BUILDING MATERIAL AND CONSTRUCTION

(CLASS NOTES 2020)

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BUILDING MATERIALS

- Cement**
- Lime
- Aggregates
- Mortar
- Admixture
- Concrete*
- Bricks
- Stones
- Steel
- Timber**
- Miscelleneous

CEMENT:

* It is an artificial building material which imparts binding property in construction, that is being developed around (1824-25) by Joseph Aspedin.

* cement broadly consists of
  1) calcareous compounds (compounds having Ca, Mg)
  2) Argillaceous compounds (compounds having silica, Aluminium oxides)

Examples of calcareous compounds & Argillaceous compounds

a) limestones
b) cement Rocks
c) chalk
d) Marine shell
e) Marl
f) Alkali waste

a) clay
b) shale
c) slate
d) Ash

* Soundness: Resistance against Volume Change

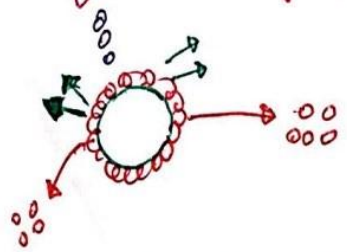
Different Constituents of OPC (Ordinary Portland cement)

(1) Lime (CaO): (62-67)%

* It imparts strength and soundness to the cement
* If it is in excess it makes the cement unsound, cause it to expand and finally disintegrate.
* If it is in deficiency, it reduces strength and causes the cement to set quickly.

$$CaO + H_2O \xrightarrow{\text{slaking}} Ca(OH)_2$$

V V'



(2) Silica (SiO_2): (17-25%)

* It also imparts strength to cement.
* If it is in excess, strength of cement increases but it also increase the setting time of cement.

(3) Alumina (Al_2O_3): (3-8%)

* It imparts quick setting property to the cement.
* It acts as a flux and helps in reducing clinkering temperature
* If it is in excess, it weakens the cement.

(4) Calcium Sulphate ($CaSO_4$): (3-4%)

* It is generally added in the form of gypsum. [$CaSO_4 \cdot 2H_2O$]
* It helps in increasing the initial setting time of cement.

(5) Iron Oxide (Fe_2O_3): (3-4%)

* It imparts strength, hardness and colour to cement.

(6) Magnesia (MgO): (1-3%)

It imparts strength, hardness and colour to cement, if it is in excess it makes the cement unsound.

(7) Sulphur (S): (1-3%)

Sulphur in cement is also responsible for volume changes in it there by leads to its unsoundness.

$Ca, Al + Mg, S \longrightarrow CaSA$

V V'

$V' > V$

(8) Alkali (Na_2O, K_2O): (0.2 to 1%)

* Alkalies in cement leads to efflorescence thereby cause the development stains over the surface of structure in which it is used for construction.
* Alkalies undergo expansive reactions with aggregates thereby leads to its disintegration.
* Alkalies also accelerate the setting of cement paste.

When all the ingredients of cements as mentioned above are intergrinded and burnt, they fuse with each other and lead to the formation of complex chemical compound termed as BOGUES COMPOUND which in actual are responsible for the properties of the cement.

BOGUES COMPOUNDS:

(1) Tri Calcium Aluminate $[3CaO \cdot Al_2O_3]$. [celite]. $[C_3A]$: [9-14%]

* It undergoes hydration within 24 hrs of addition of water into the cement, hence is responsible for flash setting of cement.
* It produces maximum heat during its hydration process thereby results in loss of wates added in cement for hydration, hence leads to the development of cracks over the surface during setting process moreover also reduces the strength by inhibiting complete hydration
* It also reduces the resistance of cement against the attack of sulphur.
* It is referred as harmful ingredient of cement.

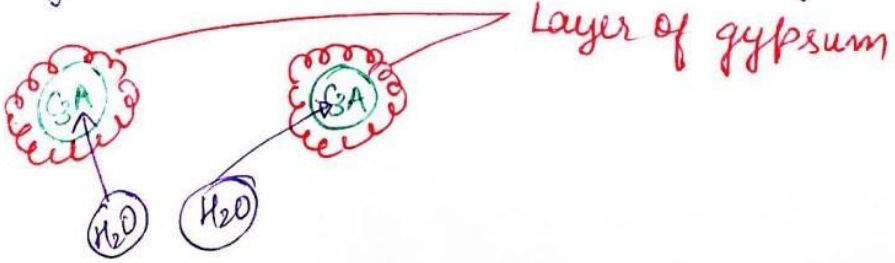
$$\underbrace{C_3A}_{V} + S \longrightarrow \underbrace{CSA}_{V'} \qquad V' > V$$

$$C_3A + MgSO_4 \longrightarrow C_3SA \qquad \boxed{V' = 227\,\% V}$$

V V'

Note: Flash setting means immediate or instant setting of the cement which takes place due to the presence of Alumina in cement.

In order to neutralise the instant setting of cement gypsum is added int it which from a layer over C_3A particles and avoids its interaction with water, but this is temporary and get removed easily. thereby has no effect on final setting time.



* water of crystallisation of gypsum vapourises either completely or partially during the manufacturing of cement, hence when water is added in cement, it first reacts with gypsum ~~and~~ to fulfil its water deficiency, during which it hardens and gives the impression of false setting of the cement which can be identified. by adding further more water into the cement.

(2) Tetra Calcium Alumina Ferrate $[C_4AF] \cdot [4CaO \cdot Al_2O_3 \cdot Fe_2O_3]$

Ferite: [10-18%]

* It also undergoes hydration within 24 hrs of addition of water into the cement, hence is responsible for flash setting of cement.

Rate of hydration $[C_4AF > C_3A]$

* It also reduces the resistance of cement against the attack of Sulphur.
* It is observed to have worst cementing property amongst all the Bogues compounds.
* ~~It also reduces the~~
* It has no engineering use as it does not impart any property to the cement.

$$\underset{V}{C_4AF} + MgSO_4 \longrightarrow \underset{V'}{C_4ASF} \qquad [V' > V]$$

* Attack of sulphur on C_4AF is comparatively less than on C_3A due to the presence of 'Fe' in it.

(3) Tri Calcium Silicate [$3CaO.SiO_2$] [C_3S] Aelite [45-65%]

* It undergoes hydration within a week or two after the addition of water in cement and hence is responsible for development of early strength.

Note: If in any construction early strength is required proportion of C_3S is increased as in:

- Pavement construction
- Prefabricated structures
- Cold weather concreting
- Where framework is to be used for speedy construction

* It is observed to have best cementous property amongst all bogues compounds
* It also increases resistance of cement against frost action [freezing and thawing] or melting.
* In real term its effect on heat of hydration is more than C_3A.

$$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H \text{ (Gel)}$$

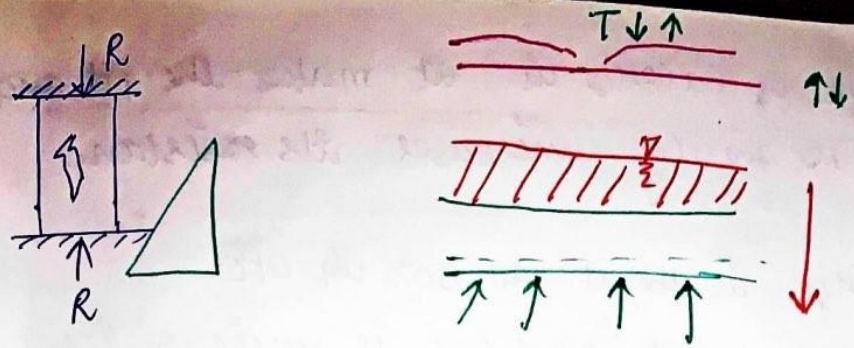
$$C_3S + H_2O \longrightarrow C\text{-}S\text{-}H + Ca(OH)_2$$
(Gel)

S-silica

C-S-H Gel: Cementous comp. possessing binding property.

C-S-H Gel: Calcium Silicate Hydrate Gel also known as thomsohydrite Gel. (also known as tobermorite gel)

$Ca(OH)_2$: released during hydration reduces the tendency of corrosion in reinforcement.



(4) Dicalcium Silicate ($2CaO.SiO_2$) (C_2S) (Belite) (15-35%)

* It undergoes hydration within a year or so after the addition of water into the cement. hence is responsible for the ultimate or progressive strength in cement.
* It also increases the resistance of cement against the attack of chemicals and acids.
* If in any construction progressive strength is required, proportion of C_2S is increased.

eg: hydraulic structure: Dams, weirs, Barrages, Bridges etc.

$$C_2S + H_2O \longrightarrow C\text{-}S\text{-}H\ (Gel) + Ca(OH)_2$$

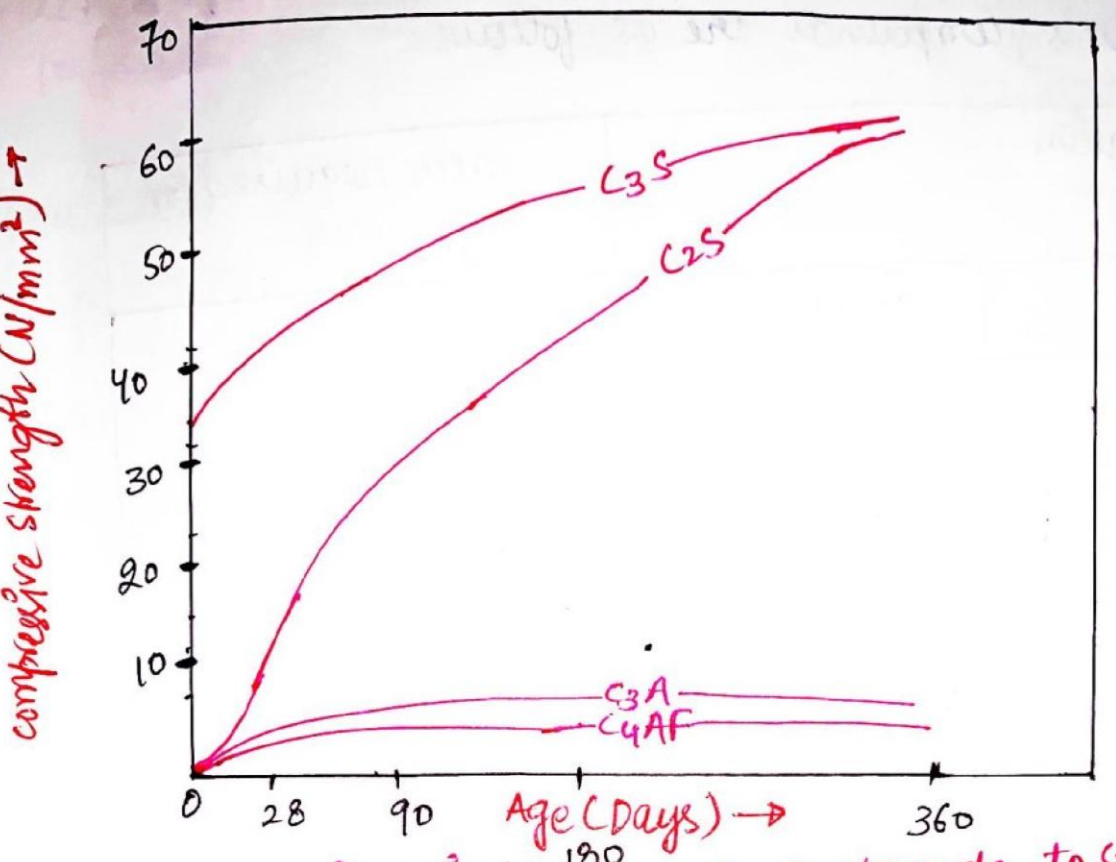
$$C_2S + H_2O \longrightarrow C\text{-}S\text{-}H\ (Gel) + Ca(OH)_2$$

(Cementous compound)

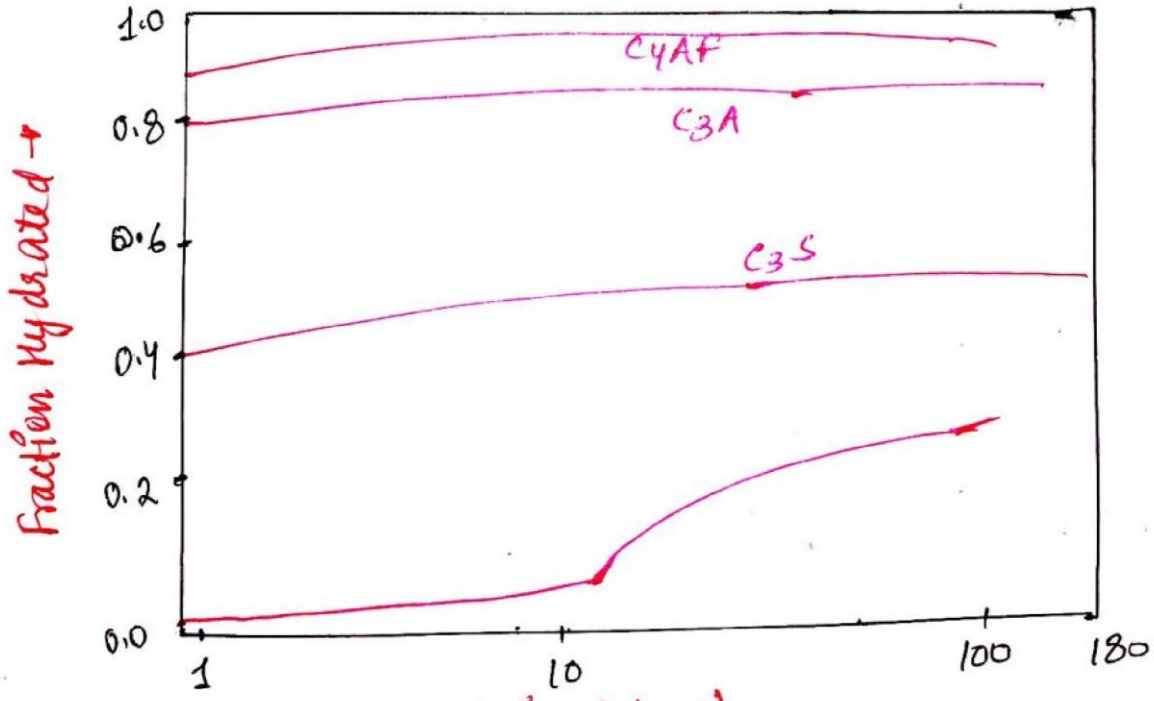
Note: It has been found that hydration of C_2S produces comparatively lower calcium hydroxide $Ca(OH)_2$ than C_3S.

* Since $Ca(OH)_2$ is soluble in water and leaches out (to drain out) making the concrete porous particularly in hydraulic structures, thereby reduces the durability of concrete.
* $Ca(OH)_2$ also reacts with sulphate present in water or soil and leads to the formation of $Ca(SO_4)$ which further reduces the durability of cement (By attacking C_3A and C_4AF)

* The only advantage of $Ca(OH)_2$ is, it makes the PH of concrete around 13 thereby increases its resistance against corrosion.
* Leaching of $Ca(OH)_2$ is about 20-30% in OPC.
* Hence % of C_3S is reduced and C_2S is increased for cement to be used in Hydraulic structures.
* Rate of setting in cement is regulated by adjusting the proportion of $\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$
* Binding Property : $C_3S > C_2S > C_3A > C_4AF$
* Rate of Hydration : $C_4AF > C_3A > C_3S > C_2S$



Contribution of cement compounds to strength of Cement



Rate of Hydration of Pure cement compounds

→ Heat of Hydration and water required for hydration for different Bogue's compounds are as follows:

	Heat of Hydration		water required for hydration
	3 days	90 days	
C_3A	210	310	≃ 20
C_4AF	70	100	≃ 20
C_3S	60	105	≃ 24
C_2S	10	40	≃ 21

Heat of Hydration

$C_3A > C_3S > C_4AF > C_2S$

Water Required for Hydration

$C_3S > C_2S > C_3A \simeq C_4AF$

Total Heat of Hydration of OPC

$H = aA + bB + cC + dD$

a, b, c, d = proportion of Bogues compound

A, B, C, D = Heat of Hydration of respective Bogues compound

100gm (OPC) = $C_3A + C_4AF + C_3S + C_2S$

= (10%) + (15%) + (40%) + (35%)

10gm 15gm 40gm 35gm

Total Heat of Hydration for 3 days = (210 × 10) + (70 × 15) + (60 × 40) + (10 × 35)

(210 × 10) → 2100

(60 × 40) → 2400

Total water Required for Hydration

$$W = aP + bQ + cR + dS$$

P, Q, R, S → water Requirement

* Heat of Hydration of OPC at the stage of 7 days is 89-90 cal/gm and at the age of 28 days 90-100 cal/gm.
* Approx 23% of water by weight is required for complete hydration of cement.
* About 15% of water added in cement gels entrapped in the voids of cement particles and is not available for hydration.
* Hence total of 38% of water by weight of cement is required to be added for complete hydration.
* water added in cement occupies or assume any of the following forms:

(1) **Combined water:** It is the water which is chemically combined with the products of hydration and is unevaporable (23%)

(2) **Gel water:** It is the water which is adsorbed over the surface of cement particles and is not available for hydration (15%).

(3) **Capillary water:** It is the water which occupy capillary pores and is easily evaporable.

Note: Specific Gravity of cement = 3.15 $\left(\frac{\gamma_{cs}}{\gamma_w} \rightarrow \text{cement solid}\right)$

Mass specific gravity of cement = 1.5 $\left(\frac{\gamma_c}{\gamma_w}\right)$

Mass of one bag of cement = 50 kg

Volume of one Bag of cement = 34.7 litre

$\frac{w}{c} = 0.5 \Rightarrow w = 0.5c$

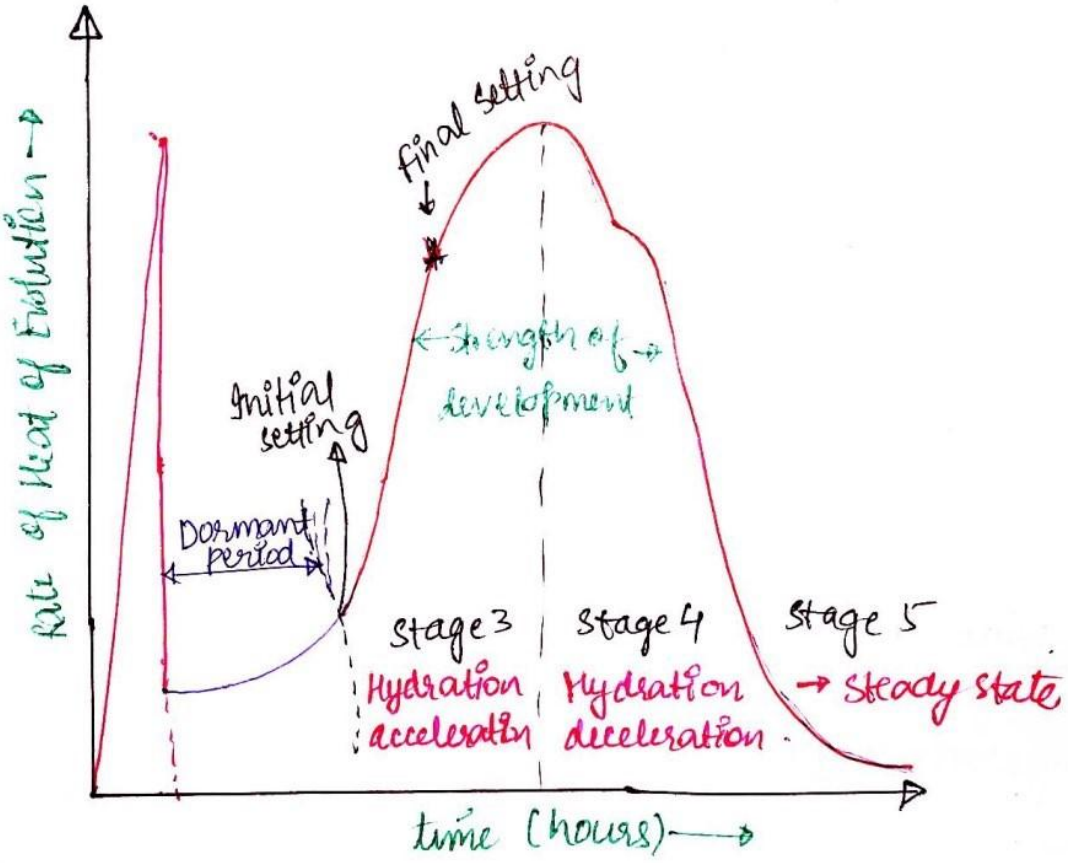
$= 50\%$.

(23) (15) (12)

combined Gel capillary

$\rho_c = 1500 kg/m^3$.

Density of cement $(\rho_c) = \frac{50}{34.7 \times 10^{-3}} = 1440 kg/m^3$



Hydration Curve of cement

Q1. A 28-S type mixer has a capacity of $10m^3$ with working efficiency of 80%. $1m^3$ of concrete requires 5.5 Bags of cement. Compute the volume of concrete to be mixed per Batch in order to avoid fractional use of cement Bag.

Soln. 28-S type mixer → $10m^3$ (capacity)

28-S type Mixer ⟶ $0.8 \times 10 = 8m^3$ (operating capacity)

$1m^3$ of concrete requires 5.5 Bags of cement

$8m^3$ of concrete requires $= 5.5 \times 8 = 44$ bags of cement

Volume of concrete to be mixed per batch $= 8m^3$

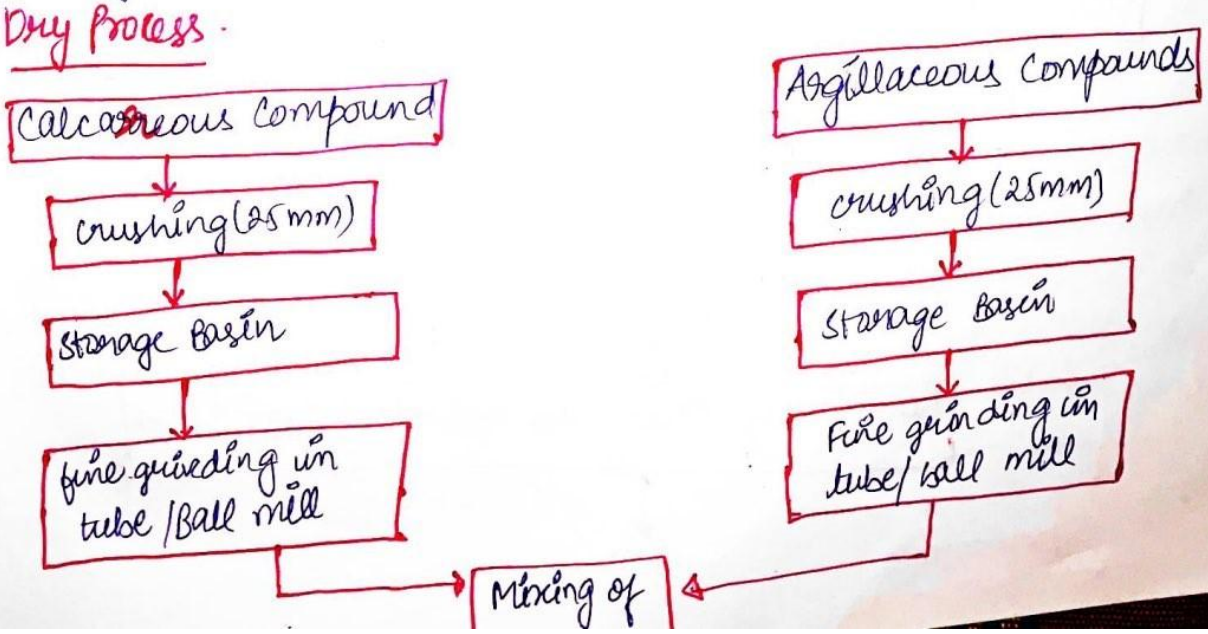
MANUFACTURING OF CEMENT

* Manufacturing of cement is done in following sequence of operation.

1) Mixing of raw ingredients
2) Burning
3) Grinding

* Manufacturing of cement can be done by any of the following methods.

(1) Dry Process.



raw ingredients in corrected proportion.

↓

Pre heating at 800°C by exhaust gases

↓

Storage of raw mix

↓

Fed to rotatary kiln (1400-1600°C)

↓

cement clinkers are formed.

↓

Fine grinding in tube/ball mill (Here gypsum is added)

↓

cement silos

(2) Wet Process

Calcareous compounds

↓

crushing 25 mm

↓

Storage Basin

Argillaceous compounds

↓

~~crushing (25mm)~~

Wash mill

↓

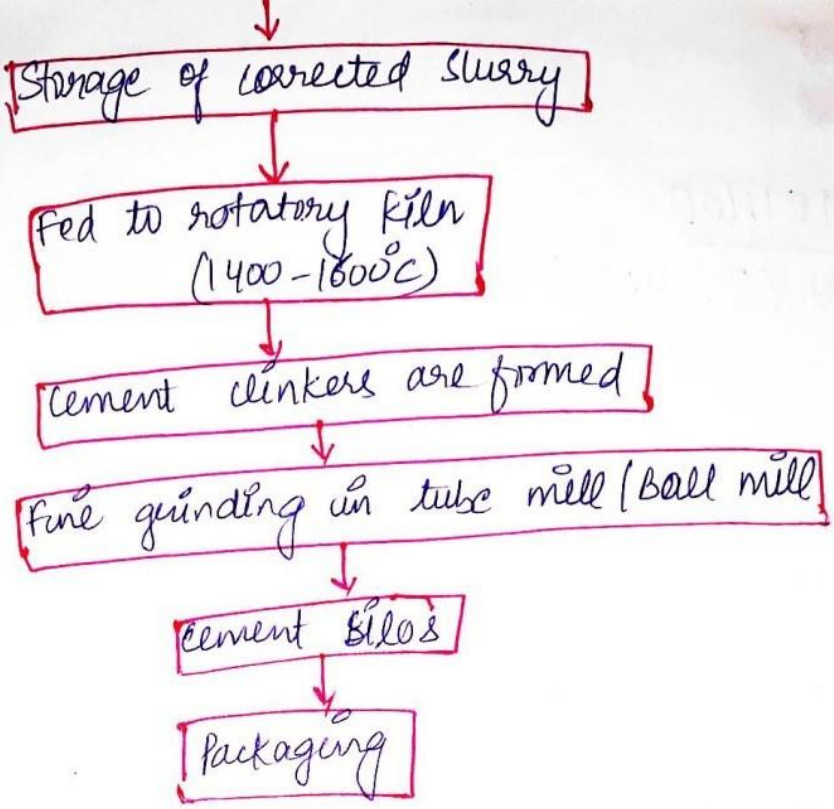
Storage Basin

Fine grinding in tube/ball mill to form the slurry

↓

Blending of slurry to corrected proportion

↓



* The chief advantage of wet process are the low cost of excavating and grinding raw material (as dry process is used for ~~grinding~~ hard raw materials)
* Accurate control of composition and homogenity of the slurry.
* Economical utilisation of fuel through the elimination of separated drying operations.
On the other hand it utilises longer kilns and more fuel for burning and are less responsive to a variable clinker demand.

#TESTING OF CEMENT

* Testing of cement is being carried out in order to check its engineering properties and performance when used for construction.
* Testing of cement can be done by any of the following methods:

(1) Field Method
(2) Lab Method

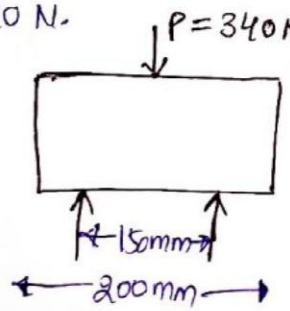
(1) FIELD METHOD

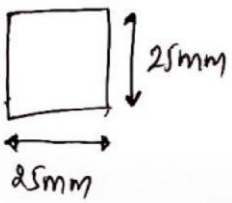
Physical Test (IS:4031)

1) The given sample of cement under test must posses uniform grey colour.
2) The given sample of cement under test must feel smooth when rubbed in between the fingers.
3) The given sample of cement under test must be free from presence of air set lumps
4) The given sample of cement under test should sink and not float when thrown in bucket of water.
5) The given sample of cement under test must feel cool and not warm.
6) A thin paste of given sample of cement should feel sticky in between the fingers.
7) A thick paste of cement over glass plate when immersed in water for 24 hrs, must set and should not show any sign of cracks.

Strength Test

1) Prepare a block 25 x 25 x 200 $(mm)^3$ for the given sample of cement and immerse it in water for 7 days. Remove the sample from water and placed over the supports 150mm apart.
The given sample of cement must not show any sign of failure when subjected to centre point load of 340 N.





LAB TEST.

1) Fineness Test (IS: 4031)

This test is performed in order to check the extent of grinding of the cement, which in turn controls rate of hydration that governs:

1) Rate of gain of strength
2) Rate of setting
3) Rate of Pre-hydration.
4) Rate of Evolution of Heat
5) Rate of Aggregate's alkalis reaction

→ Fineness of cement can be found by any of the following methods.

(1) Sieve Test: (IS: 4031 - Part 1 - 1996)

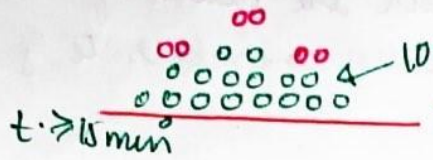
* In this test 100 gm of cement sample is placed over IS sieve Number 9 (90m) and sieving is done continuously for at least 15min. along the breaking of air set lumps.
* weight of residue left over the sieve is then noted.
* for OPC weight of residue retained over the sieve must not exceed 10%.

(2) Air Permeability Test: (IS: 4031 - Part 2 - 1998)

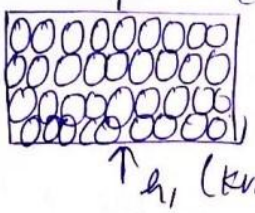
* The principal of this test is based upon the relationship between flow of air through the bed of cement particles and surface area of particles forming the cement bed.
* Generally BLANE's Air Permeability's Apparatus is used in this case.
* The fineness of cement as reported in terms of

parameter termed as "specific surface Area" i.e. S.A. per unit weight.

* For OPC, SSA ≈ 2250 cm^2/gm.



CI 75M CII 80M



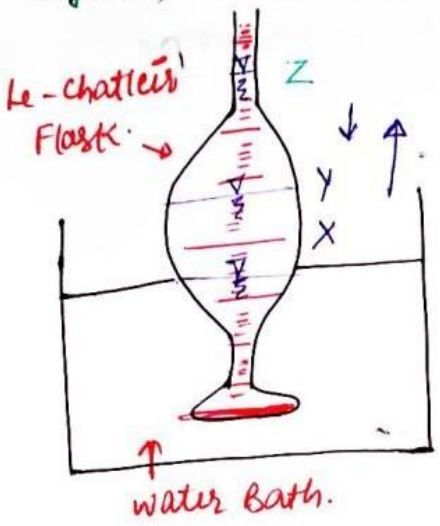
$h_2 = h_1 - h_2 \propto SSA \propto \frac{1}{d}$

$h_L \propto SSA \propto \frac{1}{d} \propto$ Grinding

(2) **Specific Gravity Test** (IS: 4031 - Part II - 1988)

* This test is performed to find specific gravity of the cement.
* In order to perform this test 'LeChatlier's Flask is placed in constant temperature water bath and non-polarising liquid like kerosene and Napthalene is added in it & level in the flask is noted as (X).
* 64gm of cement is then added in the flask and the air in it allowed to escape by continuously rolling the flask.
* For OPC $G = 3.15$
* Level of liquid in the flask is again noted (Y) to find the specific gravity of cement as follows:

64gm (Mc) → ← Kerosene / Naphthalene.



$V_K = Z - X = V_C$

$V_K = Y - X = V_{CS}$ (cement solid)

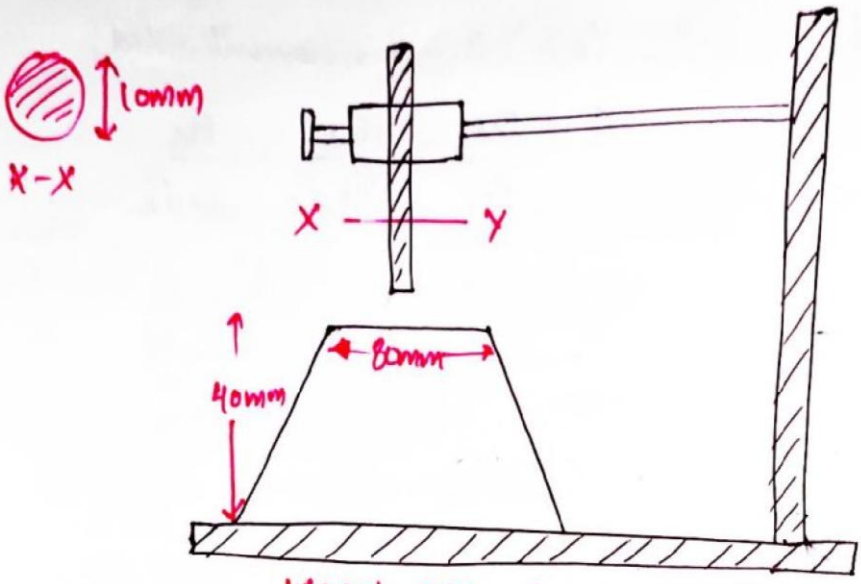
$$G' = \frac{\rho_{CS}}{\rho_K} = \frac{M_{CS}}{V_{CS}\rho_K} = \frac{M_C}{V_{CS}\rho_K}$$

$$\boxed{G = G' G_K}$$

(3) Consistency Test : (IS : 4031 - Part 4 - 1988)

* In order to find initial setting time, final setting time, strength and soundness of cement and parameter termed as standard consistency is required.
* "Standard Consistency" is defined as consistency of cement paste, which permits "VICAT APPARATUS" of dia 10mm and height 50mm to penetrate in the mould, upto the depth of 33-35mm from top or (5-7 mm) from bottom.
* This test is performed at temperature of $(27 \pm 2^{\circ}C)$ and humidity $(65 \pm 5)\%$
* The purpose this test is to find water content required to prepare cement paste of standard consistency.
* In order to perform this, 500 gm of cement sample is mixed with 24% of water by weight in the first trial and the paste formed is filled in the mould and the depth of plunger in mould is recorded / noted.

* Test is repeated at different water content up to an extent penetration of 33-35mm from top is observed.
* This water content is recorded and is termed as "P".



VICAT's Apparatus

W(%)	h(mm)
24	20
26	25
27	30
⋮	⋮
(P)	~~33~~ 33-35

(4) Setting Time Test: (IS:4031-Part 5-1988)

* This test is performed to check the ~~det~~ extent of deterioration of quality of cement during storage.
* Setting Time of cement is classified as:
(1) Initial setting Time (2) Final setting Time.

(1) Initial setting Time:

It is measured from the instant water is added into the cement upto time it starts loosing its plasticity and final setting is referred as the

time, which is measured from the instant ~~value of~~ water is added into the cement upto the extent; it completely looses its plasticity and attain sufficient firmness to resist definite loading.

* There is no clear demarkation between initial and final setting time.
* In order to perform this test, 500 gm of cement sample to be tested is mixed with "0.85P"

  P = water content required to prepare the paste of standard consistency and paste formed filled in VICAT MOULD
* Initial setting time is referred as the time in this test in which square needle of size '1mm' penetrates into the mould by distance of 33-35mm from top and 5-7 mm from bottom
* And final setting time is referred as the in which needle at the centre of annular collar is able to make the impression over the mould, but annual collar fails to do so.
* For OPC initial setting time is 30mins and final setting time is 600 mins (10hrs)

Type of Test	Type of Rod	Size (mm)	X-X
Consistency	Plunger	10	◯
Initial Setting Time	Square needle	1	▨
Final Setting Time	Annual Collar with needle 	5	⊙

t	h(mm)	
5min	35	x
30min	31	x
2hr	5	x
5hr	1	x
7hr	0	✓
9hr	0	x
10hr.	0	← (Final setting Time)

Note: Temperature during performing of this test is 27±2°c and humidity during proportion of mould is 65±5% and during test in laboratory is 90%.

	I	II
Initial	1month ↓	3month ↑
Final	↑	↓

(5) Strength Test

* This test is performed to find resistance of cement against gradual loading (strength).
* It can be determined by any of the following methods:

(1) Compressive Strength Test : IS:4031-Part 6-1988

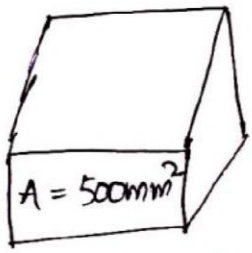
* This test is performed to find compressive strength of cement.
- In order to perform this test, mortar of cement and standard sand (Ennore sand) in proportion of 1:3 is prepared.
  (185 gm of cement and 555 gm of sand is used)
* Water in the proportion of $\left(\frac{P}{4}+3\right)\%$ by weight of mortar is added in it.
* Paste formed is then filled in cubical mould of area 5000 mm^2.

* The sample is then immersed in water for sufficient duration (to carry out curing).
* At specified age of testing sample is removed from water and subjected to gradual compressive load of 35 N/mm²/min upto failure in Universal Testing Machine.
* An average of 3 sample is taken as compressive strength having maximum deviation of ± 10%.

C:S = 1:3 [185 gm : 555 gm] + $\left(\frac{P}{4}+3\right)$%

$\left(555+185\right)\left(\frac{35}{4}+3\right)$%

mortar.



d = 70.710678 12

d = 70.7, 70.8, 70.9

OPC 33
OPC 43
OPC 53

Age	3 days	7 days	28 days.
Strength Factor	0.5 (50%) (½)	70% (0.7) 2/3	100% (1) 1

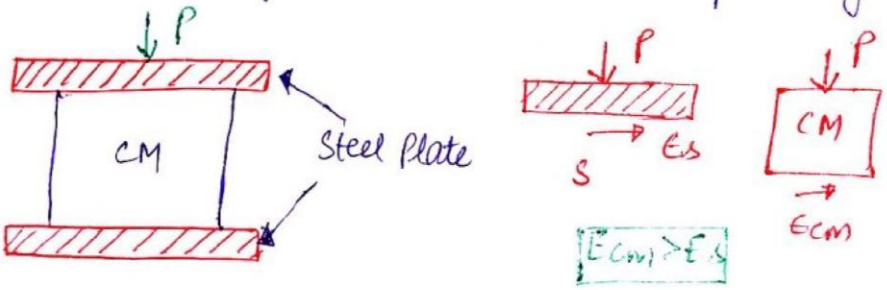
compressive strength (N/mm²)

Age	OPC 33	OPC 43	OPC 53
3 days	16	23	27
7 days	22	33	37
28 days	33	43	53

* IS 10262 has classified OPC gradewise - from A to F on the basis of 28 days compressive strength. as follows:

Category	Strength (MPa)
A	32.5 - 37.5
B	37.5 - 42.5
C	42.5 - 47.5
D	47.5 - 52.5
E	52.5 - 57.5
F	57.5 - 62.5

Note: Accordingly 33, 43, 53 grade of cement corresponds to categories A, C and E respectively.



