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Introduction for Concrete (BS 8110 , Eurocode 2 & BRE Concrete Mix Design)

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Aim of Structural Design

i. Fitness for purpose

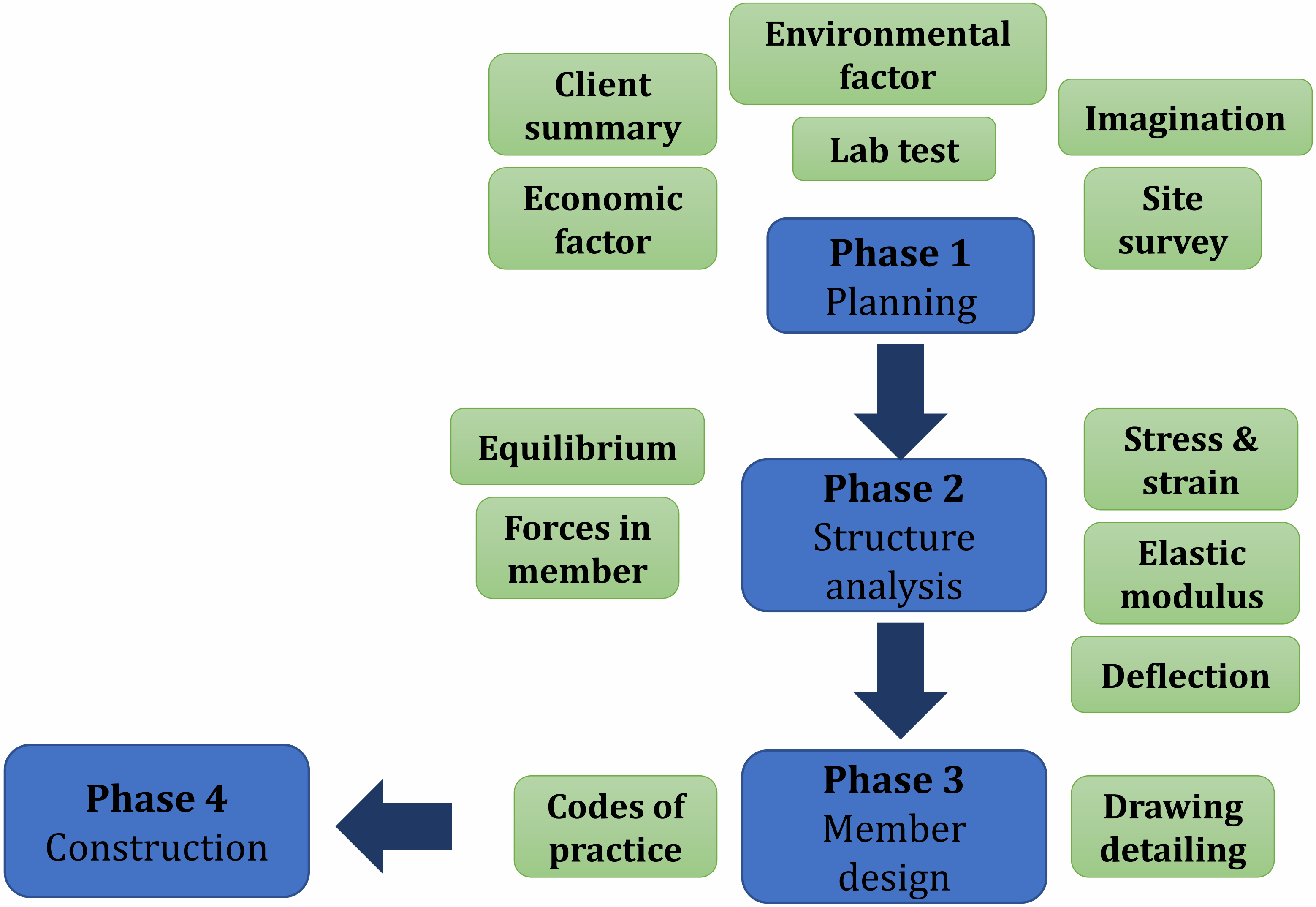
ii. Safety and reliability

iii. Economy

iv. Durability

v. Maintainability

Design Stages



What is Reinforced Concrete?

- **Reinforced concrete is concrete strengthened with steel bars or reinforcements**
- **Concrete is a mix of cement, sand, aggregate and water. High compression strength but lower in tension.**
- **Steel reinforcement has high tension strength**

THE EUROCODES

The Eurocode Family (58 all together)		
EN 1990	Eurocode	Basis of structural design
EN 1991	Eurocode 1	Actions on structures
EN 1992	Eurocode 2	Design of concrete structures
EN 1993	Eurocode 3	Design of steel structures
EN 1994	Eurocode 4	Design of composite steel and concrete structures
EN 1995	Eurocode 5	Design of timber structures
EN 1996	Eurocode 6	Design of masonry structures
EN 1997	Eurocode 7	Geotechnical design
EN 1998	Eurocode 8	Design of structures for earthquake resistance
EN 1999	Eurocode 9	Design of aluminium alloy structures

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Eurocode 2: BS EN 1992

EUROCODE 2 : DESIGN OF CONCRETE STRUCTURES	
EN 1992-1-1	General rules and rules for buildings
EN 1992-1-2	General rules – Structural fire design
EN 1992-2	Concrete bridges – design and detailing rules
EN 1992-3	Liquid retaining and containment structures

Eurocode vs British Standard

Eurocodes	Title	Superseded standards
EN 1991-2	Traffic loads on bridges	BD 37/88
EN 1991-3	Actions induced by crane and machinery	-
EN 1991-4	Silos and tanks	-
EN 1992-1-1	General rules for buildings	BS 8110: Parts 1, 2 and 3
EN 1992-1-2	Fire resistance of concrete structures	BS 8110: Part 1 Table 3.2 BS 8110: Part 2 Sect. 4
EN 1992-2	Bridges	BS 5400: Part 4
EN 1992-3	Liquid-retaining and containment structures	BS 8007

