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Design of Concrete Mix and Field Application

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Concrete Mix Design

What is Concrete Mix Design

- **Traditionally understood as proportioning of concrete materials (Cement, Aggregate and Water) for Strength and durability**
- **It is about everything that makes concrete performs well for its application. Concrete design must account for the following**
  - What strength is required
  - What slump is required for placing
  - What size of aggregate is best for its application
  - Do you need to entrain air?
  - What happens if the weather is very hot or cold?
  - What is the exposure condition?
  - Is there any special characteristics required? Such can be by;
    - Cement (SRC, Slag)
    - Admixtures (Accelerating, Retarding, Waterproofing)
    - Additions (Fibre, PFA, Silica Fume, Pigment, Polystyrene)
    - Application (CFA Pile, Bored Pile, Shortcrete)

Concrete Mix Design

Type of Concrete Design

- **Concrete Mix Design is mainly classified as:**
  - Nominal Mix Concrete
  - Design Mix Concrete

Nominal Mix Concrete	Design Mix Concrete
▪ A very rough method of concrete mix design in most site mix today ▪ It works in form of ratio. e.g. 1:2:4 ▪ Do not account for water addition in the ratio ▪ No lab testing is required ▪ Works for volumetric batching. ▪ Strength issues due to inaccurate measure	▪ Based on the principle of mix design ▪ Yields concrete of desired quality. ▪ More economical than nominal mix ▪ Constituent is tested in the lab before use (E.g. Specific gravity for volume determination) ▪ Batch is by weight ▪ Preferred over nominal mix concrete.

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Two Phase of Concrete

1. **The Granular Skeleton**

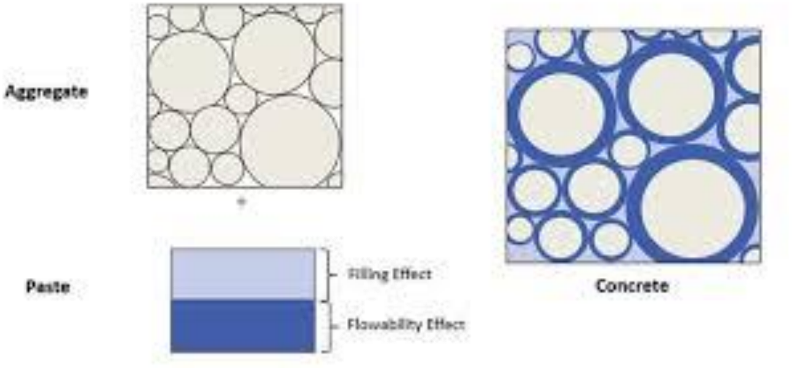
   A wide range of particle sizes:

   - Silica fume: ~ 0.1 - 1 µm
   - Cement: ~ 1 – 100 µm
   - Sand: 0 – 4 mm
   - Coarse Aggregates: > 4 mm (up to 20mm)

2. **The Paste Fraction**
   - Cement and addition < 63µm
   - Fines from sand < 63µm
   - Free water
   - Admixture
   - Air

- **Optimized packing is the objective**

- **At the skeleton's scale:** decreased paste volume
  - ✓ Cost reduction and lowered environmental footprint
- **At paste scale:** decreased water content
  - ✓ Enhanced mechanical efficiency of the cement



Concrete Mix Design

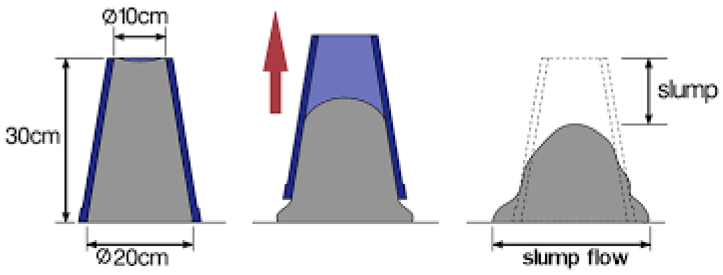
Consistence – Choose Target Slump

- **It is a workability concept (Fresh concrete)** The consistence of fresh concrete should be suitable for the conditions of handling and placing so that after compaction, concrete surrounds all reinforcement, tendons and ducts and completely fills the formwork.
- **Depending on application, see table below;**

Table 3 — Slump classes

Class	Slump tested in accordance with EN 12350-2 mm
S1	10 to 40
S2	50 to 90
S3	100 to 150
S4	160 to 210
S5[a]	≥ 220

[a] See Note 1 to 5.4.1.