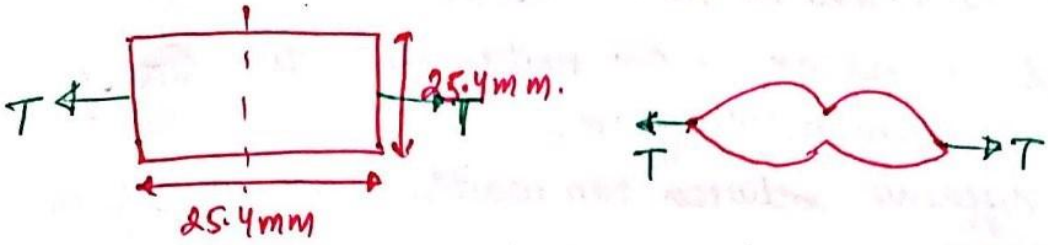
$\epsilon_s < \epsilon_s' = \epsilon_{cm}' < \epsilon_{cm}$

(2) Tensile Strength Test

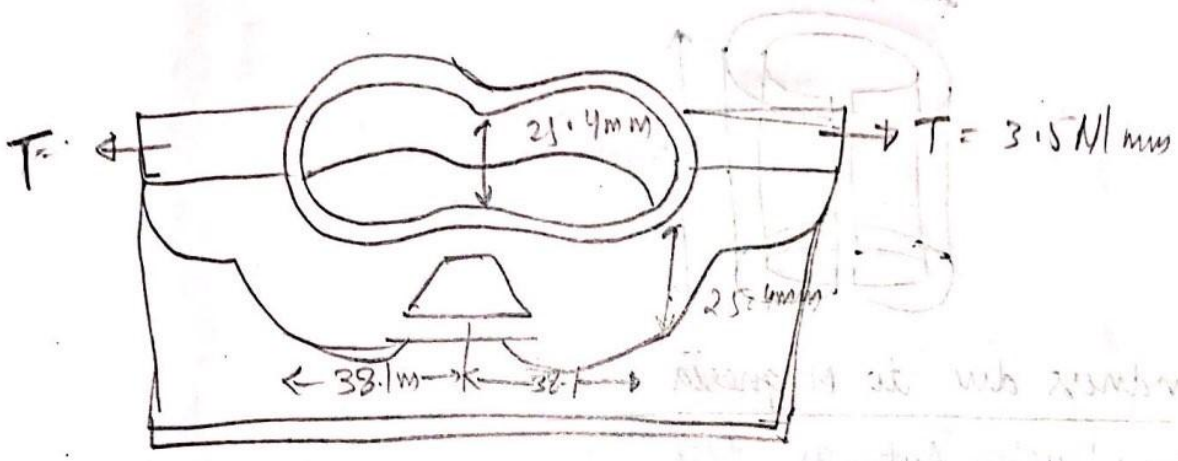
* This test is performed to find the tensile strength of cement.
* In order to perform this test mortar is prepared same as above, with the only difference that water is added in this case is $\left(\frac{P}{5} + 2.5\right)\%$ by the weight of mortar.
* The paste formed is filled in the standard briquette and uniform gradual tensile stress of 3.5 N/mm²/min.

is applied upto failure.

* An average of 12 results is taken as tensile strength.



$$\text{Tensile strength} = \frac{T}{25.4 \times 25.4}$$



(6) Soundness Test: IS: 3535-1986

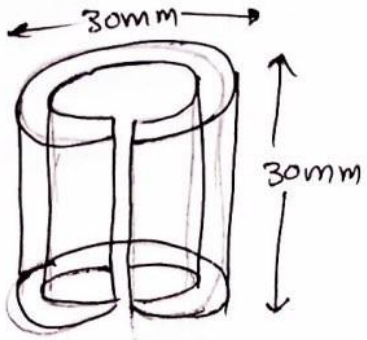
* This test is performed to find the extent of volume changes in cement during hydration.
* unsoundness in cement is due to lime, sulphur and magnesia.

(i) Unsoundness due to Lime

* unsoundness due to lime is found using "Le-Chatlier's test" which consists of split cylinder of dia and height of 30mm and indicator arms of length 165mm.
* In order to perform this test 100gm of sample cement is gauged with 0.78P and the paste formed is filled in the cylinder observed from top and bottom with glass plate. The entire assembly is immersed in water at temperature of 27 - 32°C for 24 hours and size of the split is noted. (x-mm)

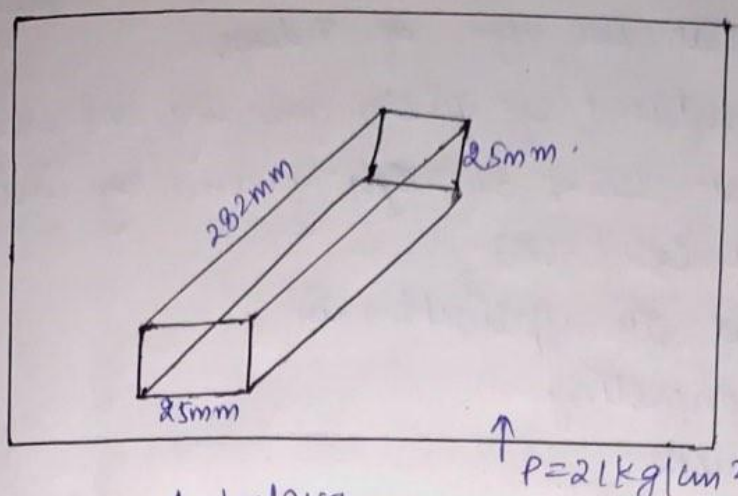
* The assembly is again immersed in water, temperature of which is increased up to its boiling point in 25-30 min and maintained for next 3 hours.
* The sample is removed from water and the size of the split is again noted (y mm)
* for OPC, difference between two readings i.e, $y - x \not> 10mm$

$y - x \not> 10mm$ → must not exceed.



(2) Unsoundness due to Magnesia

* It is found using "Autoclave test"
* This test is sensitive to both unsoundness due to lime and magnesia.
* In this test a block of 25mm x 25mm x 282 mm is prepared from the given sample of cement and is placed in autoclave.
* Steam pressure in the autoclave is then raised at such a rate that gauge P of 2.1 kg/cm² is attained in one hour and is maintained for next 3 hours.
* The sample is then removed from the autoclave and allowed to cool off and then is tested for its size.
* For OPC, increase in size of any side must not exceed 0.8%.



Autoclave

(7) Chemical Composition Test: IS:4032

* Total Magnesia ≯ 5%
* Total sulphur content ≯ 2.5%
* The ratio of percentage of alumina to that of Iron oxide must not be less than 0.66.
* Total loss on ignition ≯ 4%
* Total weight of insoluble residue ≯ 1.5%
* The ratio of percentage of lime to that of silica, alumina and Iron oxide (Lime saturation facts) LSF must not be less than 0.66 and greater than 1.02.

$$1.02 \not< \frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3} \not< 0.66$$

SPECIAL TYPE OF CEMENT

(1) Rapid Hardening Cement (IS:8041)

* It is the type of cement, which attains higher rate of gain of strength in comparison to OPC. and must not confuse with quick setting cement that only sets quickly.

* The strength of the cement at the age of 3 days is equal to strength of OPC at the age of 7 days.
* This cement is produced by finely grinding the cement clinker such that SSS ≥ 3250 cm²/g and by increasing the proportion of C_3S (56%)
* This cement find its application in
(1) cold weather concreting
(2) Pavement construction
(3) Prefabricated structure
(4) where formwork is to be reused for speedy construction.

Properties:- Initial setting Time – 30 mins (min)
Final setting Time – 10 hrs (max)

Compressive strength

1 Day	16 N/mm²
3 Day	27.5 N/mm²

* This cement also offers high resistance against frost action.
* Its cost is approximately 10% more than OPC.
* It is subjected to higher shrinkage and the water requirement for workability is also more.
* It requires addition of little more quantity of gypsum during manufacturing to counter higher rate of setting.
* It has higher percentage of C_3S than that in OPC.
* The percentage of C_3S is maximum and is of the order of 50%.

(2) Extra Rapid Hardening Cement

* It is the type of cement which attains higher rate of gain of strength than Rapid Hardening Cement.
* The strength of cement at the age of one day is 25% more, at the age of 7day is 10-15% more than RHC.
* This rate of gain of strength decreases with time and the strength of cement at the age of 90 days is same as that of RHC and OPC.
* The cement must be mixed transported placed, compacted, and finished within 20 mins of addition of water in it.
* The cement is produced by grinding the RHC clinker with 2% of $CaCl_2$ [accelerator (admixture)]
* Its application is same as of RHC

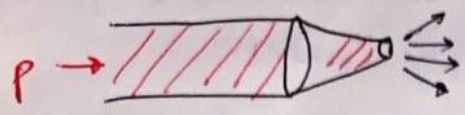
(3) IRS · T-40 Cement

* It is also a special type of cement, manufactured by by Indian railways to be used for construction of railway sleepers.
* It is produced by finely grinding the cement clinkers and increasing the proportion of C_3S.

(4) Quick setting Cement:

* It is the type of cement which looses its plasticity comparatively earlier than OPC but does not attain any early strength.
* This cement is produced by increasing the proportion of Alumina and reducing the proportion of gypsum.
* This cement find its application in under waters construction and in grouting operation (pressurised application of cement)

Properties: IST = 5mins
FST = 30mins.



(5) Low Heat Cement (IS:12600)

* It is the type of cement which evolves low heat of hydration than OPC.
* Heat of hydration of this cement at the age of 7 days is not more than 65 cal/gm and at the age of 28 days is not more than 75 cal/gm.
* This cement is produced by reducing the proportion of C_3S, C_3A and increasing the proportion of C_2S (to compensate the lost strength on account of reducing C_3S)
* The cement offers higher resistance attack of sulphur and lower rate of gain of strength.
* This cement finds its application in mass concreting works. eg: hydraulic structures, foundation
* compressive strength of this cement at the age of

  3days ≯ 10 N/mm²
  7days ≯ 16 N/mm²
  28days ≯ 35 N/mm²

* when tested by Le-Chatlier method and auto clave test, the expansion must not be more than 10mm and 0.8% respectively.
* Min IST ≯ 60 mins
* FST ≯ 600 mins
* It preserves the form of brick at higher temperature and prevents shrinkage.

* This cement has low rate of hardening.

(6) Hydrophobic cement :- (I.S: 8043)

* It is the type of cement which do not reacts with water on its own.
* This cement is produced by intergrinding cement clinkers, with water repellent film forming substances like stearic and oelic acid.
* This cement find its application where extreme environmental condition prevail e.g. coastal area, hilly areas and high storage period.

Note: In todays time almost every cement is coated with this water repellent film.

* Specific surface Area of Hydrophobic cement ≯ 3500 cm^2/g and average compressive strength should not be less than

3days ≯ 15.5 N/mm^2
7days ≯ 21.5 N/mm^2
28days ≯ 31.5 N/mm^2

* The weak point of the cement is its small strength during initial period because of hydrophobic film on cement grains but strength at the age of 28 days is same that of OPC.

(4) Sulphate Resisting Cement (IS: 12330)

* It is type of cement which offer high resistance to the attack of sulphate than OPC
* This cement is produced by integrating intergrinding cement clinkers such that proportion of lime and alumina is reduced in it thereby.
  - C_3A ≯ 5%, $2C_3A + C_4AF$ ≯ 5%.
* This cement finds its application, where ever the chance of attack of sulphur on cement is more.
  1. Sewarage System
  2. Foundation work
  3. where concrete pipes are to be laid in marshy areas
  4. Marine construction
  5. canal works (Lining of canals)
* Its compressive strength should be as follows:

  3 days ≮ 10 N/mm²
  7 days ≮ 16 N/mm²
  28 days ≮ 33 N/mm²

* It should have fineness 4000 cm²/gm. The expansion of the cement is limited to 5mm
* The IST and FST is same as that of OPC
* Lower content of C_3A than that in OPC.
* ~~Percentage of C_3~~
* Percentage of C_3S and C_2S are same and of the order of 40%.

(8) Super Sulphated Cement : (IS:6909)

* It is a type of cement which offers higher resistance to the attack of sulphur than sulphate resisting cement, but must not be confused with sulphate resisting cement.
* This cement is manufactured by intergrinding (80-85%) granulated blast furnace slag, (10-15%) hard burnt gypsum, 5% of cement clinkers.
* Application of this cement is same as that of sulphate resisting cement.
* This cement can also be produced by increasing the Ferric Oxide, which has higher resistance against the attack of sulphur.
* compressive strength should not be less.

  3days ⩾ 15 N/mm²
  7days ⩾ 22 N/mm²
  28days ⩾ 30N/mm²

* It should have fineness of 4000 cm²/gm. The expansion is limited to 5mm and setting time is same as that of OPC.

(9) Portland Slag cement : (IS: 455)

* The cement is produced by intergrinding cement clinkers, hard burnt gypsum and granulated blast furnace slag in specified proportion
* This cement offers (a) higher resistance against the attack of sulphur and chlorides
  (b) Better refinement of pore structures
  (c) Low heat of hydration
  (d) Low Cost

* The chemical requirement of this cement is same as that of 33 grade of cement.
* Specific surface Area ≥ 2250 cm^2/gm, expansion is limited to 10mm and 0.8% respectively.
* This cement find its application in mass concreting i.e. Dams and foundations

(10) Portland Pozzolona cement (IS:1489-Part 1)

* This cement is produced by intergrinding the cement clinkers with 10-15% of pozzolonic material.
* Pozzolonic material is essentially silicious or aluminous compound which in itself do not possess any binding property, but when finely grinded reacts with lime released during the hydration of cements and results in the formation of a compound possessing binding property.

eg: Blast furnace slag
Fly ash
Silica fumes
Rice Husk Ash
Slate
Surkhi

$$\underset{\text{(Si, Al)}}{\text{Pozzolonic material}} + Ca(OH)_2 + H_2O \longrightarrow \underset{\text{(Gel)}}{\text{C-S-H}}$$

(tobermolitegel)

(Non cementous compounds) (cementous comp)

* This cement offers:
  - Higher water tightness
  - Low heat of hydration.

- Low cost
- Higher resistance against chemical attacks (Chloride & Sulphate)
- Higher resistance against volume changes
- Slower rate of gain of strength.

compressive strength

3 days	16 N/mm²
7 days	22 N/mm²
28 days	33 N/mm²

* Fineness should not be less than 3000 cm²/g
* IST and FST same as that of OPC.
* It finds its application in mass concreting.

(II) High Alumina Cement: (IS: 6452)

* It is not a type of portland cement.
* It is manufactured by fusing 40% of Bauxite, 40% of lime, 15% of Iron oxide with a little silica, magnesia at a very high temperature.
* The alumina content should not be less than 32% and ratio of alumina to that lime is 0.85–1.35
* The resultant product is finely grinded.
* The main ingredient is monocalcium aluminate (CA) which reacts with water to form di calcium octahydrate hydroaluminate.

$$2(CaO \cdot Al_2O_3 \cdot 10H_2O) + H_2O \longrightarrow 2CaO \cdot Al_2O_3 \cdot 8H_2O + 2Al(OH)_2$$

* The dicalcium hydroaluminate gel consolidate and hydration products crystalise.
* The rate of consolidation and crystallisation is high leading to rapid gain of strength.

* Since, C_3A is not present, it has good resistance against sulphur and has high initial setting time.
* Its.

IST	is upto 3.5 hrs
FST	is upto 5 hrs

* It attains 20% of ultimate strength in 24 hours and substantial strength in 6-8 hours.
* It has high resistance against attack of chemical and acids.
* It offers high resistance against high temperature.
* compressive strength

1 day	30 N/mm²
3 days	35 N/mm²

* After setting and hardening $Ca(OH)_2$ is not reached as in case of OPC hence has higher durability.
* SS ≤ 2250 cm²/gm. (fineness)
* Expansion should not be more than 5mm.
* It finds its application in precasting, refractory concrete in industries

(12) Masonary Cement (IS:3466)

* The Portland cement clinker is grounded and mixed intimately with pozzolanic material (fly ash, calcined clay) or non pzzolanic material (lime stone, dolomite) and waste material (carbonated sludge, mine tailings), and admixtures if required.
* The physical properties of this are as.

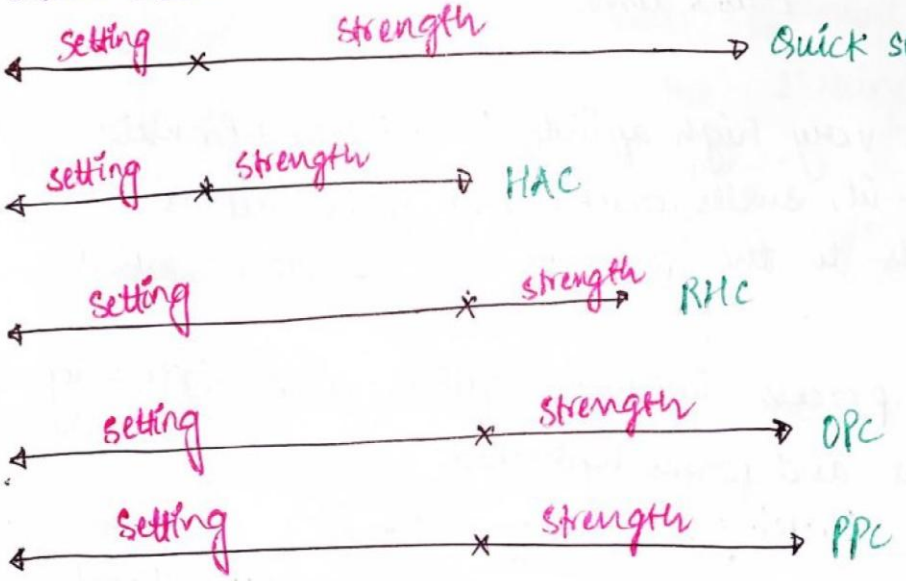
- fineness
* Setting Time: IST: 90mins, FST - 24hours
* Soundness: expansion 10mm, 1% respectively

* Compressive strength *

7 days	22.5 N/mm²
28 days	5N/mm²

(18) White and Coloured Portland Cement (IS:8042)

* It is manufactured from pure chalk clay and clay free from iron oxide
* Iron oxide impart colour into the cement so it is reduced below 1%.
* Coloured cement are made by adding 5-10% coloured pigments.
* This cement have property same as that of OPC and are non staining. because low amount of soluble alkalies.
* Its strength is approximate 90% of that of OPC.
* It is used for terazzo flooring works, face plaster of the walls (stucco), ornamental works, casting stones.

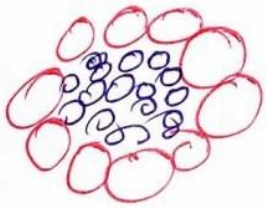


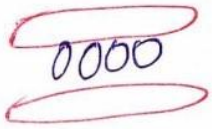
(19) Selentic Cement

It is the type of cement in which 1.5-10% of plaster of paris has been added to increase its hardening process.

(15) Air Entraining Portland Cement

* It is a special type of cement which has air bubbles introduced in it.
* It is highly resistive towards frost action in cold environment.
* Due to low temperature, water in the cement freezes and expands that causes development of cracks in it. This can be resisted by the action of air bubbles entrapped in the cement.
* Entrained Air Bubbles also helps in reducing the unit weight of construction and increases its workability and durability





Drawback: Its strength is comparitively lower than that of OPC.

(16) Calcium Chloride Cement or Deliquescent Cement

* It is also known as extra rapid hardening cement and is made by adding 2% of $CaCl_2$.
* Since it is deliquescent, it is stored under dry conditions.
* Properties: Rate of strength development is accelerated.

* Strength gained after 1day is 25% more and after 7 days about 20% more than the OPC.

Uses:- It is suitable for very cold weathers.

LIME

* Prior to introduction of cement as binding material lime was used for the same purpose. Infact it is in mix proportion in cement to impart binding property to it.
* Lime is obtained from calcination of limestone

calcination: It is the process of heating an ore up to the redness.

$$\underset{\text{Limestone}}{CaCO_3} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Lime}}{CaO} + CO_2\uparrow + H_2O\uparrow$$

* Lime obtained from calcination of relatively pure limestone (% purity - 90-95%) is referred as **quick / caustic / lump lime**

$$\underset{\text{Limestone}}{CaCO_3} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Quick lime}}{CaO}$$

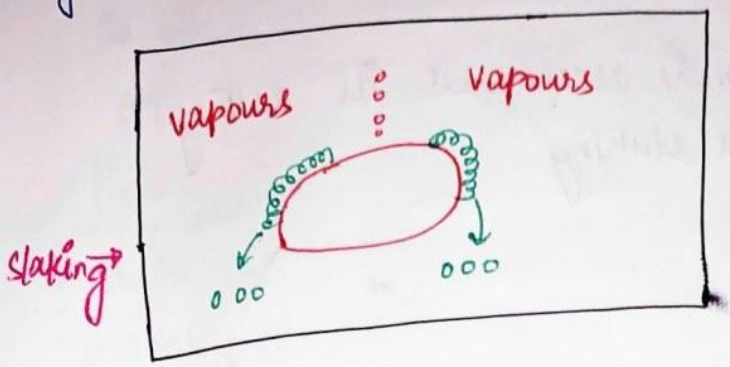
(Purity > 90-95%)

* **Quick lime:** has very high affinity (reactivity) for water, hence reacts with it, swells, cracks and falls out as powder and leads to the formation of hydrated (slaked) milk of lime.

Slaking: is the process in which quick lime vigrously reacts with water and forms hydrated lime.

$$\underset{\text{Quick lime (32\%)}}{CaO} + H_2O \xrightarrow{\text{Slaking}} \underset{\substack{\text{Hydrated /} \\ \text{Slaked /} \\ \text{milk of lime,}}}{Ca(OH)_2} + \underset{\text{15.6 (K cal/gm)}}{\text{Heat}}$$

* Hydraulic Lime must be used as fresh as possible as it has very high reactivity for CO_2, hence react with it and get wasted out as precipitate of $CaCO_3$.



$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 \downarrow$

Ingredients of Lime stone

① Clay: It imparts hydraulicity to the lime and make its insoluble in water.

Hydraulicity: It is property of the lime by which it is able to set into water or in damp location, where there is no free circulation of air eg: Trench, Basement etc.

* If it is in excess, it arrest the slaking and if it is in deficiency it retards the slaking.
* For good lime, it should be in range of 8-30%

② Soluble Silica:

* Silicate of Ca, Mg, and Al in small quantity is also responsible for hydraulicity in lime.

③ Magnesium Carbonate

* Carbonate of Magnesium allow it to slake by retarding its setting.
* If it is in proportion more than 30%, it also imparts

* Hydraulicity in lime even in the absence of clay.
* It is also responsible for strength in lime.

④ Sulphate

* Presence of sulphate in lime accelerates its setting process by retarding its slaking

Different Types of Lime

① Fat Lime

* This lime slakes vigorously, due to which its volume increases by 2 to 2.5 times than its original volume hence it is termed as fat lime and not used where strength is required.
* It possess perfect white colour thereby is termed as white lime and find its application in aesthetic works eg: white washing and plastering.
* It is obtained by calcination of limestone having purity of more than 95% hence it is termed as pure, rich/ high calcium lime eg. sea shells.
* It is highly plastic and soluble in water.

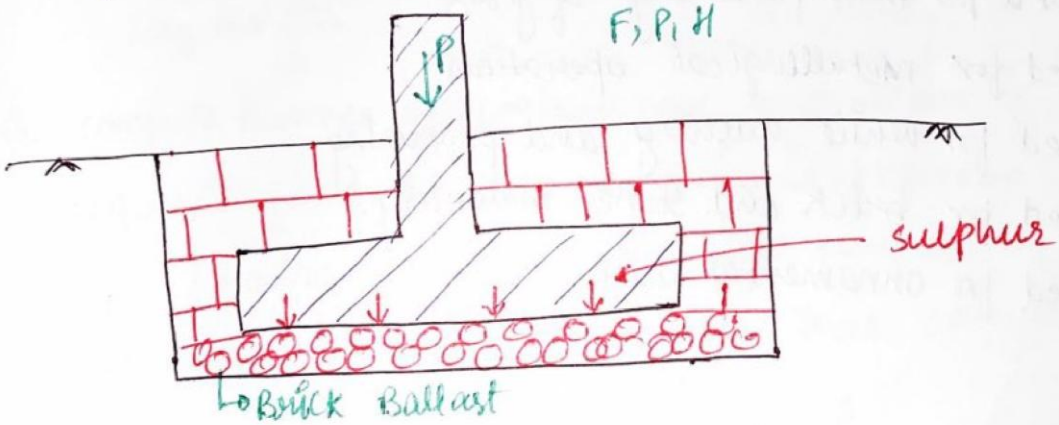
② Hydraulic Lime

* It is also referred as water lime, as it capable of setting in water.
* It is obtained from calcination of limestone having purity 90-92%

* It is insoluble in water and possess off white colour, hence is not for aesthetic works.
* It hardness comparatively faster than fat lime. hence is used for work where strength is required
  Eg: Brick and Stone Masonry.

③ Poor Lime

* It is also referred as loan / impure lime as it is obtained from calcination of limestone having purity less than 70% eg: Dolomite Stone
* It neither slakes, nor hardens, posses muddy white colour and is insoluble in water thereby is used in in minor engineering works.
  eg: Brickwork around foundation.



LIME PUTTY and COARSE STUFF

Lime Putty: It is obtained by adding hydrated lime to water, stirring to consistency of a thick cream allowing it to stand and mature for a period of about 16 hours in case of non hydraulic lime before using.

* The putty was so obtained should be protected from drying out.

COARSE STUFF

* The hydraulic lime is first thoroughly mixed and grounded with the required quantity of sand, then water is added and thoroughly mixed
* The mix is kept to mature for about less than 16 hrs in case of hydraulic lime
* coarse stuff should be protected from drying out.

Application of Lime

* It is used for treatment of water
* It is used for stabilisation of soil
* It is used for manufacturing of glass
* It is used for metallurgical operation
* It is used for white washing and plastering
* It is used for brick and stone masonary.
* It is used for ornamental works.

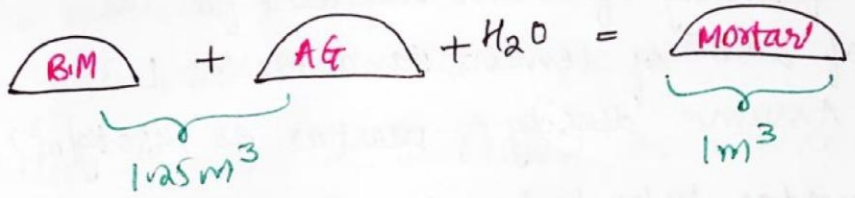
MORTAR:

Mortar is the term used to indicate the paste formed by the addition of water in specified proportion, in mixture of binding material and aggregate.

Matrix — Binding Material + (Cement, Lime, Gypsum)

Adultrant — Aggregate + H_2O = Mortar. (Sand, Surkhi)

Note: $1m^3$ of wet mortar is equal to $1.25 m^3$ of dry mortar.



Q: Compute number of cement bags and volume of sand required for preparation of mix in proportion of 1:6 (By vol) having volume of $3.5m^3$. Also compute the size of cubical room/ Box required to store these cement bags?

Ans: $3.5m^3$ of wet mortar $= 3.5 \times 1.25$

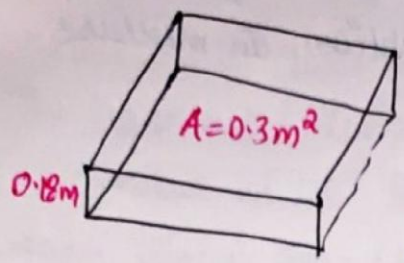
$= 4.375 m^3$ of dry mortar

$$\text{Number of bags} = \frac{\text{Volume of cement}}{\text{Volume of 1 bag of cement}}$$

$$\text{Volume of cement} = \frac{1}{7} \times 4.375 = 0.625 m^3$$

$$\text{Number of bags} = \frac{0.625}{.0347} = 18 \text{ bags}$$

Volume of sand = $\frac{6}{7} \times 4.375 = 3.75 m^3$



Volume of one cement bag
$= 0.18 \times 0.3$
$= 0.054 m^3$

Volume of 18 cement bags $= 18 \times 0.054$
$= 0.972 m^3$.

Size of box/room = $\sqrt[3]{0.972}$
= 100 cm

Q2. Calculate the quantity of water required for the preparation of $2.5 m^3$ of cement sand mortar 1:3 and W/C = 0.4. Assume density of mortar as $1450 kg/m^3$?

Ans. Weight of mortar to be prepared = 2.5×1450
$= 3625 kg$.

Let weight of cement required be x kg.

$W_c + W_w + W_s = W_m$

$x + 0.4x + 3x = 3625$

$x = 823.86 kg$

weight of water required = $0.4x$
$= 0.4 \times 823.86$
$= 329.54 kg$.

* sand used for the preparation of mortar should have following properties.
* It should be free from organic matter
* It should be chemically inert
*

* It should be free from presence of salts that absorbs moisture from the atmosphere.
* It should be well graded.

Sand used for preparation of mortar serves following purpose.

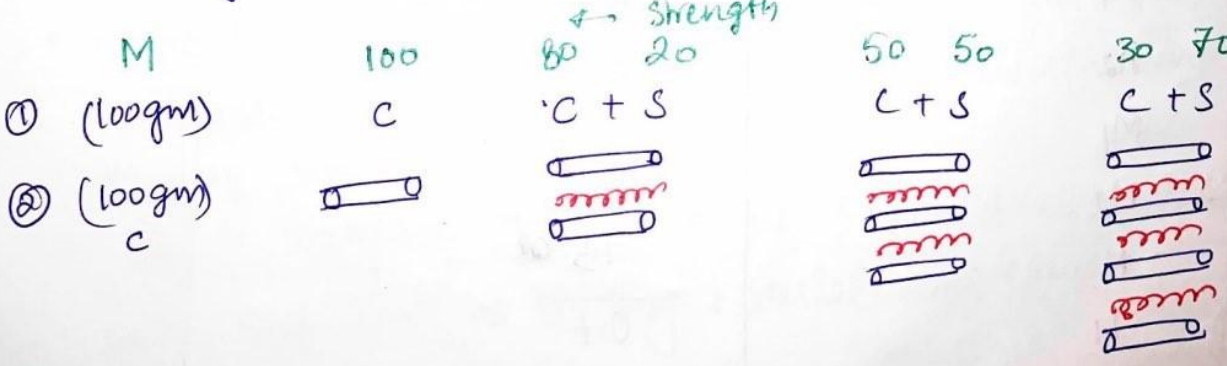
(1) **Strength:** It helps in readjustment of strength of mortar, by increasing or decreasing its proportion, but does not impart any strength.

(2) **Surface Area:** It divides the paste of binding material into number of layers, thereby helps in increasing the area over which it can be applied.

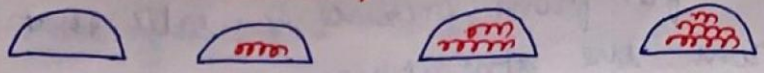
(3) **Bulk:** It helps in increasing the volume of mortar or decreasing its cost.

(4) **Shrinkage:** It helps in reducing the volume of voids in mortar, thereby reduces the tendency of volume change in it (shrinkage), hence reduce the development of cracks in it.

(5) **Setting:** It helps escape of gases and heat out from the mortar, uniformly without development build-up pressure, thereby reduces tendency of development of cracks in it.



③ (100gm) C — SSA →



④ (100gm) M — Volume →

← Vv

⑤ (100gm) M → K

Note: If Surkhi is used as an aggregate it also imparts hydraulicity of the mortar.

Classification of Mortar

Mortar can be classified on the basis of following:

(1) On the Basis of BULK DENSITY

Type of Mortar	ρ (kg/m^3)	Aggregate
① Heavy Mortar	> 1500	Heavy Quartz Sand
② Light Mortar	< 1500	Light Porous sand from slags, pumice etc

(2) On the basis of strength imparted in masonary work

Type of Mortar	Strength N/mm^2
H_1	≥ 10
H_2	6-7.5
M_1	3-6
M_2	2-3
M_3	1.5-2
L_1	0.7
L_2	0.5

③ On the basis of Binding Material

- Cement Mortar: Strength, Rate of setting.
- Lime Mortar: Shrinkage ↓ (Durable), Plasticity ↑, cost ↓, workable ↑
- Gypsum Mortar:
- Lime-cement / Gauged / composite (C:L = 1:6 - 1:8)

④ On the basis of Aggregates

- Sand Mortar
- Surkhi Mortar
- Sand-Surkhi Mortar

⑤ On the basis of Application

- Brick layer Mortar: Intended for brick laying
- Finishing Mortar: Intended for Architectural or Ornamental work, application is also found in decorative works

⑥ Special Type of Mortar

- Packaging Mortar: used for packing oil wells, these mortar may be C-S, C-L or cement loam mortar.
- Damp Proof Mortar: It is prepared using high grade sulphate resisting cement as binding material and Quartz sand.
- Sound Absorbing Mortar: It is prepared with PSC, Lime, Gypsum, as binding material and caustic

Magnesite sand as aggregate.

- Fire Resistance Mortar: It is prepared by using aluminous cement and surkhi for fire clay bricks
- X-ray Shielding Mortar:

It is heavy mortar required for plastering wall and roof of X-ray cabinets.

It is prepared from well graded sand and OPC or PSC.

Properties to be possessed by Mortar

- It should be capable of developing design stress.
- It should be capable of developing good adhesion with other building components.
- It should be capable of resisting the penetration of water through it.
- It should be durable
- It should be cheap.
- It should be workable.
- It should not effect the durability of other building components, it comes in contact with.

Selection of Mortar

The particular type of mortar to be used for construction is as follow.

Nature of Work	Type of Mortar	Proportion.
① construction work in water logged areas and exposed position.	cement or lime Mortar (Hydraulic Lime)	1:3

② Damp Proof course (DPC) and cement concrete Pavement	Cement Mortar	1:2
③ General RCC work such as columns, walls, lintels, stairs, slabs etc	Cement Mortar	1:3
④ Internal walls and surface of less importance	Lime Cinder Mortar (sand is replaced by ashes or cinder)	1:3
⑤ Mortar for laying fire bricks	Fire Resisting Mortar	1 part of HAC. 2 parts of crushed fire clay bricks
⑥ Partition wall and Parapet wall	Cement Mortar	1:3
	Lime Mortar (Hydraulic Lime)	1:2
⑦ Plaster work	Cement Mortar	1:3 - 1:4
	Lime Mortar (Fat Lime)	1:2
⑧ Pointing work.	Cement Mortar	1:1 - 1:2
⑨ Stone Masonary with Ordinary Stones	Lime Mortar	1:2
	Cement Mortar	1:6
⑩ Stone Masonary with best stone	Lime Mortar (Hydraulic Lime)	1:2
⑪ Reinforce Brickwork	Cement Mortar	1:3
⑫ Thin Joints in Brickwork.	Lime Mortar (Fat Lime)	1:3

Note: Grout and Gunting.

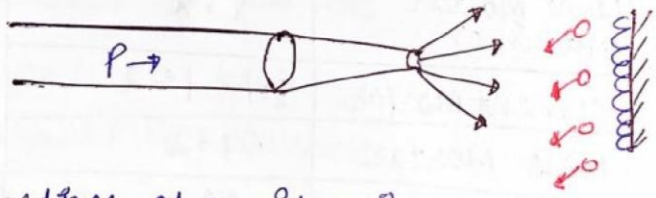
→ Cement mortar of fluid consistency used to fill the voids and joints in masonary and to repair the crack is known as Grout.

→ It is also used to increase bearing capacity of soil by injection.

→ It uniformly distributes the stresses over the strength and hollow concrete blocks.

Gunting:

- The application of mortar or concrete under pressure (pneumatic) through a cement gun is known as gunting.
- concrete or mortar becomes extremely strong and a high bond is achieved.



* Proportions of gunits mix

Nominal Mix in the gun (C:S)	Mix in place (C:S)
1:3	1:2
1:3.5	1:2.8
1:4	1:3.1
1:5	1:3.1

AGGREGATES.

* Properties of the aggregate governs the property of mixture (concrete) in which it is used.
* Properties under considerations is strength and workability of mixture.

Strength: It represents the resistance of the material against gradual loading. It depends upon interparticle locking between aggregates and bond strength (which is function of contact area and roughness).

Workability: It is the case, which we can work (mixing, transporting, placing, finishing with the mixture). This ease of work depends upon the friction b/w particles which can be reduced by lubricating action of paste of binding material.

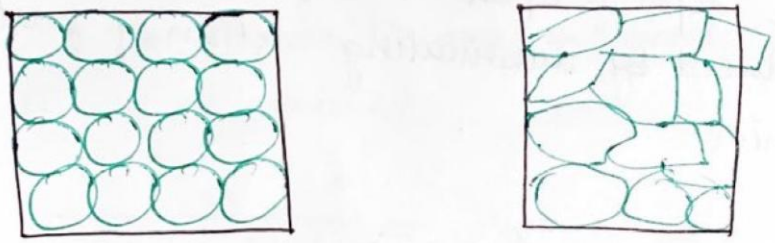
(1) **shape:**

* Shape of aggregates governs both workability and strength of mixture.
* Rounded aggregates leads to the formation workable mix, having low strength, as lesser is the area to be lubricated in this case and poorer is the interparticle locking and Bond strength.
* Angular Aggregate leads to the formation of strong mix, having less workability as better is the inter particle and bond strength but more is the area to be lubricated in this case

Note: Excellent concrete is made by using crushed stone, but the particles should be roughly cubical in shape.

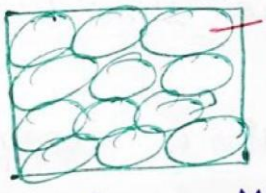
* Angularity / Roundness of Aggregate is measured in terms of parameter "Angularity Number" (AN). which represents the volume of voids in the sample.
* AN varies in the range of 0-11, If % voids in the sample are 33%, AN = 0 and % voids in sample are 44%, it is taken to be 11.

AN	0	1	2	3	- - -	10	11
%Vv →	33	34	35	36		43	44



Q1. The weight of coarse Aggregate having specific gravity 2.65, which is completely filling into a cylinder of vol. 003 m^3 is 5247 gm. what is the angularity Number and comment upon shape of aggregate.

Soln.



$M_s = 5247 gm$

$V = .003 m^3$

$G = 2.65$

$$G = \frac{\rho_s}{\rho_w} = \frac{M_s}{V_s \rho_w}$$

$$V_s = \frac{M_s}{G \rho_w} = \frac{5247 \times 10^{-3}}{2.65 \times 10^3}$$

$$V_s = 0.00198 m^3$$

$V = V_v + V_s$

$V_v = V - V_s = .003 - .00198$

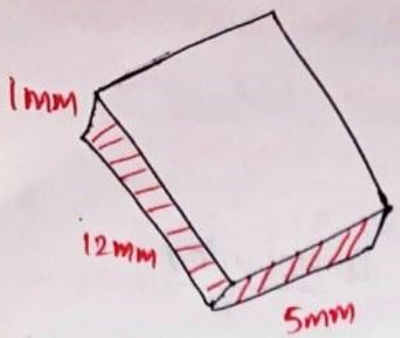
$V_v = 0.00102\ m^3$

$\% V_v = \frac{V_v}{V} = \frac{.00102}{.003} \times 100 = \boxed{34\%}$

Angularity Number = 1, Shape of aggregates is rounded

Flakiness Index and Elongation Index Test: (IS:2386-Part1)

* Flakiness of aggregate is measured in terms of parameter Flakiness Index.
* Flaky Particles are those least lateral dimension of which is smaller than $0.6\left(\frac{3}{5}\right)$ of its mean dimension.
* Flakiness is defined as % of flaky particles in the sample and is determined using flakiness Index test.
* This test is not applicable for the particles having size smaller than 6.3mm
* In order to perform this test, sufficient quantity of aggregates must be considered, such that 200 pieces of each fraction can be gauged.
* Particles of each fraction are passed turn by turn, through the respective opening over the "thickness guage" and weight of aggregates passing through the opening is noted and when expressed in terms of original weight of aggregates is termed as Flakiness Index.
* Flaky agg. must not be more than 15% in general to be used for preparation of concrete.



$$\bar{x} = \frac{1+12+5}{3} = 6mm$$

$$y = \frac{3}{5} \times 6 = \frac{3}{5} \times \bar{x}$$

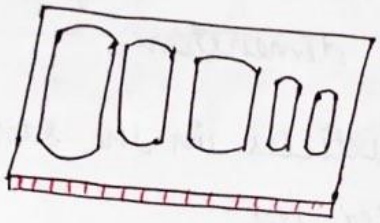
$$= 3.6mm$$

$1mm < 3.6mm$

Flaky.

$$\bar{z} = 1.8\bar{x} = 1.8 \times 6$$
$$= 10.8$$

$12mm > 10.8mm$



63-50mm ooo 63

50-40mm ooo 50

40-25mm ooo 40

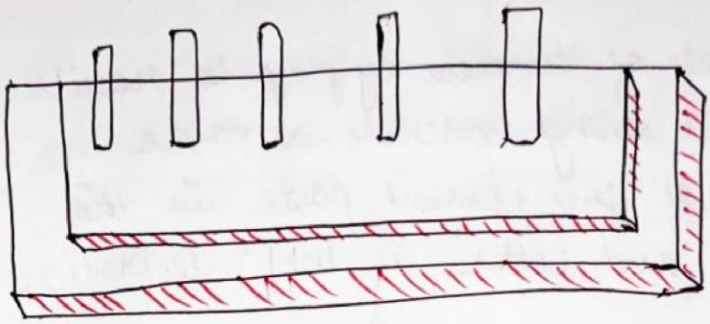
25-10mm ooo 25

ooo 10

* Elongated aggregates are those, greatest size of which is greater than 1.8 times of its mean size.
* Elongation of the aggregate is measured in terms of parameter elongation index, which represents the % of elongated particle in the sample
* This test is not applicable for agg having size smaller than 6.3mm
* In order to perform this test sufficient amount of aggregates must be taken such that 200 pieces of each fraction can be guaged.
* Particles then pass through, respective opening over the length guage and aggregates retained over those opening is weighed and expressed in terms of

original weight of aggregate and is referred as Elongation Index.