Different Terminology in EC2

Eurocode	British Standard
Action	Force or imposed displacement
Verification	Check
Resistance	Capacity
Execution	Construction
Permanent action	Dead load
Variable action	Live load or imposed load
Isostatic	Primary

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BRITISH STANDARD

BS EN 1992-1-1:20

Incorporating corrigendum January 2008

Eurocode 2: Design of concrete structures —

Part 1-1: General rules and rules for buildings

BRITISH STANDARD

BS 8110-1:1997

Incorporating Amendment No. 1

Structural use of concrete —

Part 1: Code of practice for design and construction

DESIGN LIFE

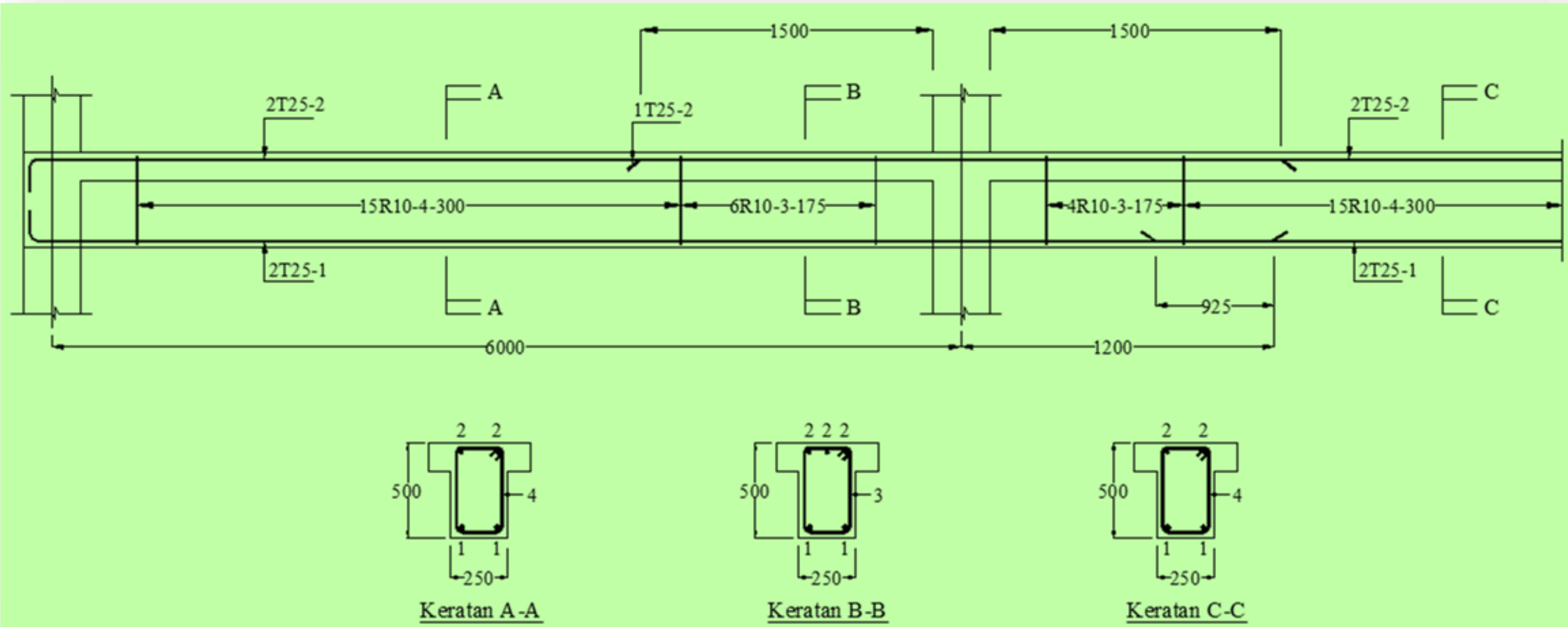
2.3 Design working life

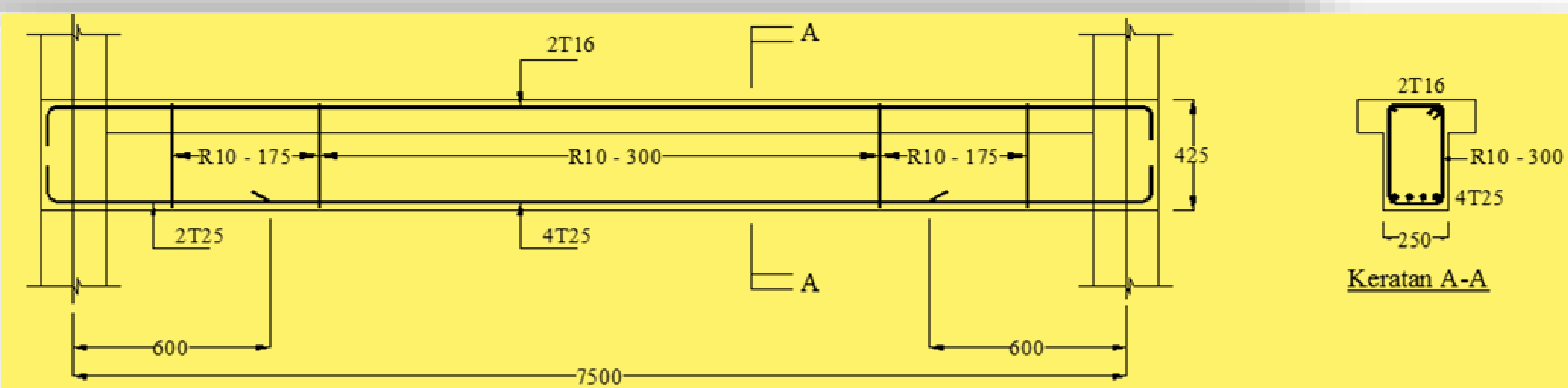
Table 2.1 - Indicative design working life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures

(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.