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Aggregate Size – Choose Maximum Aggregate Size

- **Depends on reinforcement density**
  - The aggregate must pass through the middle of steel bars. As general rules, the maximum size must be:
    - 0.8 times the free horizontal distance between reinforcements
    - 1.25 times the distance between an edge of the member and reinforcement
    - 0.25 times the minimum dimension of the member
- **Aggregate size according to EN 12620:**

Basic set mm	Basic set plus set 1 mm	Basic set plus set 2 mm
0	0	0
1	1	1
2	2	2
4	4	4
–	5,6 (5)	–
–	–	6,3 (6)
8	8	8
–	–	10
–	11,2 (11)	–
–	–	12,5 (12)
–	–	14
16	16	16
–	–	20
–	22,4 (22)	–
31,5 (32)	31,5 (32)	31,5 (32)
–	–	40
–	45	–
63	63	63

NOTE Rounded sizes shown in parentheses can be used as simplified descriptions of aggregate sizes.

Aggregate surface area influence the workability & cement content:

The smaller the size the less workable & the more the cement content (COST ⬆)

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Water – Cement Ratio. Select w/c

- Concrete required to produce Strength, Durability, Imperviousness must be as dense as possible and this requires a low water-cement ratio
- Water/cement ratio (w/c) is not just a workability concept, it is a DURABILITY concept.
- Cement needs about 0.2 of w/c to make the hydration process
- W/C is usually between 0.7 for low strength and 0.38 for high strength concrete.
- Admixtures should be used to increase workability and maintain a low water content
- Calculate the Cement content by dividing the water content by the Water-Binder Ratio