$\frac{1.8(a+b)}{2}$



a
b
c
d
e
f

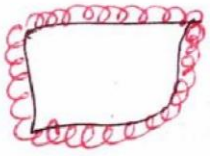
$\frac{a+b}{2}$ ↓

(2) Textures of Aggregates:-

* Surface texture of aggregate represents relative % of area of aggregate that is smooth or rough.
* Smooth textured aggregates leads to the formation of workable concrete but having low strength as lesser is the area to be lubricated in this case and lowers is bond strength and interparticle locking.
* Rough aggregate leads to the formation of strong concrete having low workability as more in the area to be lubricated in this case but better is the interparticle locking and bond strength.

IS: 2368 - Part 1

Smooth



Rough

(3) Grading of ~~concrete~~ Aggregates

* Grading of aggregates directly governs the workability and strength of concrete in which it is used for construction
* A well graded sample of concrete aggregate results in both workable and strong concrete, as more is the availability of free cement paste in this case for lubrication and better is the interparticle and bond strength
* Grading of aggregates is done by particle size of parameter Cu & Cc.

(4) Size of Aggregates (IS: 2386: Part I)

* In Sieve Analyses a parameter referred as fineness modulus is determined, which is used to indicate the fineness and coarseness of aggregates in absolute terms.
* Fineness Modulus is defined as the aggregate of cumulative (%) of aggregate retained over different sieves, ranging from 80mm - 150μ divided by a constant (generally taken to be 100)
* Higher is the value of fineness Modulus, coarser are the aggregates and vice-versa.

Sieve Size	Weight Retained	% wt. Retained	Cum % wt. Retained
80mm)	20	10	10
40mm	40	20	30
20mm	15	7.5	37.5
10mm	5	2.5	40

4.75mm	5	25	42.5
2.36mm	15	7.5	50
1.18mm	20	10	60
600M	40	20	80
300M	25	12.5	92.5
150M	15	7.5	100

$$FM = \frac{542.5}{100}$$

$FM = 5.4 \approx 5$

If FM = 1,

$\bar{x} = 150M$

FM = 2

$\bar{x} = 300M$

FM = 3

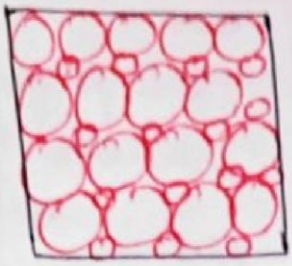
$\bar{x} = 600M$

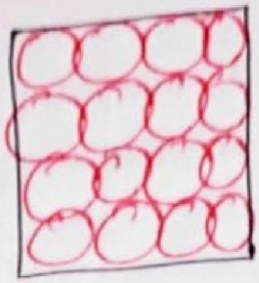
* The value of FM indicates the size of sieves mentioned, before, starting from lowest size as the mean size of aggregates in sample.

Note for sand.

Sand	FM
Fine sand	2.2 - 2.6
Medium sand	2.6 - 2.9
coarse sand	2.9 - 3.2

* Sand having FM > 3.2, is not suitable for preparation of concrete.





Q2. If 20 kg of coarse aggregate is mixed through 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600M, 300M, 150M sieves and weight retained is 0kg, 2kg, 8kg, 6kg, 4kg respectively, then the FM of the aggregate is.

Ans:

		% wt.	cum % wt
80mm	0	0	0
40mm	2	10	10
20mm	8	40	50
10mm	6	30	80
4.75mm	4	20	100
2.36mm	0	0	100
1.18mm	0	0	100
600M	0	0	100
300M	0	0	100
150M	0	0	100
			Σ740

$FM = \frac{740}{100} = 7.4$ Ans.

(10-20mm)

Q3. The % of the aggregates of FM 2.6 to be combined C.A of FM 6.8 for obtaining the agg of FM 5.4?

x% of FM 2.6 to be mixed

$x \times 2.6 + (1-x)\,6.8 = 5.4$

$\boxed{x = 33.3\%}$

$1 - x = 66.6$

$$\frac{33.3}{66.6} \times 100 = 50\%$$

* FA = x, CA = y.

$z = x + y$.

$$\frac{FA}{CA} = \frac{x}{y} = \frac{\frac{x}{x+y}}{\frac{y}{x+y}} = \frac{\frac{x}{x+y} + 1 - 1}{\frac{y}{x+y} + 1 - 1}$$

$$\frac{FA}{CA} = \frac{x + x+y - (x+y)}{y + (x+y) - (x+y)}$$

$$= \frac{x + x + y - y - x}{y + x + y - x - y}$$

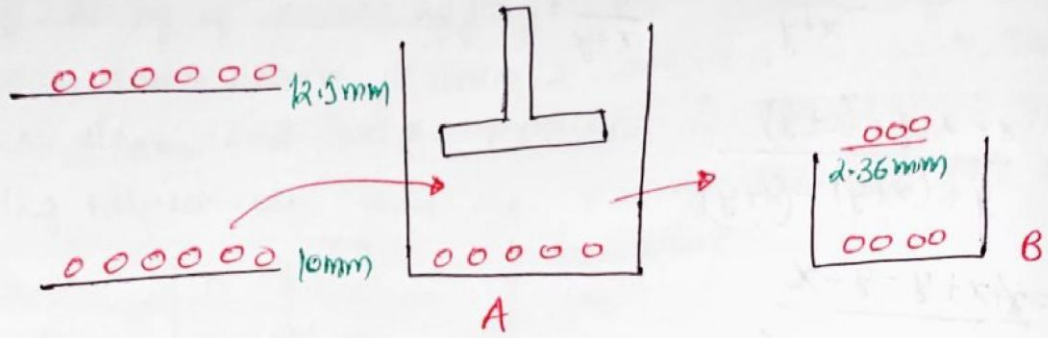
$$\boxed{\frac{FA}{CA} = \frac{z+y}{z-x}}$$

⑤ Strength of Aggregate

* Strength of aggregates directly governs the strength of concrete in which it is used for construction. It is defined as the ability of aggregate to resist gradual loading.
* It is determined in terms of parameter aggregates crushing value, which is found using aggregates crushing value test.
* In this test, sample of aggregates passing through 12.5mm sieve and retained over 10mm sieve is subjected to gradual loading with the help of 40 tonne plunger for 10 mins.
* sample is then passed through 2.36 mm sieve and weight of particle passing through sieve is noted which when

expressed in terms of original weight of aggregate is termed as aggregate crushing value.

* For aggregates to be used for pavement construction it must not exceed 30% and for general construction it must not exceed 45%.



Aggregate Crushing Value (ACV) $= \frac{B}{A} \times 100$

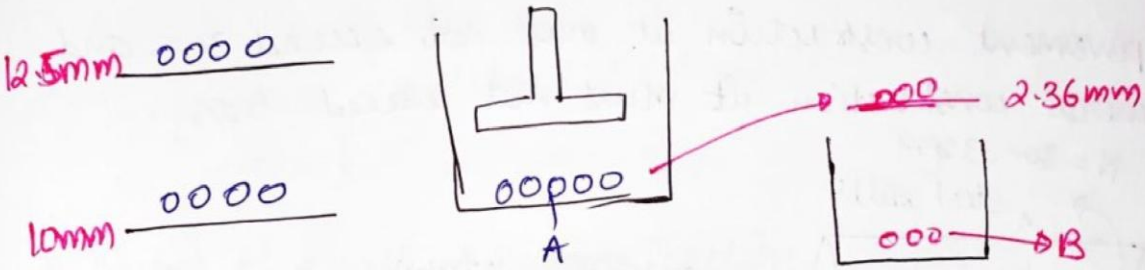
ACV $\propto \frac{1}{\text{strength}}$

(6) Toughness of Aggregate : (IS:2386-Part IV) → Impact Value Test

* Toughness of Aggregate directly governs the toughness of concrete in which it is used for construction.
* It is defined as the ability of the aggregate to resist impact loading.
* It is represented in terms of parameter aggregate impact value and is determined by performing aggregate impact value test.
* In this test, sample of aggregate passing through 12.5mm sieve and retained over 10mm sieve is subjected to impact loading with the help of 14 kg hammer i.e, allowed to fall freely from a height of 38 cm over

the sample 15 number of times

* This sample is passed through 2.36 mm sieve and weight of aggregate passing through this sieve is noted and when expressed in terms of original aggregates is termed as **Aggregate Impact Value.**
* For aggregates to be used in pavement construction it must not exceed 30%. and for general construction it must not exceed 45%.-



$$\text{Aggregate Impact Value (AIV)} = \frac{B}{A} \times 100$$

$$AIV \propto \frac{1}{\text{toughness}}$$

(7) Hardness of Aggregates (IS: 2386 - Part IV): Abrasion Value Test

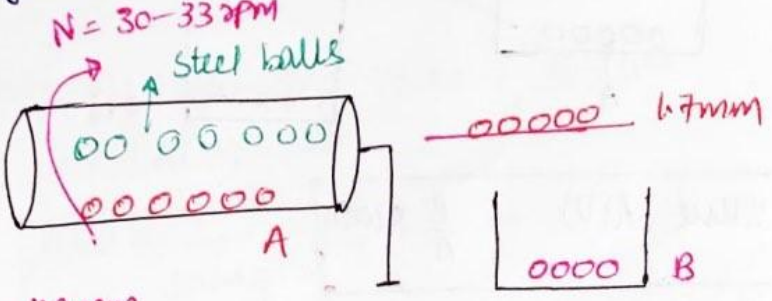
* Hardness of aggregates directly governs the hardness of concrete in which it is used for construction.
* It is defined as resistance to wear and tear or abrasion.
* It is referred in terms of parameter aggregate abrasion value and found using following test

1. Devel Abrasion Test
2. Dourg Abrasion Test
3. Los Angeles Test

In these test sample of aggregates is subjected to wear and tear and tear in rotating cylinder, having steel balls in it.

* The sample is then passed through 1.7mm sieve and weight of aggregate passing through this sieve is noted, which then expressed in terms of original weight of aggregate is termed as Aggregates Abrasion Value (AAV)

* For pavement construction it must not exceed 30% and for general construction it must not exceed 50%.



ϕ = 48mm
W = 390-450 gm
N = 30-33 rpm
n = 500

$$AAV = \frac{B}{A} \times 100$$ Aggregate Abrasion Value

AAV $\propto \frac{1}{\text{Hardness}}$

Alkali Aggregates Reaction

* Alkalies undergo expansive reaction with aggregates causing its disintegration which is also termed as cancer of concrete.

* The alkali-silica-gel imparts osmotic pressure over the set concrete gel, that is mainly responsible for formation of cracks. However, its exact mechanism is still not known.

Factors affecting alkali aggregate reaction

1. Reactive Type of aggregate
2. High Alkali Cement Aggregate
3. Availability of Moisture
4. Temperature conditions : [Favourable temp for reaction is 10-38°C]

Control of Alkali Aggregate Reaction

It can be controlled by following considerations:

1. By selecting non reactive aggregates
2. By using low alkali cement
3. By Pozzolonas (fly ash, surkhi, crushed stone dust)
4. By air entraining agents : They prevent the development of Osmotic Pressure.

ADMIXTURES / Additives

Anything added in concrete others than binding material, fine aggregate, coarse aggregate and water in order to modify its properties are termed as admixture.

Admixture are further classified into

① Chemical Admixture

② Mineral Admixture / Pozzolona

① Chemical Admixture

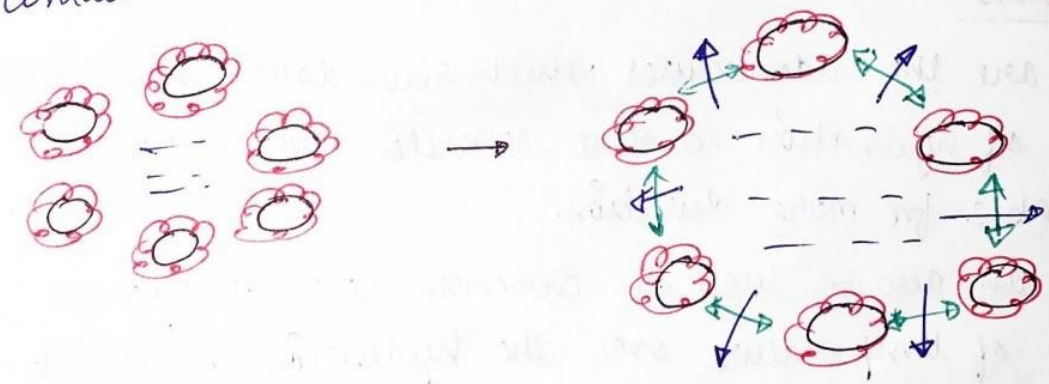
① Plasticizers (Water Reducers)

* It is a mixture of organic and inorganic substances which permits the reduction in water cement ratio at some workability or offers higher workability at same water cement ratio in either of the case it provides high strength concrete or highly workable concrete.
* These plasticizers acts as a deflocculating reagent hence gets adsorbed over the cement particle carries out repulsion b/w them, thereby makes the entrapped water free from the voids which participate in the hydration process and modify the property of concrete.
* Dose of plasticizers varies in the range of 0.1 - 0.4% by weight of cement at which they can permit reduction in water content by 5-15% or increase the slump value by 30 - 150mm.
* commonly used plasticizer includes
  ① Lignosulphate

② Polyglycolesters
③ Carbohydrates
④ Hydroxylated carboxylic Acid

Note:- Action of Plasticizers includes
① Dispersion ② Retarding Effect.

* Many research explains the working of plasticizer as follows:
(1) Reduction in surface tension of water.
(2) Induced electrostatic repulsion b/w particle.
(3) Lubricating film b/w the particles.
(4) Dispersion of cement grains, releasing water & air traped b/w the particles.
(5) Inhibition of surface hydration reaction.
⑥ change in the morphology of hydration products.
⑦ Induced steric hinderance preventing, particle to particle contact.



Plasticity ↘ $\frac{\text{Workability (I)}}{(W/C)_I} > \frac{\text{workability (II)}}{(W/C)_{II}}$

strength = const ⇒ high workable

P ↓ I $\frac{\text{workability}}{(W/C)_I^{(I)}} <$ II workability (II) / $(W/C)_{II}$

⇒ Strength ↑

workability = const → strength ↑

② Super Plasticizers

* Super plasticizers are same as that of plasticizers in terms of their action but are chemically different from plasticizers.
* The effect of super plasticizers is comparatively more than that of plasticizer such that for ~~them~~ same dose they can permit the reduction of water content by upto 30%.
* Their application is same as that of plasticizers.
* commonly used super plasticizers includes.
  ① Modified Ligno sulphate
  ② Sulphonated Melamic Formaldehyde (SMF)
  ③ Sulphonated Napthalene Formaldehyde (SNF)

③ Retarders.

* These are the admixtures which slows down the chemical process of hydration so that concrete can remain workable for more duration.
* They can also be used to overcome the acceleration effect of temperature over the hydration process upto 72 hrs.
* They find their application, where transportation period required is more and in the casting of oil well (where temp may go upto 200°C)
* commonly used retarder includes
  ① Calcium sulphate

② Tartaric Acid
③ Starch
④ Cellulose
⑤ Sugar

④ Retarding Plasticizers.

* Plasticizers also act as retarders, as they form the layers over cement particle and also delay the hydration process. Thereby acting as retarders.
* One must be very careful in the selection of such retarding admixtures, as their improper dose may impart undesirable properties in concrete.
* Retarding plasticizers or superplasticizers category of admixture is often used in Ready mix concrete (RMC)

⑤ Accelerators

* These are the type of admixtures, which increases the rate of hydration.
* They find their application in
  (1) Pavement construction.
  (2) Pre-Fabricated Structures
  (3) Cold weather concreting
  (4) where framework is to be re used for speedy construction
* Their normal dose varies in the range of 0.1-0.2% of weight of cement.
* commonly used accelerators includes
  ① calcium chloride

② Silicate
③ Flurosilicates
④ Tri ethanol Amine

⑥ Accelerating Plasticizers

* These mixture are added to accelerate the strength development of concrete. higher workability.
* Such accelerating plasticizers when added to concrete increases rate of development of higher strength.
* The accelerating materials added to the plasticizer and super plasticizers are triethanol amine, calcium Nitrate, Nitrates and fluorosilicates etc.

⑦ Air Entraining Admixture

* These are the type of admixture which entrains millions of air bubbles in voids of concrete, which act as flexible ball bearing and slip pass over each other thereby modify almost every property of cement
* These are nowadays used as fifth ingredients in the preparation of concrete.
* Commonly used air entraining admixture includes:

① Aluminium Powder
② Hydrogen Peroxide
③ Plants and Animal Fatty Acid
④ Natural wood Resin
⑤ Oelic and Ferric Acid

* These admixtures affect following properties.

(1) Increase resistance of freezing and thawing.
(2) Increase workability
(3) Reduces strength
(4) Reduces tendency of segregation and bleeding
(5) Decreases permeability
(6) Increases resistance to chemical attack.
(7) Reduces unit weight and alkalies aggregate reaction.

V. Mineral Admixtures / Pozzolonic Admixtures

* Pozzolanic Material are essentially silicious and aluminous compound which in itself do not possess any binding property, but when finely grinded reacts with lime (released during the hydration of cement in the presence of water to produce the compound which possess building property.

$$\{(Si, Al)\ Pozzolona + Ca(OH)_2 + H_2O \longrightarrow \underset{Gel}{C-S-H}\}.$$

* Use of Pozzolonic Admixture in generally gives following properties.

(1) Lower Heat of Hydration
(2) Lower Thermal Shrinkage
(3) Lower Alkali Aggregate Reaction
(4) Improve Workability
(5) Reduce Cost
(6) Improve extensibility
(7) Lower susceptibility to leaching

⑧ Improve Resistance against Sulphur attack.

* Pozzolonas are further classified into

(1) Natural Pozzolona (2) Artificial Pozzolona

(1) Natural Pozzolona

- All pozzolona are rich in silica and alumina and have small quantity of alkalies.

eg: ① clay and shales ② Diatomaceous

* Effects of Natural Pozzolona

(1) Heat of Hydration: same as that of low heat cement

② Shrinkage: same as portland cement

③ On strength of concrete: when pozzolona are used in addition of an air entraining agent, it may enable a reduction in amount of water, which imparts strength.

④ Thereby it permits less cement requirement for same strength.

⑤ At early ages the replacement of cement by a pozzolona usually results in decrease in compressive strengths, but difference becomes less or may disappear at age of 3 months or more.

Note: Replacement of cement with Natural Pozzolona in in range of 4-6%

② Artificial Pozzolona

① Fly Ash

② Grounded Blast Furnace slag

③ Silica Fumes

④ Surkhi

⑤ Rice Husk Ash

① Fly Ash

Fuel

* Fly Ash or Pulverized Ash (PFA) is a residue from the combustion of pulverized coal.

Effect of Fly Ash on cement Concrete :-

(1) On amount of mixing water : The use of fly ash in limited amount as replacement for cement requires little more water for the same workability because of fineness of fly ash.

② On strength of compression : Since the action of pozzalona is slow, addition of fly ash upto 30% may result in lower strength at 7 and 28 days, but may be about equal at 3 months and may further increase at ages greater than 3 months providing curing period is continued.

③ On Modulus of Elasticity : It is lower at early ages and higher at later ages.

④ On curing conditions : It is similar to Portland cement concrete.

⑤ On shrinkage of concrete : Coarse or flyash and those having high carbon content are more liable to increase shrinkage than finer fly ash and those having low carbon content.

⑥ On permeability : It reduces permeability of concrete because of its fineness.

⑦ On resistance of chemical Attack : It improves resistance against chemical attack.

On heat of hydration: It reduces Heat of Hydration.
Setting Time: It increases IST of cement upto 2 hours.

(2) Surkhi [Calcined Clay Pozzalona]

* It is one of the artificial pozzalonic material obtained by burning clay at specified predetermined temperature
* It is used in making mortar and concrete as an adultrant for economy.
* Its chief function is to impart strength and hydraulic properties to mortar.
* When mixed with cement to react with lime liberated during setting and Hardening of cement, it makes dense, compact and impermeable concrete.

(3) Grounded Blast Furnace Slag:

* It is obtained by smelting iron ore in blast furnace
* This slag exihibit hydraulic action in presence of $Ca(OH)_2$ liberated during hydration of cement.
* The early strength of cement might be less but ultimate strength is comparable.
* It finds its application in mass concreting and offer higher workability, resistance to chemical attack and against corrosion.

(4) Silica Fumes.

Silica fumes also called micro silica.
There are various advantages of silica fumes such as reduction in segregation and bleeding, improvement in strength and durability, offers low permeability.

Note: It is produced as a byproduct during the manufacturing of silicon metal and ferro silicon.

⑤ Rice Husk Ash.

* The combustion of agricultural residue volatises the organic matter and a silica rich ash is produced is termed as rice husk Ash.
* It offers excellent binding property in concrete.
* The rice husk mixed with hydraulic lime is termed as "Ashmah". and is mixed with cement instead of
* lime is termed as "Ashment"

Note: Metakaoline: It is a natural pozzolonic material which is inactive but when treated with water to remove inactive impurities from its surface, its reactivity increases and it is termed as High Reactive Metakaolin (HRM) → Artificial Pozzdona.

Note: Replacement of cement with artificial pozzolona is done in the range of 10-30%.

WATER

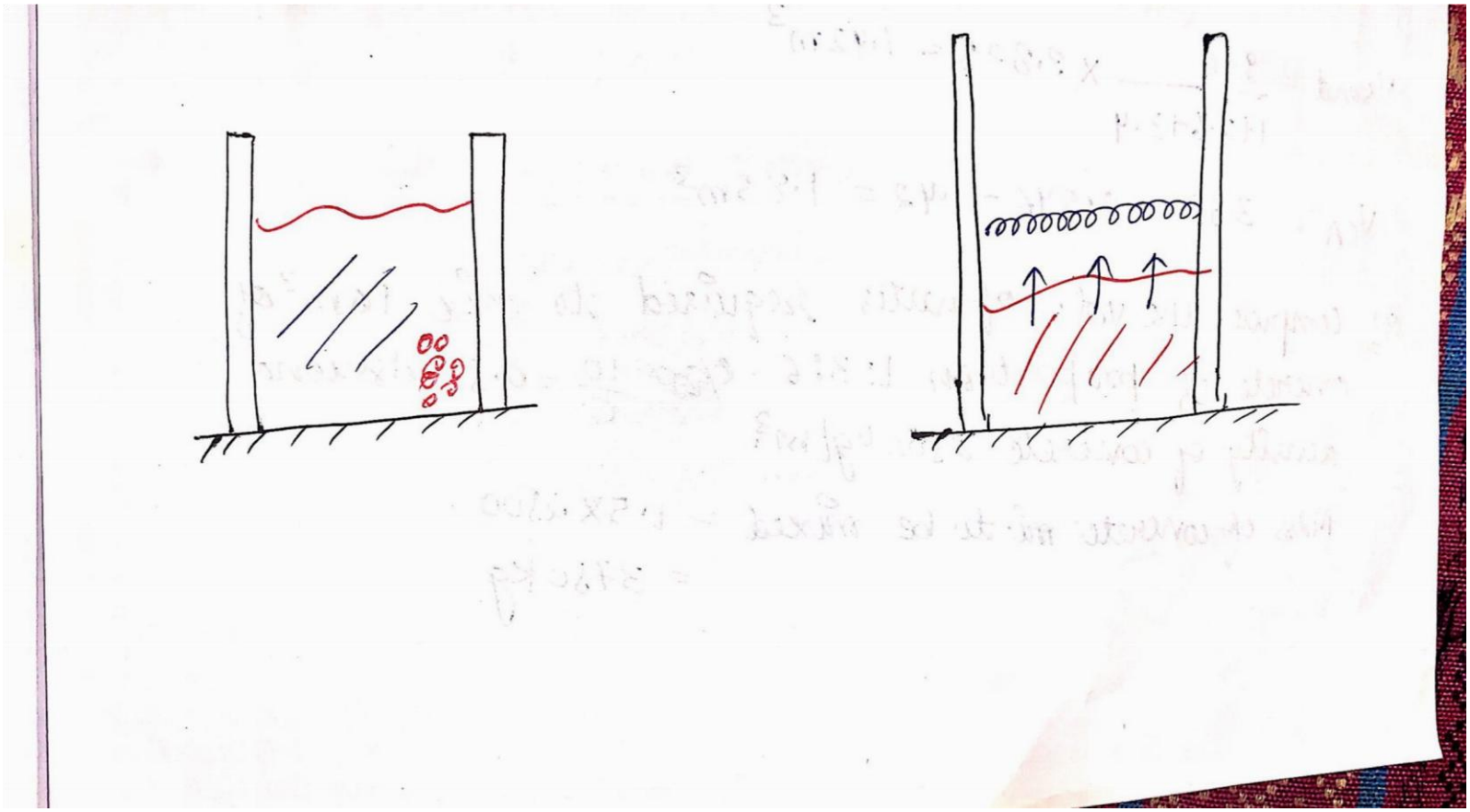
* It is the most important ingredient required for the preparation of concrete and least expensive too.
* Water is added in concrete in order to undergo hydration with binding material, which in turn imparts desirable properties in it.
* Quantity of water required to be added in concrete is carefully regulated, as if water added is less than the required, it would form poor concrete (i.e, will neither have strength nor workability) and if water is added more than the required, it would reduce strength of concrete as follows:
  - → This excess water vapourises leaving behind air voids
  - → This excess water seeps through formwork, resulting in honeycomb structure.
  - → This excess water along with cement rises to the surface and forms a layer termed as "LAITENCE" which reduces the strength b/w two successive lift.

Note: If impure water is added (used for the preparation of concrete, difference in setting time b/w concrete prepared from impure and pure water must not be greater than ±30mins and difference in strength must not be greater than ±10%

* If sea water is used in case fresh water is not available It reduces the strength by 10-20%, accelerate the setting time slightly and increase.

Permissible Quality of water to be used for concrete as per IS 456 : 2000

Impurity	Permissible Limit
Organic	200 mg/L
Inorganic	3000 mg/L
Sulphates as (SO_4)	400 mg/L
Chlorides	2000 mg/L for concrete not containing embedded steel and 500 mg/L for reinforced concrete work
Suspended Matter	2000 mg/L



CONCRETE

It is the term used to indicate the paste formed by addition of water in specified proportion in mixture of binding material, fine aggregates, coarse aggregates and admixture (if required).

Binding Material + Fine Aggregates + Coarse Aggregates + Admixture** + Water

Concrete

$1m^3$ of wet concrete = $1.53m^3$ of dry concrete

Q1. Compute no. of cement bags, vol. of sand and CA required for $2.5m^3$ of concrete having design mix of 1:2.6:3.4 by Vol.

Sol^n.

$2.5m^3$ of concrete = $2.5 \times 1.53 = 3.825$ of dry concrete

$$V_{cement} = \frac{1}{1+2.6+3.4} \times 3.825 = 0.546 m^3$$

$$\text{No. of cement bags} = \frac{0.546}{0.0347} = 15.47 \approx 16$$

$$V_{sand} = \frac{2.6}{1+2.6+3.4} \times 3.825 = 1.42 m^3$$

$$V_{CA} = 3.825 - 0.546 - 1.42 = 1.85 m^3$$

Q2. Compute the vol. of water required to mix $1.5m^3$ of concrete of proportion 1:3:6 $\frac{w}{c} = 0.5$. Assume density of concrete $2500 kg/m^3$.

Mass of concrete to be mixed = 1.5×2500

$= 3750 kg$

Let mass of cement be x kg.

$$x + 3x + 6x + 0.5x = 3750$$

$$\boxed{x = 357.142 \text{ kg}}$$

Mass of water $= 0.5 \times 357.142$

$= 178.57$ kg.

Volume of water $= 178.57 \times 10^{-3} \times 10^{3} = 178.57$ litre

Classification of concrete

Classification of concrete can be done by any of the following method.

① On the basis of binding Material

1. Cement concrete
2. Lime
3. Gypsum

② On the basis of strength of concrete

1. Low strength concrete ($S \leq 20 N/mm^2$)
2. Medium strength concrete ($S = 20-40 N/mm^2$)
3. High strength concrete ($S > 40 N/mm^2$)

③ On the basis of bulk density —

	$\rho (kg/m^3)$
1. Extra Light weight concrete	< 500
2. Light weight concrete	$500-1800$
3. Dense weight concrete	$1800-2500$
4. Super heavy weight concrete	> 2500

④ On the basis of method of casting.

① Pre Cast Concrete
② Cast in situ Concrete

⑤ On the basis of perspective specification

Grade of Concrete	Mixed Proportion	Perspective Strength (N/mm^2)
M5	1:5:10	5
M10	1:3:6	10
M15	1:2:4	15
M20	1:1.5:3	20
M25	1:1:2	25

Note: IS 456 restricts use of nominal mix upto M20 grade only.

Manufacturing of concrete

* Manufacturing of concrete is done in following sequence of operation.

① Batching :

* The process of measuring the ingredients required for manufacturing of concrete is termed as Batching.
* The accuracy of measuring equipment shall be within ±2% of the quantity of cement and mineral admixture and +3% of the quantity of chemical admixture, aggregates and water being measured.
* Batching can be done by any of the following methods.
  ① Weight Batching
  ② Volume Batching

Volume Batching is avoided and used only for minor engineering works, only after the permission of engineer in charge, as correction due to bulking is to be applied in this case.

* water is always measured in kg and litres as the case may be.
* cement is always measured by weight irrespective of method of batching.

Q. For a particular portion of work engineer permits Vol. batching of CA, for which rectangular boxes of 35cm x 45cm are fabricants unit vol. of concrete has proportion of water, cement, sand and CA as 180kg/m^3, 360 kg/m^3, 700kg/m^3 and 1210kg/m^3 respectively. Specific Gravity of CA is 2.75.

Assume the following

(1) The mixer available will mix the concrete with one bag of cement at one time.

(2) 2 boxes of CA will be used in one batch.

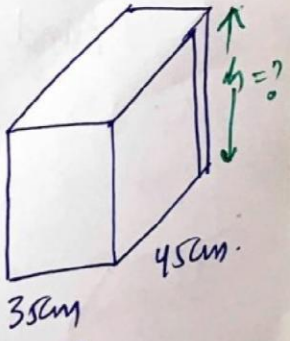
(3) When filled in normal manner, the void content in the box is 40%

find the height of box to be fabricated?

C : S : CA = 1 : 1.94 : 3.36

360 700 1210

$\frac{700}{360}$ $\frac{1210}{360}$



For 1kg of cement. CA required = 3.36

For 50 kg of cement, CA required = 50 x 3.36

= 168kg

For 50 kg of cement Vol. of CA req. = $\frac{168}{2.75 \times 10^3}$ = 0.0161m^3

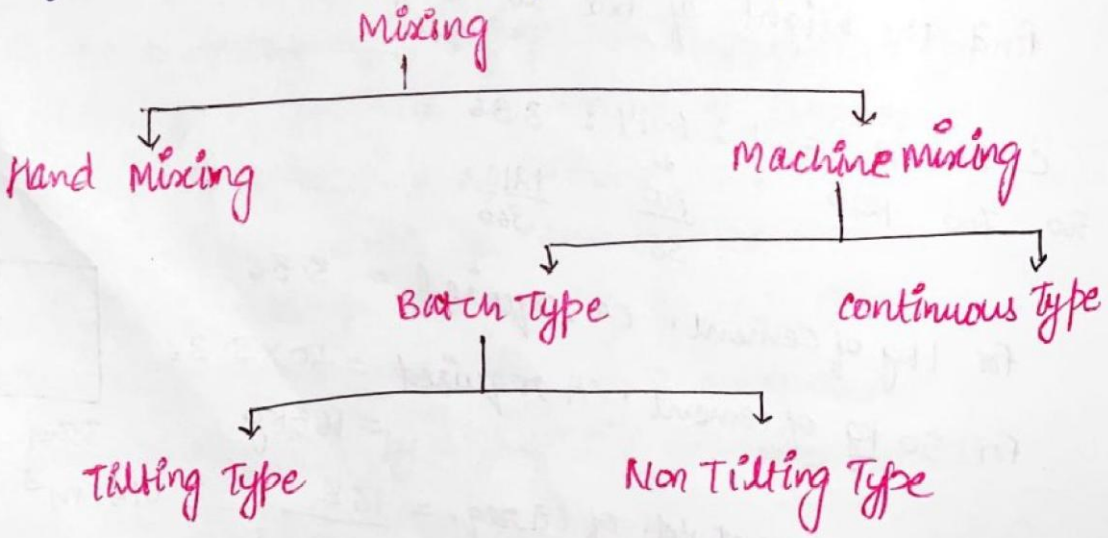
Volume of CA in boxes = $0.0161\ m^3$

$(35 \times 45 \times h) \times 10^{-6} \times 2 \times 0.6 = 0.061$

$h = 32.275\ cm$

② Mixing :

* Objective of mixing is to obtain homogenous and uniform colour concrete of desired strength.
* Mixing time depends upon type and the capacity of mixer, but IS 456 suggests the mixing time to be 2 min.
* Generally 20 revolutions of concrete in mixer provides sufficient mixing.
* If mixing time is reduced, poor quality of concrete is obtained whereas it is increased it become uneconomical.
* If mixing time is increased upto 2 min, compressive strength is observed to increase but beyond 2 min if mixing time is increased, strength again reduces due to vaporisation of water.
* Mixing can be done by any of the following methods.



③ Transporting:

* Specifications suggests the process of mixing, transporting, placing, compacting and finishing must be completed in less than the initial setting time of cement (30 mins for OPC).
* The process of carrying the concrete in desired location is termed as transporting.
* concrete can be transported by any of the following methods:

① **Pans:** used for small Jobs.

② **Hand Buggies:** used for moderate distance and medium size jobs.

③ **Power Buggies:** In this case hand buggies are operated mechanically.

④ **Tower Bucket:** used for transporting concrete in vertical direction and is suitable in congested areas.

⑤ **Crane Bucket:** Same as tower Bucket

⑥ **Dump Truck:** concrete if air entrained can be safely transported by dump trucks without any agitation

⑦ **Chutes:** used to transport the concrete below the ground level so as to reduce the height of fall.

⑧ **Transit Mixer (TM):** It is a truck on which concrete mixer is mounted (0.75 - 9.5 cum). It is used in the situation where concreting is to be done in built area and busy area and storage space is less.

④ **Belt Conveyor :** It is used when the concrete is to be transported continuously and to an inaccessible area.

* The concrete should be stiff in this case, having slump value not more than 50mm.
* common width of conveyor is 60cm and speed is about 80m/min.

⑨ **Placing :**

The process of application of concrete at the desired location is termed as Placing.

⑤ **Compaction**

* The process of removal of entrapped air, from voids of concrete and of uniform placement of concrete to form a homogeneous dense mass is termed as compaction
* If due to improper compaction, even 5-10% of air voids are left in concrete, it reduces the strength by 30-60%
* The density and consequently strength and durability of concrete depends upon the quality of compaction.

→ compaction can be done by any of the following methods.

① Hand rodding
② High Pressure/ Shock
③ Centrifugation/ spinning
④ Mechanical Vibration
  * Immersion/ Needle Vibrator (Most commonly used)
  * External or Shutter Vibration
  * Surface Vibrator
  * Vibrating Table

Note: During compaction "entrapped air" is removed from the concrete

→ Entrained air is comparatively smaller in size than entrapped air and is present uniformly throughout the concrete mass.

(6) Curing:

* Cement gives strength and hardness because of the chemical action b/w cement and water.
* Curing is the name given to the process which is employed for actively promoting the hydration of cement in a suitable environment in early stages of hardening of concrete.
* As per IS 456, curing is the process of preventing the loss of moisture from the concrete while maintaing satisfactory temperature regime.
* Curing must be done for 3 weeks and in no case for less than 10 days.
* It is carried out at temp. of 5-28°C and humidity 90%
* If concrete is cured for 1 month, its strength is nearly double than that of concrete which is exposed to air

Objective of Curing:

① To keep capillary pore saturated, to ensure hydration of cement.
② To improve wear resisting quality.
③ To prevent the loss of moisture from concrete due to evaporation or any other reason.

Curing can be done by any of the following method.

① Shading of concrete surface

② covering concrete surface with wet gunny bags

③ Sprinkling water on concrete surface

④ Ponding of concrete surface (Best Method)

⑤ Application of curing compounds like bitumen, wax, acrylates, chlorinated rubber. sodium silicates (water glass), linseed oil.

- These compounds makes a films fill the pores, seal the surface voids and prevent evaporation.

⑥ Accelerated curing [steams / Infrared Curing)

For concrete with W/C ranging 0.3-0.7, the increased rate of strength development can be achieved by using steam curing.

It does not affect ultimate strength but reduce the shear strength of concrete.

⑦ **Finishing:**

It is defined as process of levelling or smoothening of top surface of freshly placed concrete to achieve the desired appearace.

It is done as follows:

① **screeding:** Striking off the excess concrete to bring the top surface upto proper grade is called screeding.

② **Floating:** Removing the irregularities on concrete surface, which are left after screeding.

It is done by wooden float.

③ Trowelling :- Final operation of finishing and done after all excess water has evaporated by steel float in conical shape to give smooth finish.

#Properties of concrete :

① Workability :-

* It is defined as property of concrete which determines the amount of useful internal work unnecessary to produce full compaction.
* It can also be termed as the ease with which we can work with concrete.

Note: Workability is different from consistency, as consistency indicates fluidity and mobility of concrete.

* Concrete with high consistency may not be workable for a particular Job or concrete having some consistency may vary in workability.
* Since workability is not the absolute property of the concrete, it is indicated by different parameters.
* Workability depends upon the following factors.

#Factors affecting Workability

① Shape of Aggregates :-

Angular, Elongated and Flaky aggregates makes the concrete very harsh ~~and~~ when compared to rounded or cubical shaped aggregates due to their specific surface Area.

② Surface Texture:

Rough textured aggregates leads to the formation of low workable concrete in comparison to smooth textured aggregates due to their high specific surface area.

③ Size of Aggregate

The bigger sized aggregate have smaller specific surface area to be lubricated hence offers high workability.

④ Grading of concretes

Well graded aggregates results in higher workability as lesser is vol. of voids in this case and more is the availability of free cement paste to carry out lubrication.

