

# CIVIL ENGINEERING TECHNOLOGY 3

## CONCRETE TECHNOLOGY Specifications and Design

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## MAIN COMPONENTS OF CONCRETE



**CEMENT**



**WATER**



**AGGREGATES**

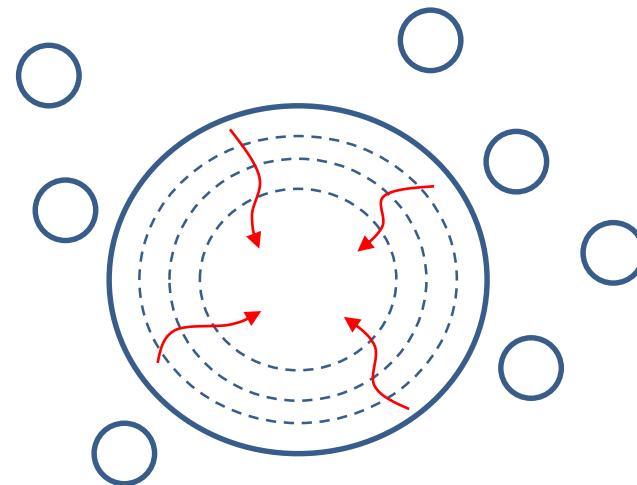
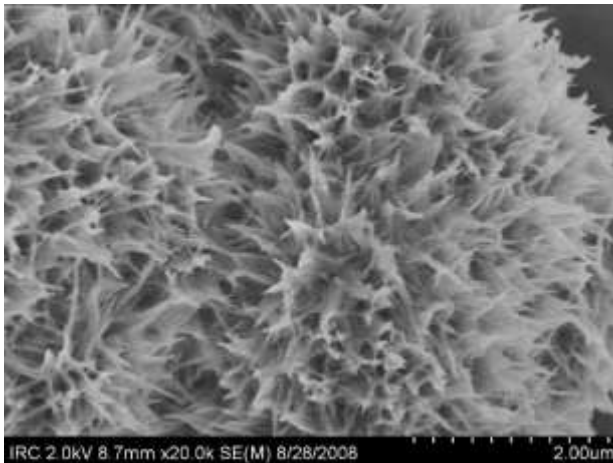


# MAIN COMPONENTS OF CONCRETE

## CEMENT

Finest part of the concrete mixture

- Work as a binder
- Strength increases as long as grains are hydrated



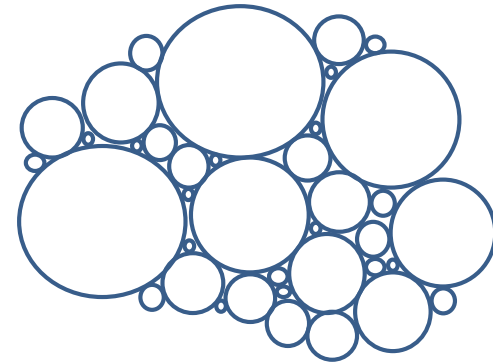


# MAIN COMPONENTS OF CONCRETE

## AGGREGATES

Material that covers the largest proportion of concrete

- Confers mechanical strength (compression and tensile)
- Composed by sand and gravel
- Gradation is very important to get good compaction and density





# MAIN COMPONENTS OF CONCRETE

## WATER

It hydrates cement to achieve adherence and strenght  
Allows the mixtute achieve workability

- Water/cement ratio
  - Proportion needed for hydration: 0.12
  - Usual w/c ratio: 0.40 – 0.60
- Porosity
- Curing



# COMPONENTS

**Cement**

**Water**

**Aggregates**

Coarse aggregates, sand

**Additions**

Pozzolans, natural or artificial such as Fly ash (FA, PFA), Ground granulated Blast Furnace Slag (GGBS), metakaolin, etc.

