed concrete surfaces exposed to alternate wetting and drying Interior concrete surfaces of pedestrian subways not subject to de-icing salts, voided superstructures or cellular abutments Reinforced or prestressed concrete beneath waterproofing
Corrosion induced by chlorides other than from sea water (XD classes) ^{a)} (where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from sea water)		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides Reinforced and prestressed concrete wall and structure supports more than 10 m horizontally from a carriageway Bridge deck soffits more than 5 m vertically above the carriageway Parts of structures exposed to occasional or slight chloride conditions
XD2	Wet, rarely dry	Reinforced and prestressed concrete surfaces totally immersed in water containing chlorides ^{c)} Buried highway structures more than 1 m below adjacent carriageway
XD3	Cyclic wet and dry	Reinforced and prestressed concrete walls and structure supports within 10 m of a carriageway Bridge parapet edge beams Buried highway structures less than 1 m below carriageway level Reinforced pavements and car park slabs
Corrosion induced by chlorides from sea water (XS classes) ^{a), d)} (where concrete containing reinforcement or other embedded metal is subject to contact with chlorides from sea water or air carrying salt originating from sea water)		
XS1	Exposed to airborne salt but not in direct contact with sea water	External reinforced and prestressed concrete surfaces in coastal areas
XS2	Permanently submerged	Reinforced and prestressed concrete surfaces completely submerged and remaining saturated, e.g. concrete below mid-tide level ^{c)}
XS3	Tidal, splash and spray zones	Reinforced and prestressed concrete surfaces in the upper tidal zones and the splash and spray zones ^{e)}
Freeze-thaw attack (XF classes) (where concrete is exposed to significant attack from freeze-thaw cycles whilst wet)		
XF1	Moderate water saturation without de-icing agent	Vertical concrete surfaces such as façades and columns exposed to rain and freezing Non-vertical concrete surfaces not highly saturated, but exposed to freezing and to rain or water
XF2	Moderate water saturation with de-icing agent	Concrete surfaces such as parts of bridges, which would otherwise be classified as XF1, but which are exposed to de-icing salts either directly or as spray or run-off
XF3	High water saturation without de-icing agent	Horizontal concrete surfaces, such as parts of buildings, where water accumulates and which are exposed to

		freezing Concrete surfaces subjected to frequent splashing with water and exposed to freezing
XF4	High water saturation with de-icing agent or sea water F)	Horizontal concrete surfaces, such as roads and pavements, exposed to freezing and to de-icing salts either directly or as spray or run-off Concrete surfaces subjected to frequent splashing with water containing de-icing agents and exposed to freezing
Chemical attack (XA classes) (where concrete is exposed to chemical attack) Use Table A.2 to determine the ACEC-class. See BRE Special Digest 1 [1] for guidance on site investigation.		
a) The moisture condition relates to that in the concrete cover to reinforcement or other embedded metal but, in many cases, conditions in the concrete cover can be taken as being that of the surrounding environment. This might not be the case if there is a barrier between the concrete and its environment (see A.3). b) For concrete in soil classed as AC-2 or above or an element with a hydraulic gradient greater than 5, the ACEC class is used to determine the concrete quality and minimum cover to reinforcement (see A.4.4). c) Reinforced and prestressed concrete elements where one surface is immersed in water containing chlorides and another is exposed to air are potentially a more severe condition, especially where the dry side is at a high ambient temperature. Specialist advice should be sought where appropriate, to develop a specification that is appropriate to the actual conditions likely to be encountered. d) The rate of ingress of chloride into the concrete will depend on the concentration at its surface: brackish groundwater (chloride content less than 18 g/l) will be less severe than exposure to sea water. e) Exposure XS3 covers a range of conditions. The most extreme conditions are in the spray zone. The least extreme is in the tidal zone where conditions can be similar to those in XS2. The recommendations given in this annex take into account the most extreme conditions within this class. F) It is not normally necessary to classify in the XF4 exposure class those parts of structures located in the United Kingdom which are in frequent contact with the sea.		

6.2 Steel classification

6.2.1 Steel designation

Eurocode 2 can be used with reinforcement of characteristic strengths ranging from 400 to 600 MPa. The properties of steel reinforcement in the UK for use with Eurocode 2 are given in BS 4449: Specification for carbon steel bars for the reinforcement of concrete. They are summarized in the following table:

Class (BS 4449) and designation (BS 8666)	A	B	C
Characteristic yield strength f_{yk} or $f_{0.2k}$ (N/mm ²)	500	500	500
Minimum value of $k = (f_t/f_y)_k$	≥1.05	≥1.08	≥1.15<1.35
Characteristic strain at maximum force ϵ_{uk} (%)	≥2.5	≥5.0	≥7.5

Table 3. (Bond et al, 2006).