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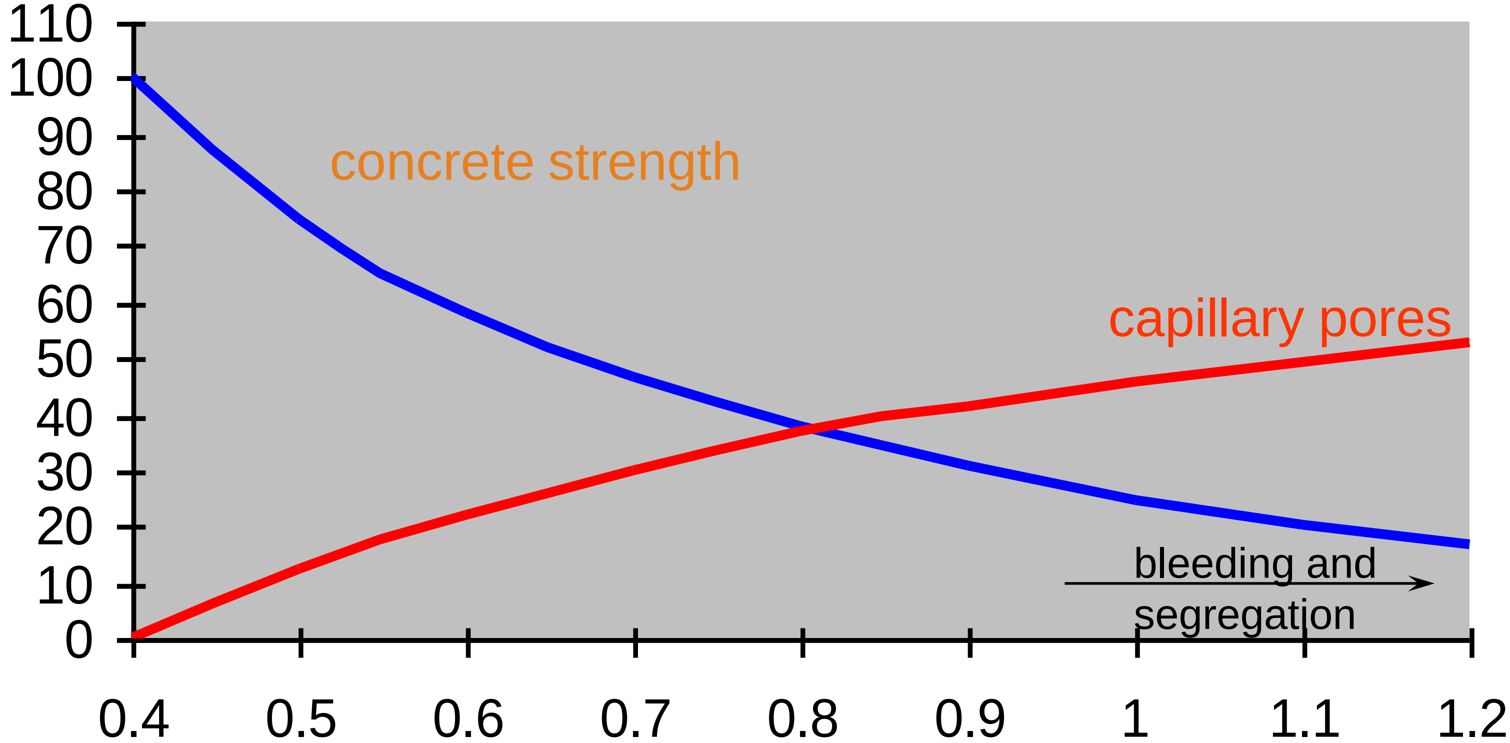
TOO MUCH WATER

LOW STRENGTH

POOR DURABILITY



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Exposure Class of Concrete

BS EN 206:2013
EN 206:2013 (E)

Table F.1 — Recommended limiting values for composition and properties of concrete

	Exposure classes																
	No risk of corrosion or attack	Carbonation-induced corrosion				Chloride-induced corrosion						Freeze/thaw attack				Aggressive chemical environments		
						Sea water			Chloride other than from sea water									
	X0	XC 1	XC 2	XC 3	XC 4	XS 1	XS 2	XS 3	XD 1	XD 2	XD 3	XF 1	XF 2	XF 3	XF 4	XA 1	XA 2	XA 3
Maximum w/c[c]	–	0,65	0,60	0,55	0,50	0,50	0,45	0,45	0,55	0,55	0,45	0,55	0,55	0,50	0,45	0,55	0,50	0,45
Minimum strength class	C12/15	C20/25	C25/30	C30/37	C30/37	C30/37	C35/45	C35/45	C30/37	C30/37	C35/45	C30/37	C25/30	C30/37	C30/37	C30/37	C30/37	C35/4
Minimum cement content[c] (kg/m³)	–	260	280	280	300	300	320	340	300	300	320	300	300	320	340	300	320	360
Minimum air content (%)	–	–	–	–	–	–	–	–	–	–	–	–	4,0[a]	4,0[a]	4,0[a]	–	–	–
Other requirements	–	–	–	–	–	–	–	–	–	–	–	Aggregate in accordance with EN 12620 with sufficient freeze/thaw resistance				–	Sulfate-resisti cement[b]	

Where the concrete is not air entrained, the performance of concrete should be tested according to an appropriate test method in comparison with a concrete for which freeze/thaw resistance for the relevant exposure class is proven.

Where sulfate in the environment leads to exposure classes XA2 and XA3, it is essential to use sulfate-resisting cement conforming to EN 197-1 or complementary national standards.