**Admixtures**

Set-retarding, air-entrainment, water-reducing, accelerating, shrinkage reducing, super-plastifiers, corrosion-inhibiting,



# CONCRETE SPECIFICATIONS

## Concrete Class. Designated concrete

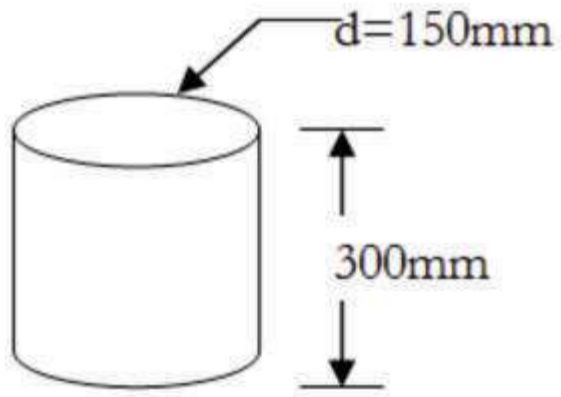
|     |                     |
|-----|---------------------|
| GEN | General             |
| RC  | Reinforced concrete |
| FND | Foundation          |
| PAV | Pavement            |

For structural concrete – RC  $f_{ck}$

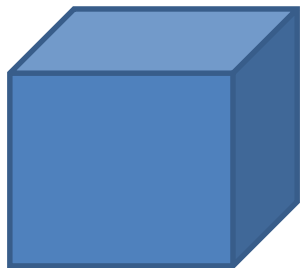
| Strength class          | 20/25 | 25/30 | 28/35 <sup>a</sup> | 30/37 | 32/40 | 35/45 | 40/50 | 45/55 | 50/60 |
|-------------------------|-------|-------|--------------------|-------|-------|-------|-------|-------|-------|
| Cylinder strength (MPa) | 20    | 25    | 28                 | 30    | 32    | 35    | 40    | 45    | 50    |
| Cube strength (MPa)     | 25    | 30    | 35                 | 37    | 40    | 45    | 50    | 55    | 60    |



# CONCRETE SPECIFICATIONS



**Standard Specimen**



$a=150\text{mm}$





## CONCRETE SPECIFICATIONS

**$F_{c_R}$  Real strength**

Reality

**$F_{c_k}$  Characteristic strength**

95% of test results over it

**$F_{c_d}$  Design strength**

$F_{c_k} / \text{safety factor}$



# CONCRETE SPECIFICATIONS

## Exposure conditions

| Class designation                             | Class description                       |
|-----------------------------------------------|-----------------------------------------|
| No risk of corrosion or attack (X0 class)     |                                         |
| X0                                            | Concrete without reinforcement          |
| Corrosion induced by carbonation (XC classes) |                                         |
| XC1                                           | Dry or permanently wet                  |
| XC2                                           | Wet, rarely dry                         |
| XC3 and XC4                                   | Moderate humidity or cyclic wet and dry |
|                                               |                                         |
| XD1                                           | Moderate humidity                       |
| XD2                                           | Wet, rarely dry                         |
| XD3                                           | Cyclic wet and dry                      |



# CONCRETE SPECIFICATIONS

## Exposure conditions

| Class designation                                                 | Class description                                                 |
|-------------------------------------------------------------------|-------------------------------------------------------------------|
| <b>Corrosion induced by chlorides from sea water (XS classes)</b> |                                                                   |
| <b>XS1</b>                                                        | Exposed to airborne salt but not in direct contact with sea water |
| <b>XS2</b>                                                        | Permanently submerged                                             |
| <b>XS3</b>                                                        | Tidal, splash and spray zones                                     |
| <b>Freeze-thaw attack (XF classes)</b>                            |                                                                   |
| <b>XF1</b>                                                        | Moderate water saturation without de-icing agent                  |
| <b>XF2</b>                                                        | Moderate water saturation with de-icing agent                     |
| <b>XF3</b>                                                        | High water saturation without de-icing agent                      |
| <b>XF4</b>                                                        | High water saturation with de-icing agent or sea water F)         |
|                                                                   |                                                                   |



# CONCRETE SPECIFICATIONS

## Consistence (workability)

We measure the flow of the fresh concrete mass with the slump

### Concrete slump test





## CONCRETE SPECIFICATIONS

### Consistence (workability)

| Slump class | Target slump mm |
|-------------|-----------------|
| S1          | 20              |
| S2          | 70              |
| S3          | 120             |
| S4          | 170             |
| S5          | 220 plus        |