⑤ Use of Admixture

Use of plasticizers, superplasticizers and air entraining admixtures increases the workability of concrete ~~and inducing millions of air bubbles~~ by liberating entrapped water from voids of concrete and inducing millions of air bubbles in voids of concrete respectively.

⑥ Mix Proportion (Agg/Cement)

Higher is the agg./cement ratio, lower is the workability of concrete as lesser is the availability of cement of cement paste to carry out lubrication of more area of aggregates and vice-versa.

Note: Agg/cement ↑ : leaner is concrete
Agg/cement ↓ : Richer is concrete

⑦ Water Content :

More addition of water has no effect on the workability of concrete, it only increases its consistency / fluidity, however in order to increase the workability of concrete by addition of water, cement is also required to be added in proportion such that $\frac{w}{c}$ ratio remains constant.

Measurement of Workability

Measurement of workability can be done by any of the following method.

① Slump Test

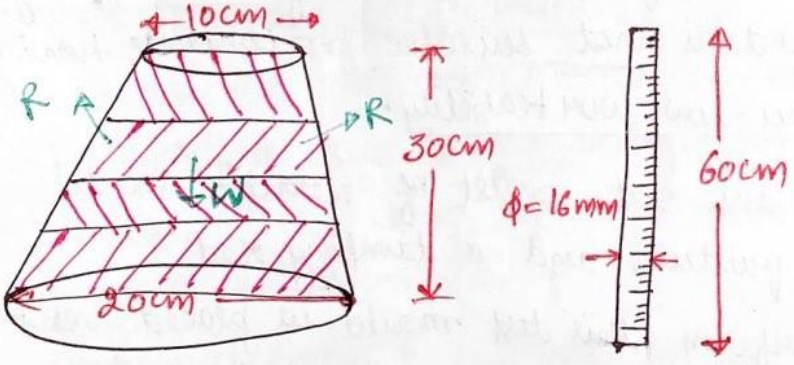
* It is the most popular method available to find the workability of concrete both in field and in laboratory due to the ease of its performance.
  But it does not include the effect of all the factors that governs the workability, hence in real terms it indicates consistency of concrete.
* This test is suitable for concrete having medium to high workability and is not suitable for concrete having very high or very low workability.
* The apparatus of this test consist of metallic mould in the shape of frustum and a tamping rod.
* In order to perform this test mould is placed over the levelled ground and concrete to be tested is filled in it in four layers and each is properly compacted by subjecting it to 25 no. of blows with the help of tamping rod.

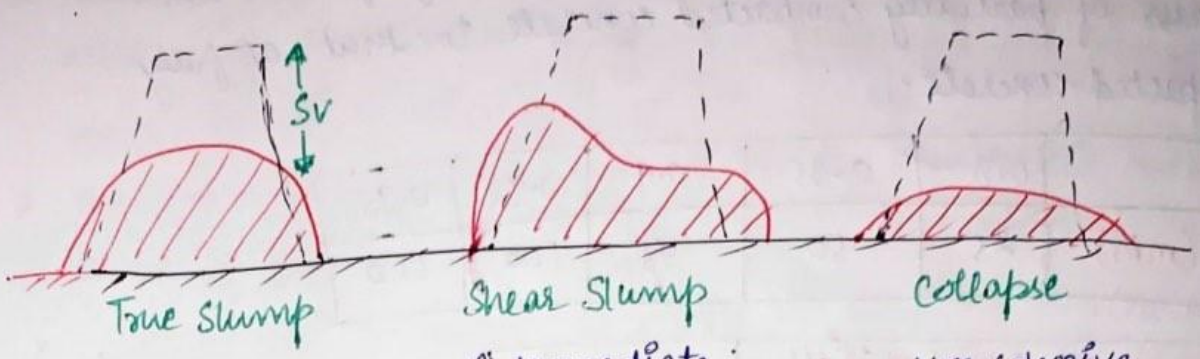
* Once the mould is completely filled it is raised in upward direction, that causes concrete to subsidise which indicates the workability of concrete in terms of parameter "slump value".

* The shape of the slump in this test is further indicates the property of concrete in terms of its cohesiveness.

* Workability of concrete required in a particular type of construction is as follows:

Type of construction	Slump (mm)
① concrete for road construction	20-40
② Parapet wall, slab, piers	40-50
③ concrete for canal lining	70-80
④ concrete for arch or wall of tunnel	90-100
⑤ Normal RCC work	80-150
⑥ Mass concreting	25-50
⑦ concrete to be vibrated	10-25





cohesiveness ↑

Intermediate cohesion

Non cohesive

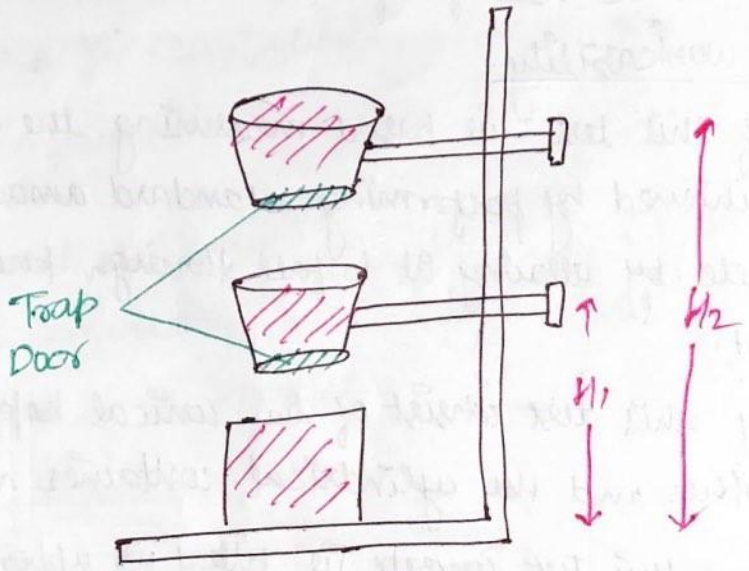
② Compacting Factor Test :

* This test is more accurate and sensitive than slump test and is suitable to be used for for the concrete having medium to low workability.
* The principle of this test is based measuring the degree of compaction achieved by performing standard amount of work on concrete, by allowing it to fall through known standard height.
* The apparatus of this test consist of two conical hopper placed one over each other and the cylindrical container at the bottom.
* In order to perform this test concrete is filled in upper conical hopper and is allowed to fall into the lower one by opening the trap door and finally into the cylindrical container at the bottom.
* Mass of concrete filling the cylinder is noted (M_{PC})
* The cylinder is emptied and is again filled with concrete which is properly compacted and its mass is again noted (M_{FC})

* Workability of concrete is then reported in terms of parameter compaction factor (CF) that signifies the ratio of mass of partially compacted concrete to that of fully compacted concrete.

CF	0.8	0.85	0.9	0.92	0.95
Slump (min)	25	50	75	100	150

Degree of Workability	CF
Low	0.85
Medium	0.92
High	0.95



compaction factor (CF) = $\frac{\text{Mass of partially compacted concrete}}{\text{Mass of fully compacted concrete}}$

$= \frac{M_{PC}}{M_{FC}}$

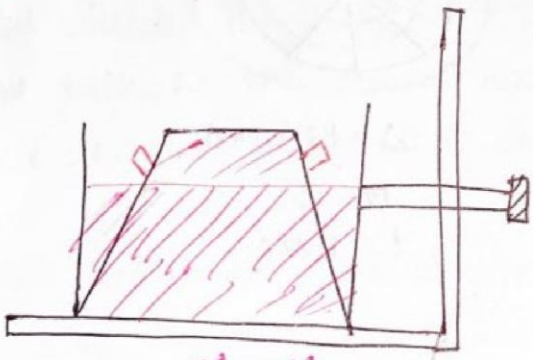
$= \frac{M_{PC} \times V_C}{M_{FC} \times V_C} = \left(\frac{M_{PC}}{V_C}\right)\left(\frac{V_C}{M_{FC}}\right)$

$= \left(\frac{M_{PC}}{V_{PC}}\right)\left(\frac{V_{FC}}{M_{FC}}\right)$

③ Vee Bee Consistometer Test

* This test is suitable for concrete having low to very low workability and is not being used even for the concrete being slump value more than 50mm.
* The apparatus of this test consest of a metallic mould in shape of frustum and cylindrical container
* concrete to be tested is filled in it in 4 layers and each layer is fully compacted by subjecting it to 25 no of blows with tamping rod.
* One mould is filled it is raised in upward in upward direction, along with initiation of vibrations.
* Time taken by concrete to assume cylindrical shape is noted, that is used to indicate the workability of concrete in terms of parameter "Vee Bee Degree"

VBD=t



Vibrating table

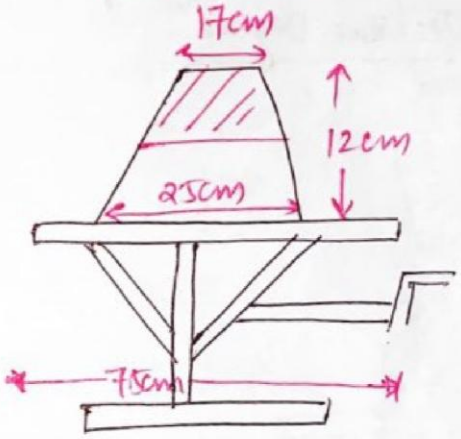
④ Flow Table Test

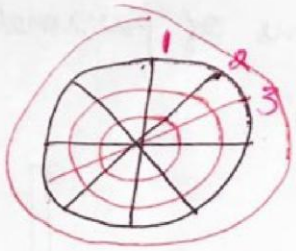
* It is a lab test which is suitable for concrete having high to very high workability for which slump test and compaction factor and Vee Bee test is not suitable
* The apparatus of this test consist of a metallic mould centered over circular flow table.

* In order to perform this test concrete is filled in mould in two layers and each layer is properly compacted.
* Once the mould is filled, it is raised in upward direction and table is lifted and dropped by 12.5mm, 15 no. of times in 15 sec; which causes concrete to flow over the table.
* This flow of concrete is further used to indicate the workability in terms of parameter flow(%) that signifies increase in avg. dia of spread over base dia.

$$\text{Flow}(\%) = \frac{\text{Avg. dia of spread (cm)} - 25}{25} \times 100$$

Flow = 0 - 150%





$\Delta = 12.5\text{mm}$
$N = 15$
$t = 15\text{sec}$

(5) Kelly Ball Test

It is simple field test of the measurement of indentation made by 15cm dia metal hemisphere weighing 13.6kg, when freely placed on fresh concrete.

* This test is not covered in Indian Standards.
* The advantage of this test is that it can be performed on concrete placed at site or in lab faster than slump test (15 seconds)

* The disadvantage of this test it requires a large sample of concrete and cannot be used when concrete is placed in thin sections.
* The min depth of concrete is 20 cm and min distance from centre of the ball to the nearest edge of concrete is 23cm.

(6) K-Slump Test

* It can be used to measure this slump directly in one min after the insertion of tester into fresh concrete. to the level of floater disc.
* This tester can also be used to measure the relative workability of the concrete..
* In order to perform this test.

(1) Wet the tester with water and shake off the excess water from it.
(2) Raise the measuring rod, tilt slightly and let it rest on the pin located inside the tester.
(3) Insert the tester on the leveled surface of concrete vertically down until the disc floater, rest over the surface of the concrete.
(4) After 1min lower the measuring rod slowly until it rest on the surface of the concrete that has entered into the tube and read the K-Slump, directly on the scale of measuring rod.
(5) Raise the measuring rod and let it rest on its pin.
(6) Remove the tester from the concrete vertically upward again, lower the measuring rod slowly till it touches the surface of concrete/mortar. retained in the tube and read workability (w) directly on the scale of measuring rod.

* The K slump tester is very simple practical and economical both in field and lab.
* It can be used to measure the slump in 1 min in cylinder, buckets, slabs etc.

Degree of Workability	Consistency	Slump (m)	CF	Vee Bee Degree (Sec)	Uses
Extremely Low	Moist Earth	0	065-0.7	>20	Precast Paving Slab
Very Low	Very dry	0-25	0.7-0.8	12-20	Road to be Vibrated
Low	Dry	25-50	0.8-0.85	6-12	Mass concreting/ Light R/F Structure
Medium	Plastic	50-100	0.85-0.95	3-6	Flat Slabs, Heavily R/F Structure RCC Structure
High	Semi-fluid	100-175	095-1	0-3	RCC High with longest RF & Tremie Concrete

Segregation and Bleeding of Concrete

* Segregation can be defined as the separation of constituent materials of concrete.
* A good concrete is that in which all the ingredients are properly mixed, distributed and forms homogeneous ~~structure~~ mixture.
* Segregations may be of following types

① coarse aggregate separating out or settling down from rest of the matrix.

② The paste or matrix separating away from coarse aggregate.
③ water separating out from rest of material, being a material of low specific gravity.

* The conditions favourable for segregations are

① Badly Proportioned Mix
② Dropping concrete from height (eg columns)
③ when concrete is discharged from a badly designer mixer or from mixer having worn out blades.
④ Conveyor of concrete on belt conveyor for long distance.
⑤ Vibration of concrete in excess

* The finishing of concrete is greatly affected by segregation, moreover it also affects durability and serviceability of concrete
* It can't be measured quantitavely and can be observed on the basis of experience during concreting operations.

Bleeding is sometimes referred as water gain.

* It is a particular form of segregation, in which some of water from concrete comes out to the surface of concrete as its 'G' is low.
* Bleeding is predominantly observed in highly wet mix, bad proportions and insufficiently mixed concrete.
* Its tendency increases in thin members like roof slabs, road slabs, where concrete is to be laid in sunny weather.
* Due to bleeding water comes up and accumulated at surface along with cement in some cases and formed a layer termed 'LAITANCE' which reduces the strength b/w two successive lift and degrade the wearing quality of surface.

* Bleeding rate increases with time upto about 1 hour or so thereafter the rate decreases but continues upto final setting of cement.
* Bleeding can measure as follows:
① A cylindrical container of $V = 0.01 m^3$ having $Di = 250mm$ and $Hi = 280mm$ is used.
② A tamping rod that is used in slump test is used.
③ A pipette for drawing the free water from the surface, a graduated jar of $100 cm^3$ for test.
* A sample of freshly mixed concrete is obtained and it is filled in 50mm layer for a depth of 250mm (5 layers), each layer is temped by giving 25 no. of blows.
* A test specimen is weighed and weight of concrete is noted.
* Knowing the weight of water concrete and the weight of water in it is noted / calculated.
* The cylindrical container is kept in a level surface free from vibration at temperature of $27 \pm 2°C$ and is covered with LED.
* water is accumulated at top is drawn with pipette at 10 min interval for first 48 min and at 30 min. interval subsequently till bleeding ceases.

$$\text{Bleeding Water Quantity} = \frac{\text{Total qty. of bleeding water}}{\text{Total qty. of concrete water in sample}} \times 100$$

Setting time of concrete

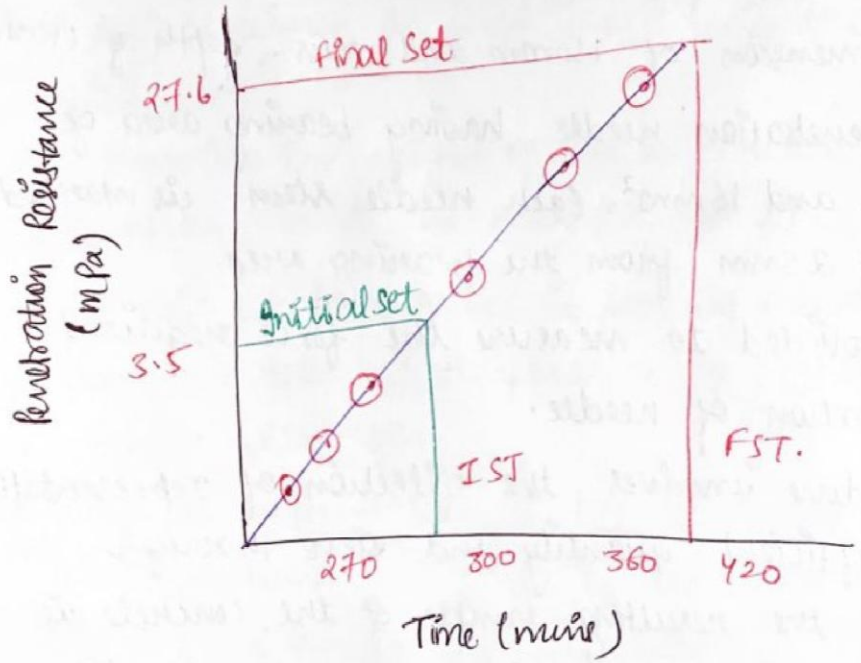
* Setting time of concrete is different from setting time of cement.
* setting time of concrete does not coincide with setting time of cement with which concrete is made.
* The setting of concrete depends upon w/c ratio, temp. conditions, type of cement, use of mineral and admixtures, use of plasticizers.
* The setting parameter of concrete is more of practical significance than setting time of cement.
* It is found by penetrometer test as follows:

① The apparatus consists of a container which should have min. lateral dimension of 150mm and min. depth of 150mm.

② There are six penetration needle having bearing area of 645, 323, 161, 32 and 16 mm^2, Each needle stem is marked at a distance of 25mm from the bearing area.

* A device is provided to measure the force required to cause penetration of needle.
* The test procedure invdves the collection of representative sample in sufficient quantity and sieve through 4.75mm sieve and the resulting sample of the concrete is sufficiently compacted by tamping rod or by vibration.
* The suface is levelled and kept covered to prevent the loss of moisture.
* Bleeding water is removed if found any during the test.

* Insert a needle of appropriate size, depending upon degree of setting of mortar in the following manner.
* Bring the bearing surface in contact with concrete, gradually apply a vertical downward on it until it penetrates to a depth of 25mm.
* The time taken to penetrate at this depth is noted.
* Test is repeated by changing the needle upto an extent penetration resistance of 27.6 MPa is reached.
* From penetration resistance equal to 3.5 MPa draw horizontal line it indicates, IST and corresponding to 27.6 MPa indicate FST.



Strength of concrete

* It is the ability of concrete to resist gradual loading or rupture.
* Strength of concrete depends upon following factors.

① water cement Ratio

* Strength of concrete primarily depends upon strength of cement paste and strength of cement paste depends upon dilution of paste or the strength of paste increases with cement content and decreases with air and water content.

* As per Duff Abrams, strength of concrete is given by.

$$S = \frac{A}{B^x}$$

A = const. 96 N/mm², B = const. 7, $x = \frac{w}{c}$ ratio by Vlume

Note: The constants are for 28 days result

* Abrams law states that the strength of concrete is only dependent of w/c provided the mix is workable.
* However it is not the case, thereby it can termed rule but now law.

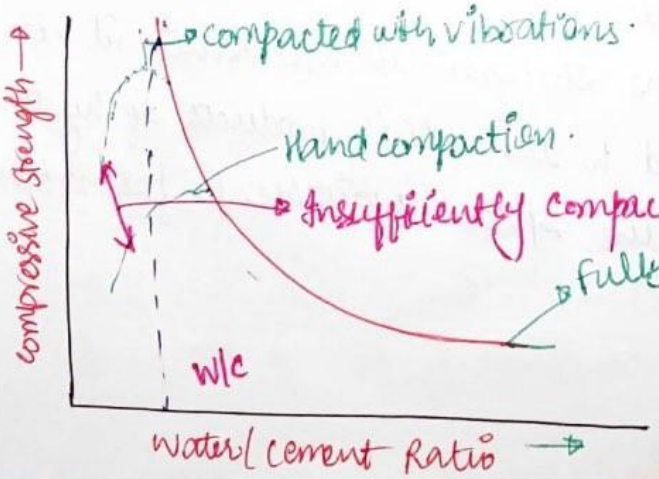
Note: Strength of concrete was also related with w/c ratio by first prior to Abram as

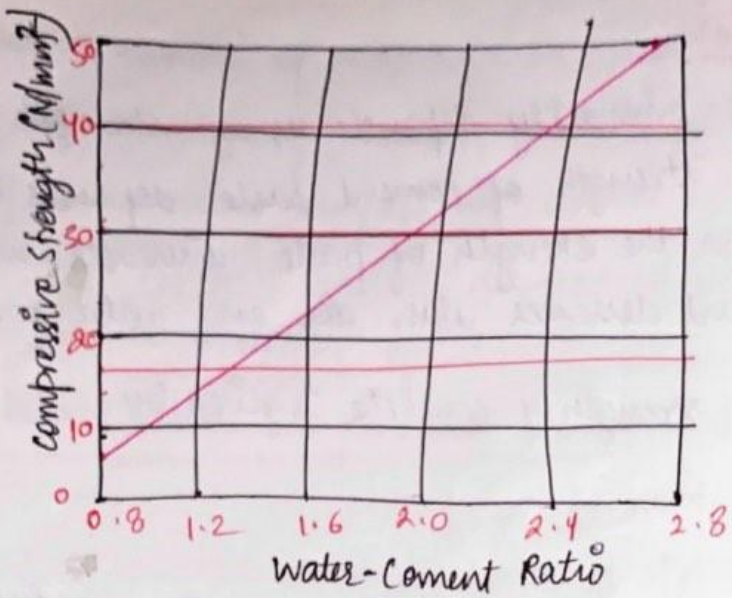
$$S = K\left(\frac{c}{c+e+a}\right)^2$$

S = Strength of concrete

c, e, a = Vol. of cement, water, air respectively.

K = constant.





* As per Feret, the vol. of air is also included because it is not only w/c ratio but also the degree of compaction which indirectly means the vol. of air filled voids in the concrete.

(2) Gel/space Ratio

* Validity of w/c ratio law as given by Abram's is limited hence be termed as rule not law.
* Strength of concrete at constant w/c depends on
(1) degree of compaction (control air in voids)
(2) degree of hydration
(3) Temp. during hydration
(4) Formation of cracks / fissures due to bleeding and shrinkage of concrete.
(5) Air content in concrete.
* Instead of relating the strength to w/c ratio, it is more correctly related to the solid products of hydration of cement (Gel) to the space available for formation of this product.

* This ratio is defined as the ratio of vol. hydrated cement paste to the sum of vol. of hydrated cement and of the capillary pores.

* Power and Brownyard related strength of concrete to gel/space ratio as follows:

$$S = 240x^3$$

S = Strength of concrete, x = gel space ratio

240 represents Intrinsic strength of concrete (mPa)

* The relationship b/w w/c ratio and strength is valid for 28 days strength for full compacted concrete, where the relationship b/w strength and gel/space ratio is independent of age.

* gel/space can be calculated at any age and for any fraction of hydration of cement as follows:

① Gel/space Ratio for complete hydration

C = wt. of cement (gm)

V_c = Sp. Vol. of cement = 0.319 ml/gm

W_o = Vol. of mixing water in 'ml'

Assuming that 1 ml of cement on hydration will produce 2.06 ml of gel.

Volume of gel = $C \times 0.319 \times 2.06 = 0.657C$

Space Available = $C \times 0.319 + W_0$

$$\text{Gel-Space Ratio} = \frac{0.657C}{0.319C + W_0}$$

(2) Gel/Space Ratio for Partial Hydration

Let α = fraction of cement has hydrated

Vol. of gel = $C \times \alpha \times 0.319 \times 2.06 = 0.657C\alpha$

Total space available = $0.319 \times C \times \alpha + W_0$

$$\text{Gel-Space Ratio} = \frac{0.657C\alpha}{0.319C\alpha + W_0}$$

Q. Calculate the gel/space ratio and theoretical strength of a sample of concrete made with 500g of cement with w/c ratio as 0.60. on full hydration & at 50% hydration.

(1) $G/S = \frac{0.657 \times 1 \times 500}{0.319 \times 500 + 0.6 \times 500 \times 1} = 0.071$

Strength = $240(0.071) = 17.16$ MPa

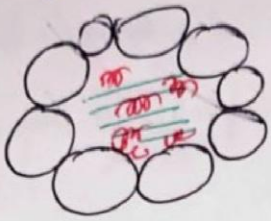
(2) $G/S = \frac{0.657 \times 1 \times 500 \times 0.5}{0.319 \times 500 \times 0.5 + 0.6 \times 500 \times 1}$

$= 0.432$

Strength = $240 \times (0.432)^3$

$= 19.37$ MPa

Note: Strength of concrete is much lower than theoritical strength of concrete due to several flaws in it.



③ Maturity of Concrete

* While referring curing and strength development only age of concrete was considered.
* But temp. during the early period of hydration also influence the rate of gain of strength of concrete.
* Since strength of concrete depends on both time and temp., it can be said to the function of summation of production of time and temp.
* The summation is called maturity of concrete.

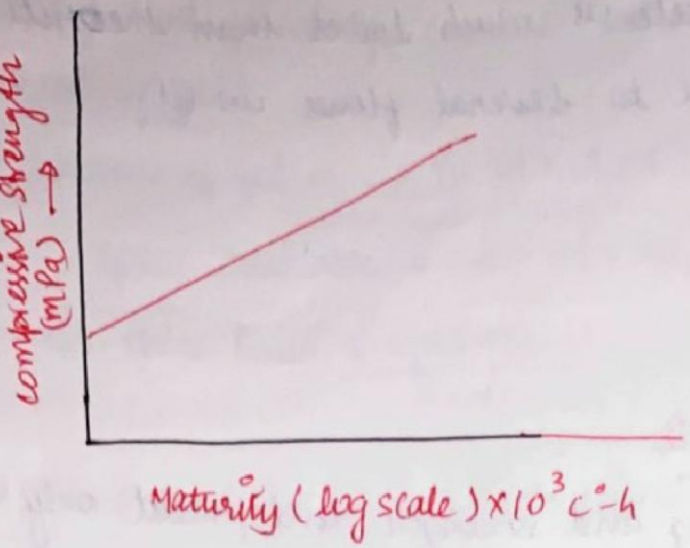
  Maturity = Σ (time x temp.)

* The temp. is considered for reference b/w -12 and -10°c, upto which hydration of concrete takes place (an avg value of -11°c is taken for calculation).
* Maturing is measured in (°c-hr) or (°c-day).
* A sample of concrete cured at 18°c for 20 days is taken or fully matured concrete. Its maturity would be

  $M = 28 \times 24\ [18° - (-11°C)]$

  $= 19488°C\text{-}hr$

* However the standard calculation are done for maturity of concrete as 19800°c hr.



* Maturity concept is useful for estimating the strength of concrete at any other maturity as % of strength of concrete of known maturity.

Strength at any maturity as % of strength at maturity of 19800°C h $= A + B \log_{10}\left(\frac{\text{maturity}}{10^3}\right)$

* The value of constant A & B depends upon strength level of concrete.

Strength after 28 days at 18°C (M = 19800°C h) (mPa)	A	B
< 17.5	10	68
17.5 – 35	21	61
35 – 52.5	32	54
52.5 – 70	42	46.5

* If the strength at given maturity is ~~not~~ known then the no. of days required to reach the same strength at any other temp. is given by :

$$T(\text{days}) = \frac{M}{24[t-(-11)]}$$

t = temp. (°C)

Q. A strength of sample of full matured concrete is found to be 40MPa. Find the strength of identical con^n at age of 7 days when cured at an avg temp. during day at 20°c and night at 10°c.

Soln. Maturity $= \Sigma(t \times T)$

$= [20-(-11)] \times 7 \times 12 + [10-(-11)] 7 \times 12$

$= 4368°c\,hr.$

% of Strength of this conc. wrt strength of conc. at maturity of 19800°c hr $= A + B\log_{10}\left(\frac{\text{maturity}}{10^3}\right)$

$= 32 + 54 \times \log_{10}\left(\frac{4368}{10^3}\right)$

$= 66.57\%$

Strength of concrete at 7 days $= \frac{66.57}{100} \times 40 = 26.63\,MPa$

$= \boxed{26.63\,MPa}$

Q. Lab experiments conducted a particular mix showed a strength of 32.5 MPa for fully matured concrete. Find whether framework can be removed for an identical concrete placed at other place at age of 15days and temp of 5°c, if concrete is likely to be subjected to stripping stresses of 25MPa? Also compute time req. to reach same strength level as was observed in lab?

Maturity = $15 \times 24 [5-(-11)]$

$= 5760°ch$

$\%S = A + B \log_{10} \left[\frac{\text{Maturity}}{10^3}\right]$

$= 21 + 61 \log_{10} \left[\frac{5760}{10^3}\right]$

$= 67.6\%$

Strength at the age of 15 days $= 32.5 \times 0.676$

$= 21.9 MPa$

(ii) $T = \frac{M}{24[1-(-11)]} = \frac{19800}{24[5-(-1)]} = 52$ days

(4) Shape of Aggregates

* Use of Angular or cubical aggregates form strong concrete as better is the interparticle locking in this case and higher is the bond strength.
* Use of rounded aggregates, flaky and elongated aggregates forms poor concrete.

(5) Texture of Aggregates

Rough textured aggregates leads to the formation of strong concrete as better is the interparticle locking & higher is the bond strength.

(6) Use of Admixtures

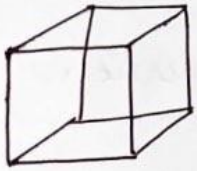
Admixtures like plasticizers and superplasticizers, helps in increasing the strength of concrete.

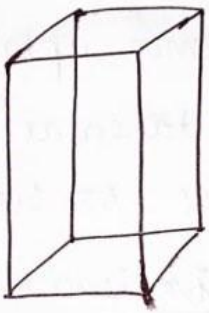
Determination of Strength of Concrete

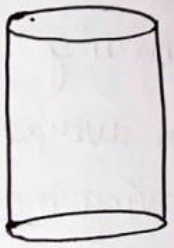
Strength of concrete can be found by any of the following method:

① Compressive Strength Test

* This test is performed to find the compressive strength of concrete.
* Mould used in this case, can either be cubical, cylindrical or prismoidal.







* If the max nominal size of aggregate is more than 20mm, 150mm sized cube is used and if max nominal size of aggregate is less than 20mm, 100mm sized cube is used.

Nominal size of aggregate : The smallest sieve opening through which entire amount of aggregate is permitted to pass.

* If cylindrical mould is used, length ratio is kept 2. [generally 30 cm length and 15cm dia is used] $\left(\frac{\text{length}}{\text{dia}}\right)$
* Prismoid mould is usually not considered for testing.
* concrete to be tested is filled in mould in layers of 50mm and each layer is compacted with the help of tamping rod. by subjecting it to 35 no. of blows with the help of tamping rod of dia. 16mm and height of 60cm.

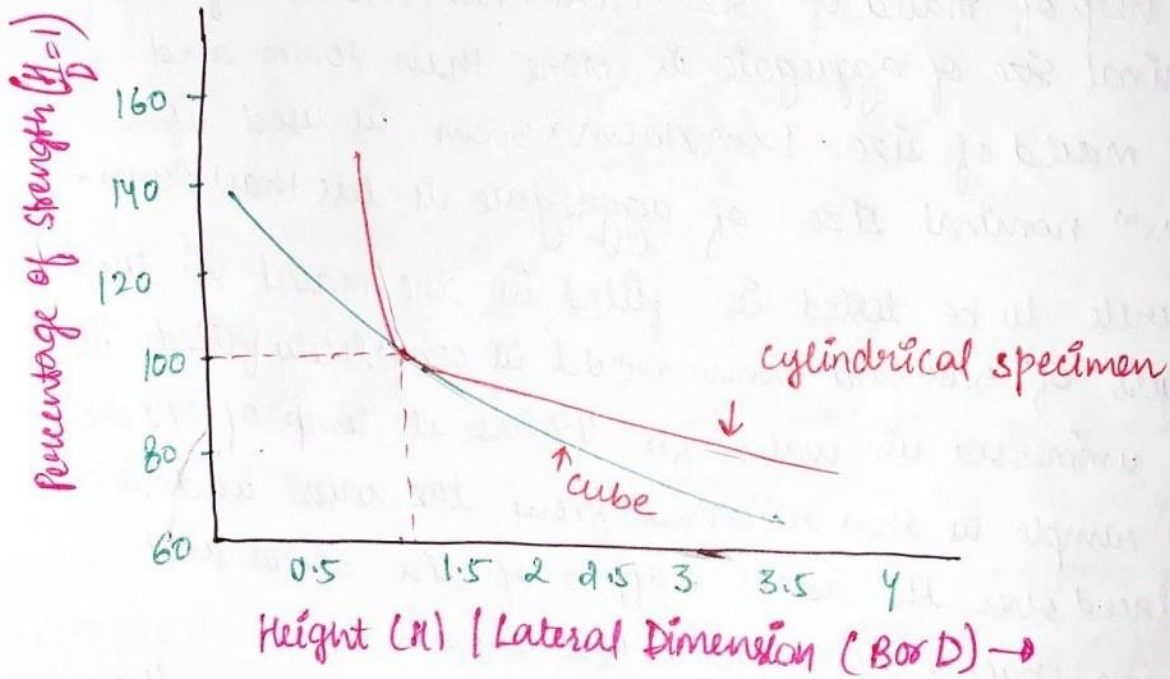
* When the mould is completely filled, it is placed at location free from vibration for $24 \pm \frac{1}{2}$ hr at temp. $27 \pm 2°C$ and the humidity of 90%.
* After 24 hrs, sample is removed from mould and immersed in water for sufficient duration. (This is one of the method to ensure curing).
* At a specified age of testing, sample is removed from the water and it is subjected to uniform gradual loading of $14 N/mm^2/min$ upto failure.
* An average 3 results is taken as strength of concrete, having more deviation of $\pm 5\%$ between them.
* Application of compressive load over the specimen lead to the development complex compressive stresses due to the restraining effect of the steel plates.
* This restraining effect is induced due to diff. in lateral strain of steel and concrete.
* Lateral strain in steel is 0.4 times of lateral strain in concrete, hence results obtained by this test are more than the actual.
* This restraining effect obtained by cylindrical specimen are less than those obtained by cubical speciment $[S_{cy} = 0.8 S_{cx}]$ and are more clear to the actual results.
* In case of cylindrical specimen, casting and loading is done in same dish as is observed in the field in actual structural components, which is not the case in cubical specimen.

* Relative strength a concrete from cubes of different sizes.

Cube Size(mm)	100	150	200	300
Relative strength to 150mm cube	1.05	1	0.95	0.87

* If size of cube is decreased the compressive strength tends to increase where as Modulus of Elasticity decreases.
* Relative strength of prism of different height to side ratio.

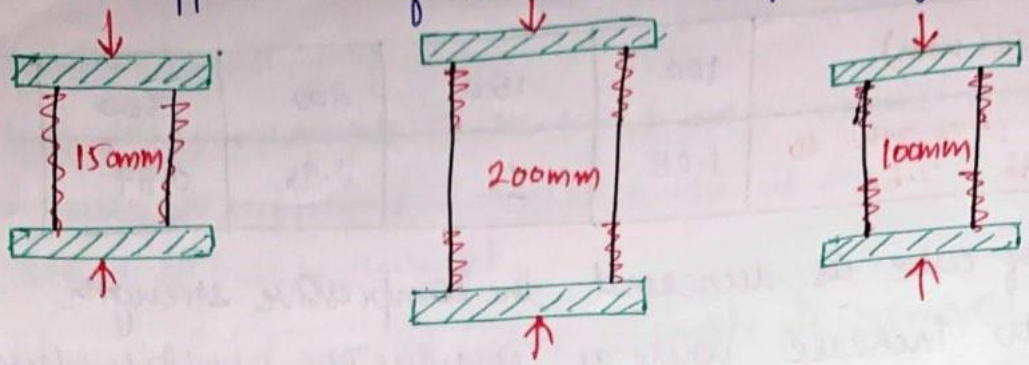
$\frac{H}{B}$ or $\frac{H}{D}$ Ratio	0.5	1	2	3	4	5.5
Relative strength	1.5	1	0.8	0.72	0.68	0.6



Note: These are different types of strength for which concrete is analysed, compressive, tensile, bending, shear strength.

There is no relationship between these structure but tensile and bending strength of concrete are of order

of 10 and 15% respectively of it. compressive strength and Shear is approx 20% of its uniaxial comp. strength.



② Tensile Strength Test

Tensile strength can be found by any of the following methods:

① Flexural Tensile Strength Test

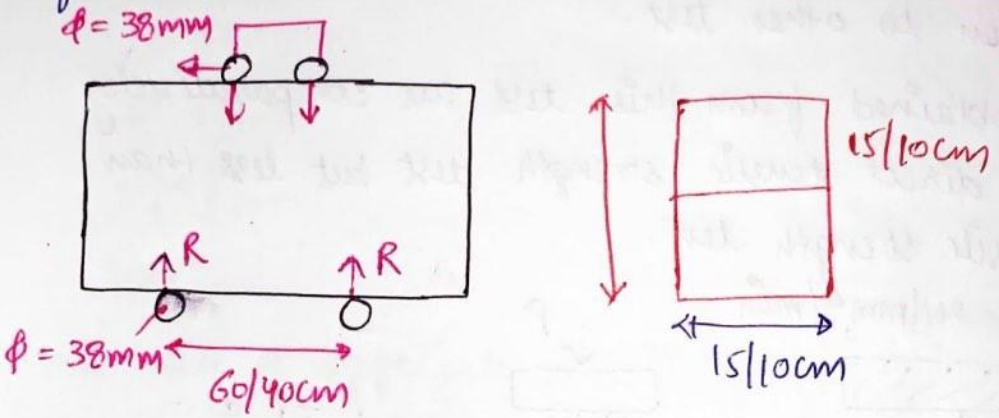
* Flexural Tensile Strength of concrete is determined with the help of mould of size 15cm x 15cm x 70cm. if max. nominal size of aggregate is more than 20mm and the mould of size. 10cm x 10 cm x 50cm is used if max^{m} nominal size of aggregate is less than 20mm.
* Concrete to be tested is filled in the mould in the layers of 5cm and when mould is completely filled it is immersed in water for 48 hrs at temp of 27 ± 2°C.
* The sample is then removed from the water and is placed over the roller supper of dia 38mm and having spacing of 60/40 cm b/w them.
* The sample is then loaded with the help of rollers of same dia, having spacing of 20/13.3cm b/w them.
* The load over the sample is increased at uniform rate of 0.7N/mm^2/min, upto failure in order to find modulus of rupture, by noting the distance of line of

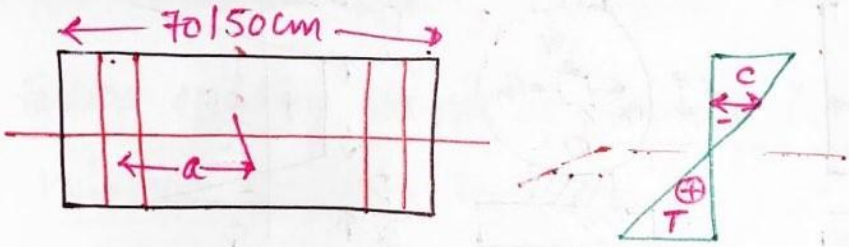
~~fracture~~ fracture from the nearest support.

* If $a > 20/13.3$cm $\quad f_{cr} = \frac{PL}{bd^2}$

* If $17/11$cm $< a < 20/13.3$cm $\quad f_{cr} = \frac{3Pa}{bd^2}$

* If $a < 17/11$cm Result is discarded.