Characteristic yield strength of 500 N/mm² (or MPa) has been adopted by the UK reinforcement industry. There are three classes of reinforcement, A, B and C, which provide increasing ductility. The designer will specify which class is required.

The way to name steel is developed with a letter designating steel type, the diameter and the designation (A, B or C).

B – Reinforced steel

S – Stainless steel

X – Designed by specifier

For example: B500A (the first “B” means “reinforced steel”).

6.2.2 Rebar designation

Reinforced steel bars (or rebars) are differentiated by the nominal diameter, which defines the cross-section of the bar. The characteristics of concrete rebars are the following, according to EN 10080 (BS 8666):

Metric bar size	Mass per unit length (Kg/m)	Nominal diameter	Cross sectional area (mm ²)
6.0	0.222	6	28.3
8.0	0.395	8	50.3
10.0	0.617	10	78.5
12.0	0.888	12	113
16.0	1.579	16	201
20.0	2.467	20	314
25.0	3.855	25	491
32.0	4.830	32	804
40.0	9.868	40	1257
50.0	15.413	50	1963
Note: Sizes 14 and 28 are excluded as they are not normally used.			

Table 4. (Bond et al, 2006).

The specified rebar is named with “H” and the nominal diameter (i.e. H16). It can also be written with “Ø” (i.e. Ø16).

6.3 Reinforcing geometry

6.3.1 Minimum concrete cover

The nominal cover can be assessed as follows:

$$C_{\text{nom}} = C_{\text{min}} + \Delta C_{\text{dev}}$$

Where C_{min} should be set to satisfy the following requirements:

- Safe transmission of bond forces
- Durability
- Fire resistance

ΔC_{dev} is an allowance which should be made in the design for deviations from the minimum cover. It should be taken as 10 mm, unless fabrication is subjected to a quality assurance system, in which case it is permitted to reduce ΔC_{dev} to 5 mm.

a) Minimum cover for bond

The minimum cover to ensure adequate bond should not be less than the bar diameter, unless the aggregate size is over 32 mm.

b) Minimum cover for durability

It is based on the exposure conditions, and can be determined by either BS 8500 or the UK National Annex. There are some selected recommendations in the table leading the following page, which can help to determine this size, as well as other considerations about concrete strength, minimum cement ratio and maximum cement content (taken from Chapter 11, originally published as *How to use BS500 with BS 8110*).

c) Design for fire resistance

The nominal axis distance is the distance from the centre of the main reinforcing bar to the surface of the member. The designer should ensure that:

$$a \geq C_{\text{nom}} + \phi_{\text{link}} + \phi_{\text{bar}}/2$$

There are three standard fire exposure conditions that may be satisfied:

R. Mechanical resistance for load bearing

E. Integrity of separation

I. Insulation

Information about how to calculate it is given in Eurocode 2 and subsequent chapters. We are not going to consider it in this module.

Exposure conditions		Cement/ combination designations	Strength class, maximum w/c ratio, minimum cement or combination content (Kg/m³), and equivalent designated concrete (where applicable)							
Primary	Secondary		Nominal cover to reinforcement							
			15+ΔC _{dev}	20+ΔC _{dev}	25+ΔC _{dev}	30+ΔC _{dev}	35+ΔC _{dev}	40+ΔC _{dev}	45+ΔC _{dev}	50+ΔC _{dev}
XO	---	All	Recommended that this exposure is not applied to reinforced concrete							
XC1	---	All	RC20/25, 0.70, 240	<<<	<<<	<<<	<<<	<<<	<<<	<<<
XC2	AC-1	All			RC25/30, 0.60, 260	<<<	<<<	<<<	<<<	<<<
XC3 & XC4	---	All except IVB-V		RC40/50, 0.45, 340	RC30/37, 0.55, 300	RC28/35, 0.60, 280	RC25/30, 0.60, 260	<<<	<<<	<<<
	XF1	All except IVB-V		RC40/50, 0.45, 340	RC30/37, 0.55, 300	RC28/35, 0.60, 280	<<<	<<<	<<<	<<<
	XF3	All except IVB-V		RC40/50, 0.45, 340	<<<	<<<	<<<	<<<	<<<	<<<
XD1	---	All			C40/50, 0.45, 360	C32/40, 0.50, 320	C28/35, 0.60, 300	<<<	<<<	<<<
XD3	---	IIB-V, IIIA						C35/45, 0.40, 380	C32/40, 0.40, 360	C28/35, 0.50, 340
		CEM I, IIA, IIB-S, SRPC						See BS 8500	C40/50, 0.40, 380	C35/45, 0.45, 360