A good compaction is achieved with hand tamping in S3

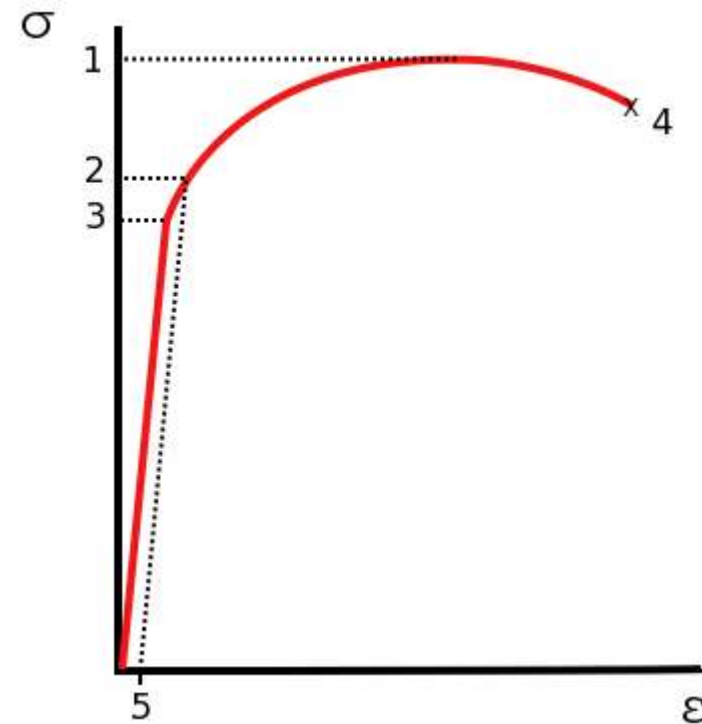
We can use S2 for steep slopes, but must ensure a good compaction with vibration



# STEEL SPECIFICATIONS

Yield Strength

Ultimate Estate Strength



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



## STEEL SPECIFICATIONS



**B – Reinforced steel**

**S – Stainless steel**

**X – Designed by specifier**



**B 500 A**



# STEEL SPECIFICATIONS

## Rebar designation

| Metric bar size | Mass per unit length (Kg/m) | Nominal diameter | Cross sectional area (mm <sup>2</sup> ) |
|-----------------|-----------------------------|------------------|-----------------------------------------|
| 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.**



# GEOMETRY

## Nominal concrete cover



"Qew bruecke nf beton kaputt 33 von 46" by Achim Hering - Own work. Licensed under CC BY 3.0 via Commons - [https://commons.wikimedia.org/wiki/File:Qew\\_bruecke\\_nf\\_beton\\_kaputt\\_33\\_von\\_46.jpg#/media/File:Qew\\_bruecke\\_nf\\_beton\\_kaputt\\_33\\_von\\_46.jpg](https://commons.wikimedia.org/wiki/File:Qew_bruecke_nf_beton_kaputt_33_von_46.jpg#/media/File:Qew_bruecke_nf_beton_kaputt_33_von_46.jpg)











## GEOMETRY

### Nominal concrete cover

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

Depending factors:

- Concrete strength
- Type of cement and proportion (w/c ratio)
- Production (precast or on site)
- Bond with concrete (rugosity)
- Exposure conditions
- Fire resistance