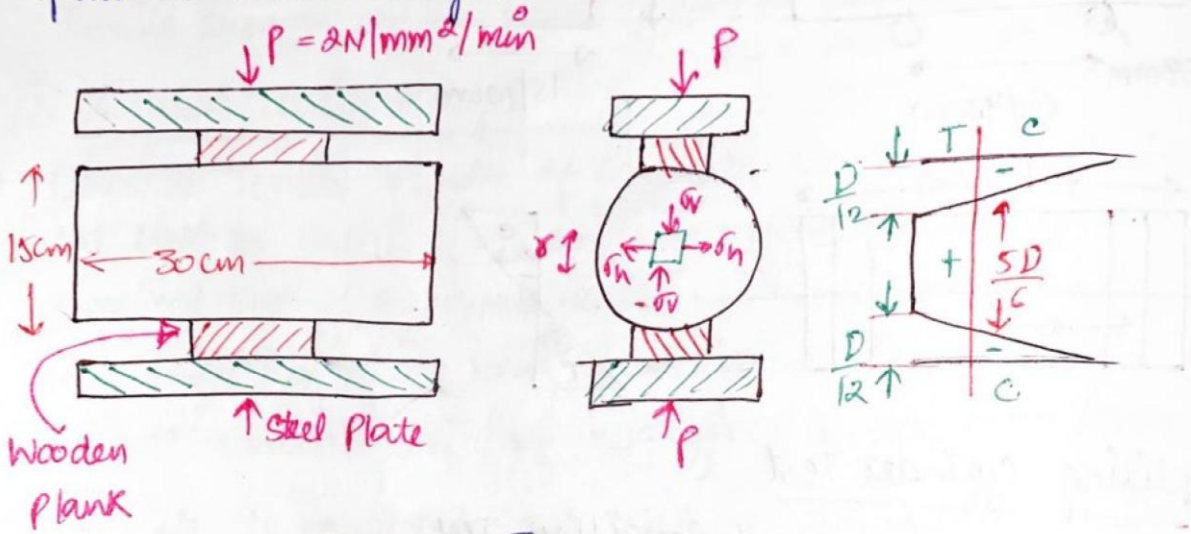


③ Spliting Cylinder Test

→ It is also termed as Brazilian Test.

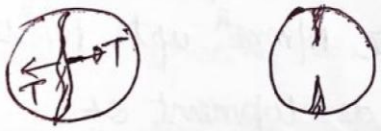
* In this test the cylindrical specimen of size $(\frac{L}{D} = 2)$ is adopted (generally 30 cm length and 15cm dia. is adopted)
* The sample is loaded b/w the steel plates of UTM and compressive load is applied is at rate N/mm² upto failure.
* Application of compression leads to development of compressive stresses upto a certain depth below the application of load $(\frac{D}{6})$ but the substantial portion is bring subjected to induced tensile stresses $(\frac{5D}{6})$ that causes the splitting failure to the cylinder.

* The greatest advantage of this test is that the same mould and apparatus can be used to find the both compressive and tensile strength of the concrete.
* This test is very easy to perform and loads to the development of uniform stresses across the failure plane in compression to other test.
* The result obtained from this test are comparatively greater than direct tensile strength test but less than flexural tensile strength test.



$$\sigma_v = \frac{-2P}{\pi LD}\left[\frac{D^2}{r(D-r)} - 1\right]$$

$$\sigma_h = \frac{2P}{\pi LD}$$



Note: The smallest size ~~of~~ through which entire amount of aggregate is required to pass (or the smallest size through which 100% of aggregate sample particle pass) is termed as max. size of aggregate.

* The smallest size through which entire amount of aggregate is permitted to pass or the largest sieve that retains some of the aggregate particles on it, is termed as nominal maxm size of aggregate.

100gm

— 40mm

— 37.5mm

5gm — 25mm

55gm — 18mm

40gm — 12mm

Maxm size of aggregate is = 37.5mm

Maxm Nominal size of aggregate = 25mm

Factors affecting strength of Concrete (Indirectly)

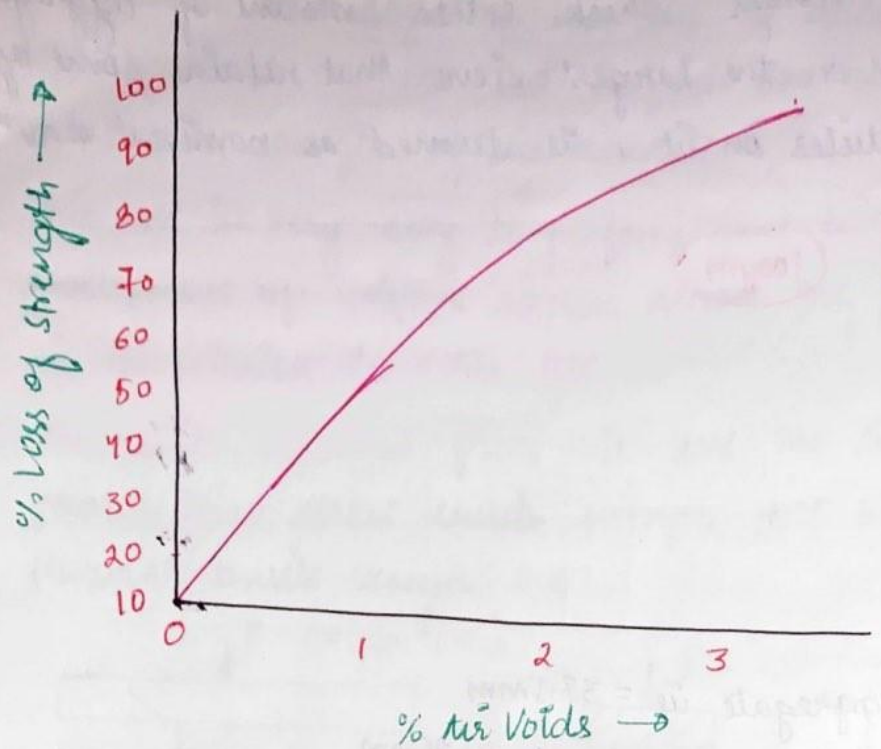
① Moisture condition of specimen

* Dry cubes may have drying shrinkage and bond failure leading to smaller strength.
* Moisture content in concrete provides lubrication effect and reduces its strength.
* In general dry strength comes out to be more strength of saturated sample.

Strength of dry sample = (1.1 - 1.2) strength of saturated sample

② Air voids

* Strength of concrete decrease with increase in air voids.
* Air voids are formed by vapourisation of water used in making of concrete (capillary water)



③ Rate of loading.

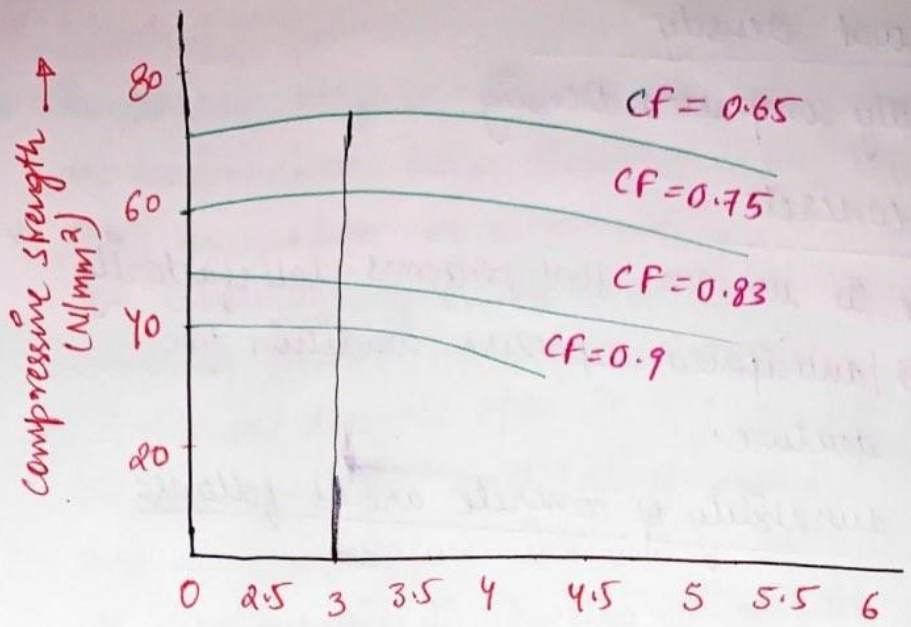
* Strength of concrete increase with the increase in loading.
* At low rate of loading there is more time for creep to occur, so that the ↑ strength of with rate of loading provides justifies for the failure occuring due to limiting values of strain, rather stress.

④ Age of Cement

As cement ages, it strength reduces due to its pre hydration

⑤ cement-Aggregate Ratio

By increasing cement to aggregate ratio ultimate strength of concrete increases to so extent.

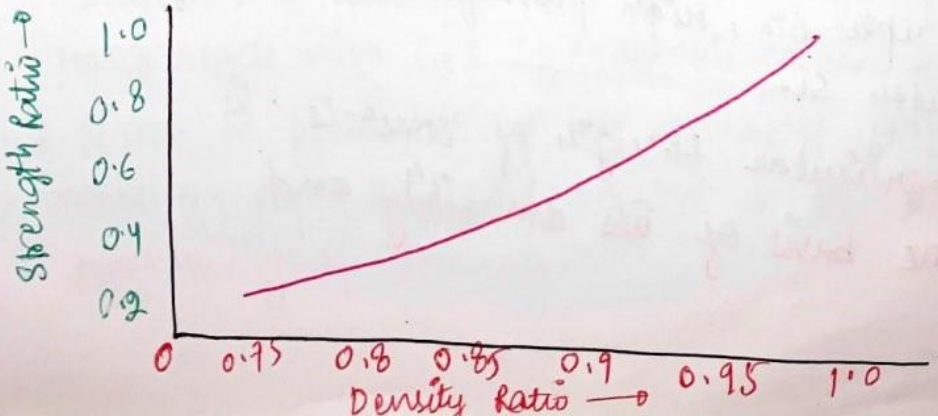


⑥ Size of Aggregate:

* It is observed that higher strength concrete gives lower strength as compared to lean concrete if larger size aggregates is used.
* Generally it is believed that the larger max.^{m} size of aggregate, denser and stronger will be the concrete because larger aggregates have lower total surface area and required lower w/c ratio resulting in high strength.
* But in actual large aggregate gives lower surface area for development of gel bonds which leads to low strength.

⑦ Degree of Compaction

Inadequate compaction leading to air void content of 5-10% can reduce the strength of concrete drastically, due to reduction in availability of area to transfer the load.



Density Ratio = $\frac{\text{Actual Density}}{\text{Fully compacted Density}}$

Durability of concrete

* A durable concrete is the one that performs satisfactorily under the expected/anticipated exposure condition for stipulated life of structure.
* Factors affecting durability of concrete are as follows:

① Permeability:

* All forms of deterioriation in concrete are due to penetration of water in it.
* The ways in which durability of concrete may be affected because of permeability are:
  ① The chemicals in liquid form affects the concrete by penetrating into it.
  ② Frost action, rusting of steel.
* concrete has gel pores and capillary cavities.. About 1/3rd of gel pores are so small that they hardly pass any water through them.
  The extent of capillary cavities which depend upon the w/c ratio, is major factor contributing to the permeability.
* The remedy to this is, use of pozzolonic material, air entrainment upto 6%, High pressure steam curing in conjugation with Si.

Note: $\frac{w}{c}$ for a particular strength of concrete is regulated on the basis of its durability and workability

② Frost Action :

* The concrete may be affected due to being permeable or by temperature below 0°c.
* The mechanism of attack in this case is attributed to the expansion of water on freezing, causing the disintegration of concrete.
* Horizontal surface open to sky absorbing maximum water in wet condition and cooling quicker by radiation and low temperature increasing the extent of migration of water resulting in freezing at greater depth in concrete favours frost action.
* Repeated freezing and thawing and use of de-icing salts also favours frost action.
* It can be controlled by increasing the proportion of C_3S in cement or by use of special cement.

③ Sulphate Attack :

* It denotes an increase in volume of cement paste due to the chemical action b/w products of hydration of cement and solution containing sulphates. (C_3A, C_4AF, $Ca(OH)_2$)
* Sulphate attacks in three forms on concrete Ca, Mg, Na. Ca has low solubility so does not constitute high risk and Mg has most severe disruptive effect over the concrete, because the reaction products is insoluble, precipitating out of the solution and leaving the way clear for further attack and $MgSO_4$ reacts with C_3S hydrate in cement.
* It can be prevented by use of blast furnace slag, sulphate resisting, super sulphated cement or by reducing the permeability of concrete.

④ Carbonation :

* Concrete is alkaline in nature and has pH of 12-13. However carbon steel reinforcement in alkaline environment is not affected by corrosion but CO_2 present in the atmosphere react with concrete in the presence of water and forms carbonic acid which attack the concrete.
* $Ca(OH)_2$ present in concrete is converted to $CaCO_3$ causing reduction in pH of concrete.
* Thus it turn acidic, initiating corrosion in it.
* Along with the corrosion it volume increases and consequently the concrete cracks and spalling takes place.

⑤ Mineral Oils :

Petroleum oil and its products donot have direct effect over the hardened concrete but affects the permeability of fresh concrete.

⑥ Organic Acids :

Acetic Acid, Lactic Acid, Butyric Acid severely affect concrete
Formic Acid is corrosive to concrete.

⑦ Sugar :

It is retarding agent and gradually corrodes the concrete.
Remedy is to coat the concrete with Sodium silicate solution, tar or Asphalt.

⑧ Vegetable and Animal Oil and fats :

These consists of free fatty acids which deteriorates the concrete.

⑨ Sewage:

H_2S gas evolved from septic sewage promote H_2S corrosion.

⑩ Thermal Effects:

Since concrete is heterogeneous the ingredients of concrete have dissimilar thermal coefficients which leads to cracking.

⑪ Cracks:

These are inherent to concrete and cannot be prevented leading to decreased durabilities of concrete.

Defects in Concrete

① Cracks:→

Cracks in concrete may originated from one or more of the following reasons.

- Excess water
- Early loss of water
- Alkali-aggregate reaction
- Freezing and Thawing
- Corrosion in steel.

Development of cracks reduces load carrying capacities of concrete

② Crazing:

Crazing of concrete results from ~~difference in~~ difference in shrinkage btw surface and interior.

* The cracks rarely exceeds 12mm or 50 ~~cracks~~ in depth and therefore are not serious, apart from the unsightness.

③ Sulphate Deterioration:

Sulphate attack is mainly caused by soil containing, excess of sulphate or by sulphate water.

④ Efflorescence:

It is the appearance of fluffy white patches on the surface of concrete. It is caused by poorly wasted aggregates, salty water used in formation of concrete.

⑤ Segregation and Bleeding:

Separation or setting of coarse aggregate from mix is termed as segregation and separation of water from the mix is termed as Bleeding

⑥ Laitance :→

It is defined as water cement slurry coming out on the top of concrete surface and setting over it. It reduces the strength b/w two successive lift of concrete.

Physical Properties of concrete

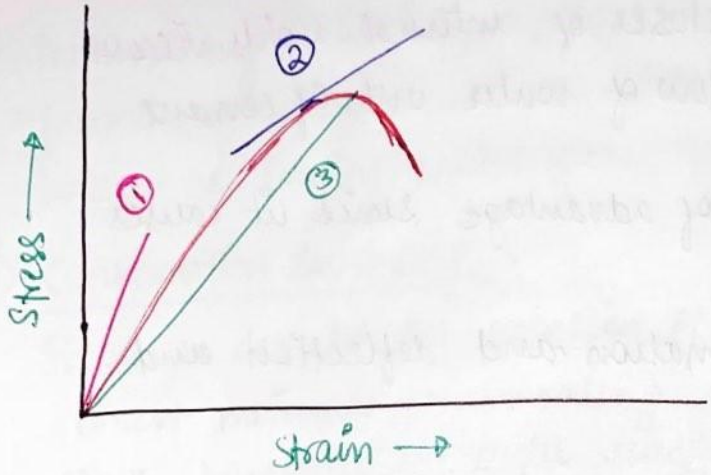
① Modulus of Elasticity : (Ec)

* The true elastic curve for concrete in compression can be plotted by applying and releasing load until the set at zero load become constant.
* By subtracting the set from the total deformation, the elastic deformation at a given load is determined.

* Since Mortar and concrete has no elastic limit, the Ec for concrete must be the slope of stress-strain curve at zero stress.

$E_c = 5000\sqrt{f_{ck}}$, f_{ck} = characteristic strength of concrete

$E_c = 14 \times 10^3 - 40 \times 10^3 \ N/mm^2$.



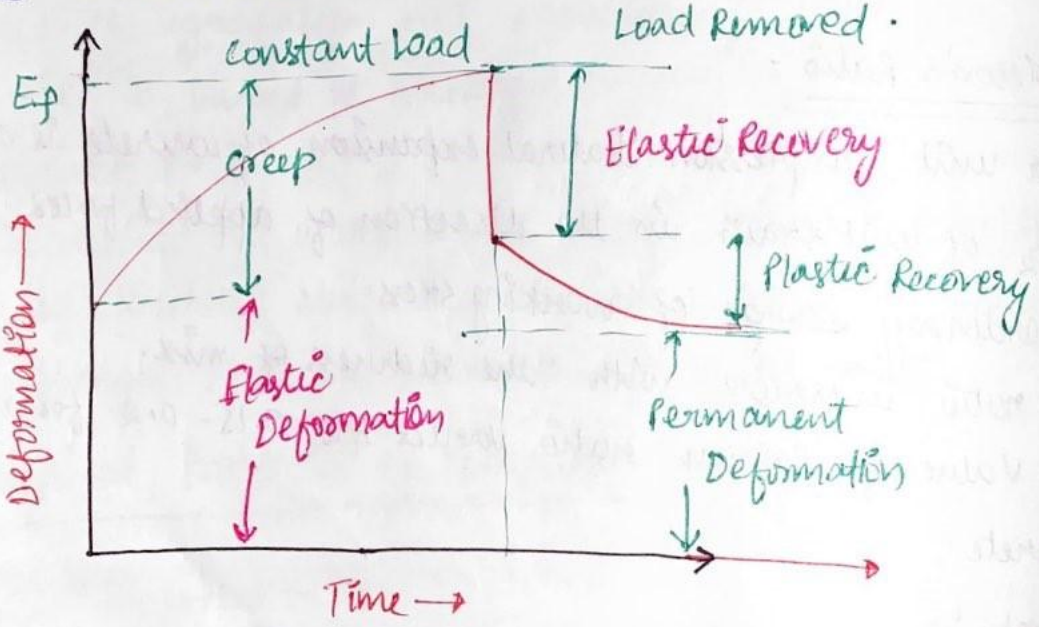
(2) Poisson's Ratio :

* Under unit compression, lateral expansion of concrete is about $\frac{1}{6} - \frac{1}{12}$ of unit strain in the direction of applied forces for the ordinary sewage of working stress.
* The ratio increases with the richness of mix.
* The value of Poisson ratio varies b/w 0.15 - 0.2 for normal concrete.

(3) Creep :

* The continued deformation with time under applied load is creep.
* It may be defined as an increase of strain in concrete with time under sustained stress.
* This is also termed as plastic flow/time yield.

* The rate of creep decreases with time and the creep strain at "5 years" are taken as terminal creep.
* Creep increases rapidly with stress. loading at an early age of concrete, use of broken ballast, soft, porous concrete aggregate, poorly graded and improper compacted concrete.
* Creep may be due to closer of internal voids, viscous flow of cement paste, flow of water out of cement gel.
* In RCC structure. it is of advantage since it causes better distribution stresses.
* Creep causes large deformation and deflection and is undesirable.



(4) Shrinkage:

Contraction of concrete in the absence of load is known as shrinkage.

It may be of following types

① Plastic Shrinkage :-
It occurs very soon after the pouring the concrete in the forms. The hydration of cement results in the reduction in the volume of concrete due to evaporation from the surface of concrete which lead to cracking.

② Drying Shrinkage:
The shrinkage that appears after the setting and hardening of concrete mixture due to loss of capillary water is known as Drying shrinkage.

③ Carbonation Shrinkage:
It occurs due to the reaction of CO_2 with the hydrated cement minerals, carbonating $Ca(OH)_2$. The carbonation slowly penetrates the outer surface of concrete.
This type of shrinkage mainly occurs at medium humidities and results in increased strength and reduced permeability.

④ Autogeneous Shrinkage:-
It occurs due to no moisture movement from concrete paste under constant temperature. It is a minor problem of concrete and can be ignored.

Factors Affecting Shrinkage:

① W/C Ratio : It increases with increase in shrinkage

② Environmental Condition : It is one of the major factor affect the total shrinkage. It is mostly occured due to drying conditions of atmosphere. It increases with decrease in humidity.

③ Time: The rate of shrinkage rapidly decreases with time It is found that 14-34% of 20 years of shrinkage occur in two weeks and 40-80% of shrinkage occurs in 2 months and rest 66-85% in one year.

④ Type of Aggregates: Aggregates with moisture movement and low E_c causes large shrinkage. The ratio of shrinkage generally decreases with increase in the size of aggregates.

⑤ Admixture: The shrinkage increases with the addition of accelerating admixture due to presence of $CaCl_2$ and it can be reduced by lime replacement.

- Shrinkage of concrete can be computed by:

$$E_s = 0.00125(0.90 - h)$$

E_s = Shrinkage strain

h = relative humidity

Non Destructive Testing of Concrete (NDT)

* The testing of concrete being referred uptil now was for representative sample, which does not indicate in properties of concrete actually used in construction.
* Information about the in-situ strength of concrete may be required for both construction as well as existing concrete structure for which NDT is suitable.
* It is also needed in following situations:

① Non-compliance of the material supplied in terms of works specimen test result or other specified requirements.

(b) Uncertainties concreting - the level of workmanship involved in construction.

(c) Quality control of const

(d) Monitoring the strength development in to formwork removal, curing etc.

Advantages of NDT.

(1) The measurement can be done in-situ.

(2) Variation in quality of concrete with time and external influence can be studied.

(3) In the method, concrete is not loaded to destruction and hence be used after the test. also.

(4) There is not wastage of material in these test.

Following types of NDT are available

(1) schmidt test Hammer.

(2) Ultrasonic Pulse Velocity.

(3) Maturity Test

(4) Concrete Core Test

(5) Pull Out Test

(6) Penetration Test

(7) Radioactive method.

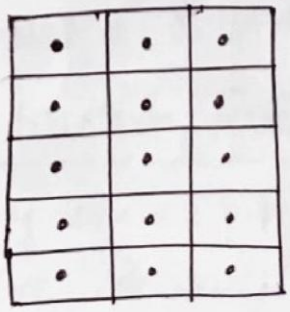
(1) Schmidt Rebound Hammer Test

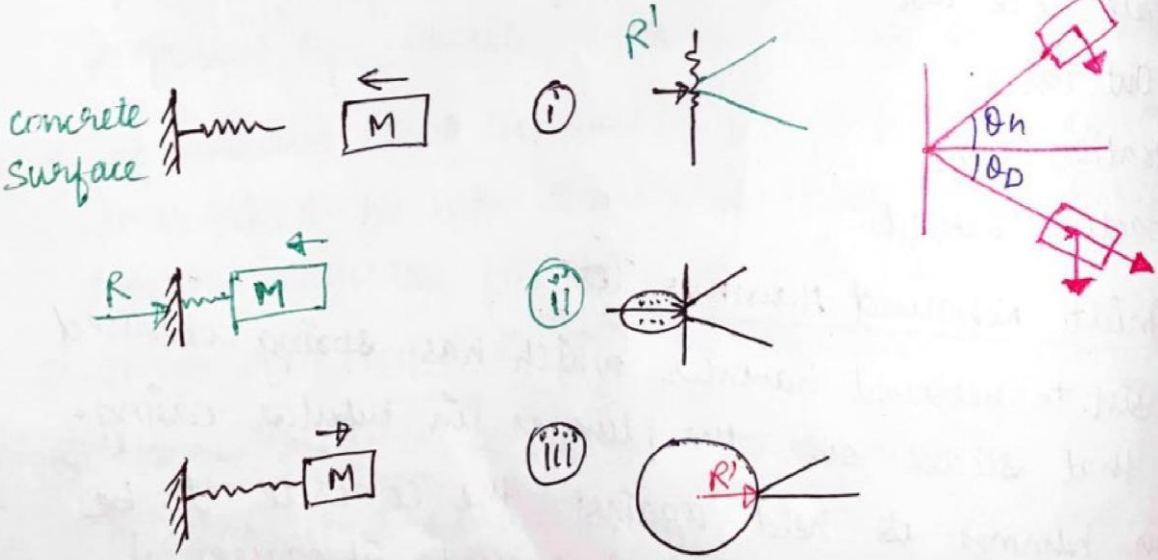
It consist to rebound hammer which has spring controlled mass that slides over the plunger in tubular casing.

* When hammer is held against the concrete to be tested and release button is pressed, it causes the rebound mass to strike against concrete surface,

that retract back against the force of the spring, displacement of which is measured over scale in terms of parameter 'Rebound Hammer' which is further used to indicate the strength of concrete.

* The result of this test depends upon following factors:
  1. Age of Specimen.
  2. Smoothness of the surface under the test.
  3. Internal and External Moisture ~~Contain~~ Content
  4. Size, shape and Rigidity of the Specimen.
  5. Type of Coarse Aggregate used.
  6. Type of Cement used.
  7. Angle at which hammer is pressed against the concrete surface.





(II) Ultrasonic Pulse Velocity Test

* The principle of this test is based upon the fact that velocity of sound in solids depends upon both its modulus of Elasicity and density.

$$V_s = F[E, e]$$

* The apparatus of this test consist of a transmitter and a receiver, when transmitter is used to generate a pulse of ultrasonic frequency and receiver is used to detect it.

* The time required by the pulse to travel through the known distance in specimen to tested is noted, that is further used to calculate the velocity of pulse which is then rotated with the quality of concrete as follows:-

Velocity of Pulse (km/s)	Quality of Concrete
>4.5	Excellent
3.5 - 4.5	Good
3 - 3.5	Medium
<3	Doubtfull

* The dynamic young's Modulus of Elasticity of the ~~cent~~ concrete may also determined from the pulse velocity and the dynamic poisson's ratio as follows:

$$E = \frac{\rho(1+\mu)(1-2\mu)V^2}{1-\mu}$$

E = dynamic young's Modulus of Elasticity (MPa)

ρ = density (kg/m^3)

V = Pulse Velocity (m/s)

μ = Dynamic Poisson Ratio

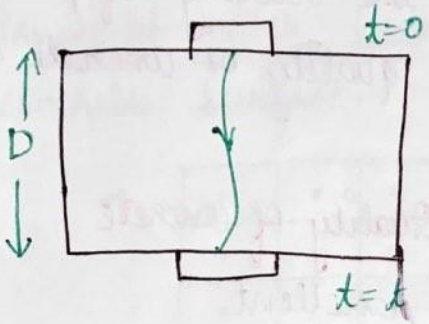
Hence, $E = \rho f(\mu) V^2$

$$F(\mu) = \frac{(1+\mu)(1-2\mu)}{1-\mu}$$

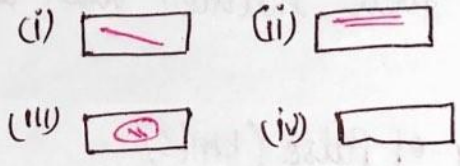
$\mu = 0.2 - 0.35\ (0.24)$

The results of this test depends upon following parameters:

① Temperature during the Test
② % of r/f provided
③ Internal and External Moisture condition
④ Smoothness of surface under Test



$V_s = \frac{D}{t}$



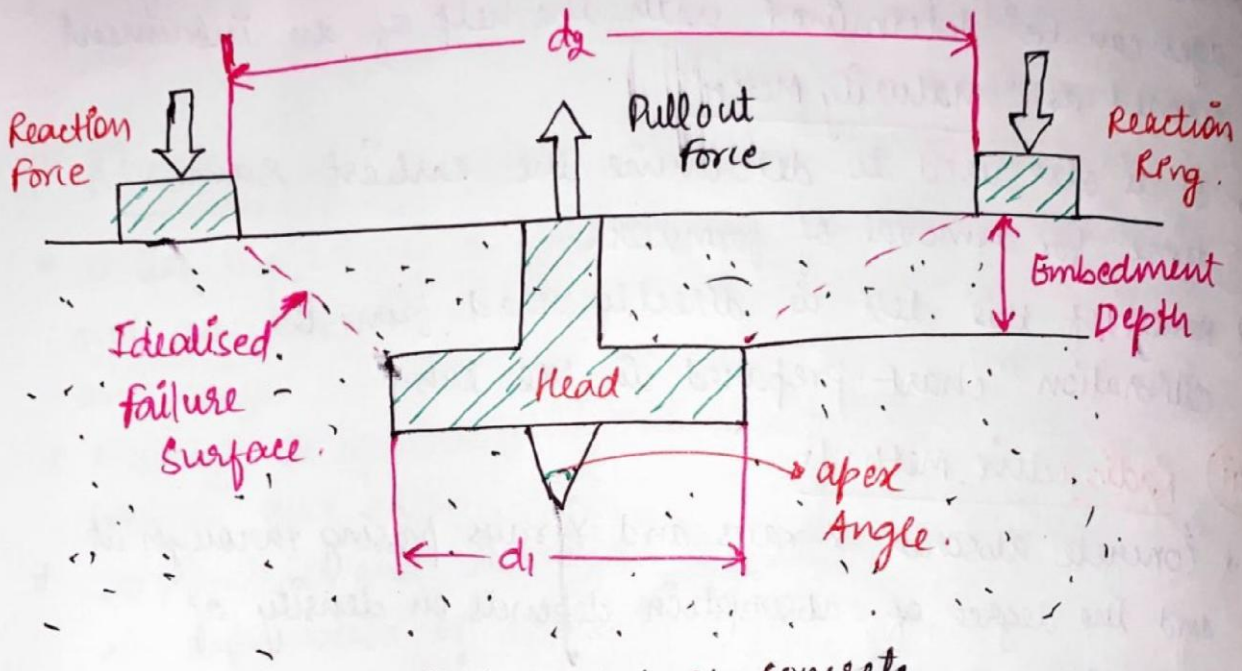
(III) Concrete Core Test:

In this test concrete cores are drilled from the structure and are tested in UTS. The average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the concrete specified for the corresponding age.

(IV) Pull Out Test

* It is more authentic than concrete core test.
* A special shaped steel rod with one end enlarged is embedded in concrete in the form work.

* After the concrete hardness the rod is pulled out and in doing so it comes out with a block of concrete.
* The pulled out force as determined by a hollow tension ram is related to the compressive strength of concrete.



Pull out Test of concrete

(V) Penetration Test

* In this test windsor probe is generally used as the best means of testing penetration
* It consists of powder-actuated gun or driver, hardend alloys probes, loaded catridges, a depth gauge for measuring penetration of probes and other related equipments.
* A probe of dia 6.5mm and length 80mm is driven into the concrete by means of precision powder charge.
* Depth of penetration provided an indication of the compressive strength of the concrete.

(vi) Maturity Test

* It is found based on the principle that the concrete having equal maturity will have equal compressive strength.
* The maturity of the in-situ concrete at the early ages can be determined with the help of an instrument termed as "Maturity Meter"
* It is also used to determine the earliest same time for removal of formwork.
* Result of this test is directly read from the calibration chart prepared in the lab.

(vii) Radioactive Methods

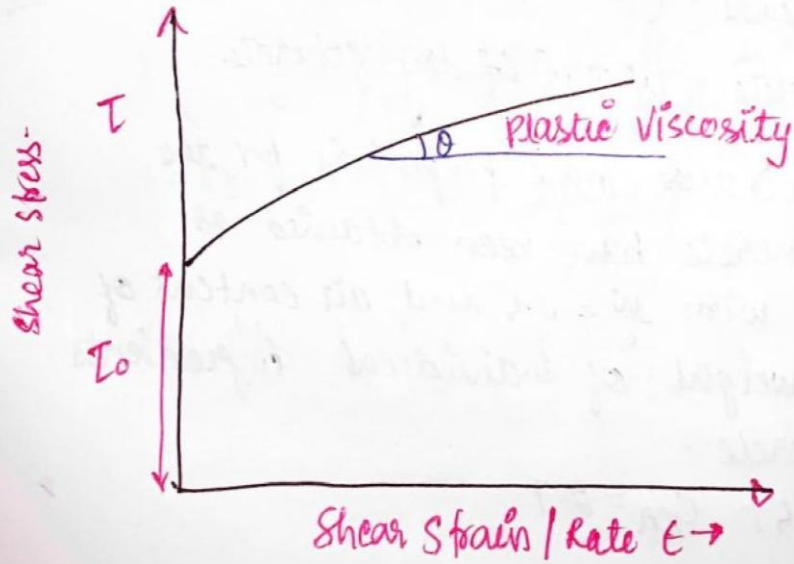
* Concrete absorbs X-rays and Y-rays passing through it and the degree of absorption depends on density of concrete.
* These rays while passing through concrete are partly absorbed and partly scattered.
* The scattered radiation can be shielded and from the measuring device and density of concrete determined by the degree of absorption of the rays traversing a direct path of known length.
* Radium and radiocobalt are as source of rays.
* Radium has the advantage that its activity can be regarded as constant (since it takes 1000 - 2000 years for its activity to be reduced to half)

Note: Any of the methods discussed may be used to assess the quality of concrete depending upon the following consideration.

* The availability and reliability of caliberation charts
* The effects and acceptability of surface damage.
* The accuracy desired
* Economic consideration
* Practical Limitations such as a member size and a type surface condition and access to the test point.

Rheology of Concrete:

* It is the science of flow and deformation of material and describes the inter-relation b/w force, deformation and time.
* Rheology is applicable to all the materials i.e for gases, liquids and solids.
* Its principles and techniques as applied to concrete include the deformation of hardend concrete.
* It also applies with fresh properties of the concrete by considering it as a fluid [Non Newtonian Fluid]
* The Bingham model is most commonly used to represent concrete flow due to its simplicity and ability to represent the majority of concrete mixtures.



Rheology of the concrete is measured with the device termed as Rheometer.

* Rheology is a better indicator of consistency of concrete than its workability.

* Factors affecting Rheological properties of concrete.

① Mix Proportion

② Aggregates Shape and Texture

③ Aggregates Grading

④ Max^{m} Size of Aggregate

⑤ Admixtures

$\tau = \tau_0 + \mu\gamma$ $\quad \tau \geq \tau_0$

$\mu = 0$ $\quad \tau \leq \tau_0$

τ = Shear stress

τ_0 = yield stress

γ = Shear Strain / Rate

μ = Plastic Viscosity

$[y = mx + c]$

Quantities of ingredients required for preparation of mix (Mortar / Concrete)

$V_{concrete} = V_{voids} + V_{solids}$

$V_{concrete} = (V_{air} + V_{water})_{voids} + (V_c + V_{FA} + V_{CA})_{solid}$.

Note: $1\,m^3$ of wet concrete $= 1.53\,m^3$ of dry concrete

Q. Using mix design procedure, mix proportion for the desired grade of concrete have been obtained as 1 : 2.1 : 3.5 (By mass) with $\frac{w}{c} = 0.5$ and air content of 3%. Calculate the weight of individual ingredients to make $0.25m^3$ concrete.

$G_c = 3.15$, $G_s = 2.65$, $G_{CA} = 2.7$

Soln $V_{concrete} = V_a + V_w + V_s$

$$V_{conc.} = a_c V_c + \frac{M_w}{\rho_w} + \frac{M_c}{G_c \rho_w} + \frac{M_s}{G_s \rho_w} + \frac{M_G}{G_G \rho_w}$$

$$V_{conc} = a_c V_{conc} + \frac{0.5 M_c}{\rho_w} + \frac{M_c}{G_c \rho_w} + \frac{2.1 M_c}{G_s \rho_w} + \frac{3.5 M_c}{G_G \rho_w}$$

$$= \frac{3 \times 0.25}{100} + \frac{0.5 M_c}{1000} + \frac{M_c}{3.15 \times 1000} + \frac{2.1 M_c}{2.65 \times 1000} + \frac{3.5 M_c}{2.7 \times 1000}$$

$M_c = 83.44 kg$

$M_s = 2.1 M_c = 175.224 kg$

$M_c = 3.5 M_c = 292 kg$

$a_c = \frac{V_a}{V_{conc}} \times 100$, $\frac{W}{C} = \frac{M_w}{M_c} = 0.5$, $\rho = \frac{M}{V}$

$G = \frac{\rho_s}{\rho_w} = \frac{M_s}{\rho_w V_s} = \frac{M}{V_s \rho_w} \Rightarrow V_s = \frac{M}{G \rho_w}$

Q. calculate the quantity of cement, sand and coarse aggregates required to produce one cubic metre to concrete for mix proportion 1 : 1.4 : 2.8 (By Vol) with $\frac{W}{C} = 0.48$. Bulk Density of cement, sand, coarse agg are 14.7, 16.66, 15.68 kN/m^3 respectively. Percentage of air is 2.0. $G_C = 3.15$, $G_S = 2.6$, $G_G = 2.5$

Soln $V_{conc} = V_a + V_w + V_c$

$$1 = \frac{2 \times 1}{100} + \frac{M_w}{\rho_w} + \frac{M_c}{G_c \rho_w} + \frac{M_s}{G_s \rho_w} + \frac{M_G}{G_G \rho_w}$$

$$1 = \frac{2 \times 1}{100} + \frac{0.48 M_c}{1000} + \frac{\rho_c V_c}{G_c \rho_w} + \frac{\rho_s V_s}{G_s \rho_w} + \frac{\rho_G V_G}{G_G \rho_w}$$

$$1 = \frac{2 \times 1}{100} + \frac{0.48 \rho_c V_c}{\rho_w} + \frac{\rho_c V_c}{G_c \rho_w} + \frac{\rho_s (1.4) V_c}{G_c \rho_w} + \frac{\rho_G (2.8) V_c}{G_G \rho_w}$$

$V_c = 0.251 m^3$ $M_c = 369 kg$

$V_s = 1.4 V_c = 0.351 m^3$ $M_s = 585 kg$

$V_G = 2.8 V_c = 0.703 m^3$ $M_G = 1102 kg$

$V_w = 177 lit$ $M_w = 177 kg$

Note: As per fineness modulus of mix design the minimum quantity of water required to be added in the first batch is given by.

$$0.3P + 0.1Y + 0.01Z = \frac{W}{C} \times P$$

P = Quantity of cement by weight

Y = Quantity of FA by weight

Z = Quantity of CA by weight

$\frac{W}{C}$ = water cement

Q. Calculate the mix quantity of water required for preparation of design mix 1:3:6 (By weight) in which cement added is 300 kg?

Soln $0.3 \times 300 + 0.1 \times 3 \times 300 + 0.01 \times 6 \times 300 = \frac{W}{300} \times 300$

$W = 198 kg = 198 lit.$

Q. Estimate the quantity of cement, FA and CA per cubic metre of concrete if void ratio in cement FA, CA is 62%, 41% and 45% respectively. The material property are as follows:
Mix is 1:2:4 with $\frac{W}{C} = 0.55$, one bag of cement contains 50 kg and its density is $1440 kg/m^3$. The density of FA is $1700 kg/m^3$ and CA = $1600 kg/m^3$. One bags of cement has 34.7 litre of volume.

Sol^n. $V_{concrete} = V_{voids} + V_{solids}$

$V_{concrete} = (V_a + V_w)_V + (V_c + V_s + V_G)_S$

Assume $a_c = 2\%$.

$$V_s = \frac{V}{1+e} = \frac{M}{S(1+e)}$$

$$1 = \frac{2\times 1}{100} + \frac{0.55\,M_c}{S_w} + \frac{M_c}{S_c(1+e_c)} + \frac{M_s}{S_s(1+e_s)} + \frac{M_G}{S_G(1+e_G)}$$

$$1 = \frac{2\times 1}{100} + \frac{0.55\,M_c}{S_w} + \frac{M_c}{S_c(1+e_c)} + \frac{2M_c}{S_s(1+e_s)} + \frac{4M_c}{S_G(1+e_G)}$$

$$1 = \frac{2}{100} + \frac{0.55\,M_c}{1000} + \frac{M_c}{1440(1+0.62)} + \frac{2M_c}{1700(1+0.41)} + \frac{4M_c}{1600(1+0.45)}$$

$M_c = 277\,kg$

$M_s = 554\,kg$

$M_G = 1108\,kg$

$M_w = 152.35\,kg$

Q. The data of material for making a cement concrete mix may be assumed as follows:

① $\frac{w}{c} = 0.48$ ② Entrained Air = 2%

Material	G	$S\,(kg/m^3)$	Proportion in mix by dry weight.
Cement	3.15	1500	1 part
Fine Aggregate	2.61	1620	1.359 part
20mm nominal size crushed CA	2.7	1530	2.79 part

Determine the following:

(1) Absolute Vol. of fully compacted fresh concrete (ignoring air content) produced by one bag of cement of 50kg.