		IIIB, IVB-V						C32/40, 0.40, 380	C28/35, 0.45, 360	C25/30, 0.50, 340
	XF2	IIB-V, IIIA						C35/45, 0.40, 380	C32/40, 0.40, 360	C28/35, 0.50, 340
		CEM I, IIA, IIB-S, SRPC						See BS 8500	C40/50, 0.40, 380	C35/45, 0.45, 360
		IIIB, IVB-V						C32/40, 0.40, 380	C28/35, 0.45, 360	C25/30, 0.50, 340
	XF4	CEM I, IIA, IIB-S, SRPC						See BS 8500	C40/50, 0.40, 380	<<<
XS1	XF1	CEM I, IIA, IIB-S, SRPC				See BS 8500	C35/45, 0.45, 360	C32/40, 0.50, 340	<<<	<<<
		IIB-V, IIIA				See BS 8500	C32/40, 0.45, 360	C28/35, 0.50, 340	C28/35, 0.55, 320	<<<
		IIIB				C32/40, 0.40, 380	C25/30, 0.50, 340	C25/30, 0.50, 340	C25/30, 0.55, 320	<<<
	XF3 or XF4	CEM I, IIA, IIB-S, SRPC				See BS 8500	C40/50, 0.45, 360	<<<	<<<	<<<

Table 5. (Bond et al, 2006).

6.3.2 Rebar position

We must differentiate between longitudinal and transversal rebars.

Longitudinal

These rebars support the perpendicular efforts to every cross section of the element, and must occupy a specific position according to the element work (i.e., peripheral in columns; up or down side in beams).

Transversal

They contribute to the absorption of shear force and help the jail construction and reinforcing works. It is usually constituted by links.

6.3.3 Jail construction

The reinforcing construction gives a shape like a jail, which is much easier to build off site and transport. We need specific rebars to build this jail, in a way that it can be transported. Many times, this jail rebars are also considered as reinforcement in a way to reduce the steel section. Some conditions are given below.

6.3.4 Rebar spacing

It is necessary spacing between rebars so as to get a good cover and adherence between concrete and steel. The minimum spacing should be as follows:

Longitudinal bars: the maximum distance of the following:

- Maximum nominal diameter
- Maximum aggregate size plus 5 mm
- 20 mm

Minimum vertical distance between groups: the maximum distance of the following:

- Maximum nominal diameter
- 20 mm

Maximum distance between longitudinal bars without any link: 150 mm

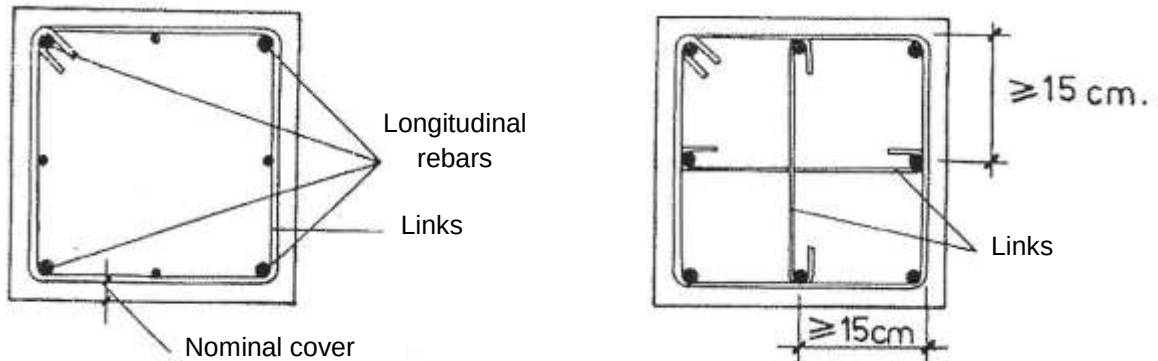
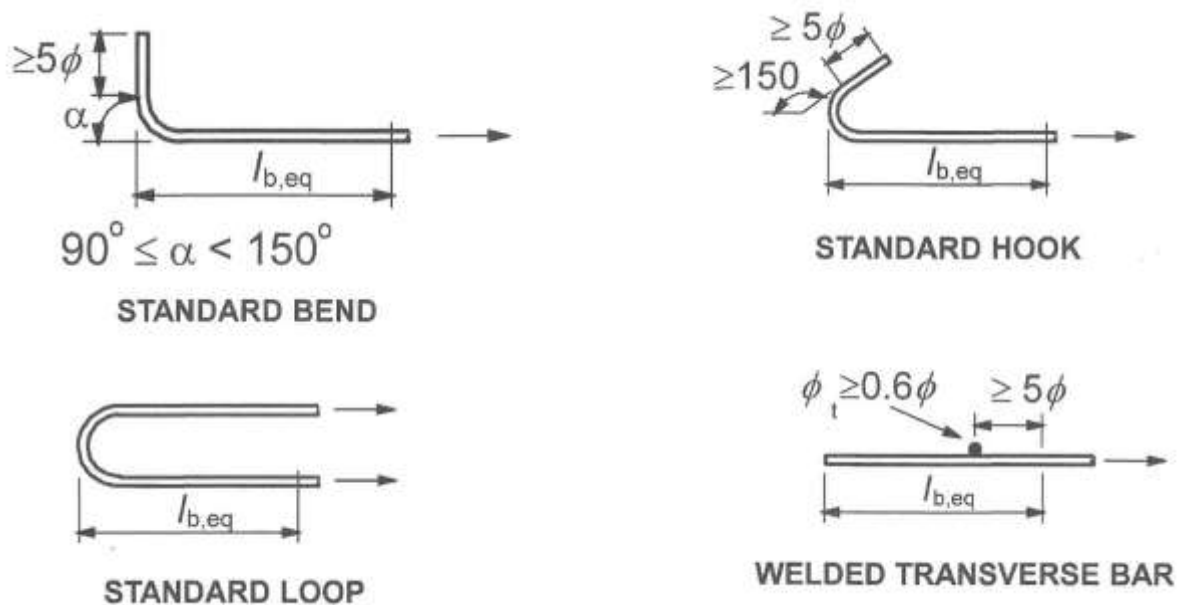


