Concrete Technology

Functions of ingredients of OPC Raw material

Ingredient	Oxide	%	Property	Excess quantity
Lime	CaO	63	Sound & Strong	Unsound, Expand & Disintegrate
Silica	SiO_2	22	Provide Strength due to formation of C_2S & C_3S	Setting Slowly
Alumina	Al_2O_3	6	Quick Setting and lowers the Clinkering temp	
Iron oxide	Fe_2O_3	3	Colour, Hardness & Strength Helps in fusion of raw materials during manufacture of Cement.	
Magnesium oxide	MgO	2	Hardness & Colour	Unsound
Sulphur trioxide	SO_3	2	Sound	Unsound
Alkalies	K_2O, Na_2O	1	No use, Hence Should be present in Small quantity	Efflorescence

Bogue's Compounds

The above mentioned ingredients/oxides are presents in Raw materials [like Limestone, Clay shale] used for the manufacture of Cement.
These oxides interact with eachother in the kiln at high temperature to form more Complex Compounds, identified by R.H. Borges, hence it is called 'Bogue's Compounds'.

① Name of Compounds (Major)	Formula	Abbrivated formula	%	Also called
Tricalcium Silicate	$3CaO.SiO_2$	C_3S	45	Alite
Dicalcium Silicate	$2CaO.SiO_2$	C_2S	25	Belite
Tricalcium ~~Silicate~~ Aluminate	$3CaO.Al_2O_3$	C_3A	11	Celite
Tetracalcium Allumino ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	9	Felite

② Minor Compounds

Alkalies → K_2O and Na_2O

Sulphate attack

Step ① Formation of Calcium hydroxide $Ca(OH)_2$, due to C_3S & C_2S

$$(CaO)_3 \cdot SiO_2 + 3H_2O \rightarrow CaO \cdot SiO_2 \cdot H_2O + 2Ca(OH)_2$$

$$(CaO)_2 SiO_2 + 2H_2O \rightarrow CaO \cdot SiO_2 H_2O + Ca(OH)_2$$

(∵ $CaO \cdot SiO_2 \cdot H_2O$ is called C-S-H gel & also called Tobermorite gel)

→ Hence, C_3S produce more $Ca(OH)_2$. Hence it is more responsible than C_2S

Step ② Formation of Calcium Sulphate.

$$Ca(OH)_2 + \text{Sha Sulphate} \longrightarrow \text{Calcium Sulphate} + H_2O$$

Step ③ Finally react with C_3A

Calcium Sulphate + C_3A → Causes deterioration of Concrete.

→ Hence to Reduce Sulphate attack by Reducing C_3A (nearly 5%.)

$Ca(OH)_2$

By using fly ash, Silica fume.. etc, may reduce the bad effect of $Ca(OH)_2$ in concrete.

The only advantage is that $Ca(OH)_2$ being alkaline in nature, maintain pH around 13 in the concrete, which resist the Corrosion of Reinforcement

*) Functions of Bogue's Compounds.

1)	C_3S	1. Hydrates more rapidly, Hence Generate large heat of hydration. 2. Responsible for Early strength of Concrete.
2)	C_2S	1. Hydrates slowly - Hence Generates less heat of hydration. 2. Responsible for Later strength of Concrete. 3. provides good Ultimate strength.
3)	C_3A	1. It is the 1st compound react with water, Hence Causes initial Setting of Cement. 2. Harmful to the durability of Concrete, especially where the Concrete attacked by Sulphates.
4)	C_4AF	1. It reacts slowly with water and Generates very small amount of heat of hydration. 2. Hence, it has poor Cementing value.

Case(i) High % of C_3S and low % of C_2S, results
1. Rapid hardening → High early strength
2. Produces high heat of hydration
3. Less resistance to Sulphate attack.

Case(ii) Low % of C_3S and High % of C_2S, results
1. Slow hardening → Much more Ultimate strength
2. produces less heat of hydration
3. Greater resistance to Sulphate attack.

Types of Cements

a) Ordinary portlant Cement (OPC)

1. These are three typey OPC 33, 43 & 53 gradey (eg: 28 days Strength & 33 N/mm²
2. It has adequate resistance to dry shrinkage & cracking.
3. But hay Less resistance to Chemical attacle, Hence Should not be used for where Sulphaty in the Soil/water.