Detailing & Durability





Durability

- Detailing and durability requirements are to ensure that a structure has satisfactory durability and serviceability performance under normal environments throughout its lifetime.

- These requirements will involve aspects of design, such as concrete mix selection and determination of cover to reinforcing bars, as well as selection of suitable materials for the exposure conditions which are expected.

Cover Design- EC2

The nominal cover can be assessed as follows:

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

where C_{min} shall be provided in order to ensure:

- The safe transmission of bond forces
- The protection of steel against corrosion (durability)
- An adequate fire resistance

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

Concrete Spacer

Concrete Cover

4.4 Methods of verification

4.4.1 Concrete cover

4.4.1.1 General

(1)P The concrete cover is the distance between the surface of the reinforcement closest to the nearest concrete surface (including links and stirrups and surface reinforcement where relevant) and the nearest concrete surface.

(2)P The nominal cover shall be specified on the drawings. It is defined as a minimum cover, c_{min} (see 4.4.1.2), plus an allowance in design for deviation, Δc_{dev} (see 4.4.1.3):

$$c_{nom} = c_{min} + \Delta c_{dev} \qquad (4.1)$$

Concrete Cover

4.4.1.2 Minimum cover, c_{min}

(1)P Minimum concrete cover, c_{min}, shall be provided in order to ensure:
- the safe transmission of bond forces (see also Sections 7 and 8)
- the protection of the steel against corrosion (durability)
- an adequate fire resistance (see EN 1992-1-2)

- Bond
- Durability
- Fire Resistance

Concrete Cover (Bond)

Minimum cover for bond, $C_{min, b}$ (EN 1992-1-1)

Table 4.2: Minimum cover, $c_{min,b}$, requirements with regard to bond

Bond Requirement	
Arrangement of bars	Minimum cover $c_{min,b}$*
Separated	Diameter of bar
Bundled	Equivalent diameter (ϕ_n)(see 8.9.1)
*: If the nominal maximum aggregate size is greater than 32 mm, $c_{min,b}$ should be increased by 5 mm.	

Note: The values of $c_{min,b}$ for post-tensioned circular and rectangular ducts for bonded tendons, and pre-tensioned tendons for use in a Country may be found in its National Annex. The recommended values for post-tensioned ducts are:

circular ducts: diameter

rectangular ducts: greater of the smaller dimension or half the greater dimension

There is no requirement for more than 80 mm for either circular or rectangular ducts.

The recommended values for pre-tensioned tendon:

1,5 x diameter of strand or plain wire

2,5 x diameter of indented wire.

Concrete Cover

Minimum cover for bond, $C_{min,b}$ (EN 1992-1-1)

Arrangement of bars	Minimum cover $C_{min,b}$*
Separated	Diameter of bar
Bundle	Equivalent diameter $\phi_n = \phi \sqrt{n_b} \leq 55$ mm where n_b is the number of bars in the bundle, which is limited to $n_b \leq 4$ for vertical bars in compression $n_b \leq 3$ for all other cases
* If the nominal maximum aggregate size is > 32 mm, $c_{min,b}$ should be increased by 5 mm	

Concrete Cover (Durability)

Minimum cover for durability, $C_{min,\,dur}$ (EN 1992-1-1)

Table 4.4N: Values of minimum cover, $c_{min,dur}$, requirements with regard to durability for reinforcement steel in accordance with EN 10080.

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	Exposure Class according to Table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

Recommended structural class

Table 4.4N: Values of minimum cover, $c_{min,dur}$, requirements with regard to durability for reinforcement steel in accordance with EN 10080.

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	Exposure Class according to Table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

Table 4.5N: Values of minimum cover, $c_{min,dur}$, requirements with regard to durability for prestressing steel

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	Exposure Class according to Table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	15	20	25	30	35	40
S2	10	15	25	30	35	40	45
S3	10	20	30	35	40	45	50
S4	10	25	35	40	45	50	55
S5	15	30	40	45	50	55	60
S6	20	35	45	50	55	60	65

Concrete Cover

(5) The minimum cover values for reinforcement and prestressing tendons in normal weight concrete taking account of the exposure classes and the structural classes is given by $c_{min,dur}$.

Note: Structural classification and values of $c_{min,dur}$ for use in a Country may be found in its National Annex. The recommended Structural Class (design working life of 50 years) is S4 for the indicative concrete strengths given in Annex E and the recommended modifications to the structural class is given in Table 4.3N. The recommended minimum Structural Class is S1.

The recommended values of $c_{min,dur}$ are given in Table 4.4N (reinforcing steel) and Table 4.5N (prestressing steel).

Table 4.3N: Recommended structural classification

Structural Class							
Criterion	**Exposure Class according to Table 4.1**						
	X0	XC1	XC2 / XC3	XC4	XD1	XD2 / XS1	XD3 / XS2 / XS3
Design Working Life of 100 years	increase class by 2	increase class by 2	increase class by 2	increase class by 2	increase class by 2	increase class by 2	increase class by 2
Strength Class [1) 2)]	≥ C30/37 reduce class by 1	≥ C30/37 reduce class by 1	≥ C35/45 reduce class by 1	≥ C40/50 reduce class by 1	≥ C40/50 reduce class by 1	≥ C40/50 reduce class by 1	≥ C45/55 reduce class by 1
Member with slab geometry (position of reinforcement not affected by construction process)	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1
Special Quality Control of the concrete production ensured	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1

4.0 DURABILITY, FIRE AND BOND REQUIREMENTS
(Ref. Section 4: MS EN 1992-1-1: 2010)

Exposure Class

Table 4.1: Exposure class related to environmental conditions in accordance with EN 206-1
(Ref. MS EN 1992-1-1: 2010)