Where the k-value concept is applied the maximum w/c ratio and the minimum cement content are modified in accordance with 5.2.5.2.

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Estimate Aggregate Content

- **Estimate the Coarse Aggregate content.**
- **Estimate the Fine Aggregate content.**
- **Adjust for aggregate moisture—wet aggregate can significantly reduce the amount of water to be added.**

Hand Held Moisture Meter

Speedy Moisture tester

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Trial Batch

- **Do small volume trial to access performance**
  - Check for workability
  - Whether the mix is segregating or bleeding
  - Temperature check where necessary
  - Air content & Fresh density
  - Sample for cube test & label for identity
  - Curing and test for compressive strength up to 28 days
  - Review performance, adjust design, and repeat trial

Cube sampling

Curing of labeled cube samples

Laboratory Concrete Mixer

Slump Test

Segregation in concrete

Strength test

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Factors Affecting Concrete Mix Design

- **Compressive Strength of Concrete**
  - It is the major factor influencing the mix design. It is one of the most important properties of concrete and influences many other desirable properties of the hardened concrete. **TMS = fck + 1.48 x stdev**
- **Workability of Concrete**
  - The workability of concrete for satisfactory placing and compaction is controlled by the size and shape of the section to be concreted, the quality and spacing of reinforcement, and the methods to be employed for transportation, placing and compaction of concrete.
- **Durability of Concrete**
  - The durability of concrete can be defined as the resistance to deterioration due to aggressive environment. The requirements of durability are achieved by restricting the minimum grade of concrete, minimum cement content and the maximum water cement ratio
- **Water – Cement Ratio**
  - The lower the w/c ratio the greater is the compressive strength and vice versa

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Factors Affecting Concrete Mix Design

- **Choice of Aggregate Size**
  - The maximum nominal size of aggregate to be used in concrete depends by the size of section and the spacing of reinforcement.
- **Choice of Cement**
  - Cement choice varies depending on usage. The cement should be tested for performance required before use in the design mix. (**32.5N classic vs 42.5N supaset**)
- **Quality Control**
  - The variability in the strength of concrete may be considered due to variation in the quality of the constituent materials – particle size and grading, variations in moisture content of aggregates, variations in the quality of batching and mixing equipment available, and the quality of workmanship. The variation in strength results from the variations in the properties of the mix ingredients and lack of control in batching, mixing, placing, curing and testing. **The factor controlling this difference is termed as quality control**

Concrete Mix Design

Field Application of Concrete – Lafarge Ultra Series

Piling Solution: Available for CFA Pile & Bored Pile for deep foundations

- **Applications**

✓ Use in cohesive soil for Tremie operations with Bentonite, CFA and bored piles

✓ used for bridge work, tall buildings, and massive industrial complexes, all of which requires deep foundations

- **Benefits**

✓ Easy void filling

✓ Self-compacting solution without the use of vibrator

✓ Fluidity enhances the placing of reinforcement cages into piles

CFA Piling

Bored Piling

Concrete Mix Design

Field Application of Concrete – Lafarge Ultra Series

Shortcrete: Specially formulated to allow user to have a high speed of placing by projection method

- **Applications**
  - ✓ Cover large surfaces when difficult to access placing area
  - ✓ Easy to cast and speed of delivery
  - ✓ For commercial, industrial or housing projects, inside or outside application
- **Benefits**
  - ✓ Shortcrete provides economic benefits through thinner construction
  - ✓ Higher durability
  - ✓ Ease of placing
  - ✓ Speed of delivery