Cement mortar - 1:3
Cube size - 7.07cm
Surface Area - 50cm²

b) Rapid Hardening portlant Cement

1. It develops Some Strength in 3 days, as expected of OPC in 7 days.
2. By making High % of C_3S & low % of C_2S.
3. Used in Road repair works, Cold weather Concrete, early formwork...etc.
4. Do not used in mass Concrete Construction

c) Sulphate Resisting Cement

↦ Generally Limits the C_3A Content to 5% & $2C_2A + C_4AF$ ≯ 25%.

Recommended under following conditions.

1. Marine Conditions (i.e Alternate welting & drying). Like Culverts, lined canals...
2. Sewage treatment works, like sewer pipes.
3. Basements & foundations having Sulphate attack.

d) Low heat portland Cement

Is achived by reducing the % of C_3S & C_3A and increasing C_2S.

1. Useful for mass Concrete works, Such as Dams.
2. Also called Low Hardening portlant Cement, but great ultimate Strength.

e) High Alumina Cement

Achived by increasing Alumina % ≃ 35%.

1. Useful in Chemical plants & Sea water
2. Used in having high temperatur like Furnaces, kilns, Chimneys...etc.

f) Blast Furnace Slag Cement

It is Cheap & economical, although Safe upto M20

1. Useful in mass Concrete works
2. It causes efflorescence, due to the presence of Alkaliney.

g) Pozzolona Cement (PPC)

It is made by integrating (70% OPC + 30% Pozzolona). Pozzolona is essentially a Silicious material Containing Clay upto 80%.

1. Widely used for Hydraulic Structurey, Such as Dams, Weirs..etc.

h) Coloured Cement

Prepared by adding 5-15% of Suitable Colouring Pigment before the Cement is finally placed on ground. Also Called "Colocrete".

1. Widely used for finishing of floors, external Surfaces..etc,

Testing of Portland Cement

1. Field / Physical Testing

Only used for Minor work. (it givy some ideo about Good/Badness of Cement)

1. Colour of Cement should normally be Greenish grey.
2. The bag looking good surface, do not have any lumps.
3. Handfull of Cement thrown into bucket of wate, it float for some time befor they sink.
4. Thrust your hand into Cement bag. It must give you a cool feeling.
5. Rubbed in b/n fingers, it feels Smooth.

2) Fineness Test

Finer Cement (3-25μ) hay great functioning than Coarser Cement (< 100μ) due to the least void ratio and more Cohesiveness/adhesiveness.

a) Sieve method (Finer cement has quicker action with wate & gain early Strength)

Weight of residue left after Sieve through IS Sieve No:9 (90μ)

- ⊁ 10% for opc
- ⊁ 5% for PPC

b) Air permeability method

Accurate method. Finess can be found by passing Dry air through the bed of Cement. "Blain air permeability apparatus" is more Commonly employed in india.

Specific Surface ⊁ 2250 cm^2/gm → OPC

3000 cm^2/gm → PPC

3200 cm^2/gm → Rapid & low heat

3) Consistency Test

This test is Conducted to determine the percentage of wate (P) required for preparing Cement pasty of Standard Consistency for other tests (eg: Selting time, Soundness & Compressive Strength tests)

→ Vicat's apparatus used to determine the (initial selting time, Final Selting time & Normal Consistency) of the Cement.

→ For this Consistency test Vicat's apparatus Consisty of a plunger having 10mm dia & 50mm length.

Test!

→ Take 500gm of Cement & mixed with wate 25% (For first trail) the paste filled into the Vicat's mould with in 3-5 minuty.

→ Release the plunger from the top Surface of Cement paste.

→ observe the penetration of plunger.

→ The Cement paste is said to be Standard Consistency if the plunger is penetraty for a depth of 33-35mm from top.

→ If not Satisfied increase/decrese the wate by 1-2% & Conduct trails.

∴ P = Percentage of wate required to produce a Cement paste of Standard Consistancy.

4) Selting Time Test

Instrument - Vicat's apparatus
Cement Sample - 500gm
% of water = 0.85p

Room temperature = 27 ± 2°C
Stop watch started - From the addition of water to Cement.

a) Initial selting Time ≯ 30min

Penetration needle - Square needle (1mm x 1mm)
Permissible penetration level = 5mm from bottom.
Stop watch stopped - when the needle stops penetration at 5mm

b) Final Selting Time ≯ 10 hr's

Penetration needle - Circular needle (1mm dia) having sharp end (also called "Annular Collar".
Stop watch stopped - When the needle stops penetration at 0.5 mm from the top.