Class designation	Description of the environment	Informative examples where exposure classes may occur
1	**No risk of corrosion attack**	
XC0	For concrete without reinforcement or embedded metal: all exposure except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidity
2	**Corrosion induced by carbonation**	
XC1	Dry or permanently wet	Concrete inside building with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within the exposure class XC2
3	**Corrosion induced by chlorides**	
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools Concrete components exposed to industrial waters containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs
4	**Corrosion induced by chlorides from sea water**	
XS1	Exposed to airborne salt but not in direct contact to sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5	**Freeze/Thaw attack**	
XF1	Moderate water saturation, without de-icing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with de-icing agent	Vertical concrete surfaces of road structures exposed to freezing and air-borne de-icing agents
XF3	High water saturation, without de-icing agents	Horizontal concrete surfaces exposed to rain and freezing
XF4	High water saturation, with de-icing agents or sea water	Road and bridge decks exposed to de-icing agents Concrete surfaces exposed to direct spray containing de-icing agents and freezing Splash zone of marine structures exposed to freezing
6	**Chemical attack**	
XA1	Slightly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA2	Moderately aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA3	Highly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water

Concrete Cover

- Bond
- Durability
- Fire Resistance
-

Class Exposure-Marine Structure

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Class Exposure- Marine Structure

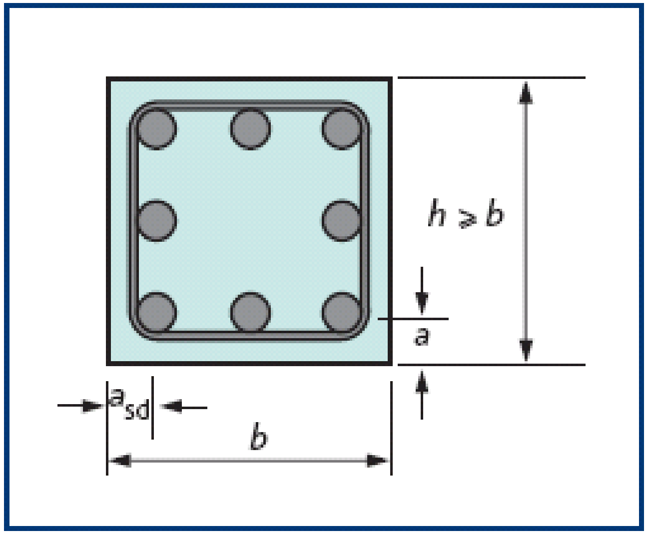
4	**Corrosion induced by chlorides from sea water**	
XS1	Exposed to airborne salt but not in direct contact to sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures

Concrete Cover (Fire Resist.)

Minimum cover for fire resistance, $C_{min, fire}$

Rather than giving a minimum cover, the tubular method based on nominal axis distance is used. This is the distance from the centre of the main reinforcement bar to the top or bottom surface of the member.

Section through structural member, showing nominal axis distances a and a_{sd}



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

$$a_{sd} = a + 10 \text{ mm}$$

From Table 5.5 and 5.6 BS EN 1992-1-2: 2004

Concrete Cover

Table 5.5: Minimum dimensions and axis distances for simply supported beams made with reinforced a[nd] prestressed concrete

Standard Fire Resistance		Minimum Dimensions (mm)						
		Possible combinations of a and b_{min} where a is the average axis distance and b_{min} in the width of beam (mm)				Web thickness, b_w (mm)		
						Class WA	Class WB	Class WC
1		2	3	4	5	6	7	8
R 30	b_{min} =	80	120	160	200	80	80	80
	a =	25	20	15*	15*			
R 60	b_{min} =	120	160	200	300	100	80	100
	a =	40	35	30	25			
R 90	b_{min} =	150	200	300	400	110	100	100
	a =	55	45	40	35			
R 120	b_{min} =	200	240	300	500	130	120	120
	a =	65	60	55	50			
R 180	b_{min} =	240	300	400	600	150	150	140
	a =	80	70	65	60			
R 240	b_{min} =	280	350	500	700	170	170	160
	a =	90	80	75	70			
$a_{sd} = a + 10$ mm (see note below)								

For prestressed beams the increase of axis distance according to 5.2(5) should be noted.

a_{sd} is the distance to the side of beam for the corner bars (or tendon or wire) of beams with only one layer of reinforcement. For values of b_{min} greater than that given in Column 4 no increase of a_{sd} is required

* Normally the cover required by EN 1992-1-1 will control

Table 5.6: Minimum dimensions and axis distances for continuous beams made with reinforced and prestressed concrete

Standard Fire Resistance		Minimum Dimensions (mm)						
		Possible combinations of a and b_{min} where a is the average axis distance and b_{min} in the width of beam (mm)				Web thickness, b_w (mm)		
						Class WA	Class WB	Class WC
1		2	3	4	5	6	7	8
R 30	b_{min} = a =	80 15*	160 12*			80	80	80
R 60	b_{min} = a =	120 25	200 12*			100	80	100
R 90	b_{min} = a =	150 35	250 25			110	100	100
R 120	b_{min} = a =	200 45	300 35	450 35	500 30	130	120	120
R 180	b_{min} = a =	240 60	400 50	550 50	600 40	150	150	140
R 240	b_{min} = a =	280 75	500 60	650 60	700 50	170	170	160
$a_{sd} = a + 10$ mm (see note below)								

For prestressed beams the increase of axis distance according to 5.2(5) should be noted.

a_{sd} is the distance to the side of beam for the corner bars (or tendon or wire) of beams with only one layer of reinforcement. For values of b_{min} greater than that given in Column 3 no increase of a_{sd} is required

* Normally the cover required by EN 1992-1-1 will control

Table 5.8: Minimum dimensions and axis distances for simply supported one-way and two-way solid slabs

Standard Fire Resistance	Minimum Dimensions (mm)			
	Slab thickness, h_s (mm)	One-way spanning	Two-way spanning	
			$\frac{l_y}{l_x} \leq 1.5$	$1.5 < \frac{l_y}{l_x} \leq 2.0$
1	2	3	4	5
REI 30	60	10*	10*	10*
REI 60	80	20	10*	15*
REI 90	100	30	15*	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

l_x and l_y are shorter and longer span of the two-way slab

- For prestressed slabs the increase of axis distance according to 5.2(5) should be noted
- The axis distance *a* in Column 4 and 5 for two-way slabs relate to slabs supported at all four edges. Otherwise, they should be treated as one-way spanning slab.