(II) cement content per cubic metre of concrete (ignoring air content) produced by one bag of cement of 50kg.

(III) Quantity of materials to make one cubic metre of concrete?

Soln (iii) $V_{concrete} = V_{voids} + V_{solids}$

$= (V_a + V_w) + (V_c + V_s + V_G)_s$

$G = \frac{\rho_s}{\rho_w} = \frac{M_s}{V_s \rho_w} = \frac{M}{V_s \rho_w} = \frac{\rho V}{V_s \rho_w}$

$$V_s = \frac{\rho V}{G \rho_w}$$

$$1 = \frac{2 \times 1}{100} + \frac{M_w}{\rho_w} + \frac{\rho_c V_c}{G_c \rho_w} + \frac{\rho_s V_s}{G_s \rho_w} + \frac{\rho_G V_G}{G_G \rho_w}$$

$$1 = \frac{2 \times 1}{100} + \frac{0.48 V_c \rho_c}{\rho_w} + \frac{\rho_c V_c}{G_c \rho_w} + \frac{\rho_s (1.359 V_c)}{G_s \rho_w} + \frac{\rho_G (2.79 V_c)}{G_G \rho_w}$$

$$1 = \frac{2}{100} + \frac{0.48 \times 1500 V_c}{1000} + \frac{1500 V_c}{3.15 \times 1000} + \frac{1620 \times 1.359 V_c}{2.61 \times 100} + \frac{1520 \times 2.79 V_c}{2.7 \times 1000}$$

$V_c = 0.2706 m^3$ $M_c = 406 kg$

$V_s = 0.3677 m^3$ $M_s = 595.6 kg$

$V_G = 0.755 m^3$ $M_G = 1155.15 kg$

$M_w = 194.88 kg$

(i) 406 kg of cement produce = $1 m^3$ of concrete

406 kg of cement produce = $(1 - 2\% \text{ of } 1) m^3$ of conc. (excluding air)

406 kg of cement produce = $0.98 m^3$ of conc. (excluding air)

50 kg of cement produce = $\frac{0.98}{406} \times 50$ of

$= 0.1206 m^3$ of conc. (excluding air)

(ii) Vol. of 50kg of cement = $\frac{50}{1500}$

$= 0.034 m^3$

Cement content = $\frac{0.034}{0.1206} \times 100$

$= 28.19\%$

#Special Type of Concrete

① Self Compacting Concrete

* It is the type of concrete which undergoes compaction on its own and number of normal or mechanical measures are required for compaction of this concrete.
* It offers the following advantages.
  (i) Faster construction
  (ii) Reduction in site manpower
  (iii) Better surface finish
  (iv) Easier Placing
  (v) Improved Durability
  (vi) Thinner concrete section
  (vii) Reduced Noise Level/ safer working Environment.
* This concrete is produced by use of OPC 43, 53 aggregates having max^m size limited to 20mm and chemical or mineral admixture.

Chemical Admixture — Plasticizers, Super plasticizers

Mineral Admixtures — Fly Ash, Slag, Silica Fumes

② Ferrocement

* As conventional concrete too heavy, brittle and cannot be satisfactorily repaired if damaged, develop cracks undergoes corrosion in reinforcement, a raw material was thus required to overcome these short comings.
* Ferrocement consists of wire meshes and cement mortar, which offers all the above advantages.
* The wire mesh is usually of 0.5-1.0mm diameter and have 5-10mm spacing, cement mortar used in this case 1:2 - 1:3 with $\frac{w}{c} = 0.4-0.45$.
* The ferro cement elements are usually of the order of 2-3cm in thickness with 2-3mm external cover to the reinforcement.
* The steel content varies b/w 300 - 500 kg/m³ of mortar.
* The basic idea is that concrete undergo large strains in the neighbourhood of reinforcement and magnitude of strains depends on distribution of reinforcement throughout the mass of concrete, which is eliminated in this case.

③ Shotcrete / Guniite

* It is defined as mortar conveyed through hoe and it mechanically / Pneumatically projected over the surface.
* There is not much difference b/w guniting and shotcreting.

④ Vaccum concrete

* $\frac{w}{c}$ ratio in concrete controls both strength and workability.

* Low $\frac{w}{c}$ gives higher strength but compressive compromise with the workability whereas high $\frac{w}{c}$ ratio gives workable concrete, but affects the strength.
* Hence in order to obtain both the properties in concrete i.e, workability and strength, vaccum concrete is used.
* In this process, excess water used for higher workability not required for hydration and harmful in many ways to the hardend concrete is withdrawn by means of vaccum pump, subsequent to the placing of concrete.
* This process when proper applied produces concrete of higher quality and also permit removal of formwork at early age.

(5) Fibre Reinforced Cement

* Plain concrete possesses very low tensile strength limited ductility and little resistance to cracking.
* Interwal micro cracks are inherently present in concrete and its ~~proper~~ poor tensile strength is due to propogation of these micro cracks, leading to the brittle fracture of concrete.
* To overcome the concrete is reinforced with fibres having high tensile strength and concrete is termed as fibre reinforced concrete.
* Some of the fibres that could be used are steel fibres, polypropylene, nylones, asbestos, glass, carbon.
* fibre is a small piece of reinforcing material possessing certain characteristic ~~strength~~ property.

* They can be circular or flat.

(6) Cyclopean Concrete

* Mass concrete in which large stone of weight approx 45 kg or more are placed and embedded as concrete is deposited is termed as cyclopean concrete.
* Stone used in this case are termed as pudding stone/ plum and are usually not less than 15cm in size and have spacing of 20cm.

(7) Hempcrete / Hemplime

* It is bi-composite material, a mixture of hemp and lime, sand or pozzolonas, which is used as a material for construction and insulation.
* It is to work with time and acts as an insulator and moisture regulator.
* It lacks the brittleness of concrete and hence does not need joints.
* It is light in weight and is also a source of thermal storage.

(8) Ready Mix Concrete

* It is the concrete that is manufactured in a batching plant according the quantity required in field and transported to the desired place in trucks or in transit mixers.
* RMC is often used over other materials due to the cost and wide range of uses in building.
* It is used in situations where limited availability of space is there.

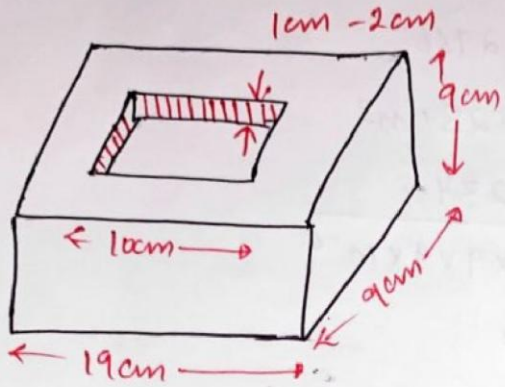
(8) Structural concrete

* It is the term which indicates all types of concrete used in structural application.
* Structural concrete may be plain, reinforced prestressed or partially prestressed concrete, in addition to concrete used in composite design such as beam, column etc.

BRICKS

* It is one of the oldest and leading building material used for construction due to its less cost, durability and ease of handling.
* It is rectangular block in shape and size that conveniently handled with one hand.
* It is made up of clay or mixture of sand and lime or OPC.
* Clay bricks are commonly used since it is more economical and easily available.
* The L, B, H of a brick are inter related.
* Length of Brick = 2x Width of Brick + thickness of mortar
  Height of Brick = Width of Brick
* Size of Standard / Modular Brick = 19cm x 9cm x 9cm
  Nominal Size of Brick = 20cm x 10cm x 10cm
  (six including thickness of Mortar)
  Size of conventional / Traditional Brick = 9" x 4.5" x 3"
  = 23cm x 11.4cm x 7.6cm
* Weight of Brick is in the range of 3-3.5 kg.
* An indent called frog is called placed over the brick to
  (a) indicate the trade name of manufacture
  (b) act as a shear key b/w the two bricks, there by increase its strength in lateral direction.
* Size of Frog is 10cm x 4cm x 1cm.

* It is not provided in 4cm high brick or extruded bricks.



Q. Compute the no. of traditional bricks required for $1m^3$ of masonry work.

(a) 5050 (b) 4500 (c) 4950 (d) 5075

Soln. $N = \frac{\text{Total Volume of Bricks}}{\text{Volume of one brick.}}$

$N = \frac{\text{Total Vol. of Bricks + Mortar}}{\text{Volume of 1 Brick including Mortar}}$

$N = \frac{10}{23 \times 11.4 \times 7.6 \times 10^{-6}} = 5019.$

Q. Modular bricks of Nominal size 20x10x10 cm are used for masonary work having 20% of the Vol. of mortar lost b/w joints. Compute the no. of modular bricks required per cubic metre of Brickwork?

Soln No. of Bricks $= \frac{1}{20 \times 16 \times 10 \times 10^{-6}} = 500$

Vol. of Brick $= 500 \times 19 \times 9 \times 9 \times 10^{-6} = 0.7695 m^3$

Vol. of Mortar $= 1 - 0.7695$

$= 0.2035 m^3$

Vol. of set Mortar $= 0.2035 + 0.2035 \times \frac{20}{100}$

$= 0.2766 m^3$

Actual Vol. of 1 brick $= 1 - 0.2766$.

$= 0.7234 m^3$

No. of Modular Bricks $= \frac{0.7234}{19 \times 9 \times 9 \times 10^{-6}}$

$= 470$

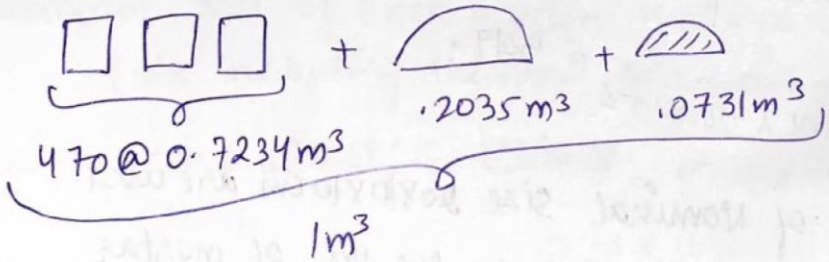
Note: Vol. of Mortar used in $1 m^3$ of masonary work $= 0.2035 - 0.2766 m^3$

Depending upon the wastage $= 0\% - 20\%$.

Equivalent Vol. of Dry Mortar $= 1.25[0.2035 - 0.2766]$

$= 0.288 - 0.345$

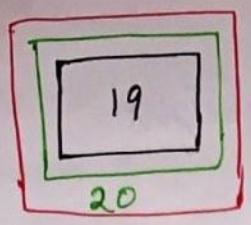
Note: Mortar required for $1 m^3$ of brick masonary $= 28-35\%$



Q. For flatly laid single brick soling, what is the no. of bricks required of nominal size 20x10x10cm with 1.2cm cement mortar all around and with allowing upto 1% wastage of bricks ~~upto~~ for $10 m^2$ area.

No. of Bricks (N) $= \frac{10 \times 10^4}{22.4 \times 12.4}$

$= 360$



Total no. of bricks allowing wastage @ 1% = 1.01 x 360
= 363

Classification of Bricks.

Bricks can be classified on the basis of following:

(i) On Field Practice

1) First Class Bricks:

* These are thoroughly burnt, deep red in colour.
* They have smooth and rectangular surface with sharp edges.
* They are free of flaws, cracks, stone.
* They have uniform texture.
* They must not absorb more than 12-15% of its dry weight water, when immersed in cold water for 24 hours.
* They must possess crushing strength of $10 N/mm^2$.
* They find their applications in pointing, work exposed face work, flooring, reinforced brickwork.

2) Second Class Brick:

* Their specifications are same as I st class brick except:

(i) Small cracks are permitted

(ii) Water absorption are about (16-20%) of dry weight is allowed.

(iii) Crushing strength ≤ 7 N/mm².

They find their application in unimportant hidden masonry or in RCC structure.

(3) Third Class Bricks:

* These are underburnt bricks, soft, light colored, producing a dull sound when stick against each other.
* water absorption is about 25% by dry weight.
* They are used temporary structure.

(4) Fourth Class Bricks:

These are overburnt, badly distorted in shape and size, are brittle in nature, hence used for ballast work or for floor work in line.

(ii) On the basis of Strength (IS:1077)

On the bases of strength bricks are classified as follows:

Class	Average compressive Strength (N/mm²)
35	35
30	30
25	25
20	20
17.5	17.5
15	15
12.5	12.5
10	10
7.5	7.5
5	5
3.5	3.5

Note: Minimum compressive strength of brick is 3.5 N/mm².

* The burnt clay bricks having compressive strength more than 40 N/mm² are known as heavy duty bricks and are used for heavy duty structure.
  e.g. bridges, foundations (Industries, Multistorey building).
* Their water absorption is limited to 5%.
* Each class of brick is subdivided into subclass A and B based on tolerance and shape.
* Subclass A brick should have smooth rectangular face with sharp corners and uniform colour.
* Sub class B brick may have slightly distorted and round edges.

	Subclass A		Subclass B	
~~Length~~	Dimension (mm)	Tolerance (mm)	Dimension (mm)	Tolerance (mm)
Length	380	±12	380	±30
Width	180	± 6	180	±15
Height				
(i) 9cm	180	± 6	180	±15
(ii) 4cm	80	± 3	80	±6

(iii) On the basis of use

① Common Brick: It is general multipurpose unit manufactured without any special reference to appearance. These may vary greatly in strength and durability and are used for filling, backing and in walls where appearance is of number of consequence/significance.

② Facing Brick: It is made primarily with a view to have good appearance either of colour, texture or both.

* These are durable under severe exposures and are used in fronts of building walls for which a pleasing appearance is desired.

③ Engineering Bricks: These are strong, impermeable, smooth, table moulded, hard, confo to define units of absorption and strength.

* These are used for all load bearing strength.

(iv) On the basis of finish:-

① Sand faced Brick: It has textural surface manufactured by sprinkling sand on the inner surface of mould.

② Rustic Brick: These bricks have mechanically textured finish, varying in pattern.

(v) On the basis of Manufacturing:-

① Hand made

② Machine made

(vi) On the basis of types:

① Solid: It should have holes not exceeding 25% of the Vol. of the brick and frog not exceeding 20% of the total Vol.

② Perforated: Small holes may exceed 25% of total volume of brick.

③ Hollow: The total no. of holes, which need to be small, may exceed 25% of the volume of bricks.

④ Cellular: Holes closed at one end, exceed 20% of volume of bricks.

Note: Small holes are less than 20mm or less than 500 mm^2 in cross-section.

Ingredients of Good Brick Earth

Brick Earth: soil used for preparation of Brick.

① Silica (50-60%):

* It enables the brick to retain in shape and size.
* It imparts durability to the bricks, by preventing shrinkage and warping in it.
* Excess of silica makes the brick brittle and weak on burning.
* A large % of sand or uncombined silica (in clay) is undesirable.
* However is added to decrease shrinkage in during burning.

② Alumina (20-30%):

* It absorbs water and imparts plasticity to the brick earth, hence helps in its moulding.
* If it is in excess it produces cracks on drying.
* Clays have excess of alumina are likely to be very refractory.

③ Lime (~10%):

Lime in bricks serves following purposes.

(1) reduces shrinkage on drying.
(2) causes silica in clay to melt on burning thus help to bind it.

③ Excess of lime causes melting of brick.
④ Excess of lime develops cracks in it due to calcination and slaking.

④ Magnesia (<1%):

* It affects the colour and make the brick yellow during burning.
* It causes the clay to soften at slower rate than in most case.
* It reduces working of bricks.

⑤ Iron Oxide (<7%)

* It gives red colour to the brick.
* It improves impermeability and durability
* It imparts strength and Hardness to bricks.

Alkalis <10%

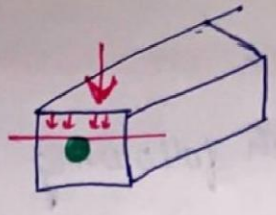
CO_2, SO_3, H_2O } Negligible

Harmful Ingredients of Brick Earth:

① Lime: When it is present in desirable amount in clay, it results in good bricks but when it found in excess leads to melting of bricks during burning and slaking (which causes disintegration of bricks).

② Pebbles, Gravels, Grits, Stones:

Presence of stones and pebbles reduces the strength of bricks by reducing the area availability to transfer the Load.



* They do not allow the clay to be mixed thoroughly and spoil the appearance of the brick.

③ Iron Pyrite :

* It leads to oxidise and decompose the brick during burning, the brick may split into pieces due to volume change.
* It also decolourises the brick.

④ Alkalies :

* If present in proportion less than 10%, it is of great values as fluxes but when in excess leads to the development of stains over the surface (termed as efflorescences)

⑤ Organic Matter :

They help in burning of bricks during manufacturing but if left unburnt undergoes decomposition, thereby produces gases which when escapes, makes the brick porous.

⑥ Carbonaceous Material :

In the form of bituminous matter or carbon generally affects the colour of raw bricks.

⑦ Sulphur :

It is usually found in clay as the sulphate of Ca, Mg, Na, K, or Fe.
If found in excess it makes the brick spongy with swollen structure.

Manufacturing of Bricks.

Manufacturing of Bricks is carried out in following sequence of operation.

1. Preparation of Clay / Brick earth.
2. Moulding
3. Drying
4. Burning

① **Preparation of Clay:** It consist of following operations:

(1) **Unsoiling:** It is process in which 300mm (top layer) of soil layer is removed and is not being used for the manufacturing of bricks as it consists of most of impurities (plant fibres, stone, pebbles etc)

② **Digging:** It is the process of excavating the soil and spreading it over the level ground.

③ **cleaning:** It is the process of removal of stones, pebbles, organic matter from the excavated soil.

④ **Weathering:** It is the process in which cleaned soil is left in heaps and is exposed to weather for atleast one month or so in order to develop homogenity and also to eliminate the impurities from clay (by oxidation)

⑤ **Blending:** Here the earth is mixed with sandy earth and calcareous earth in suitable proportion along with water to modify the compaction of soil as desired.

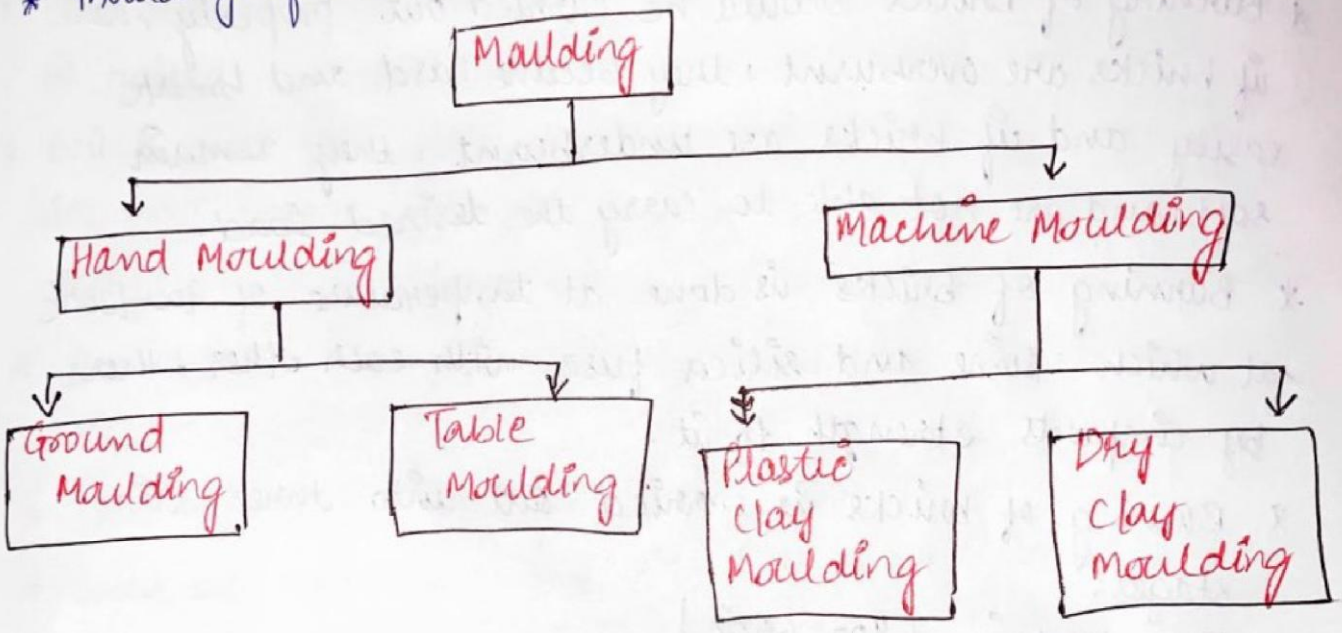
⑥ **Tempering:** It consist of kneading the earth so as to make the soil mass stiff and (impart desired plasticity in it unit termed as Pug Mill).

② **Moulding :** It is the process of giving the required shape and size to the brick earth.

Moulding can be done either manually or mechanically.

Moulding is done with the help of units termed as moulds which may be of wood or steel.

* The size of the mould is kept 8-12% greater than the actual size of the brick, in order to account for shrinkage during drying or having burning process.
* During moulding only, frog is placed over the brick.
* Moulding of bricks can be done as follows:



③ **Drying :**

* Green bricks contains about (30-7)% moisture in it, hence cannot be burnt directly, as it would lead to sudden loss of water, that causes distortion/ cracking of bricks.
* During drying moisture content of the bricks is reduced upto 3% before subjecting it to next operation of burning.

* Drying of bricks can be done manually or artificially.
* Natural Drying is not preferred as all the factors which governs vaporisation [temperature, humidity, wind] cannot be regulated and time required in this case is more.

(4) Burning :- It is the most significant operation in manufacturing of Bricks.

* It imparts strength and hardness to the brick and make it more durable and dense.
* Burning of Bricks should be carried out properly, as if bricks are overburnt, they become hard and break easily and if bricks are underburnt, they remain soft and are not able to carry the desired load.
* Burning of bricks is done at temperature of 900-1200°C at which lime and silica fuse with each other, thereby imparts strength to it.
* Burning of bricks is carried out into three main stages:

(1) Dehydration (400-650°C)
(2) Oxidation Period (650-900°C)
(3) Vitrification (900-1200°C)

* During dehydration the water which has been retained in the pores of clay after drying is removed off and the clay looses it plasticity.
* During oxidation stage remainder of carbon is eliminated and Ferrous iron is oxidised to Ferric form.

* During oxidation stage remainder of carbon is eliminated and Ferrous iron is oxidised to ferric form.
* In this process glass like appearance over the brick surface is attained.
* Burning of bricks can be ~~classified~~ carried out in either in clamps or in kilns.

I CLAMP (PAZAWAH):

* In order to prepare the clamp a suitable price of land is selected, generally trapezium in plan.
* The shorter side is kept in excavation and longer is raised by angle of 15°.
* Brick wall in mud is constructed along the shorter side and locally available fuel is applied over the surface, followed by 4-5 courses of bricks.
* The entire clamp consist of alternative layer of bricks and fuel.
* Total height of clamp is 3-4m.
* when one clamp is constructed fuel in the lower layer is burnt and when complete clamp is formed, it is covered with mud lining.
* Bricks are allowed to burn for 2-4 weeks and followed by its cooling for next 2-4 weeks.
* As locally available fuel is used and no skilled man power is required, it is economical.
* As there is control over temperature during burning uniform quality bricks are not obtained.

* As weight of bricks in upper is supported by bricks in lower layer, there shape and size is distorted.
* Strength of bricks obtained by this method is comparatively more due to gradual burning and cooling of bricks.

II) Kilns :-

* These are large ovens used for burning of bricks
* Depending upon supply of bricks obtained from it, they are classified into
  ① Intermittent kiln
  ② continuous kiln

① Intermittent kiln:

* From the kilns supply of bricks obtained is intermittent as all operation of loading, burning, cooling and unloading are done one after the another.
* These are further classified as:

① **UP-Draught kiln**: Here movement of gases during burning is in upward direction.

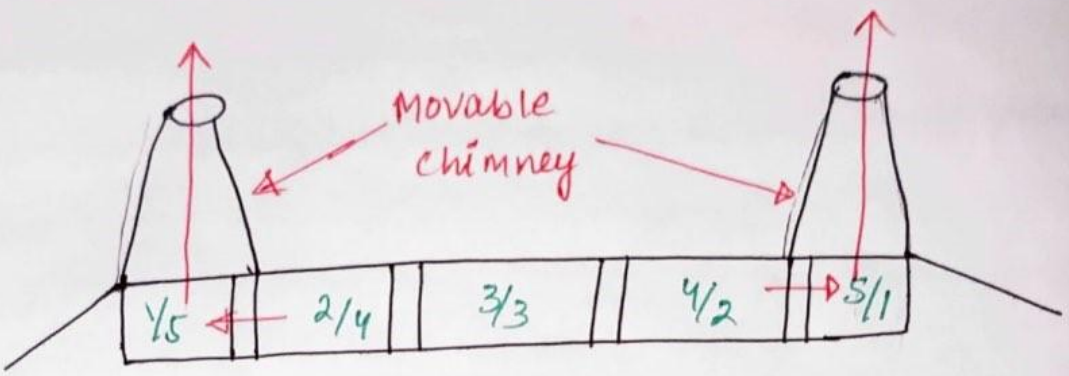
② **DOWN-Draught kiln**: Here movement of gases during burning is in downward direction.
Hence more uniform burning takes place.

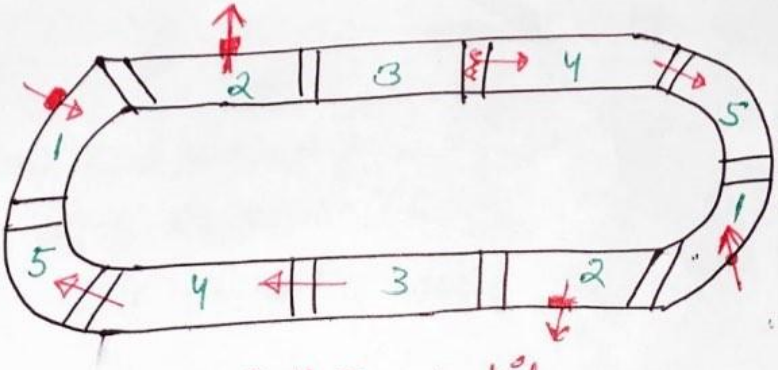
② Continuous kiln:

* These are the types of kilns in which supply of all the bricks is continuous, as all the operation of loading, burning, cooling and unloading is done simultaneously.

These are classified as:

1. Bull Trench Kiln
2. Hoffman Kiln
3. Tunnel Kiln

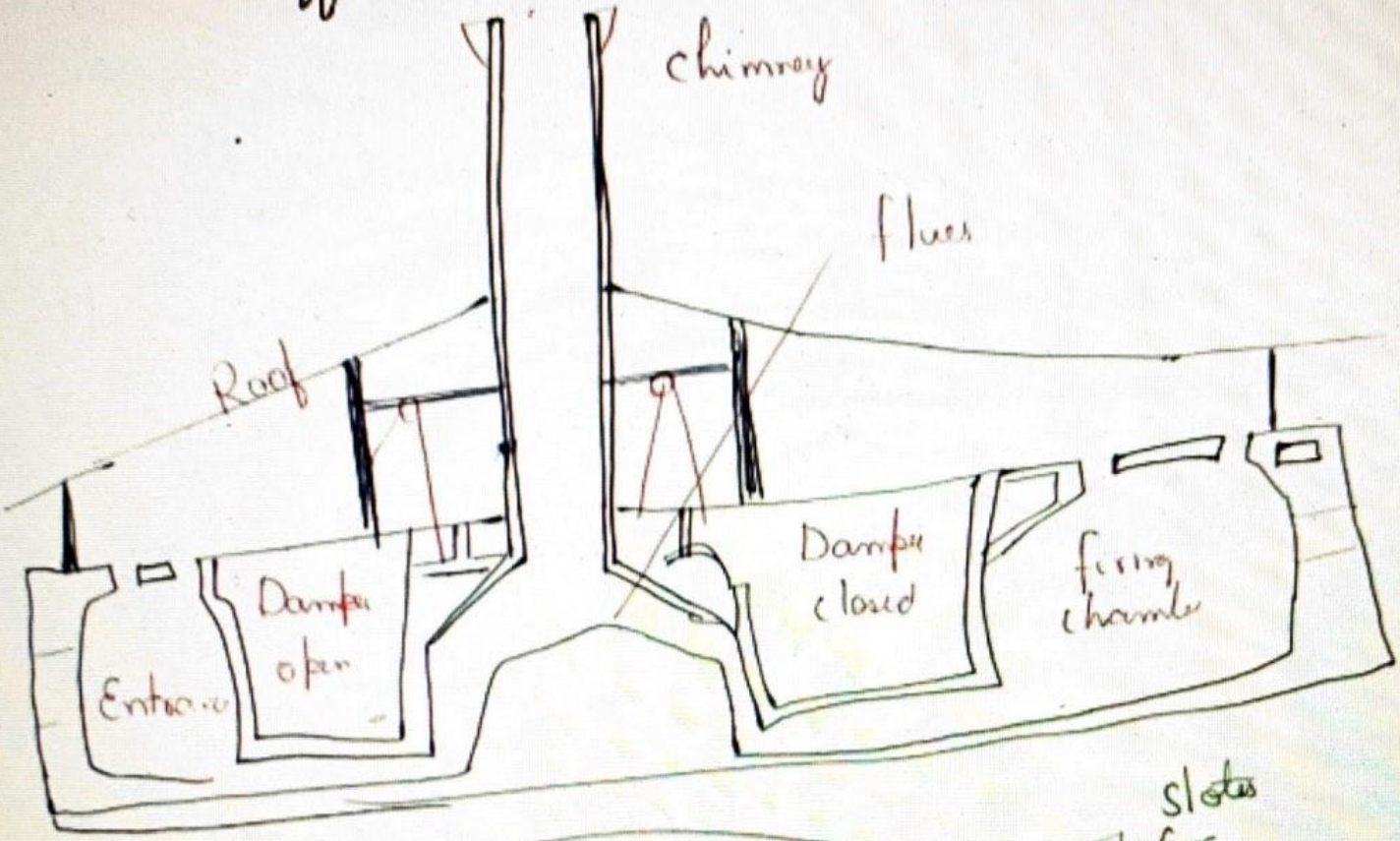


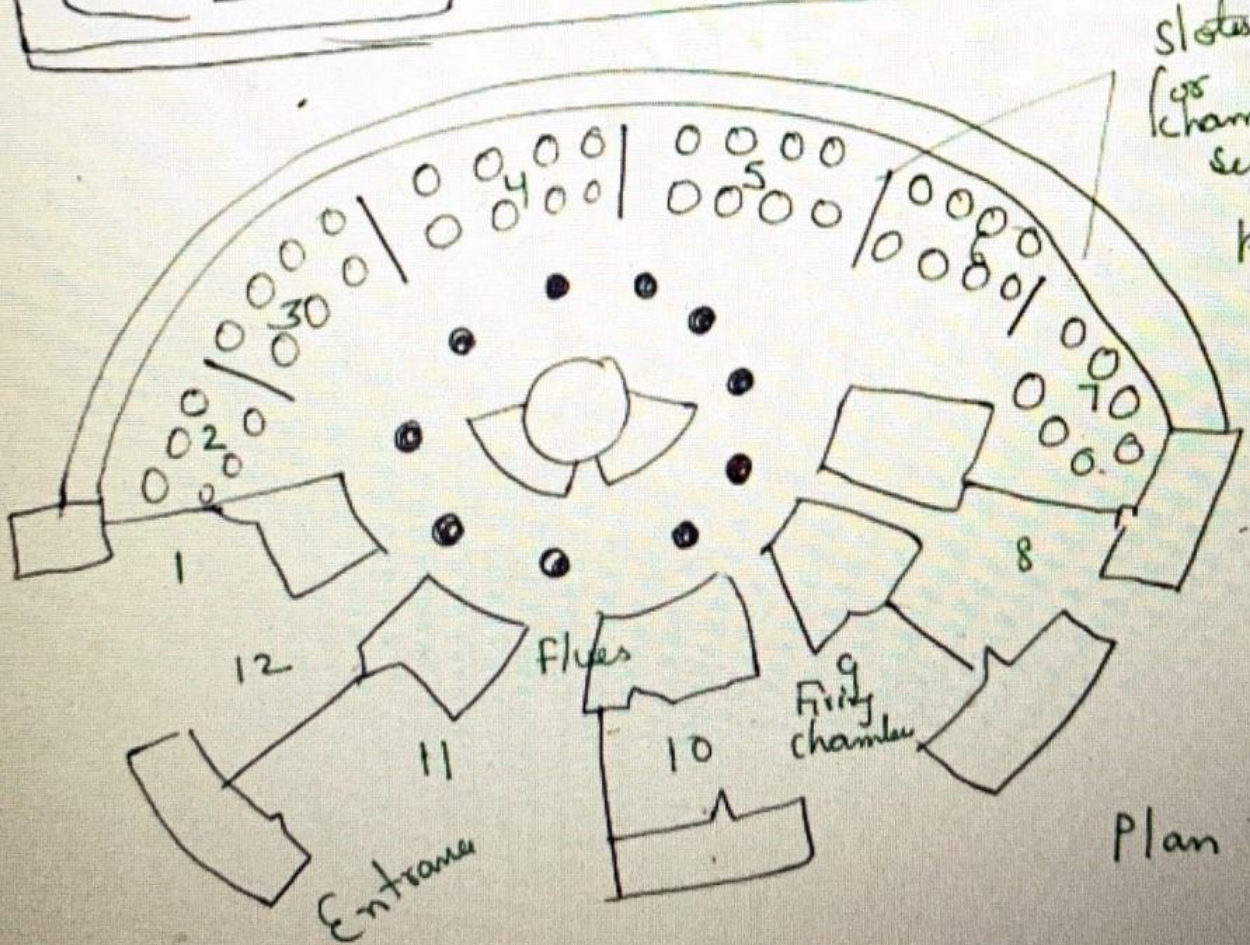


Bull Trench Kiln

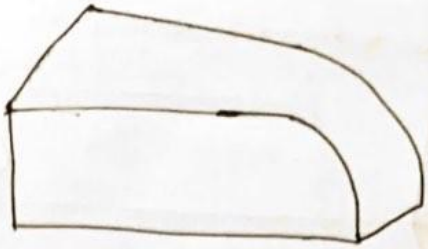
1 : Loading
2 : Unloading
3 : Cooling
4 : Burning
5 : Heating

② Hoffmann kiln



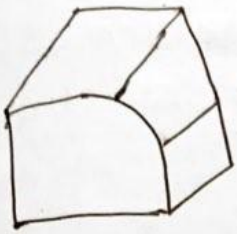


(a) Rounded Ended.

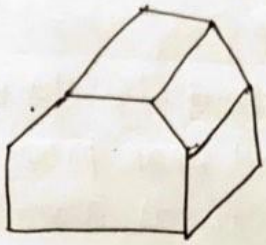


Bull nosed.

Rounded Ended and Bull nosed are used to construct open drains.

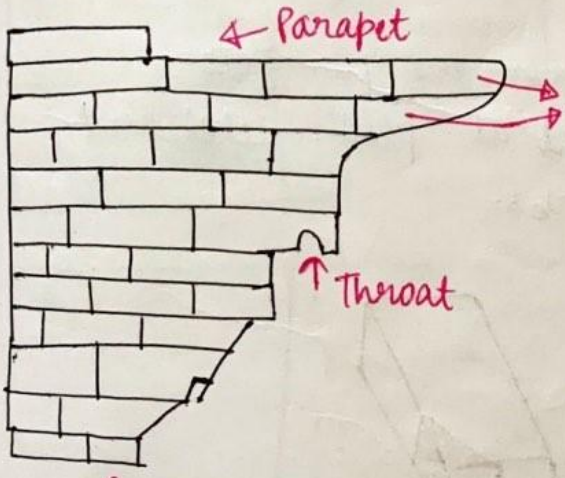


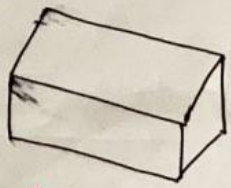
Cant



Double Cant

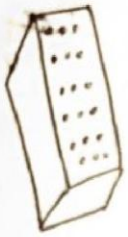
* For door and window jambs, cant bricks also called splay brick are most suitable.
* Double cant brick is used for octagonal pillars.



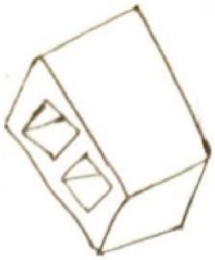


Compass.

* Cornice Brick is used for architectural point of view.
* Compass Brick tapering in both the directions along its length; is used to construct furnaces.

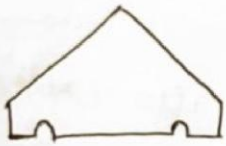


Perforated

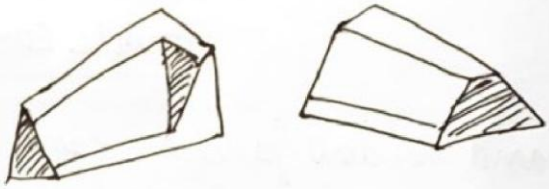


Hollow.

* Perforated brick is well burnt brick but is not sound proof.
* Hollow Brick are about 1/3 the weight of normal brick and are sound and heat proof, but are not suitable where concentrated loads are expected.

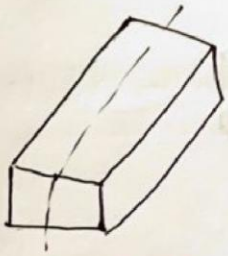


Coping

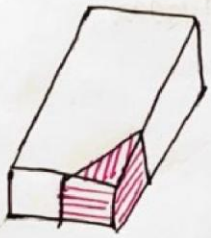


Thamb.

* Topmost brick course of parapet is made with coping bricks.
* These drain off the water from the parapets.
* Brick (fig): Thamb is used at plinth level and for door and window Thambs.



Queen closer



King Closer.

* These are the split bricks.
* When brick is cut along the length, it is called Queen closer.

* When the brick cut at one end by half headers and half stretcher. it is k/w as king closer.

TESTING OF BRICKS:

* About fifty pieces of bricks are taken at random from different parts of the stock to perform various tests.
* For this purpose of sampling, a lot should contain maximum of 50,000 bricks.
* The no. of bricks selected for forming as sample for physical characteristics as follows:

No. of Bricks in a lot	For characteristics specified for individual brick.		For dimension characteristics for group of bricks - no. of bricks to be selected
	No. of bricks to be selected	Permissible No. of defective Bricks	
2001-10,000	20	1	40
10001-35000	32	2	60
35001-50000	50	3	80

Lot Size	sampling size for compressive strength, breaking load, transverse strength bulk density, water absorption & Efflorescence	Permissible No. of defective for efflorescence
2001-10000	5	0
10001-35000	10	0
35001-50000	15	1

LOT SIZE	WARPAGE	
	Sample size	Permissible No. of Defective.
(1)	10	0
(2)	20	1
(3)	30	2

Following tests are performed over the bricks.

① Dimension Test

* 20 pieces out of selected pieces are taken and are laid flat and the cumulative dimensions are recorded.
* Tolerance on the size of bricks are fixed by maxm and minm dimensions. not on individual bricks but on batches of 20 bricks chosen at random.
* It follows from this method of measurement that batches are likely to contain brick outside the prescribed limit of tolerance.
* Such lot should be rejected to avoid variation of properties.

Dimensions and Tolerances.