5) Soundness Test

Instrument - Le-Chatelier apparatus
% of water - 0.78 p
Unsound causes - Due to the presence of Excess Lime & Magnesia

→ The difference b/n two readings (initial & after cooling the boiled concrete with water) indicates the Expansion of cement.

∴ This Expansion ≯ 10mm

6) Compressive Stength Test

Mortar - 1:3, Cube Size - 7.07cm, Surface area - 50 cm²
% of water = $\left(\frac{P}{4} + 3\%\right)$ of Combined weight of (Cement + Sand)

→ Compressive Strength ≮ 11.5 N/mm² at the end of 3 days
17.5 N/mm² at the end of 7 days.

7) Tensile Strength Test

→ Tensile Strength ≮ 2 N/mm² 3 days
2.5 N/mm² 7 days

[Mortar - 1:3
% of water - $\left(\frac{P}{5} + 25\%\right)$

Aggregates

Natural aggregaty - Sand, Gravel, Crushed rock are used for R.C.C

Artificial aggregaty - Furnace Clincker, Coke breeze, Saw dust and Foamed Slag are used for Concrete of low density.

Shape of aggregaty [Size > 75mm, called Cyclopean aggregate]

1. Roundshape aggregaty (River (or) Sea Shore gravel)

   Has minimum voids → 32-38%

2. Irregular aggregaty (Pit Sand & gravel)

   Has high % of voids → 35-38%.

3. Sharp & Angular aggregaty (Crushed rocks)

   Hay Maximum voids → 38-40%.

4. Flacky aggregates

   Thickness is very small as Compared to Length/width.

   Least dimension (Thickness) $\leq \frac{3}{5}$ of mean dimension

5. Elongated aggregates

   Length is very large as Compared to width/thickness.

   Great dimension (Length) > 1.8 × mean dimension.

(∵ Mean dimension = Avg Sievesizes, as aggregate is 1st retained & last passing)

Weight of aggregates

1. Normal weight

   Sands, Gravels & Crushed rocks of Granite, Basalt, quartz, Sandstone & limestone.

   Sp.gr - 2.5-2.7 Concrete (γ) = 23-26 kN/m³

2. Heavy weight

   Hematite, magnetite, Geothite, baryte, Scrap iron.. etc.

   Sp.gr - 2.8-3.0, Concrete (γ) = 28-30 kN/m³

   → These are not appropriately graded.

3. Light weight

   Cinder, pumice, Volcanic, diatomite.. etc & artificial aggregaty

   ~~Sp.gr - 1.5-2.0~~ Unit wt of only aggregaty ≃ 12 kN/m³

   → It provide high resistance to fire

Dryness of aggregates

Very dry aggregate - Zero moisture in pores & Surface

Dry aggregate - May be moisture in pores &, but Surface dry.

Saturated-Surface dry aggregate - Fully moisture in pores, but Surface dry

Moist aggregate - pores & Surface are fully wet.

Specific gravity

$$\text{Apparent Specific gravity} = \frac{\text{Weight of Oven dry aggregates}}{\text{Absolute volume, Excluding natural pores in aggregate}}$$

$$\text{Bulk Specific gravity} = \frac{\text{Weight of oven dry aggregates}}{\text{Absolute volume, Including natural pores in aggregate}}$$

Testing of aggregate

a) Impact Value Test

To determine the Toughness of the aggregate.

→ Hammer is lifted up 38cm & Subjected to 15 blows (14kgs)

b) Crushing Value Test

To determine the Crushing Strength of the aggregate.