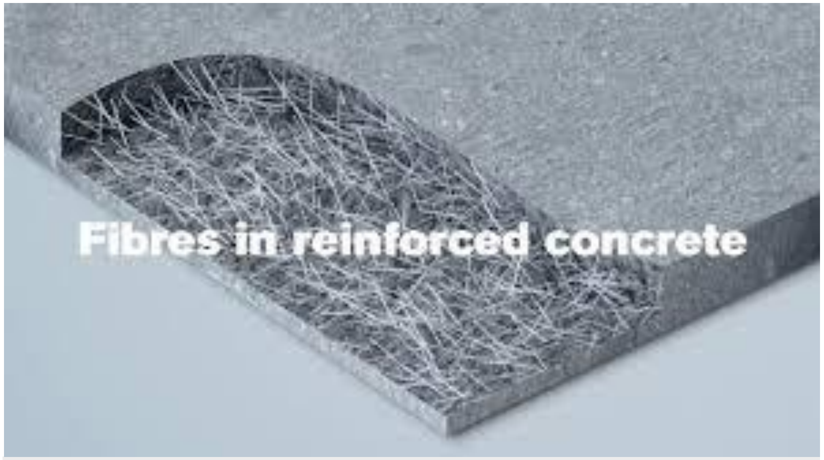
Shortcrete in Dome Construction

Shortcrete

Concrete Mix Design

Field Application of Concrete – Lafarge Ultra Series

- **Fibre Concrete:** Polypropylene fiber should be considered in any application where steel reinforcement, such as WWF (Welded Wire Fabric) or WWM (Welded Wire Mesh), is used for temperature and shrinkage performance
  - **Applications**
  - ✓ Residential and commercial pavements
  - ✓ Shortcrete
  - ✓ Decorative and architectural concrete
  - ✓ projects, inside or outside application
  - **Benefits**
  - ✓ Reduce cost of labor to transport and place steel
  - ✓ Reduce warranty issues due to plastic cracking



Fibre Concrete

Fibre Reinforced Concrete

Concrete Mix Design

Field Application of Concrete – Lafarge Ultra Series

- **Low Shrinkage Concrete:** Specifically designed with low shrinkage feature, reduced curling, with or without fibre
  - **Applications**

    Low Shrinkage is used in the slab where you need to:

    ✓ Have very flat finishing

    ✓ Reduce the thickness of the slab, while maintaining its structural properties

    ✓ For commercial, industrial or housing slabs

  - **Benefits**

    ✓ Reduced maintenance of the slab

    ✓ Higher durability

    ✓ Reduced element weight

    ✓ Reduce material costs (concrete and steel rebar)

    ✓ Thinner design

Concrete Mix Design

Field Application of Concrete – Lafarge Ultra Series

- **High Early Strength:** Your jobsite is delayed… You want to accelerate… You want to save time and optimize your formwork capacity. High Early Strength range is developed to reach specific strengths at early ages (1 day, 3 days, 7 days).
  - **Applications**
  - ✓ All elements which need to reach strength earlier
  - ✓ Structural elements (columns/beams/slabs)
  - ✓ Bottleneck elements in the building
  - **Benefits**
  - ✓ Gain time and associated costs
  - ✓ Optimize your formworks

Precast Structures

Rail Sleepers

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Field Application of Concrete – Lafarge Ultra Series

- **High Strength:** High Strength is a range of concretes from 50MPa to 80MPa at 28 days
  - **Applications**

  High Strength is used where you need to:

  ✓ Reduce the section or increase the length of concrete elements

  ✓ Lighten the structure to optimize and even push the model a step ahead

  ✓ Decrease the steel reinforcement

  - **Benefits**

  ✓ Greater usable space

  ✓ Lower element weight

  ✓ Reduced material costs (concrete and steel rebar)

  ✓ Thinner design

Elalan-Kaizen Tower

Concrete Bridge

Concrete Mix Design

Field Application of Concrete – Lafarge Ultra Series

- **Self Compacting Concrete:** Designed to flow under its own weight, requiring no vibration and is able to completely fill all spaces within formwork. Typical flow of 500 – 700mm

  - **Applications**

  Ideal to be used in the following applications:

  ✓ Areas with a high concentration of rebar and pipes/conduits
  ✓ Vertical and horizontal applications
  ✓ Dense reinforcement of architectural projects, etc.