Dimensions:

The standard modular size of common building bricks shall be as follows:

Length (L) (mm)	width (w) (mm)	Height (H) (mm)
190	90	90
190	90	40

* The following non-modular sizes of the bricks may also be used:

Length (L) (mm)	width (w) (mm)	Height (H) (mm)
230	110	70
230	110	30

* ~~For obtaining~~ In obtaining proper bond arrangement and non modular dimensions for the brickwork, with the non-modular sizes, the following sizes of the bricks may also be used.

Length (L) (mm)	width (w) (mm)	Height (H) (mm)
70	110	70 $\frac{1}{2}$ Length brick

Tolerances.

The dimensions of bricks when tested in accordance with 6.2.1. shall be within the following limits per 20 bricks.

(1) For modular size

Length 3720 to 3880mm (3800 ± 80mm)
Width 1760 to 1840mm (1800 ± 40mm)
Height 1760 to 1840mm (1800 ± 40mm)

For 90mm High bricks
760 to 840mm (800 ± 40 mm) → For 40mm High bricks

(2) Water Absorption Test:

* Absorption of water into the bricks takes place due to existance of minute pores in it (which are also formed as capillary pores).
* The durability and strength of the bricks is affected by the absorption of water in it.

* This test is of two types:

① 24 hrs Immersion cold water Test:

* Dry bricks are put in an oven at temp. of 105°C - 115°C and weight (W_1) of the bricks is recorded after cooling at room temperature.
* The bricks are then immersed in water at temp. 27 ± 2°C for 24 hrs and are again weight (W_2) after removing it from water.

$$\% \text{ Absorption} = \frac{W_2 - W_1}{W_1} \times 100$$

* The avg. water absorption shall not be max^m than 20% by weight upto class II and 12.5 and 15% by weight for higher classes.

② Five hours Boiling water Test

* Here W_1 is recorded as same as above.
* Then the specimen is immersed in water and boiled for 5 hrs followed by cooling down for next 16-19 hrs at temp. of 27 ± 2°C and its weight (W_3) is noted again.

$$\% \text{ Absorption} = \frac{W_3 - W_1}{W_1} \times 100$$

③ Toughness Test

* The brick must not break into pieces when dropped over the hard surface from the height of 1 m.

④ Hardness Test

The brick must not show any sign of indentation mark over its surface when scratched with finger nail.

⑤ Soundness Test

The brick must produce clear ringing sound when stucked against each other.

⑥ compressive Strength Test

* This test provides a basis of comparing the quality of bricks, but is of little use in determining the strength of masonary, which primarily depends upon strength of mortar.
* For testing bricks of compressive strength from a sample the two bad faces of bricks are grounded to provide smooth, even and parallel surface faces.
* The bricks are then immersed in water at room temp for 24 hrs.
* These are then taken out of water and surplus water on the surface is wiped off.
* The frog of the brick is flushed level with cement mortar and the brick is stored under damp jute bags for 24 hrs followed by its immersion in water at room temp. for 3 days.
* The specimen is placed in the compression testing machine with flat faces horizontal and mortar filled face using upwards.
* Load is applied at a uniform rate of 19 N/mm^2/min upto failure.

* The maximum load at failure is used to give compressive strength as follows:

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Max}^m \text{ Load at failure } (N)}{\text{Average are of bed faces } (mm^2)}$$

* The average of result shall be reported. The compressive strength of any individual brick tested in the sample should not fall below the min^m avg. compressive strength specified for the corresponding class by more than 20%.
* An average of 6 bricks is taken here.

⑦ Warpage Test:

* Warpage of the brick is measured with the help of a flat steel or glass surface and measuring ruler graduated in 0.5mm division or wedge of steels.
* For warpage test the sample consists of 10 bricks from a lot.
* **Concave Warpage:** The flat surface of the brick is placed along the surface to be measured, selected the location that gives the greatest deviation from straightness.
* The greatest distance of brick surface from the edge of straightness is measured by a steel ruler.

Convex Warpage: The brick is placed on the plane surface with the convex surface in contact with the flat surface.

* The longest distance is reported on warpage.
* The higher of the distance measured in concave and convex warpage test is reported as "warpage".

(8) Efflorosence Test

* This ends of the brick are kept in a 150mm diameter procelain or glass disc containing 25mm depth of water at room temperature (20°C–30°C), till the entire water is absorbed or evaporated.
* The water is again filled to 25mm depth in the dish and allowed to be absorbed by the brick or evaporated.
* The water is again filled to 25mm depth in the dish and allowed to be absorbed by the brick or evaporated.
* Presence of efflorescence is classified as below:

① Nil: When the deposits of efflorescence is imperceptible

② Slight: When the deposits of efflorescence does not cover more than 10% of exposed area of brick.

③ ~~Moderate~~ Heavy: When the deposits of efflorescence cover more than 50% but do not powder or flake away the brick surface.

④ Moderate: When the deposits of efflorescence cover more than 10% but less than 50% of exposed area of the brick.

⑤ Serious: When the deposits are heavy and powder or flaky surface is obtained.

* The specification limit the efflorescences to be not more than moderate (10-50%) upto class 12.5 and not more than slight (<10%) for lighter classes.

Defects of Bricks.

① Over Burning of Bricks:

If the bricks are overburnt, a soft molten mass is produced and brick loose their shape. Such bricks are not for construction works.

② Under Burning of Bricks:

When bricks are not burnt properly, the clay remains soft due to insufficient heat and are not able to carry the desired load.

③ Bloating:

* This defect is observed as spongy, swollen mass over the surface of burnt bricks.
* It is caused due to the presence of excess carbonaceous matter and sulphur in brick Earth.

④ Black Core:

When brick-clay contains bituminous matter or carbon, they are not completely removed by oxidation, the brick results in black core mainly of improper burning.

⑤ Efflorescence:

* This is caused due to alkalies present in the bricks.
* When bricks come in contact with moisture, water is absorbed and alkalies crystalises.
* After drying grey and white, powder patches appear on the brick surface termed as Efflorescence.

⑥ Chuffs:

Deformation of the shape caused rain water falling on hot bricks is termed as chuffs.

⑦ Checks / Cracks:

These are because of dumps of lime in brick earth or excess of water.

⑧ Spots:

If sulphide is present in ~~water~~ bricks, it causes dark surface spots on the brick, which reduces its aesthetic value.

⑨ Blisters:

Broken Blisters are generally caused on surface of sewers - pipes/drain due to air entrapped during their moulding.

⑩ Laminations:

It is induced by entrapped air in voids of clays. It produces thin lamina/layer on the brick face which whether

Properties of Good Bricks:

① **Shape and Size:**

Brick should have uniform shape and size, rectangular surface with parallel sides and straight edges.

② **Colour:**

Brick should have a uniform deep red/ cherry colour, which indicates uniformly in chemical composition.

③ **Texture and compactness**

Surface should not be too smooth to cause sliping of mortar. The brick should have precompact and uniform texture free from cracks.

④ **Hardness:**

Brick should be so hard that when scratched by a finger nail, no impression is made.

⑤ **Soundness:**

When two bricks are struck together, a metallic clear ringing sound should be produced.

⑥ **Water Absorption:**

Less than 20% of its dry weight when immersed in water for 24 hours.

⑦ **Crushing strength:**

Greater than 10 N/mm^2, however min^m strength is 3.5 N/mm^2.

⑧ **Brick Earth:**

It should be free from stone, grit, organic matter. Most preferred soil is Alluvial soil. [Black cotton soil is not desired)

⑨ Structures:

Brick should possess uniform structure free from voids across any section.

Special Types of Bricks:

① Heavy Duty Burnt Clay Bricks: (2180)

* These bricks are similar to burnt clay bricks and of same size but with high compressive strength.
* These are free from cracks, flaws etc.
* These are used in masonary heavy engineering works such as bridges, industrial foundation and multi storied buildings.
* These are further classified as:

  Class 400 : comp. Strength ≯ 40 N/mm²

  class 450 : comp. Strength ≯ 45 N/mm²

These are further classified on the basis of tolerance as.

Dimension (cm)	Tolerance (mm)	
	Subclass A	Subclass B
9	±3	±7
19	± 6	±15

* Water absorption < 10% after 24 hr of immersion in water
* Efflorescence should be nill and Bulk density < 2500 kg/m³.

② Burnt Clay Perforated Bricks (2222)

* These bricks have cylindrical holes throughout their thickness, have high compressive strength and less water absorption.

* These bricks are light in weight, require less quantity of clay, get dried and burnt easily and economically.
* Area of perforations should not exceed 30-45% of the area of the face.
* In case of rectangular perforation, larger dimension should be parallel to longer side of bricks.
* These are used in building wall / partition wall.

Tolerance :	Dimension (cm)	Tolerance (mm)
	9	±4
	19	±7

* Area of each perforation $\neq 500 mm^2$
* compressive strength $< 7 N/mm^2$
* Efflorescence < 15%
* Warpage < 3%

③ Burnt Clay Facing Brick (2691)

* These are used in the exposed face of masonary without any further surface protection.
* In corrosive atmosphere and high rise building use of facing brick is economical.
* Water Absorption < 15%
* Efflorescence - Nil
* Warpage < 2.5mm
* These are classified as:

Class I : Compressive strength $> 16 N/mm^2$

Class II : Compressive strength $> 7.5 N/mm^2$

* These bricks should be free from cracks and flaws.

④ Burnt Clay Paving Brick (3583)

* In these Bricks iron content is more than that in Ordinary clay Brick.
* Excessive iron cause vitrification of bricks while burning at a low temperature, give natural glaze to the brick, making it more resistant to Abrasion.
* Paving Bricks are manufactured from surface clays.
* These are generally burned in continuous Kiln for 7-10days

Tolerances	Dimension (cm)	Tolerance (mm)
	19.5	±6
	9.5	±3
	9	±3

⑤ Burnt Clay Soiling Bricks (5779)

* These are used for soiling of roads.
* compressive strength >5 N/mm²
* Water Absorption < 20%
* Efflorescence < slight

⑥ Burnt Clay Hollow Bricks (3952)

* These are blocks also known as cellular or cavity blocks are manufactured from a thoroughly ground, lump free, well mixed clay.
* Process of Manufacturing is similar to that of burnt clay bricks.
* used to reduce dead weight of masonary, partition walls, etc.
* they reduce the transmission of heat, sound & dampness.

* Crushing Strength > 3.5 N/mm²
  Water Absorption < 20%

⑦ Sand Lime Bricks (IS: 4139)

* These bricks are also termed as Calcium Silicate Bricks.
* It consist of an intimate and uniform mix of silicious sand or crushed silicious rocks and lime combined by the action of steam water pressure.
* By heating the mixture under pressure, hydrated silicates and aluminates are formed which bind the sand grain together.
* Used for masonary construction same as burnt clay bricks.

Tolerance:

Dimension (cm)	Tolerance (mm)
19	±3
9	±2
9	±2

These bricks are classified depending on their average compressive strength as follow:

Class	Average compressive strength	
	Min	Max
75	7.5	10
100	10	15
150	15	20
200	20	20

Average Drying shrinkage of these bricks shall be less than as follows:

Class	Drying shrinkage (% of Length)
75	0.025
100	0.025
150	0.035
200	–

(8) Sewer Brick (IS: 4885)

* These bricks are manufactured from surface clay
* They are used for lining of walls, roofs, floor of sewerage system.
* Generally common building brick used for construction of sewer, which is not satisfactory.
* It is observed that sewer bricks are also not suitable for which acid resistant bricks are used.

Tolerance.

Dimensions (cm)	Tolerance (mm)
19	±5
9	±2
9	±1.5

Warpage : 2.5mm

Avg. comp. Strength : 17.5 N/mm²

Water Absorption : < 12%

Efflorescence : less than slight

(9) Acid Resistant Bricks (IS: 4860)

* Used for masonary construction subjected to acid attacks, lining of cambers. and towers of chemical plant. lining of sewers carrying industrial sewage to prevent deterioration of surface by acid except Hydrochloric Acid and perchloric Acid.
* These bricks are made up of raw materials such as clay, shale of suitable composition with low lime and iron content, feldspar, sand and are vitrified at high temperature.

* Dimension 23 X 11.4 & 6.4 cm
* Tolerance

Dimension (cm)	Tolerance (mm)
23	± 3.5
11.4	± 2
6.4	± 1

* These bricks are manufactured by in two classes satisfying different requirements

(10) Refractory Bricks / Fire Clay Bricks

* These are defined as Non metallic material suitable for construction or lining of furnaces operated at high temp.
* These bricks are made from fire clay or refractory clay

Note: Fire clay is term applied to include those sedimentary or residual clays which vitrify at very high temp. and which when so burnt, possess great resistance to heat.

These bricks are of following types:

① Acid Bricks
② Basic Bricks
③ Neutral Bricks

(i) **Acid Bricks:** These are further classified as

→ Fire Bricks
→ Silica Bricks

Fire Bricks: are made of fire clay which are generally mixed with small % of sand to reduce shrinkage during burning.

Silica Bricks: are made from Quartizite and sand stone which contains more than 95% of silica.

② **Basic Bricks**: These are manufactures from magnesite, dolomite Bauxite. Eg.
Magnesite Brick
Dolomite Brick
Bauxite Brick

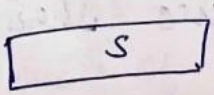
③ **Neutral Bricks**: In furnaces and in certain flues, where the reaction of the surrounding medium may be either acidic or basic, neutral brick are used.
These are of following types.
- Chrome Bricks
- Chrome-Magnesite Brick
- Spinal
- Forsterite Brick

Note: Spinal Brick are special refractory bricks produced in an electric furnance consisting of Mg and Al.
- Forsterite Brick are made of mineral forsterite having less shrinkage and possess good mechanical properties at high temperature forsterite – $2MgO \cdot SiO_2$

Bonding in Bricks.

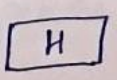
Terms used in Banding Bricks

① **Stretcher**: The longer face of brick is termed as stretcher. (19×9cm)



(4 No's)

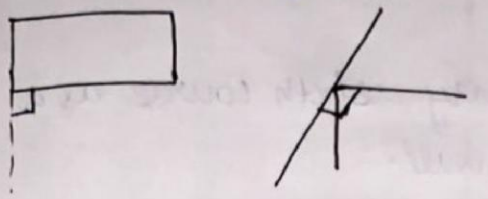
② **Header**: The shorter face of Brick is termed as Header (9×9cm)



(2 No's)

③ Quoin:

It is the outer of exterior angle on the face side of wall. It is generally kept 90°.



④ Closer:

The portion of brick obtained by cutting along the length is termed as Closer.

⑤ Bat:

The portion of brick obtained by cutting along the width is termed as Bat.

Bonds in Bricks

* It is a method of arranging bricks in courses such that individual units are field together and vertical joints of the successive course do not lie in same vertical line.
* Bonds of various types are distinguished by their elevation or face appearance.
* If the bonds are not arranged properly, continuous vertical joints will result in unbounded wall.
* Bonds help in distributing concentrated load over a large area.

Rules of Bonding:

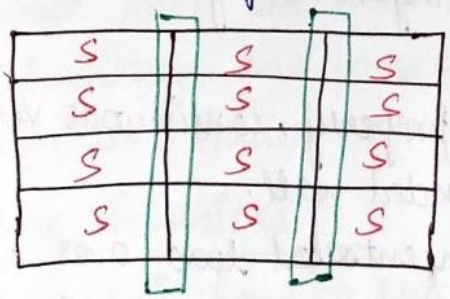
* Bricks should be of uniform size.
* Amount of lap should be min^m $\frac{1}{4}$ brick along the length of the wall and $\frac{1}{2}$ brick across the thickness of wall.

* Use of Brick bat should be avoided, except in some special location.
* Vertical joints in alternate courses should be along the same line.
* It is preferable to provide every sixth course as a header course on both sides wall.

Types of Bond

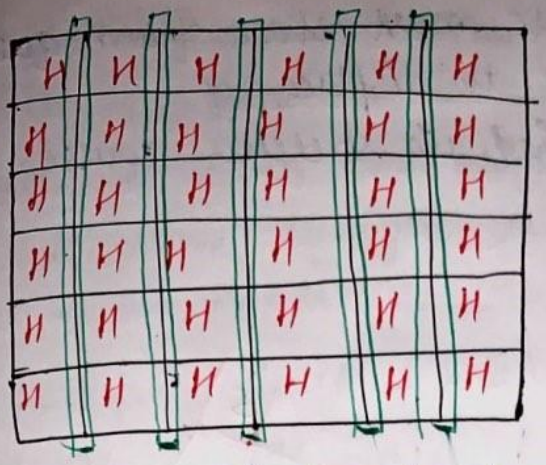
① Stretcher Bond :

* It is the arrangement of bonding which consist of stretcher in all the courses.
* In order to break alignment of vertical joint to fall in same straight line, half bat is provided in every alternate course.
* An overlap of $\frac{1}{2}$ brick is available for all stretches. This pattern is used only ~~how~~ for which having thickness of half brick eg: partition walls, sleeper walls division walls or chimney stack.



② Header Bond.

- It is the arrangement of bonding which consist of header in all the courses.
- In order to break the alignment of vertical joints to fall in same straight line, three quarter bat is provided in every alternate courses.



- An overlap of $\frac{1}{4}$ brick length is available for the header.
- In this case width of the wall is thus along the direction of wall.
- * This is used when thickness of wall equal to one brick is required.

Note: Minimum thickness of load bearing wall is one brick.

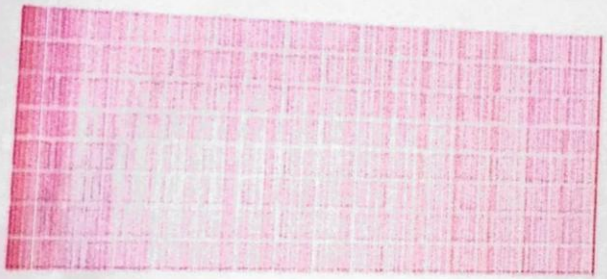
- * It is useful for curved brick work where stretchers is used, would project beyond the face of the wall.
- * It is also used in construction of footings due to its ability to distribute transverse loading.

③ English Bond

- * This is most commonly used wall, for all wall thickness and is considered to be strongest.
- * It consist of alternate of courses of stretcher and header one over each other
- * In order to break the alignment of vertical joints to fall in same straight line. queen closer half is provided next to quoin header.
- * An overlap of atleast of $\frac{1}{4}$ brick is available for the the stretcher over the header in every course.

* No header course in this case must start from queen closer half, as it is liable to displace off.
* Queen closer are not required in stretcher course.

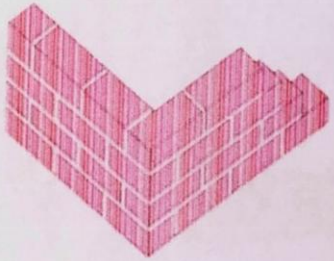
- Stretcher Bond



Front Elevation

Plan of Course 1

Plan of Course 2

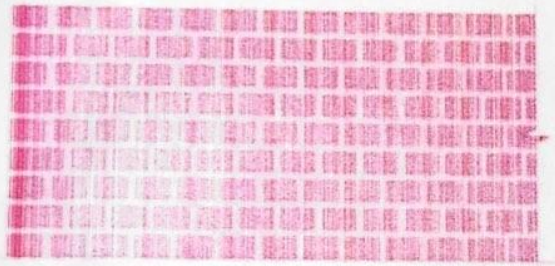


Isometric view of L-Junction

Plan of 1,3,5... courses

Plan of 2,4,6... courses

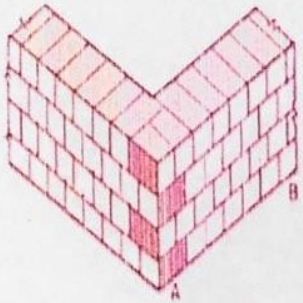
- Header Bond



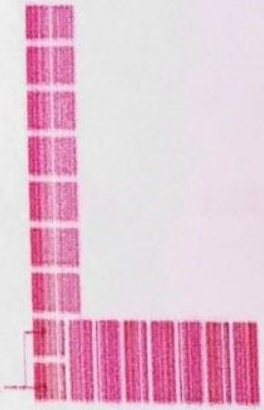
Elevation

Plan of 1,3,5.. courses

Plan of 2,4,6.. courses



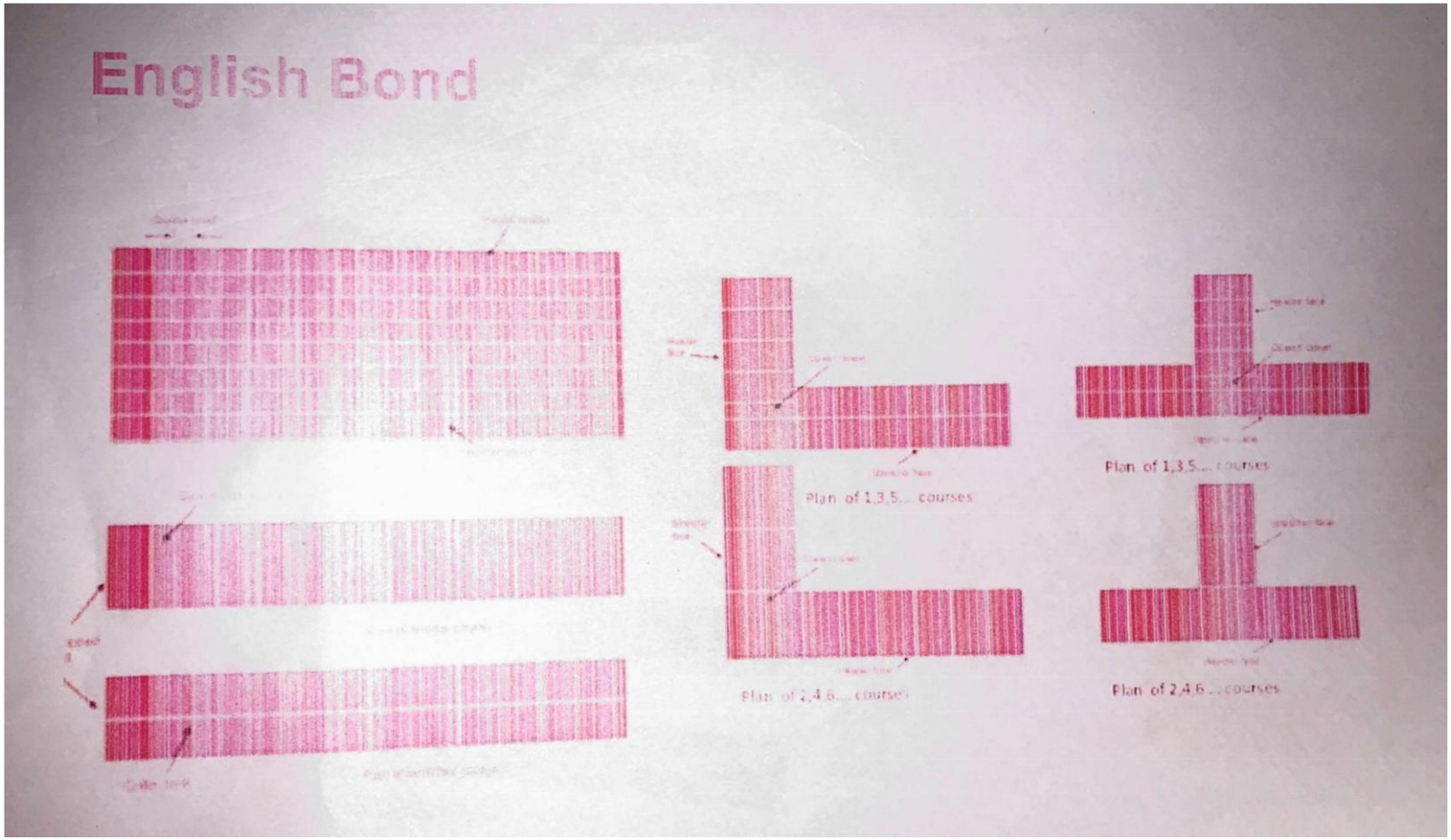
Isometric View Of L-junction



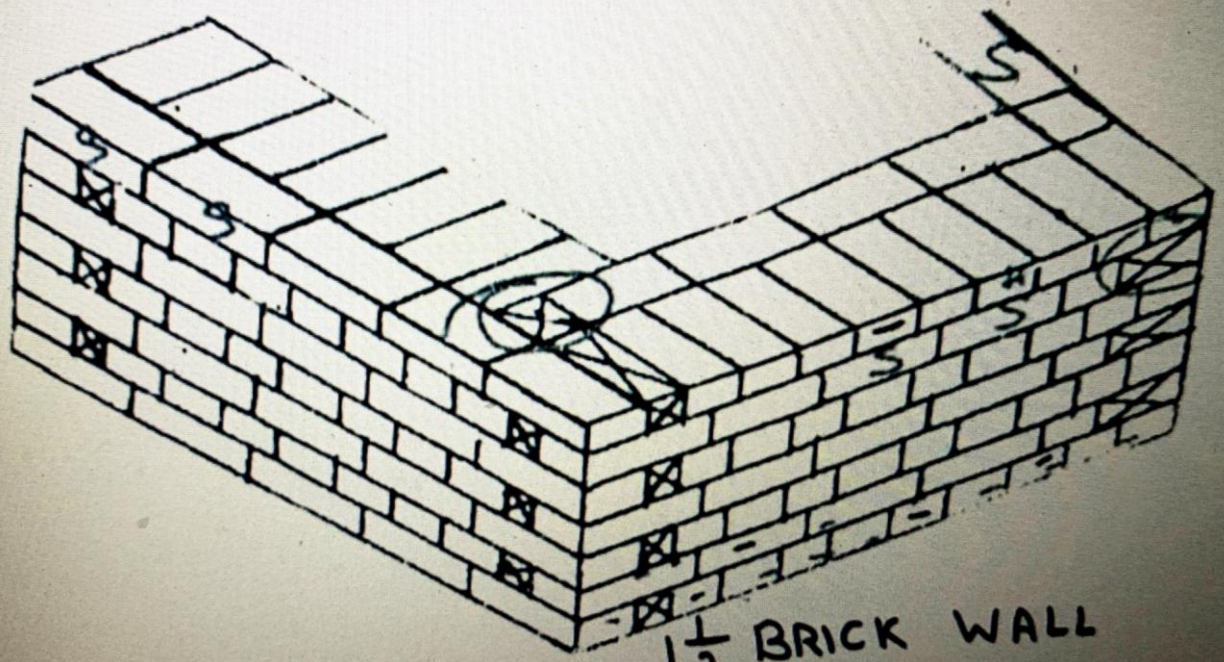
Plan Of 1,3,5... Courses

Plan Of 2,4,6... Courses

English Bond



(iv) FLEMISH BOND



$1\frac{1}{2}$ BRICK WALL

* It is arrangement of banding which consist of alternate header and stretcher in every course.
* In order to break the alignment of vertical joints to fall in same straight line queen closer half is provided next queen header.
* An overlap of atleast $\frac{1}{4}$ brick length is available for stretcher in all courses.
* Every alternate course $\frac{1}{4}$ brick length is available for stretcher in all courses.
* Every alternate course in this case starts from header.
* Every header is centered over the stretcher below it
* These bond are further of two types:

(a) Double Flemish Bond
(b) Single flemish Bond

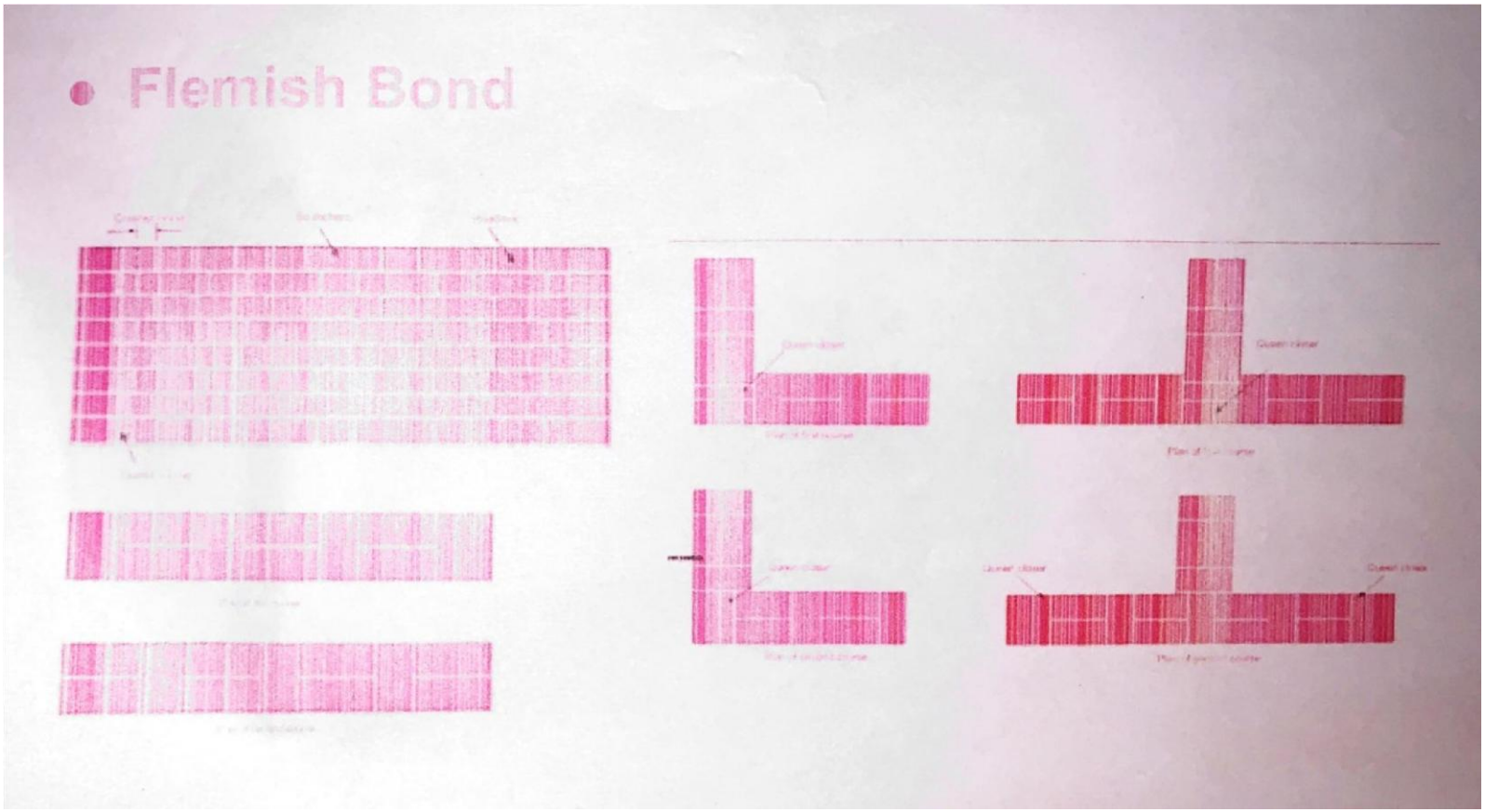
(a) Double flemish Bond:

* In this bond, back and front face are same in appearance.
* Each course has alternate header and stretcher. wall having thickness equal to add multiple of half bricks, half bats and 3 quarter bats are usually used.
* For walls having thickness equal to even multiple of half bricks, no bats are required.

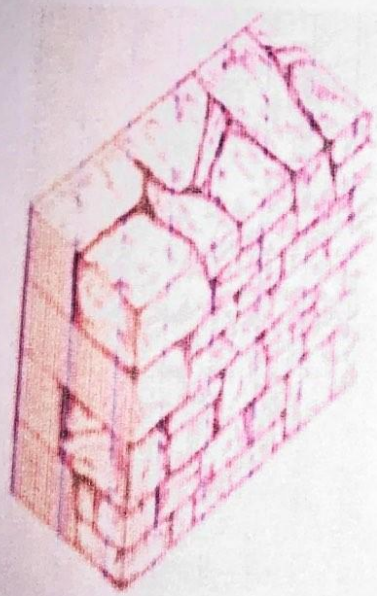
(b) Single Flemish Bond:

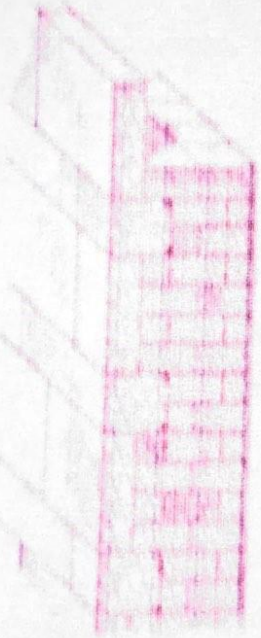
* In this bond facing has appearance of double flemish bond and backing of English Bond.

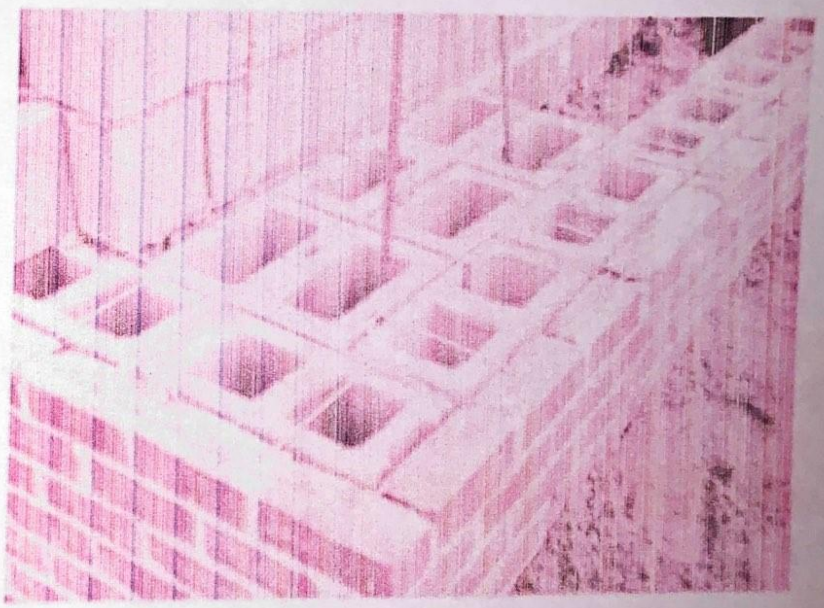
- Flemish Bond



- Facing Bond





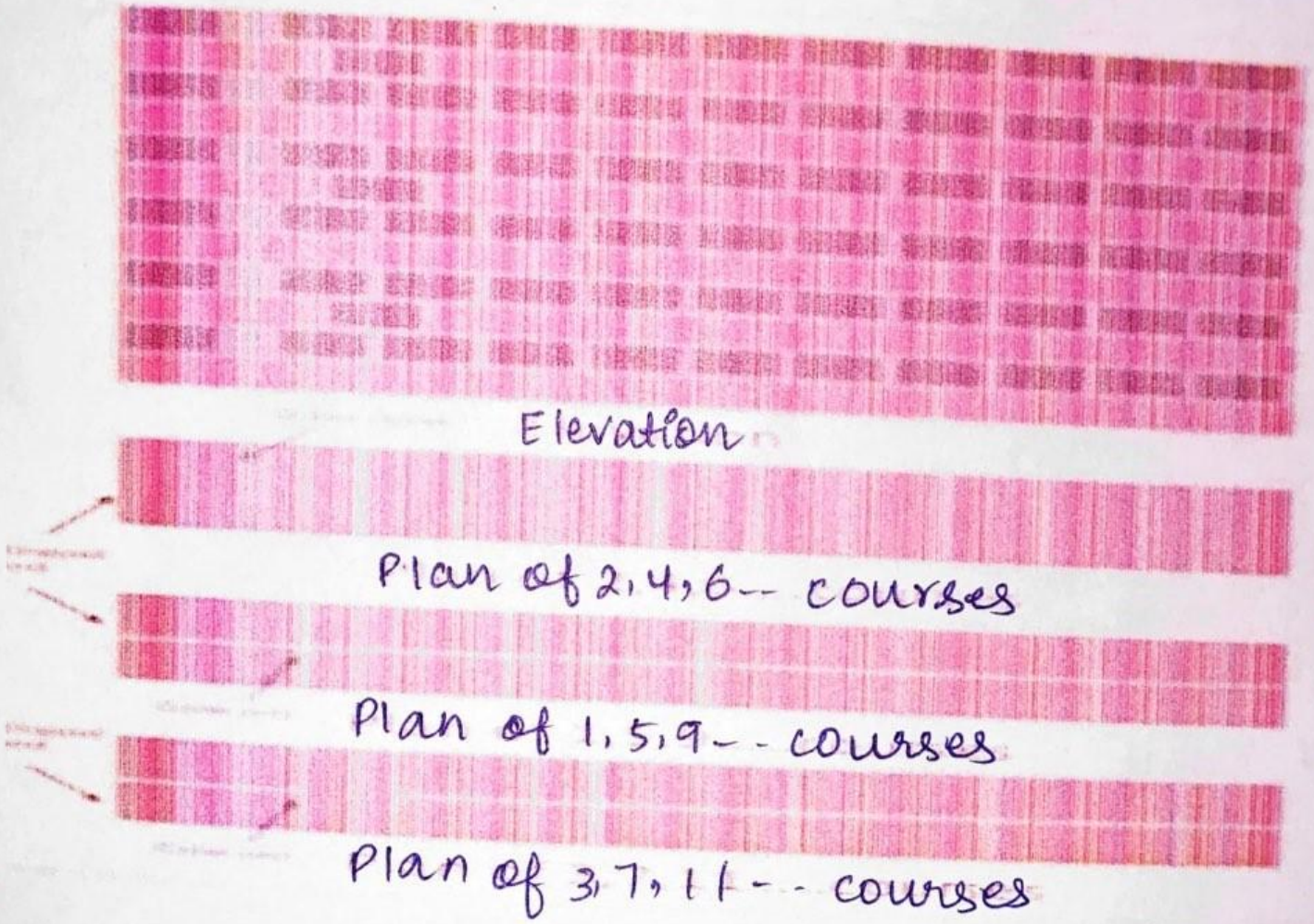


* This bond can be used for those walls having thickness at least equal $1\frac{1}{2}$ brick.
* Double Flemish Bond facing is done with good quality bricks and cheaper brick can be used for brick and hearting.

⑥ English Cross Bond.

* This is a modification of English Bond, used to improve the appearance of the wall.
* In this bond, alternate courses of headers and stretchers are provided as English Bond.
* Queen closers are placed next to Quoin headers.
* A header is introduced next to the quoin stretcher in every alternate stretcher course.

English Cross Bond



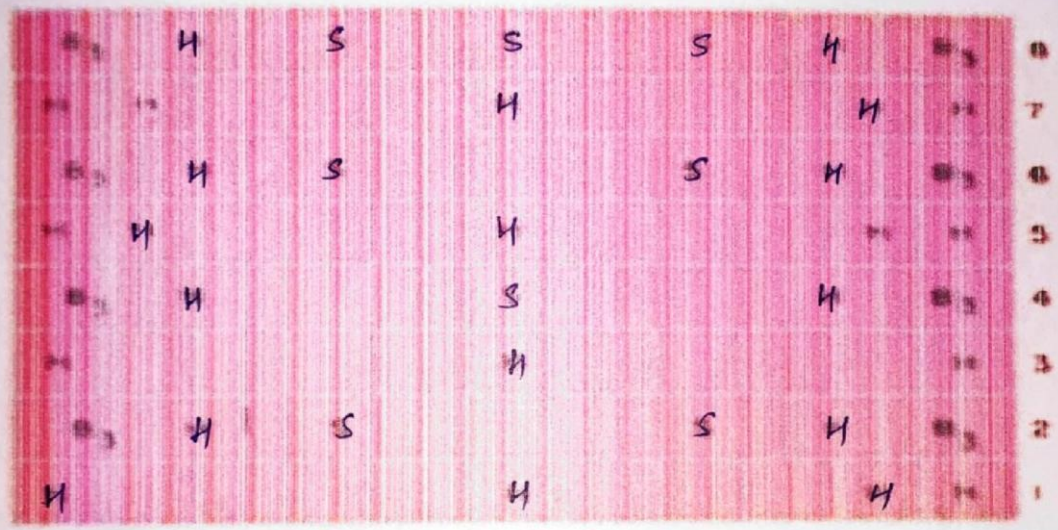
(7) Brick on Edge Bond (Silver Lock's Bond/Soldier's Bond)

* This bond is inspired by English Bond but in this bond the stretcher course are replaced by laying the bricks on edges and header course are laid on the beds.
* Queen Closer is provided after quoin header in the header course
* This type of bond is weak in strength but economical, so usually used as garden walls or compound walls.