→ Constant load of 40 tons applied at the rate of 4 tons/minute

→ Crushing value < 30% for Concrete used for road pavements
45% for other structures

$$\therefore \text{Aggregate Crushing/Impact value} = \frac{\text{wt passing through 2.36 mm sieve after test}}{\text{overall weight of aggregate}} \times$$

c) Abrasion value

To determine the resistance of an aggregate to wear (ie Hardness) when it is rotated in a cylinder of about 1000 revolutions.
by using Los Angles machine

$$\text{Abrasion value} = \frac{\text{wt passing through 1.7mm sieve after test}}{\text{original overall wt of aggregates}}$$

$$\text{(Dorry abrasion test) Hardness} = 20 - \frac{\text{wt through 1.7mm (i.e Loss in grams)}}{3}$$

→ Abrasion value < 30% for wearing surfaces
50% for Non-wearing surfaces.

d) Bulking of Sand

The increase in volume of sand due to the presence of moisture upto certain extent is called bulking of sand. (Bulking ∝ void ratio)

$$\text{Bulking factor} = \frac{\text{Volume of moist sand}}{\text{Volume of dry sand}} = 1 - e$$

e) Deleterious materials in aggregate

They produce bad effect on the function & property of aggregate.

∴ The sum of % of all deleterious materials ≯ 5%.

f) Fineness Modulus

$$\left[\% \text{ of F.A} = \frac{F_{CA} - F}{F - F_{FA}} \times 100\right]$$

It gives some idea ~~of~~ of the average size of particle in the aggregate.

Fine sand	: 2.2 - 2.6
Medium sand	: 2.6 - 2.9
Coarse sand	: 2.9 - 3.2

A sand having Fineness modulus (F.M) more than 3.2 will be unsuitable for making satisfactory Concrete.

Admixtures

1. **Accelerators** (Calcium Chloride $CaCl_2$)

Used to accelerate the initial setting time of Concrete
→ Needed when Concrete placed at low temperature

2) **Retarders** (Calcium Sulphate & Gypsm)

Used to delay the hydration process ⇒ initial setting time.
→ Needed in hot weather and long transportation time.

3) **Plasticizers** (Carbohydrates)

Also called "water reducers".
→ Needed at high workability causey segregation & bleeding.
*) other important plasticizers = Calcium, ammonium & Sodium ligno Sulphonates.
→ They permit water reduction upto 5-15%.

4) **Super plasticizers** (Modified ligno Sulphonaty & Acylic polymer)

Are the improved version of plasticizers.
→ They permit water reduction upto 30%.
→ Mostly used for flow, self levelling, self compacting Concrete
→ It can be mixed with Air-entrainment agents for reducing air entrainment and increasing the workability.

5) **Air-Entraining** (Animal & vegitable fats, oils and their fatty acids)

Entraining - Air added/distributedd evenly in the entire mass of Concrete. ranging from 5-80μ.

Entrapped - Voids present in the Concrete due to insufficient Compaction

→ These air-Entraining agents forms bubbles in voids, where excess water present. (They can be seperated out by capilary pores). Since, the excess water may converted into Ice which increas pressure on Concrete.
(∵ Ice is 10% more volume than water)
→ Hence, majorly used where alternating freezing & thawing
→ It also increasy the workability of Concrete.

6) **Air-detraining** (Tri-butyl-phosphate)

→ Dissipating excess air or other gases and
→ Removing excess entrained air from Concrete.

7) **Pozzolanic** (Finely divided Siliceous Substances)

→ To reduce the Calcium hydroxide Concentration.

$$\text{Pozzolanic material} + Ca(OH)_2 \longrightarrow H_2O + C\text{-}S\text{-}H\ (gel)$$

8) **Corrosion inhibiting** (Sodium benzoate, Sodium nitrate.. etc)

→ Is employed to control the Corrosion of Steel reinforcement in Concrete.

Water & water-cement Ratio

Water

Portable waters are generally considered satisfactory for mixing & curing of concrete.

pH value of water should be 6-8 & ≠ 6

Water-cement Ratio (By Duff Abram)

$$W/C \text{ ratio} = \frac{\text{Weight of water}}{\text{Weight of Cement}}$$

- 0.45 → 1:1:2 Concrete
- 0.50 → 1:1½:3 "
- 0.5-0.6 → 1:2:4 "

→ According to Abram lesser the W/c in a workable mix greater will be its strength.

→ if W/c < 0.45, the concrete is not workable, causes Honey-combed structure, will be harsh containing a large no of voids.

eg: W/c = 0.5

⇒ The quantity of mixing water required per one bag of cement

= 0.5 × 50 kg

= 25 kg or 25 litre

Solids in water	Permissible Limit (IS 456)
1. Organic	200 mg/L
2. Inorganic	3000 mg/L
3. Sulphates (as SO_4)	400 mg/L
4. Chlorides (as Cl)	2000 mg/L → plain concrete 500 mg/L → R.C.C
5. Suspended matter	2000 mg/L

Workability

The ease with which it can be mixed, transported and placed in a position in homogeneous state.