* Normally the cover required by EN 1992-1-1 will control

Example Cover Design- EC2

- Min cover regard to Bond, $C_{min,bond}$ **=20 mm**
- Min cover regard to Durability, $C_{min, Dur}$ = **45 mm**

- Min cover regard to Fire Resist, $C_{min, Fire}$

a_{sd}= 30 +10 = 40 mm

Cmin= a_{sd}-$Ø_{link}$-$Ø_{bar/2}$

= 40-6-(20/2)

=24 mm

- ∴ Nominal Cover , ***Cnom*= *C_{min}* + Δ*C_{dev}***
- **Cnom = 45 + 10**

= 55 mm

Cover Design- BS8110

Table 3.2 — Classification of exposure conditions

Environment	Exposure conditions
Mild	Concrete surfaces protected against weather or aggressive conditions
Moderate	Exposed concrete surfaces but sheltered from severe rain or freezing whilst wet Concrete surfaces continuously under non-aggressive water Concrete in contact with non-aggressive soil (see sulfate class 1 of Table 7a in BS 5328-1:1997) Concrete subject to condensation
Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing or severe condensation
Very severe	Concrete surfaces occasionally exposed to sea water spray or de-icing salts (directly or indirectly) Concrete surfaces exposed to corrosive fumes or severe freezing conditions whilst wet
Most severe	Concrete surfaces frequently exposed to sea water spray or de-icing salts (directly or indirectly) Concrete in sea water tidal zone down to 1 m below lowest low water
Abrasive[a]	Concrete surfaces exposed to abrasive action, e.g. machinery, metal tyred vehicles or water carrying solids

NOTE 1 For aggressive soil and water conditions see **5.3.4** of BS 5328-1:1997.
NOTE 2 For marine conditions see also BS 6349.

[a] For flooring see BS 8204.

Concrete Cover (Durability)

Table 3.3 — Nominal cover to all reinforcement (including links) to meet durability requirements (see NOTE 1)

Conditions of exposure (see **3.3.4**)	**Nominal cover** Dimensions in millimetres				
Mild	25	20	20[a]	20[a]	20[a]
Moderate	—	35	30	25	20
Severe	—	—	40	30	25
Very severe	—	—	50[b]	40[b]	30
Most severe	—	—	—	—	50
Abrasive	—	—	—	See NOTE 3	See NOTE 3
Maximum free water/cement ratio	0.65	0.60	0.55	0.50	0.45
Minimum cement content (kg/m^3)	275	300	325	350	400
Lowest grade of concrete	C30	C35	C40	C45	C50

NOTE 1 This table relates to normal-weight aggregate of 20 mm nominal size. Adjustments to minimum cement contents for aggregates other than 20 mm nominal maximum size are detailed in Table 8 of BS 5328-1:1997.

NOTE 2 Use of sulfate resisting cement conforming to BS 4027. These cements have lower resistance to chloride ion migration. If they are used in reinforced concrete in very severe or most severe exposure conditions, the covers in Table 3.3 should be increased by 10 mm.

NOTE 3 Cover should be not less than the nominal value corresponding to the relevant environmental category plus any allowance for loss of cover due to abrasion.

[a] These covers may be reduced to 15 mm provided that the nominal maximum size of aggregate does not exceed 15 mm.

[b] Where concrete is subject to freezing whilst wet, air-entrainment should be used (see **5.3.3** of BS 5328-1:1997) and the strength grade may be reduced by 5.

Concrete Cover (Fire Resist.)

Table 3.4 — Nominal cover to all reinforcement (including links) to meet specified periods of fire resistance (see NOTES 1 and 2)

Fire resistance *h*	Nominal cover						
	Beams[a]		Floors		Ribs		Columns[a] mm
	Simply supported mm	Continuous mm	Simply supported mm	Continuous mm	Simply supported mm	Continuous mm	
0.5	20[b]	20[b]	20[b]	20[b]	20[b]	20[b]	20[b]
1	20[b]	20[b]	20	20	20	20[b]	20[b]
1.5	20	20[b]	25	20	35	20	20
2	40	30	35	25	45	35	25
3	60	40	45	35	55	45	25
4	70	50	55	45	65	55	25

NOTE 1 The nominal covers given relate specifically to the minimum member dimensions given in Figure 3.2. Guidance on increased covers necessary if smaller members are used is given in section 4 of BS 8110-2:1985.

NOTE 2 Cases that lie below the bold line require attention to the additional measures necessary to reduce the risks of spalling (see section 4 of BS 8110-2:1985).

[a] For the purposes of assessing a nominal cover for beams and columns, the cover to main bars which would have been obtained from Tables 4.2 and 4.3 of BS 8110-2:1985 has been reduced by a notional allowance for stirrups of 10 mm to cover the range 8 mm to 12 mm (see also **3.3.6**).

[b] These covers may be reduced to 15 mm provided that the nominal maximum size of aggregate does not exceed 15 mm (see **3.3.1.3**).