## GEOMETRY

### Nominal concrete cover

## Use of spacers





## GEOMETRY

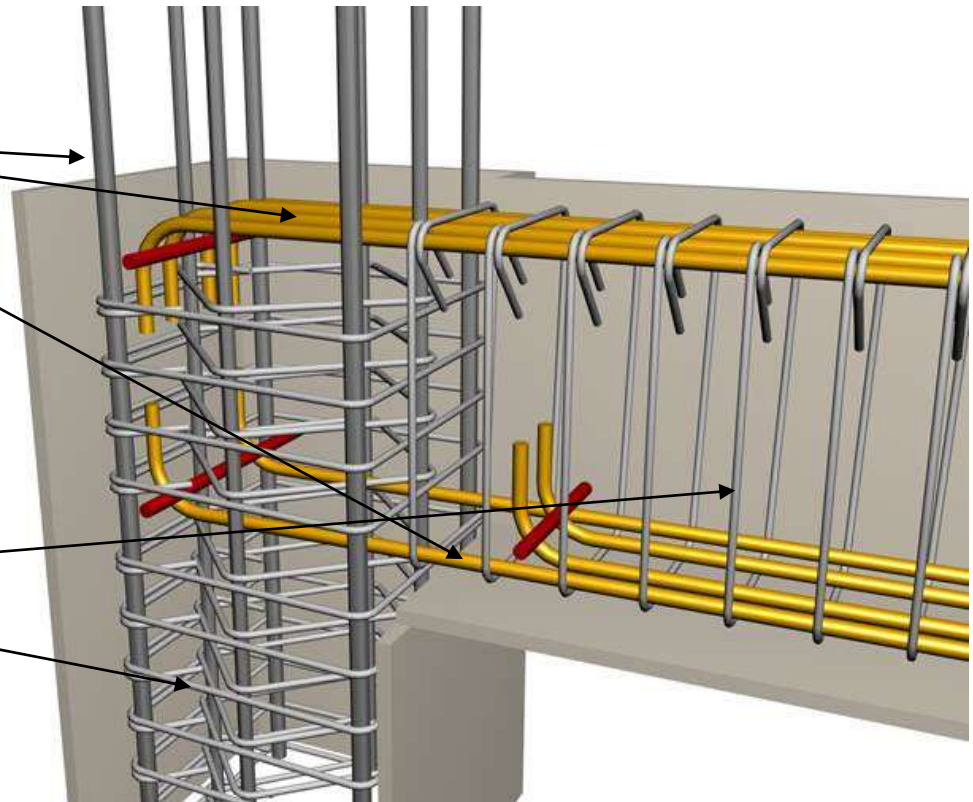
### Rebar position

#### Longitudinal

Support efforts to every cross section

#### Transversal

Support shear force and jail construction  
(i.e. links)





## GEOMETRY

### Rebar spacing

Longitudinal bars: the maximum distance of the following:

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

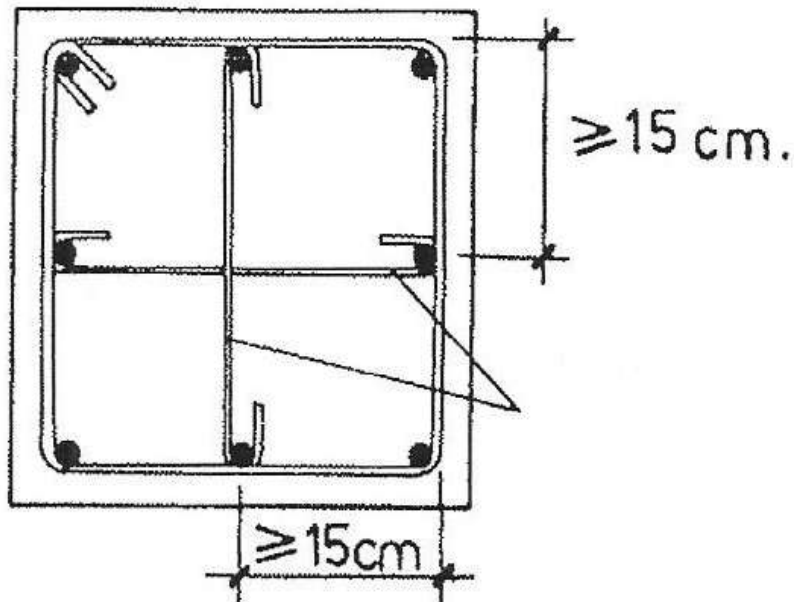
Minimum vertical distance between groups: the maximum distance of the following:

- Maximum nominal diameter
- 20 mm

## GEOMETRY

### Rebar spacing

Maximum distance between longitudinal bars without any link: 150 mm



For construction:  
Maximum distance  
without any bars: 25 cm.



## GEOMETRY

### Rebar spacing

#### Exercises

Calculate the following rebar distribution (nominal cover 35mm):

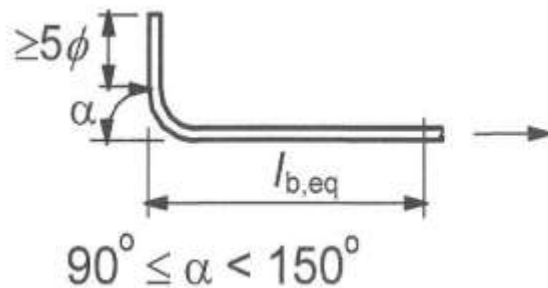
- 1.- A column of 400x400mm with 4Ø20 at each side. Links Ø8
- 2.- A column of 600x400mm with 3Ø25+4Ø16 at the long side, and 2Ø25+2Ø16 at the small side.
- 3.- A beam of 400x500mm with 5Ø20 at the bottom and 3Ø12 at the top.
- 4.- A beam of 400x500mm with 10Ø20 at the bottom and 5Ø16 at the top.