→ Concrete is said to be workable if it is mixable, stable, flowable/movable, compactable & finishable.

a) Water Content

At low W/c not workable. At high W/c it highly workable (but not finishable)

b) Size of aggregate

Large size agg are more workable. (∵ F.A requires more water for lubrication)

c) Shape of aggregate

Round Shape - Increases

Angular, Flaky, elongated - Decreases workability

d) Surface texture of aggregate

Smooth Surface increases workability

e) Void ratio

Uniform void ratio (i.e well graded aggregates) increases workability.

f) Air entraining agents

Produced air bubbles act as rollers and thus increases workability.

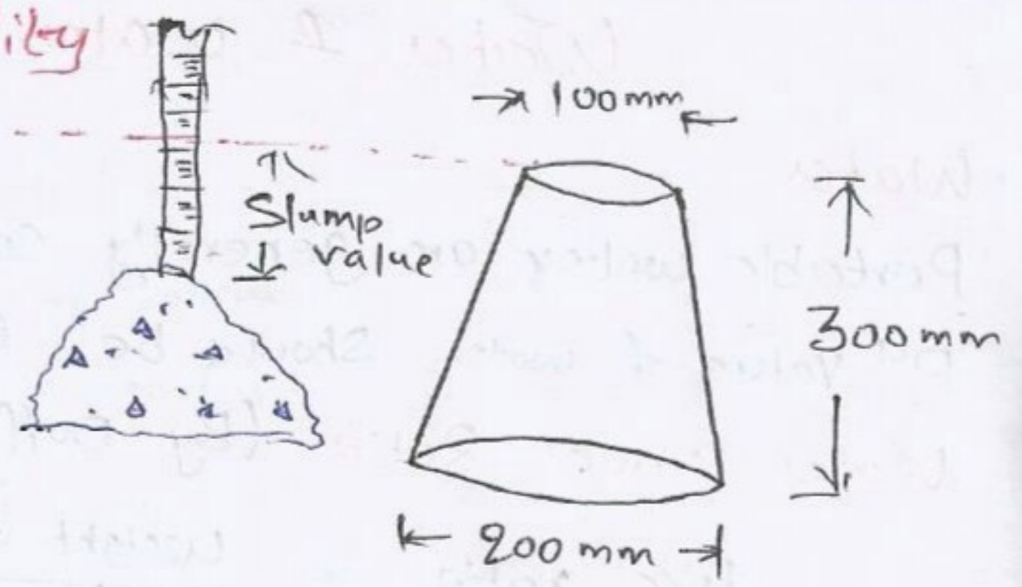
g) Admixtures

The use of plasticizers will increase the workability

h) Temperature

workability of Concrete mix reduces at higher temperature.

Measurement of Workability



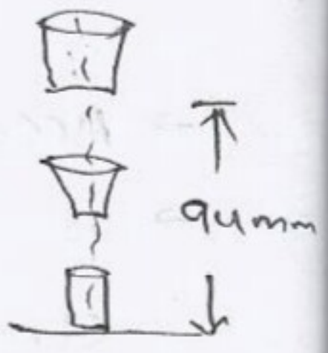
1. Slump Test

→ Suitable only for Medium - High workability
→ Max size of agg ≯ 38mm
→ Slump value increase - workability increase.

2. Compaction factor test

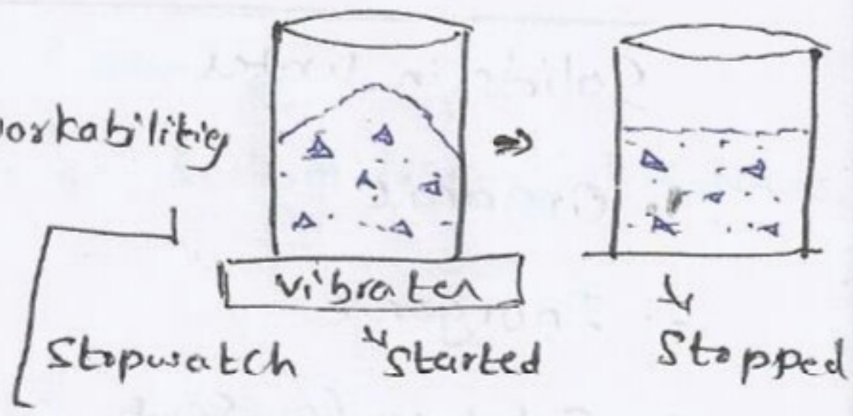
→ Suitable for Medium - low workability
→ Concrete can be compacted by falling from upper cone - lower cylinder.

$$\text{Compaction factor} = \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}}$$



3. Vee-Bee test

→ Suitable for stiff concrete having low - very low workability
→ The time required for the shape of concrete change from slump cone shape to cylindrical shape in seconds is known as vee-bee time.