Example Cover Design- BS8110

- Min cover regard to Durability, $C_{min,\ dur}$ = **40 mm**
- Min cover regard to Fire Resist, $C_{min,\ Fire}$= **20 mm**

- ∴ Nominal Cover , ***C*nom= 40**

Material selection

Denseness

Strength

Durability

Concrete Mix Design - BRE

Designing a concrete mix consists of selecting the correct proportions of **cement, fine and coarse aggregate and water** to produce concrete having the specified properties. **Sometimes additional ingredients** such as ground granulated blastfurnace slag (ggbs), pulverised-fuel ash (pfa), **or admixtures**, are used. There are many properties of concrete that can be specified, eg workability, strength, density, thermal characteristics, elastic modulus and durability requirements. The properties most usually specified are:

- The workability of the fresh concrete
- The compressive strength at a specified age
- The durability, by means of specifying the minimum cement content and/or the maximum free-water/
- cement ratio and, in some cases, requiring the use of selected types of materials

Table 1 Concrete mix design form

Job title ....

Stage	Item	Reference or calculation	Values
1	1.1 Characteristic strength	Specified	.... N/mm^2 at .... days; Proportion defective .... %
	1.2 Standard deviation	Fig 3	.... N/mm^2 or no data .... N/mm^2
	1.3 Margin	C1 or Specified	(k = ...) .... × .... = ... N/mm^2; .... N/mm^2
	1.4 Target mean strength	C2	.... + ... = ... N/mm^2
	1.5 Cement strength class	Specified	42.5/52.5
	1.6 Aggregate type: coarse; Aggregate type: fine		Crushed/uncrushed; Crushed/uncrushed
	1.7 Free-water/cement ratio	Table 2, Fig 4	.... } Use the lower value [ ]
	1.8 *Maximum free-water/cement ratio*	*Specified*	....
2	2.1 Slump or Vebe time	Specified	Slump .... mm or Vebe time .... s
	2.2 Maximum aggregate size	Specified	.... mm
	2.3 Free-water content	Table 3	.... [ ] kg/m^3
3	3.1 Cement content	C3	.... ÷ .... = ... kg/m^3
	3.2 *Maximum cement content*	*Specified*	.... kg/m^3
	3.3 *Minimum cement content*	*Specified*	.... kg/m^3
			use 3.1 if ≤ 3.2; use 3.3 if > 3.1 [ ] kg/m^3
	3.4 Modified free-water/cement ratio		.... [ ]
4	4.1 Relative density of aggregate (SSD)		.... known/assumed
	4.2 Concrete density	Fig 5	.... kg/m^3
	4.3 Total aggregate content	C4	.... − .... − .... = ... kg/m^3
5	5.1 Grading of fine aggregate	Percentage passing 600 μm sieve	.... %
	5.2 Proportion of fine aggregate	Fig 6	.... %
	5.3 Fine aggregate content	C5	.... × .... = [ ] kg/m^3
	5.4 Coarse aggregate content	C5	.... − .... = [ ] kg/m^3

Quantities	Cement (kg)	Water (kg or litres)	Fine aggregate (kg)	Coarse aggregate (kg) 10 mm	20 mm	40 mm
per m^3 (to nearest 5 kg)	....	....	....	....	....	....
per trial mix of .... m^3	....	....	....	....	....	....

Items in italics are optional limiting values that may be specified (see Section 7).
Concrete strength is expressed in the units N/mm^2. 1 N/mm^2 = 1 MN/m^2 = 1 MPa. (N = newton; Pa = pascal.)
The internationally known term 'relative density' used here is synonymous with 'specific gravity' and is the ratio of the mass of a given volume of substance to the mass of an equal volume of water.
SSD = based on the saturated surface-dry condition.

5 Stages of Design

1. Strength → w/c
2. Workability → Free water content
3. Cement content
4. Total aggregate content
5. Fine & coarse Aggregates

Trial Mix

Stage	Item		Reference or calculation	Values
1	1.1	Characteristic strength	Specified	30 N/mm² at 28 days Proportion defective 2.5 %
	1.2	Standard deviation	Fig 3	N/mm² or no data 8 N/mm²
	1.3	Margin	C1 or Specified	(k = 1.96) 1.96 × 8 = 16 N/mm² N/mm²
	1.4	Target mean strength	C2	30 + 16 = 46 N/mm²
	1.5	Cement strength class	Specified	42.5/~~52.5~~ **+ Fly Ash**
	1.6	Aggregate type: coarse Aggregate type: fine		~~Crushed~~/uncrushed ~~Crushed~~/uncrushed
	1.7	Free-water/cement ratio	Table 2, Fig 4	0.47 } Use the lower value **0.47**
	1.8	*Maximum free-water/ cement ratio*	Specified	0.55 }
2	2.1	Slump or Vebe time	Specified	Slump 10 – 30 mm or Vebe time s
	2.2	Maximum aggregate size	Specified	20 mm
	2.3	Free-water content	Table 3	**160** kg/m³
3	3.1	Cement content	C3	160 ÷ 0.47 = 340 kg/m³
	3.2	*Maximum cement content*	Specified	kg/m³
	3.3	*Minimum cement content*	Specified	290 kg/m³
				use 3.1 if ≤ 3.2 use 3.3 if > 3.1 **340** kg/m³
	3.4	Modified free-water/cement ratio		

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4	4.1 Relative density of aggregate (SSD)		2·6	~~known~~/assumed
	4.2 Concrete density	Fig 5		2400 kg/m³
	4.3 Total aggregate content	C4	2400 - 340 - 160	= 1900 kg/m³
5	5.1 Grading of fine aggregate	Percentage passing 600 μm sieve	70	%
	5.2 Proportion of fine aggregate	Fig 6	25 to 30, say 27	%
	5.3 Fine aggregate content	C5	1900 × 0·27	= 515 kg/m³
	5.4 Coarse aggregate content	C5	1900 - 515	= 1385 kg/m³