Figure 1. (Construction Technology notes, University of Alicante – Spain).

6.3.5 Rebar anchorage

The calculated reinforcement section gives a specific length for each rebar, but besides, we need additional length for anchorage. This anchorage can be straight, bended, hooked or looped. These lengths for longitudinal rebars are calculated by the structure designer. Transversal rebars have standard lengths.

We can also develop this anchorage by welding.



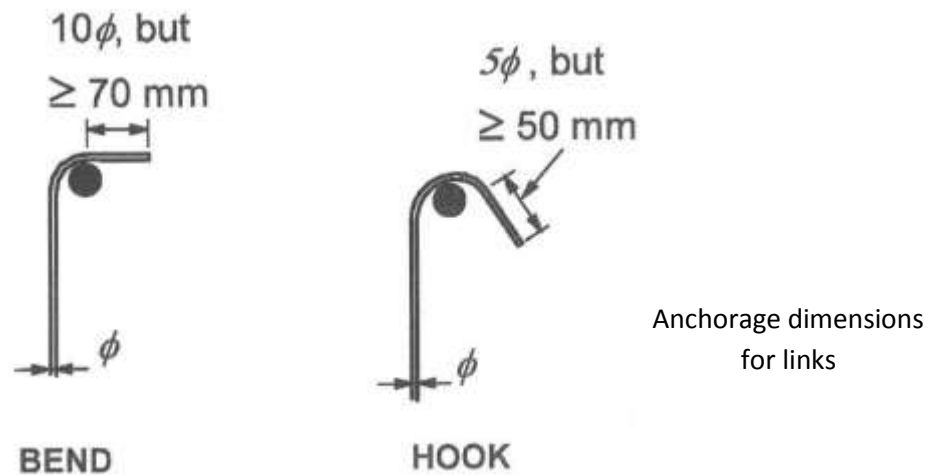


Figure 2. (BS EN 1992, Eurocode 2).

6.4 Reinforcing works

The steel reinforcement is usually built off site and transported. Once in its place, rebars must be clean, without any rust, paint, fat or another dangerous substance. It will be placed according to the project, held to one another and the framework to avoid any movement when concreting. The rebars can be tied or welded.

It is not allowed mixing different steel designations for the same purpose to avoid any confusion, although we can use one designation for longitudinal reinforcement and another designation for links.

Spacers will be used to guarantee the distance to frameworks for the nominal cover and to avoid any movement. They will be placed on the floor or tied to the steel jail.

6.5 Concrete works on site

See “Do’s and Don’t’s of Ready-Mixed Concrete”.

REFERENCES

Bond, A.J. et al (2006) *How to Design Concrete Structures Using Eurocode 2*. Surrey: The Concrete Centre.

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