Placing Conditions	Degree of workability	Slump (mm)	Compaction factor	Vee-bee (Seconds)
1. Building concrete, Shallow sections Pavements using pavers	Very Low	∠25	0.75-0.80	20-10
2. Mass concrete, Lightly reinforced Sections in slabs, beams, walls, Columns & Floors.	Low	25-75	0.80-0.85	10-5
3. Hand placed pavements, Canal lining & strip footings				
3. Heavily reinforced sections in slabs, beams, walls & columns. Slip formwork, pumped concrete	Medium	50-100 75-100	0.85-0.92	5-2
4. Trench Fill, In-Situ piling	High	100-150	>0.92	2-0
5. Tremie Concrete (Device lowered into water to deposit)	Very High	>150		

Process of Manufacture of Concrete

1. Batching (or) Measurement of materials

a) Volume Batching

It is an approximate method, Hence used for small jobs.

→ The volume of one bag of cement is taken as 35 litres. for agg proportion (But cement it always measured by weight. It is never measured in volume).

→ Wooden gauge boxes (called Farmas) are used for measuring F.A & C.A

For measuring 50 lit of aggregate, inner dimension of farma = 31 x 31 x 52 cm.

[Floor area of 1 bag of Cement = 0.3 m² & Height = 0.18 m]

b) Weight Batching

Strictly Speaking, weigh batching is correct method of measuring materials. Hence adopted for important concrete works.

[eg: For concrete mix of 1:2:4, the material req

50 kg (Cement) : 70 litres (F.A) : 140 litres (C.A) volume batching

50 kg (cement) : 100 kg (F.A) : 200 kg (CA) weigh batching]

2. Mixing

Concrete mixers are designed to run at a speed of 15-20 rev/min (Normal mix)

25-30 rev/min (well designed mix)

3. Trasporting

Concrete is transported by pumps for concreting of tunnel lining.

→ The concrete can be lifted by pumps through a maximum vertical distance of 50m.

→ While transporting by pumps the w/c should be 0.5 - 0.65.

4. Placing

→ Concret should not be drop from a height more than 1.5m. (IS 456)

→ placing of Concret start from width wise in RCC slabs from one end.

5. Compaction

Is the process adopted for expelling the entrapped air from the concrete.

a) Hand Compaction

Only adopted for small & unimportant works

b) Internal Vibrator (Also called Immersion (or) Needle (or) Pocker vibrator)

Consisty of a power unit, a Flexible shaft and a needle at end.

→ used for large sections of mass concrete work.

c) External vibrator (Also called Farm work (or) Shutter vibrator)

The vibration is given to the formwork so that the concrete in the vicinity of the shutter gets vibrated.

→ used for columns, lateral tie, & heavily reinforced sections & thin walls.

→ Care shall be taken for bleeding & Leakages.

d) Surface (or) Screed Board Vibrators

A small vibrator placed on the screed board gives an effective method of compacting & levelling of thin Concrete members.

→ Such as mostly, Floor slabs & roof slabs of thickness ≤ 15cm.

→ For slabs of > 15cm thickness " Double beam screed board vibrators" are may be used.

e) Table Vibrator

Concrete is so placed on the table, it can be vibrated.

→ These are commonly used in labboratories for making Cubes, Cylinders. etc.

Platform vibrator

Is nothing but a table vibrator, but it is large in size.

→ Used in the manufacture of large pre-fabricated Concrete elements such as electric poles, railway sleepers, roofing elements ... etc.

f) Vibratory Roller

A vehicle containing roller, which vibrates the Concrete.

→ Generally to compact the Base-Coarse of the road.

Note

→ Vibrators are most suitable for Low-medium workable Concrete.