# GEOMETRY

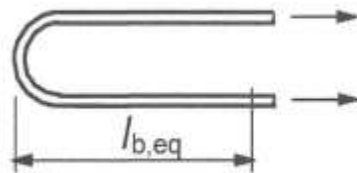
## Rebar anchorage

Calculated by the designer

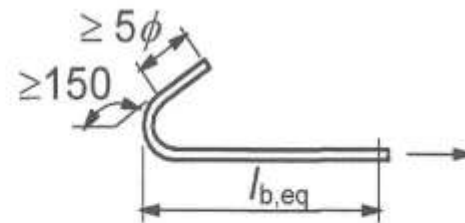
Types:



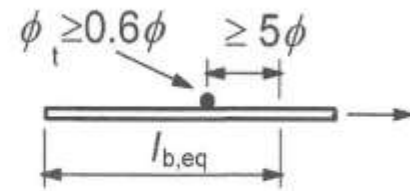
STANDARD BEND



STANDARD LOOP



STANDARD HOOK

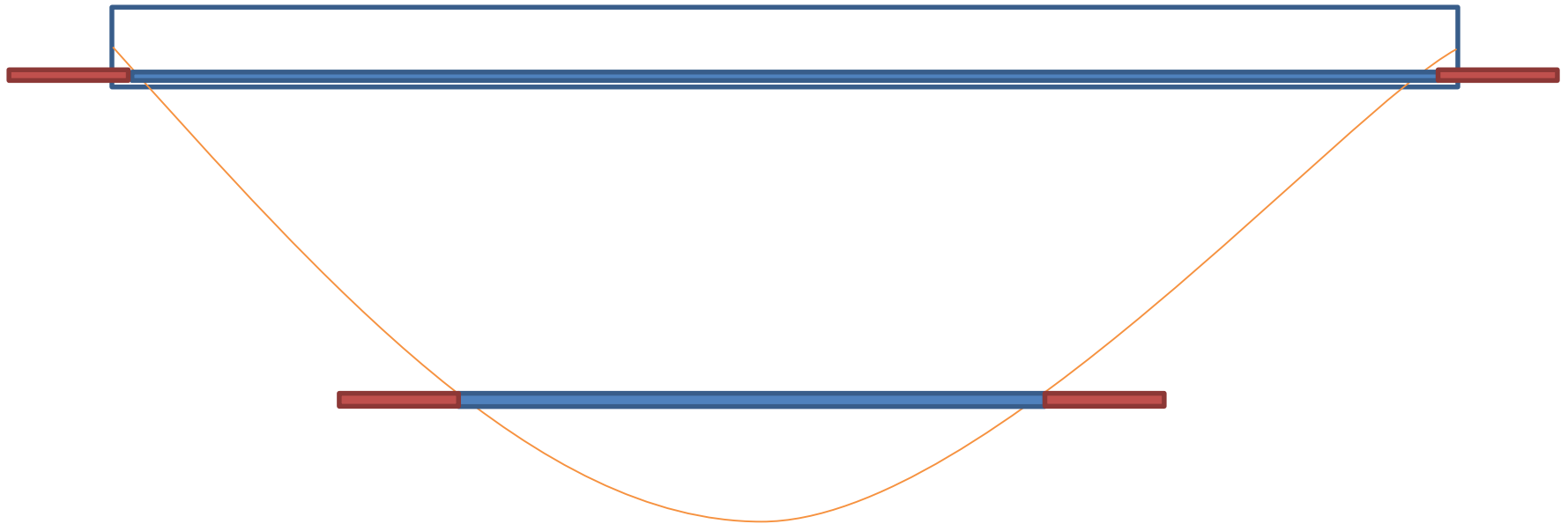


WELDED TRANSVERSE BAR



# GEOMETRY

## Rebar anchorage





# GEOMETRY

## Rebar anchorage