Quantities	Cement (kg)	Water (kg or litres)	Fine aggregate (kg)	Coarse aggregate (kg) 10 mm	20 mm	40 mm
per m³ (to nearest 5 kg)	340	160	515	460	925	/
per trial mix of 0·05 m³	17·0	18·0	25·7	23	46·2	/

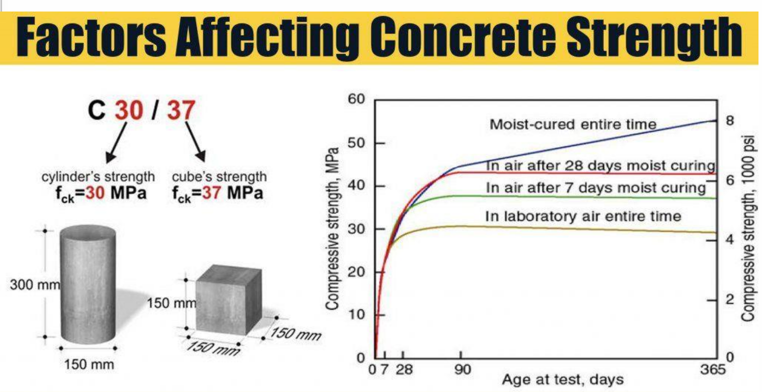
Items in italics are optional limiting values that may be specified (see Section 7).
Concrete strength is expressed in the units N/mm². 1 N/mm² = 1 MN/m² = 1 MPa. (N = newton; Pa = pascal.)
The internationally known term 'relative density' used here is synonymous with 'specific gravity' and is the ratio of the mass of a given volume of substance to the mass of an equal volume of water.
SSD = based on the saturated surface-dry condition.

What to consider?

What to consider?

Workability

Concrete



Strength

Durability

Type of Cement and Replacement of Cement

3.2 Type and strength class of cement

Different types and strength classes of cement produce concretes having different rates of strength development. In class 52.5 Portland cements the chemical reaction initially proceeds at a faster rate than in class 42.5 Portland cements; the effect of this on typical concretes having a free-water/cement ratio of 0.5 is shown in Table 2. If there is more appropriate information available related to local materials, this can be used instead of the values given in Table 2. A class 42.5 sulfate-resisting Portland cement is assumed to have the same rate of strength development as a class 42.5 Portland cement.

- Which cement to use?
- 42.5 or 52.5?

Sulphate Resistance Cement:

OPC+ Fly Ash

OPC+ GGBS

OPC+ PFA

Secondary reaction in case of blended cement:

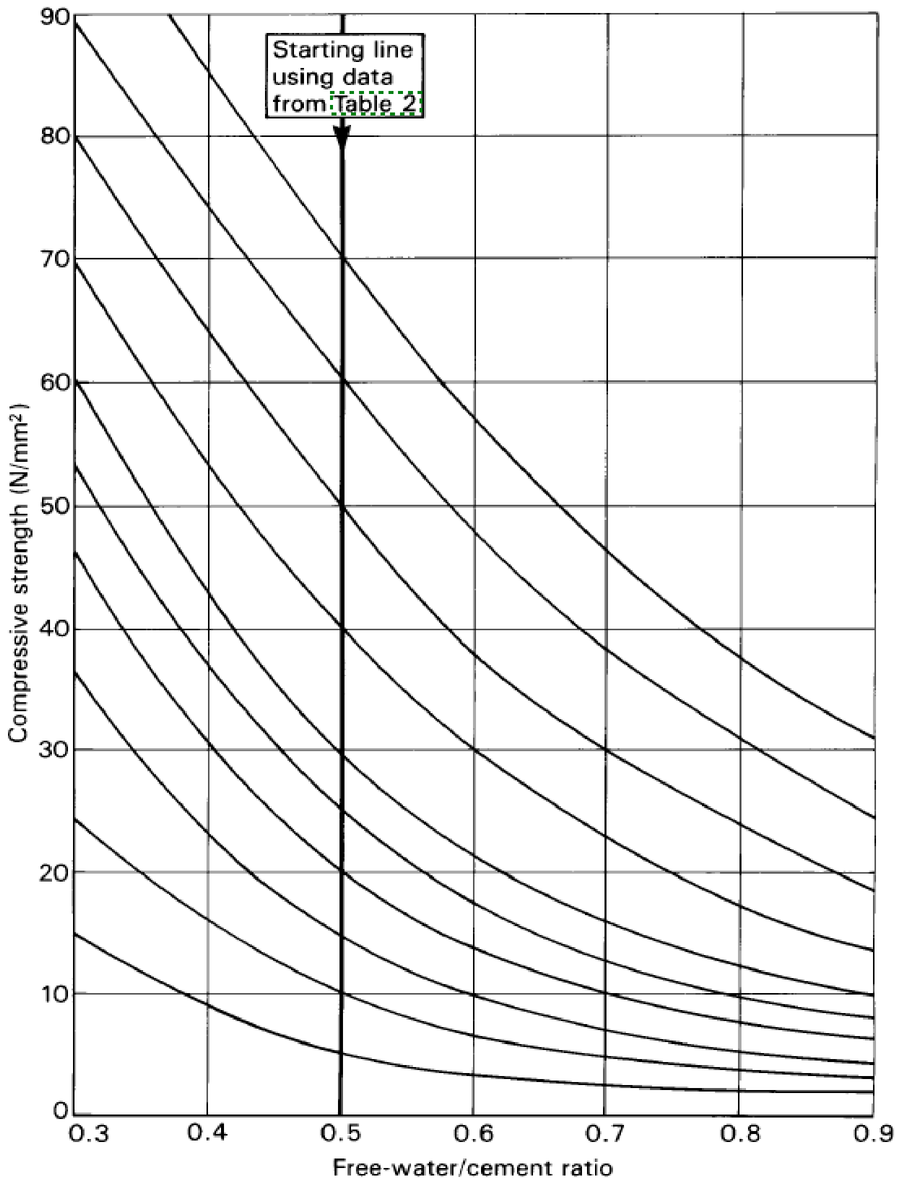
1. Portland Pozzolana cement (PPC)