→ For High workable Concrete it may lead to Segregate.

6. Curing

Concrete derives it's Strength by the hydration of Cement particles.

Note:

→ Cement req a w/c of 0.23 for hydration & 0.15 for filling the voids

→ Hence minimum requirement of w/c = 0.38

→ Although practically req of w/c = 0.50

→ By applying heat (it will accelerate the hydration) by keeping Concrete wet will results faster curing.

→ Concrete gains Strength upto 100% after the curing of 28 days.

~~7. Finishing~~

→ Concrete should be kept Constantly wet for at least

7 days → Normal OPC

10 days → Where admixtures or blended cements are used

10 days → Concrete exposed to dry & hot weather Condition

14 days → admixture + hot Condition.

7. Finishing

The results of ~~Curing~~ Finishing are good if Slump is about 50mm

a) Screeding : It is the levelling operation that removes humps & hollows and give a true and uniform Concrete Surface.

b) Floating : It is the process of removing the irregularities from the surface of Concrete left after Screeding.

c) Trowelling : It is the final operation of finishing the Concrete surface. It is performed where Smooth and dense surface is required, (1:4) mortar

8. Stripping of Formwork

→ Formwork shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking.

→ Forms shall not be released/removed until the concrete has achieved a strength of at least Twice the stress to which the concrete may be subjected at the time of removal of formwork.

Type of Formwork	Minimum period before Stripping.
a) Vertical formwork to Columns, walls & beams.	16-24 h
b) Soffit formwork to Slabs (props to be refixed immediately after removal of form work)	3 days
c) Soffit formwork to beams (props to be refixed immediately after removal of form work)	7 days
d) props to Slabs	
1) Spaning upto 4.5m	7 days
2) Spanning over 4.5m	14 days
e) props to beams & arches	
1) Spanning upto 6m	14 days
2) Spanning over 6m	21 days

Durability of Concrete

It is the property by which Concrete possesses same strength throughout it's life time without much shrinkage & cracking.

*) Factor affecting durability are W/c & Cement content.

→ Maximum Cement Content = 450 kg/m³

→ Minimum Cement Content = is based on Exposure Conditions.

Exposure Condition	Plain Concrete			Reinforced Concrete		
	Grade (min)	W/C (max)	Min Cement	Grade (min)	Max W/C	Min Cement
Mild	M15	0.60	220	M20	0.55	300
Moderate	M15	0.60	240	M25	0.50	300
Severe	M20	0.50	250	M30	0.45	320
very Severe	M20	0.45	260	M35	0.45	340
Extreme	M25	0.40	280	M40	0.40	360

→ above values are Specified for, Aggregate of 20mm Nominal max size.

→ +40kg/m³ → 10mm , −30kg/m³ → 40mm Should be adjusted for Cement.

Concrete Grades

Types of Concrete

1. Ordinary Concrete	$M_{10} - M_{20}$	→ Grade $\geq M_{30}$, rate of increase of compressive strength with age shall be based on actual investigation
2. Standard Concrete	$M_{25} - M_{55}$	→ Grade $> M_{55}$, fck will determined by specialized experimental results.
3. High strength Concrete	$\geq M_{60}$	

Mix proportion

a) Design Mix Concrete (For any Grade of Concrete)

b) Nominal mix Concrete $\leq M_{20}$ (may be used with the permission of Engineer-in-Charge, if design mix not needed)

Note:

→ For Nominal mix, proportion of F.A : C.A is generally 1 : 2, but subjected to an upper limit of 1 : 1½ & and lower limit of 1 : 2½.

→ Max size of aggregate for 1 : 1½, 1 : 2 and 1 : 2½ are 10mm, 20mm, 40mm respec

Type of Construction.	Minimum Grade
1. Lean Concrete bases	M5 + M7.5
2. plain concrete Cement (PCC)	M10
3. RCC general construction	M15
4. Water tanks, domes, Folded tanks.	M20
5. In sea water	M30 (RCC) M20 (PCC)
6. post-tensioned PSC	M30
7. pre-tensioned PSC	M40

Grade	Nominal mix (IS 456-1978)
M_5	1 : 5 : 10
$M_{7.5}$	1 : 4 : 8
M_{10}	1 : 3 : 6
M_{15}	1 : 2 : 4
M_{20}	1 : 1½ : 3
M_{25}	1 : 1 : 2