  - **Benefits**

  ✓ Improved structural integrity
  ✓ Flows into complex forms
  ✓ Minimizes voids on highly reinforced areas
  ✓ Produces superior surface finishes

Flow Test for SCC

SCC in Heavy Reinforced Structure

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Field Application of Concrete – Lafarge Ultra Series

- **Sulphate Resistant Concrete:** The perfect solution to use wherever moderate to aggressive sulfate attack is found
  - **Applications**

  Requested in commercial, building and infrastructure for:

  ✓ Underground footings and foundations
  ✓ Sewage treatment plants
  ✓ Embedded concrete ducts and pipes
  ✓ Tunnels and culverts
  ✓ Piles and diaphragm walls
  ✓ Quay walls and shoreline protection

  - **Benefits**

  ✓ High durability and good structural integrity
  ✓ Reduced occurrence of efflorescence
  ✓ Various levels of strength depending on need

Structures at Lagos Bar Beach

Marine Concrete Structure

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Field Application of Concrete – Lafarge Ultra Series

- **Extruded Concrete:** Gomako has been developed to be used by extruding machines
  - **Applications**

    Applications are:

    ✓ Curbs and culverts

    ✓ Simple or double highway guardrails
  - **Benefits**

    Extruded - Gomako provides:

    ✓ Less joints

    ✓ Concrete strength and durability

    ✓ Variation of different aesthetic finishing (exposed aggregate, colored)

C

Marine Concrete Structure

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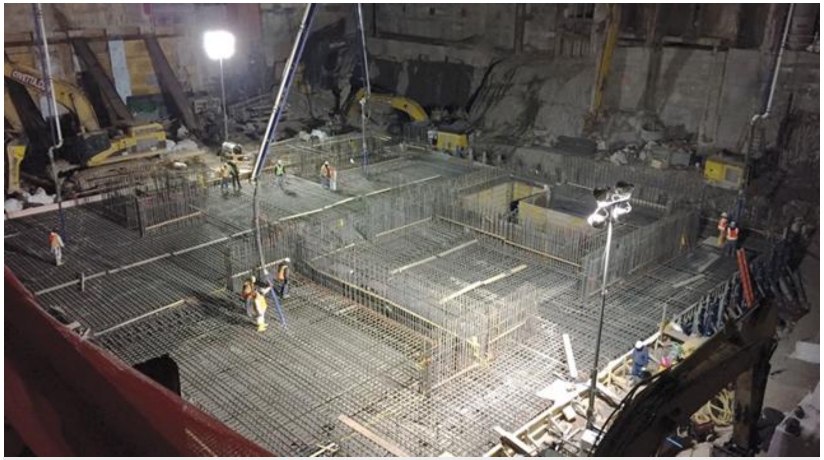
Field Application of Concrete – Lafarge Ultra Series

- **Low Heat Concrete:** Designed for mass concrete, this solution takes special measures to cope with heat generation and volume change in order to mitigate the risk of internal thermal cracking
  - **Applications**
    - ✓ Mass concrete foundations
    - ✓ Marine concrete structures exposed to sea waters
    - ✓ Deep raft foundations, slabs, bored piles, sub-structure
  - **Benefits**

    A lower heat of hydration concrete mitigates the risk of thermal cracking which gives some direct benefits:
    - ✓ Reduce permeability due to greater pore filling capacity
    - ✓ Better sulfate/chloride resistance
    - ✓ Greater durability

Mass Concrete



Mass Foundation

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Field Application of Concrete – Lafarge Ultra Series

- **Light Weight Concrete:** Designed to achieve lower density compared to normal weight concrete. Density is typically 800 - 2200kg/m3
  - **Applications**

✓ Structural light weight requirements
✓ Precast units
✓ Light Weight screeds
✓ Light Weight roof slope screed
✓ Void filling

  - **Benefits**

✓ Reduce the dead load of structures
✓ Optimize the structure design
✓ Ease of placement

Lightweight Concrete

THANK YOU

Any Question?