OPC+Water → C-S-H gel + $Ca(OH)_2$ (Primary gel)

$Ca(OH)_2$ + SiO_2 (Fly ash) → C-S-H gel (Secondary gel)

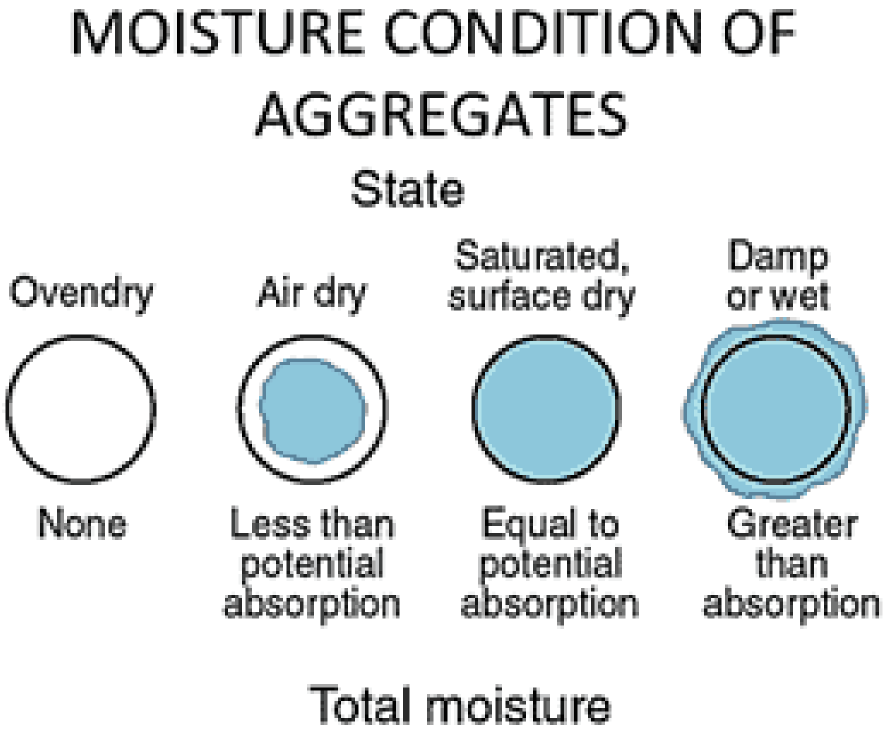
What happen if cement is solely OPC?

Water to Cement Ratio (w/c)



What happen if add more water in concrete mix?

Moisture Condition of Aggregate



Design based SSD condition

Concrete Mix Design - BRE

Table 1 Concrete mix design form

Job title ....

Stage	Item		Reference or calculation	Values
1	1.1	Characteristic strength	Specified	.... N/mm^2 at .... days; Proportion defective .... %
	1.2	Standard deviation	Fig 3	.... N/mm^2 or no data .... N/mm^2
	1.3	Margin	C1 or Specified	(k = ...) .... × .... = ... N/mm^2; .... N/mm^2
	1.4	Target mean strength	C2	.... + ... = ... N/mm^2
	1.5	Cement strength class	Specified	42.5/52.5
	1.6	Aggregate type: coarse Aggregate type: fine		Crushed/uncrushed Crushed/uncrushed
	1.7	Free-water/cement ratio	Table 2, Fig 4	.... } Use the lower value [ ]
	1.8	*Maximum free-water/ cement ratio*	*Specified*	....
2	2.1	Slump or Vebe time	Specified	Slump .... mm or Vebe time .... s
	2.2	Maximum aggregate size	Specified	.... mm
	2.3	Free-water content	Table 3	.... [kg/m^3]
3	3.1	Cement content	C3	.... ÷ .... = ... kg/m^3
	3.2	*Maximum cement content*	*Specified*	.... kg/m^3
	3.3	*Minimum cement content*	*Specified*	.... kg/m^3
				use 3.1 if ≤ 3.2 use 3.3 if > 3.1 [kg/m^3]
	3.4	Modified free-water/cement ratio		.... [ ]
4	4.1	Relative density of aggregate (SSD)		.... known/assumed
	4.2	Concrete density	Fig 5	.... kg/m^3
	4.3	Total aggregate content	C4	.... − .... − .... = ... kg/m^3
5	5.1	Grading of fine aggregate	Percentage passing 600 μm sieve	.... %
	5.2	Proportion of fine aggregate	Fig 6	.... %
	5.3	Fine aggregate content	C5	.... × .... = [kg/m^3]
	5.4	Coarse aggregate content	C5	.... − .... = [kg/m^3]

Quantities	Cement (kg)	Water (kg or litres)	Fine aggregate (kg)	Coarse aggregate (kg) 10 mm	20 mm	40 mm
per m^3 (to nearest 5 kg)	....	....	....	....	....	....
per trial mix of .... m^3	....	....	....	....	....	....

Items in italics are optional limiting values that may be specified (see Section 7).
Concrete strength is expressed in the units N/mm^2. 1 N/mm^2 = 1 MN/m^2 = 1 MPa. (N = newton; Pa = pascal.)
The internationally known term 'relative density' used here is synonymous with 'specific gravity' and is the ratio of the mass of a given volume of substance to the mass of an equal volume of water.
SSD = based on the saturated surface-dry condition.

Good understanding could design durable concrete within 15 minutes

Factor Affecting Durability of Concrete

- Cover Design
- Concrete Mix Design
- Correct Selection of Materials
- Compaction
- Curing Process
- Quality of workmanship

Thank you