(8) Dutch Bond:

* This is another modified form of English Bond. In this bond the corner of the wall are strengthened by adding three quarter bat as quoin for every alternate course.
* Alternate course are of header and stretcher are provided as in English Bond.

- **Dutch Bond:**



In every stretcher course, a header is placed next to 3Quarter brick Queen.

⑨ Raking Bond.

This bond is used in thick walls. In this type of bond, the bonding bricks are kept at an inclination to the direction of the wall.

Due to this longitudinal stability of thick wall built in English Bond is increased.

The bricks are arranged in inclined direction in the space b/w the external stretcher of the wall.

The raking or inclination should be in opposite direction in alternate course of raking.

The raking bond is not provided in successive courses it is provided at a regular interval of four to eight courses in the height of the wall.

The raking course is generally provided b/w two stretchers courses of wall. having thickness equal to even multiple of half brick, to make the bond more effective.

These are of two types

① Diagonal Bond

② Herring- Bone Bond

⑩ Zig-Zag Bond

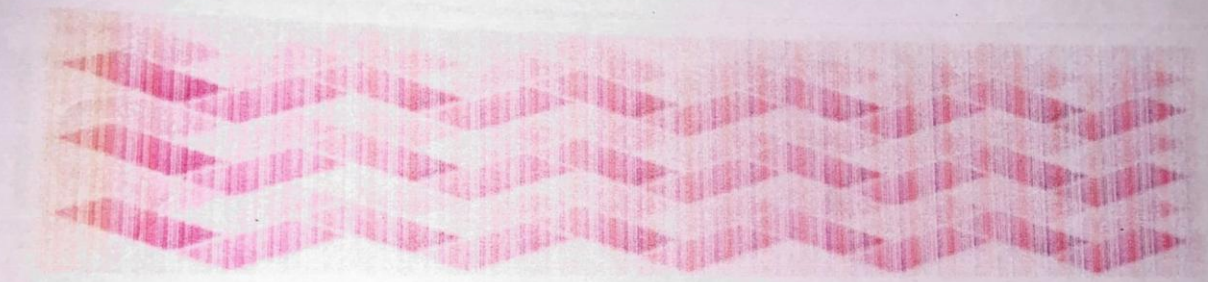
* This bond is similar to herring-bone bond, except that the bricks are laid in zig-zag pattern.
* This bond is commonly used for making panels in the brick flooring or walls.

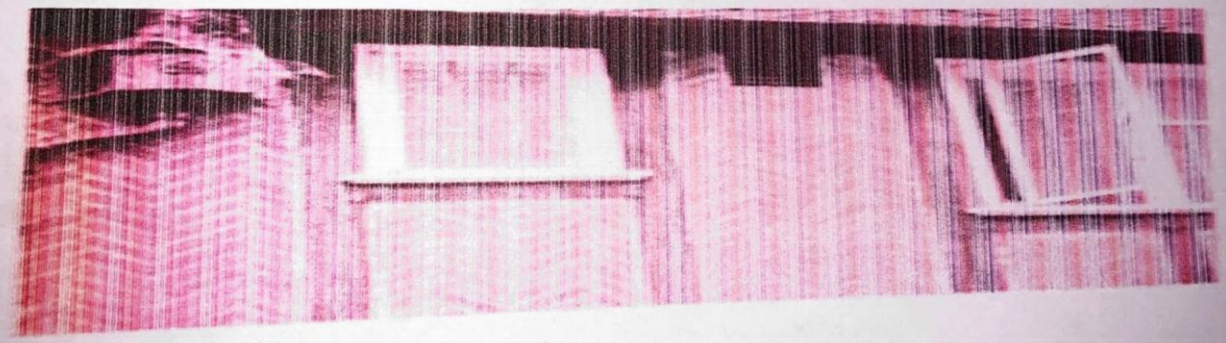
- Raking Bond

Diagonal Bond

Herring bone Bond

- Zigzag Bond





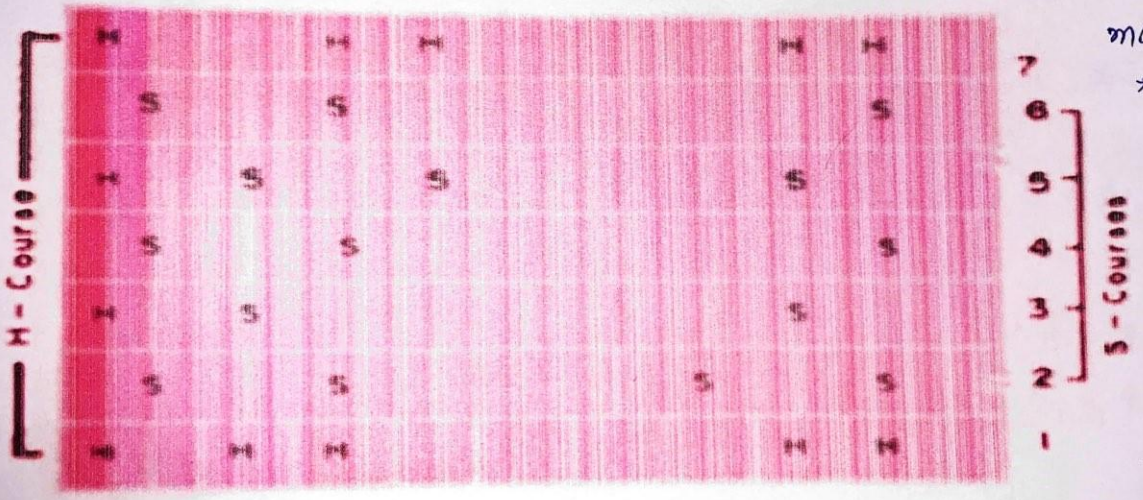
(11)

• Garden Wall English Bond :

provided only after 3-5 stretcher courses.

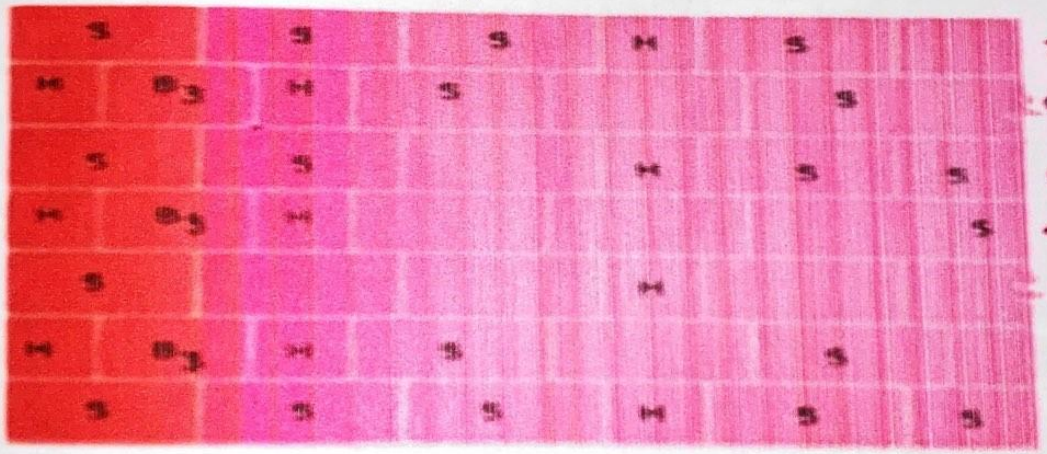
In this Bond, the header course is

* In each header course, a quoin header is provided to make necessary lap.
* In stretcher course, quoin headers are placed in alternate courses.



(12) Garden Wall Flemish Bond :-

In this bond each course contain one header after 3 to 5 stretchers continuously placed throughout the length of the course.



* Each alternate course contains a 3 quarter brick bat placed next to quoin header.
* This bond is also called "SCOTCH Bond"

ROCKS And STONES

* Stone has been defined as the natural hard substance formed from minerals and earth materials which are present in rock.
* Rock may be defined as the portion of the earth crust having no definite shape and structure
* Almost all rocks have a definite chemical composition and are made up of minerals and organic matter. Some of the rock forming minerals are as follows:

① Quartz
② Feldspar
③ Mica
④ Dolomite

Being aggregates of minerals, the properties of rock are dependent upon the character of minerals, constituents, identified by their physical properties as follows:

① **Hardness:** It is most important property for rapid determination of minerals
It is measured by scratching the mineral with a series of substances of known variation in hardness using the following scale of Mohs.

Substances	Hardness	Scale
Talc	Easily scratched with thumb nail	1
Gypsum	scratched by thumb Nail	2
calcite	not scratched by thumb nail but easily scratched by knife	3

Fluorite	can be cut with a knife with greater difficulty than calcite	4
Apatite	can be cut only with difficulty by knife	5
Orthoclase	can be cut with knife with difficulty on thin edges.	6
Quartz	not scratched by steel scratches glass	7
Topaz	–	8
Sapphire	–	9
Diamond	–	10

Note: If a given substance is scratched by fluorite and not calcite its Hardness is in b/w 3 & 4.

② Cleavage: It is the measure of capability of some minerals to split along certain plane parallel to the crystal force.

③ Streak: It is the colour of the mineral in powder form.

④ Colour: It is used for metallic minerals but for non metallic minerals it is less reliable.

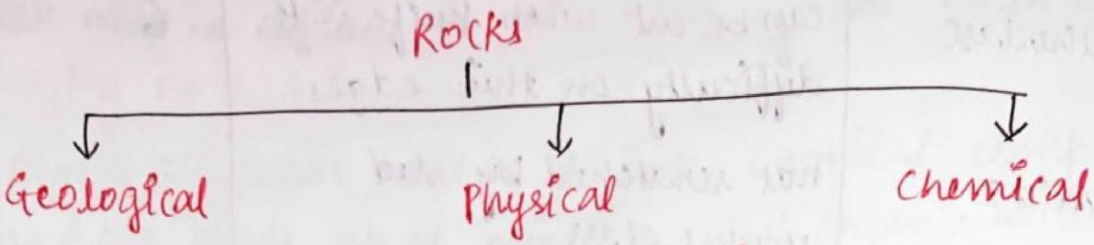
⑤ Luster: It is the shine on a surface of the mineral and its appearance under reflected light.

⑥ Crystal: The crystal form is of importance when a

mineral has the opportunity to develop its natural shape.

Classification of Rocks:

The rocks can be classified on the basis of the following:



① On the basis of Geological Formation

① **Igneous Rocks**: It is also known as primary unstratified or eruptive rocks of volcanic ~~region~~ origin and are formed as a result of solidification of molten mass lying below or above the surface of the Earth.

Eg: Granite, Rhyolite, Syenite, Andesite, Gabbro, Peridolite.

② **Sedimentary Rocks**: These are known as aqueous or stratified rocks. The various weathering agencees is air, water, sun, gravity, ice etc. breaks up the surface of the Earth, leading to the formation of these rocks. The properties of these rocks are very considerable depending upon the nature of sediment and type of bond b/w them.

Eg: Gypsum, Magnesite, chalk, Diatomite, Limestone

③ **Metamorphic Rocks**: These are formed from igneous or sedimentary rocks as a result of action of the earth movement, temp and liquid pressure etc.

Eg: Granite → Gneiss
Dolomite → Marble
Shale → Slate, Schist

② On the basis of Physical Characteristics

(1) Stratified Rocks:

* Shows distinct layer along which the rock can be split.
* eg: Sandstone, Limestone, Slate, Shale, Marble etc.

(2) Unstratified Rocks:

They do not show any stratification and cannot be easily split into layers of Granite, Basalt etc.

③ Foliated Rocks:

These rocks have a tendency to split up only in a definite direction. Most of the metamorphic rock have a foliated strength.
eg: Gneiss

③ Based on Chemical Characteristics:

① Argillaceous Rocks: Al_2O_3 eg: Slate
② Silicous Rocks: SiO_2 eg: Gneiss
③ Calcarious Rocks: CaO eg: Marble

Quarrying of Stones:

The only operation involved in the production of natural stone is termed as the Quarrying process.

→ While selecting the quarrying site, following points must be considered.

① Availability of sufficient quantity of stone of desired quality.
② Proper transportation facilities
③ Availability of cheap labour and are a available for dumping of refuse.
④ Problem of penetration of rain water.

→ Quarrying can be done by following method.

① Excavation
② Wedging
③ Heating
④ Blasting

Seasoning of stone:

* A freshly cut stone carries some natural moisture known as Quarry sap making it soft and workable.
* The Quarry sap is a mixed solution and reacts chemically with the minerals constituents when the stone is exposed to the atmosphere after Quarrying.
* The stones become harder and compact after this.
* This process takes about 6-12 months for complete seasoning.
* When the quarry sap evaporates it leaves a crystalline film on the faces of the stones and makes them weather resistant.
* The dressing before seasoning improves the weather resistance of the stone.
* As such the dressing, the carving and moulding etc should be done as early as after quarrying is possible.

Dressing of Stone

* A quarried stone has rough surface which are dressed to obtain definite and regular shape.
* Dressing of stones is done immediately after quarrying and before seasoning to achieve less weight for transportation.
* Dressing of stone provides pleasant appearance, proper bedding with good mortar joints, spherical shape for arches, coping, pillars etc.

Notes: Stones obtained from quarrying process can be used in following activities:-

(1) Foundation and wall work
(2) Facing and Architectural Items
(3) Building Items
(4) Road construction Items
(5) Underground Structure and Bridges
(6) Heat and Chemically Resistant Item

Characteristics of Good Building Stone

A good building stone should have following characteristics.

① Appearance: For face work it should have fine, compact texture, light coloured stones are preferred as dark colour are likely to fade away.

② Structure: A broken stone should not be dull in appearance and should have uniform texture free from cavities, cracks and patches.

③ Strength: A stone should be strong and durable and have strength in b/w 60-200 N/mm².

④ Weight: It is an indication of the porosity and density.
For stability of structure heavier stones are required whereas in case of arches and domes, vaults light stones are preferred.

⑤ Hardness: This property is important for floor, pavements, apron of bridges.

⑥ Toughness: stones should be tough enough to resist vibratory and impact loading.

⑦ Porosity and Absorption: Porosity depends on the minerals cooling time and structure formation.
Permissible water absorption for diff. stone are as follows:

Type of Stone	Water Absorption (%)
Sandstone	10
Limestone	10
Granite	1
Trap	6
Shale	10
Gneiss	1
Slate	1

* Stone should be well seasoned, weathered and workable.
* Specific Gravity : 2.4 - 2.7
* Stone should be fire resistant (It can withstand upto temp. 800°C]

Tool used for dressing of stones

Mash Hammer
Face Hammer
Mason's Hammer
Spalling
Scabbling
Drafting chisel
Pointing chisel
Mallet

Durability of Stones

* Quarrying and cutting have a great bearing on the weathering properties of stones.
* Stones from top ledges of limestone, granite and slate and from exposed faces of the rock bed is likely to be less hard and durable.
* Durability of stones is also affected by temp, humidity, method of blasting, cutting, hammering etc.

Durability of stones can be found as follows:

① Smith Test

In this test, break all the freshly quarried stone chippings to about the size of aggregates and put them in glass of clean water, $\frac{1}{3}$ full.
If the water becomes slightly cloudy, the stone is good and durable, If water becomes dirty it indicates that the stones contain too much of earthy material and mineral matter.

② Brard's Test:

* This test is performed for frost resistance.
* In this few small pieces of freshly quarried stone are immersed in boiling solution of sulphate of soda [Glauber's salt] and are weighed.
* These are then removed and kept suspended for few days and weighed again. The loss in weight indicates the probable effect of frost.

③ Acid Test:

* This test is performed to check weather resistance of stone.
* It confirms the power of stone to withstand atmospheric conditions.

④ Crystallisation Test

This test is specified by IS: 1125 to find the durability of stone.

Preservation of Stones

* Preservation of stones is essential to prevent its decay. Different types of stones require different
* treatment for its preservation.
* In general stone should be made dry with help of blow lamp and then a coating of paraffin, linseed oil, light paint etc. is applied over surface.
* This makes a protective layer over the stone. However this is periodic and not permanent.
* When treatment is done with linseed oil, it is boiled and applied in three coats over the stones.

Notes: In industrial town, stones are preserved by application of solution of Barium Hydrate also termed BARYTA ($Ba(OH)_2$)

It work in following manner:

$$Ba(OH)_2 + CaSO_4 \rightarrow BaSO_4 + Ca(OH)_2$$

Here Baryta reacts with $CaSO_4$ deposited on stones and forms insoluble Barium sulphate and Calcium Hydroxide. The calcium Hydroxide absorbs CO_2 from the air to form $CaCO_3$ ppt.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow$$

Artificial Stones:

Where durable stones are not available at reasonable costs artificial stone known as cast stone is used.

Artificial stone is made with cement and natural aggregate of the crushed stone and sand with desired finish (surface).

Some of the following artificial stones available are as follows:

① Garlic Stones

It is produced by moulding of iron slag and portland cement.

These are used as surface drains.

② Concrete Block

These are cast at site in the construction of pier or are used for steps, windows, sills, etc.

③ Ransom Stone

* These are prepared by mixing soda silicate with cement to provide decorative flooring.
* These are also known as chemical stones.

④ Victoria Stone

These are granite pieces with surface hardened by keeping it immersed in soda silicate for 2 months.

⑤ Bituminous Stone

* Granite and diorite are impregnated with prepared or refined tar to form bituminous stone.
* These are used to provide noise, wear and dust resistante stone.

⑥ Imperial Stone

These are finely crushed granite mixed with portland cement. These are similar to Victoria stones.

⑦ Artificial Marble

* It can be either pre cast or cast in situ.
* These are made of portland gypsum cement and sand.

TIMBER

Wood is hard and fibrous substance which forms a major part of the trunk and branches of a tree.
It can also be defined as a natural polymeric material which practically does not age.
Timber is obtained from the trees which can be classified as follow:

① On the basis of mode of growth

(1) Exogeneous Trees ② Endogeneous Trees.

Exogeneous Trees.

These are the types of trees which grows in bulk in outward direction and distinct consecutive rings are formed across their horizontal section termed as "Annular Rings" as they are added up each year and are helping in predicting the age of the tree.
Woodused in engineering activities is mostly derived from these trees only.
These trees are further classified into following:

① Conifer Trees.

These trees bear cone shaped fruit hence are termed as conifers trees.
They are also termed as evergreen trees as they never shed their leaves ~~on time~~, until the new ones are grown.
These trees ~~are~~ posses distinct annual rings and indistinct medullary rays.

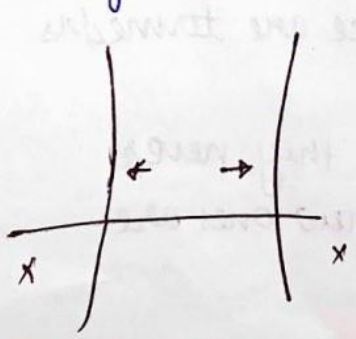
* Wood obtained from these trees is soft, weak, light in weight, light in colour, resinous hence have limited engineering applications:
  eg: chir, deodar, pine, spruce.

(2) Deciduous Trees:

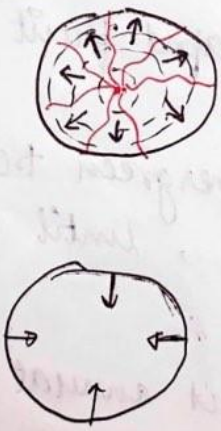
* They are also referred as broad leafed trees.
* They shed their leaves in autumn which again grows back in spring.
* These trees posses indistinct annual rings and distinct medullary rays.
* Wood obtained from these trees are hard, heavy, dark in colour and non resinous. Hence is suitable for engineering applications.
  Eg: Babul, Mahagony, Teak, sal, Oak.

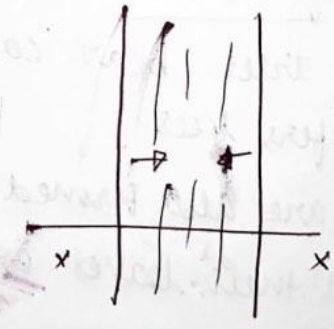
(ii) Endogeneous Trees-

* These are the types of trees which grows in bulk in inward direction and fibrous mass can be seen across their longitudinal section.
* Wood obtained from these trees have limited engg. application.
  Eg: Bamboo, cane, Palm



Exogenous Trees





Endogeneous Trees

Difference b/w Softwood and Hard wood

Property	Softwood	Hardwood
Colour	Light	Dark
Growth	Faster	Slower
Weight	Light	Heavy
Density	Low	High
Annual Rings	Distinct	Indistinct
Heartwood and Sapwood	cannot be distinguished	can be distinguished
Strength	Weak (strong along the grains)	Strong (strong along and across the grains)
conversion	Easy	Difficult
Resinous Material.	More	Less

II) On the basis of Modulus of Elasticity –

Class A: E in bending > 12.5 kN/mm^2.
Class B: E in bending 9.8 – 12.5 kN/mm^2.
Class C: E in bending 5.6 – 9.8 kN/mm^2.

III) On the basis of Availability :

Grade X : Most common. ≥ 14.5 m^3/yr
Grade Y : common, 355 – 14.5 m^3/yr
Grade Z : Less common, < 355 m^3/yr.

IV On the basis of its Position

① Standing Timber → It implies standing tree.

② Rough Timber → It forms part of falled tree.

③ Converted Timber / Lumber → These are logs of timber sawn into planks or posts etc.

⑤ On the basis of grading:

① Structural Grading: It is also termed as stress loading. It refers to the principle by which material is graded on the basis of visible defects. which have known effects on strength of material.

It is further divided as:

(1) Grading based on known effects of defects and estimating accumulative value.

(2) Machine Grading.

② Commercial Grading / Yard / Utility Grading:

It refers to the principle by which the material is graded by consideration of usefulness of the material and price factors.

⑥ On the basis of Durability

High Durable: Average Life span of ≥120 months

Moderate Durable: Avg. Life span of 120-60 months

Low Durable: Avg. Life span of < 60 months

⑦ On the basis of seasoning:

Highly Refractory (Class A): These are slow and difficult to season free from defects.

Moderately Refractory (Class B): These may be seasoned free from surface defects, if some protection

is given against rapid drying.

Non refractory : These are rapidly seasoned free from defects. (Class C)

(3) On basis of Treatability -

(a) Easily Treatable
(b) Treatable but complete preservation not easily obtained
(c) Only partially treatable
(d) Refractory to treatment
(e) Very refractory to treatment

Structure of Tree :

Tree broadly consist of 3 components

(a) Trunk
(b) Crown
(c) Roots

* The purpose of the root is to implant the tree into the soil and absorb moisture and nutrients from the soil and transfer it to crown through trunk.
* Crown is the portion of the tree which bears leaves and fruits.
* Trunk imparts strength and rigidity to the tree. It hold the crown in position and help transmit moisture and nutrients from roots to the crown and from crown back to the roots.
* From visibility point of view, structure of tree can be divided into:

(1) Macro structure
(2) Micro Structure

(v) Macro Structure : It is the structure of the tree that can be seen by naked eye.

(1) Pith : The inner most central portion or core of the tree is called pith.

* It varies in shape and size for different types of trees.
* Trees in its young age grows by the transmission of the nutrients to and fro from pith region itself, but as the tree grows old this portion dies and decays up getting converted to plt in its present age.

(2) Heartwood :

* The inner annual rings surrounding the pith is known as heartwood. It is usually dark in colour.
* It indicates dead portion of the tree, as it don't take active part in the growth of tree but imparts strength and rigidity to it.
* It makes the wood strong and durable and suitable to be used for engineering purposes.

(3) sapwood :

* The outer annual rings b/w heartwood and cambium layer is known as Sapwood.
* It is usually light in colour and weight which indicates recent growth and it contains sap.
* The annual rings of sapwood are less sharply defined than those of heartwood.
* It takes active part in the growth of the trees and sap moves in the upward/downward direction through it.

Note : Sapwood is also known as "ALBURNUM"

④ Cambium Layer:-

* The thin layer of sap and b/w sapwood and innerbark is known as cambium layer.
* It indicates the sap which has yet not been converted into sap wood, hence future of tree depends upon cambium layer only.

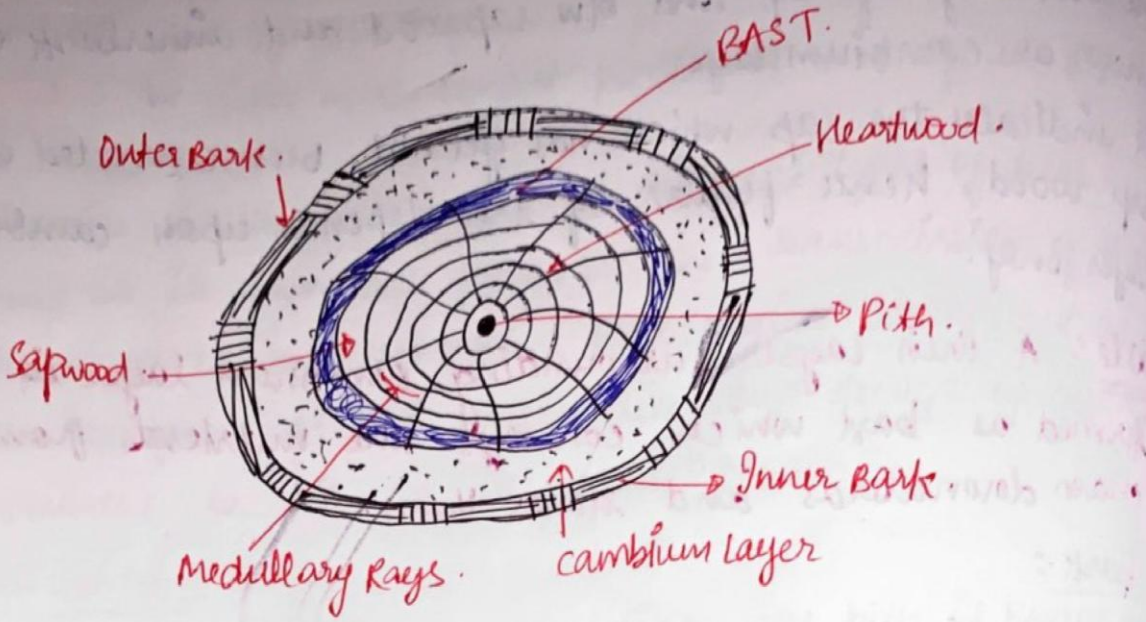
Note: A thin layer surrounding cambium layer is termed as bast which conveys the nutrients from crown downwards and stores them.

⑤ Bark:-

The protective layer surrounding the bast or cambium layer, thereby ensuring it safely against the any injury is termed as Bark.
It further classified into inner and outer bark.

⑥ Medullary Rays.

The thin radial fibres extending from pith to the cambium layer are known as Medullary rays.
The function of these rays is to hold together the annular rings of heartwood and sapwood thereby impart strength to it.
If these medullary rays are cut or broken due to any reason, it leads to subsequent decrease in strength of timber.



(b) Microstructure

The structure of wood apparent only at great modification is called microstructure that is studied under microscope. Core of cells in timber differs from protoplasm only by the presence of phosphorus.

Cells according to the function they perform are classified as:

① Conductive cell: They serve mainly to transmits the nutrients from the roots to the branches and leaves.

② Mechanical cell: These cells are elongated, thick walled and have tightly interconnected narrow interior cavities. which impart strength to the wood.

③ Storage cell: These cells serve to store and transmit nutrients to the living cells in the horizontal direction and are located in medullary rays.

Note: ① Specific Gravity of timber is 1.54 for all types of trees but their mass specific Gravity varies from tree to tree.

② The weight of the tree is noted at the moisture content of 12%.

③ Timber is non homogeneous, anisotropic material i.e. its properties are different in different direction at different points.

④ shrinkage in longitudinal direction is observed to be minimum, followed by radial direction and circumferential direction.

⑤ compressive strength of timber is found to be max^{m} parallel to grains i.e. in the longitudinal direction.

⑥ Tensile strength of timber is 2-4 times greater than its compressive strength.

⑦ Velocity of sound through timber is 2-17 times greater than air

Characteristics of Good Timber

* Narrow annular rings, closer the rings greater is the strength.
* compact medullary rays
* Dark colour
* Uniform structure
* Swell, smell and shinning surface (fresh)
* when stuck metallic sound is produced.
* Free from defects
* Heavy weight
* No woolines at fresh cut surface

Processing of Timber

Processing of timber can be carried out in following sequence of operation.

① Felling of Trees
② seasoning of Trees
③ conversion of Trees
④ Preservation

① Felling of Trees.

* To get timber, trees are knocked down or cut down or caused to fall to the ground.
* This process is termed as felling of trees.
* Felling of trees must be done, keeping in following points in considerations.

(1) Age of Felling of Trees.

Trees should be cut when they have attained sufficient maturity as if under mature trees is cut, it would have excess of sapwood, and if over mature tree is cut; it would have excess of pith. In either case it would not provide required strength.

The age of good trees for felling is 50-100yrs.

(2) Method of Felling.

Trees should be cut just above the base such that maxm timber is obtained from it.

(3) seasoning of felling:-

* Trees should be cut when sap is at rest.
* It should be avoided in autumn and spring when sap is in vigrous motion.

* For hilly area, mid summer is proper season, as there is heavy rainfall in winter and for plain areas mid winter is proper season as in summer temperature would be very high that will lead to vapourisation of water.

(2) Seasoning of Timber

When a tree is newly filled, it contains about 50% or more of its oven dry weight as water.

This water is in the sap or moisture.

water is to be removed before timber can be used for any engineering purpose.

This process of drying of timber is termed as seasoning.

Wood being a hygroscopic material, it attains a level of equilibrium moisture content under the given climatic condition of temp. and relative humidity.

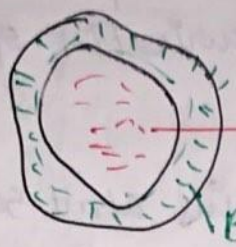
By the process of seasoning the excess water of timber is extracted in such a way that moisture content of seasoned timber corresponds to that required to attain equilibrium conditions.

Moisture in timber can be present either in cell cavities or in cell walls.

water in cell cavities is termed as free moisture/ water whereas water in cell wall is termed as bound moisture.

when timber is seasoned it starts loosing moisture content. free water is evaporated first and the point at which cell cavities is no longer contains free water is termed as "FIBRE SATURATION POINT".

* After FSP has been reached the tendency of shrinkage appears in the timber which is proportional to loss in bound water.



The moisture content of timber is determined by laying timber at temp. of 100 - 105°C till dry weight remains same. $\left(P = \frac{W_1 - W_2}{W_2} \times 100\right)$

Seasoning of timber is carried out for following purposes.

① To allow the timber to burn rapidly when used as fuel.
② To decrease cost of transportation.
③ To impart strength, hardness, stiffness
④ To increase the resistance of timber against decay.
⑤ To maintain shape and size when used for engg. construction.
⑥ To make timber easily workable.
⑦ To make timber for receiving decoration treatments
⑧ To make timber against attack of algae and fungi
⑨ To reduce the tendency of cracking, twisting and warping.

* Seasoning of timber can be done by any of the following method.

① Natural seasoning ② Artificial seasoning

Natural seasoning of the timber is not preferred as:

① Time required in the case is more.
② There is no control over the factor which governs vapourisation like wind, temp. and humidity.

Artificial seasoning of timber can be done by any of the following method:

① Boiling
② chemical seasoning (salt seasoning
③ Electrical Seasoning
④ Kiln seasoning
⑤ Water seasoning
⑥ Mc Neills Process

① Boiling :-

* In this method of artificial seasoning, timber is immersed in water and water is then boiled. This is a very quick method.
* Timber after boiling for about 3-4 hrs it then dried very slowly.

The period of seasoning and shrinkage is thus considerable reduced by this method.

The method affects the elasticity and strength of wood.

In place of boiling water, timber may be exposed to the action of hot steam (is comparatively costly).

② Chemical Seasoning :-

It is also termed as salt seasoning.

In this method timber is immersed in the solution of soluble salts like sodium chloride, Ferrous sulphate, Aluminium sulphate, Calcium Acetate, Sodium Phospate which increases the rate of vapourisation of water from the timber section.

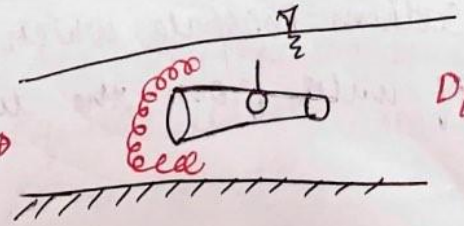
* The interior surface of timber dries in advance to the exterior one and chances of formation of cracks are reduced.

③ Electrical seasoning :

* In this method high frequency alternating currents are passed through timber section.
* As timber is bad conductor of Electricity it offers resistance to the flow of current, due to which heat is produced, that carries out the early seasoning of the timber
* This is the most rapid method available for seasoning.
* But it is uneconomical to be used on commercial scale.

④ Water seasoning :

* In this method timber is cut into pieces of suitable size.
* These pieces are immersed in stream of flowing water such that thicker and larger portion is kept pointing up stream side. (as the result of which turbulence is developed).
* Timber is taken out after a period of 2-4 ~~months~~ weeks, during which sap contained in timber is washed away by the water.
* Timber is then allowed to dry free in air.
* It is quick method and it renders timber which is less liable to shrinkage or warp. However it weakens the timber and makes it brittle.



⑤ Kiln seasoning:-

* In this method drying of timber is carried out inside an air tight chamber or even
* Timber is arranged inside the chamber such that spaces are left for free circulation of air.
* Air which is fully saturated with moisture and which is heated to a temp. of about 35°C - 38°C is then forced inside the chamber by suitable ~~measurement~~ arrangement.
* This forced air is allowed to circulate around the timber pieces.
* As air is fully saturated with moisture evaporation from the surface of timber pieces is prevented but carries out uniform heating of the timber section.
* The relative humidity is now gradually reduced.
* The temperature is then raised and maintained till the desired degree of moisture content is attained

Depending upon mode of construction and operation kiln are further divided into two:

1. Stationary Kilns
2. Progressive Kilns

⑥ MC NEILL'S Process:-

* This process has no adverse effects.
* It is the best method although most expensive.
* The timber is staked in chamber with free air space ($\frac{1}{3}$ of its capacity) and containing products of combustion of fuels in the free place.

* The time required for complete seasoning in this case is 50-60 days.

(3) CONVERSION OF TIMBER:

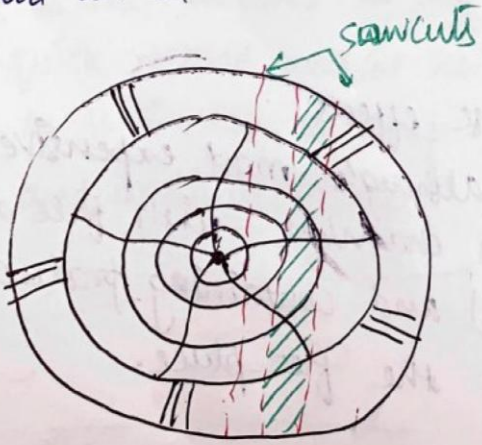
It is the process giving required shape and size to the timber section.

It can be done by any of the following method:

(1) Ordinary / Slab / Flat Sawing
(2) Quarter Sawing
(3) Tangential Sawing
(4) Radial / Rift Sawing

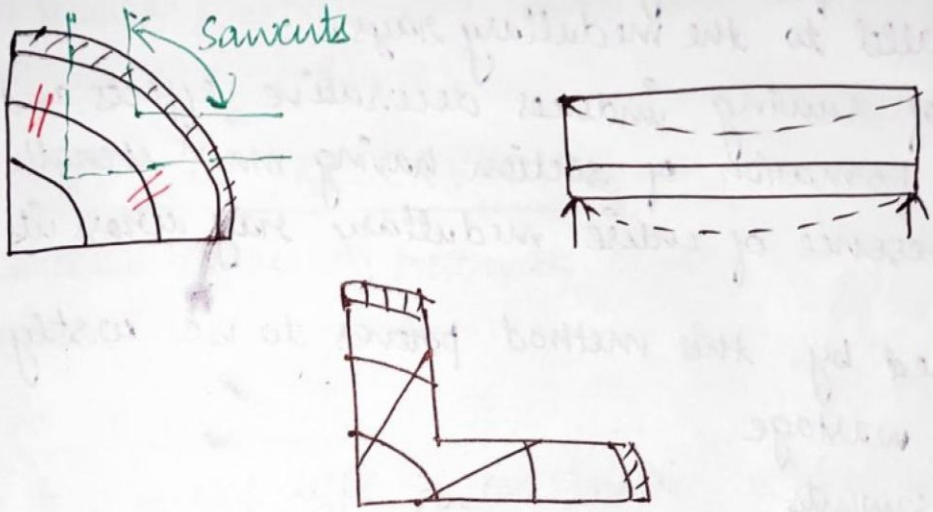
(1) Ordinary / Slab / Flat Sawing:

* It is most quickest, easiest and cheapest method available for conversion of timber.
* In this method saw cuts are made, tangential to the annular rings.
* The wastage of the timber in this method is observed to be least as entire section can be used in this case
* section obtained by this method of conversion is liable to twist and wrap due to the presence of sapwood and heartwood in it.



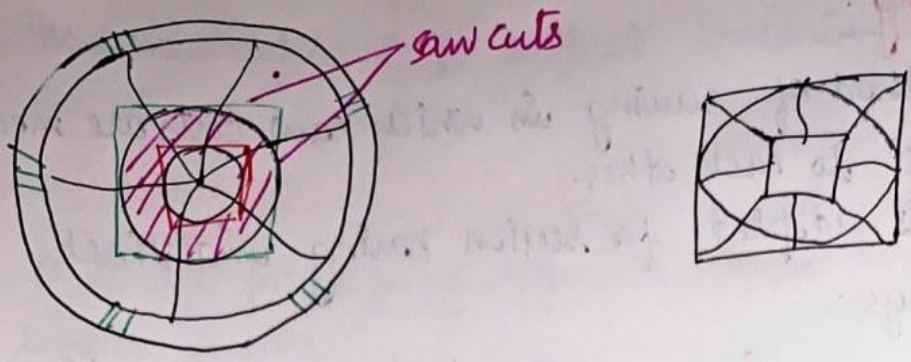
② Quarter Sawing :-

It is the method of sawing in which saw cuts are made at right angle to each other.
This method is adopted for section having undistinct medullary rays.
Timber section obtained by this method of sawing is liable to bend in transverse direction.



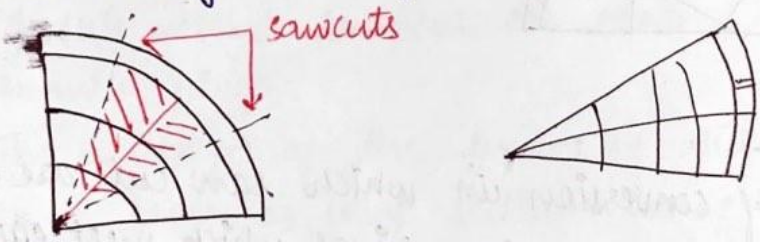
③ Tangential Sawing :-

It is the method of conversion in which saw cuts are made tangential to the annular rings which meet each other at right angles.
This method is adopted for these sections which have distinct annular rings and undistinct medullary rays.
Section obtained from this method are weak due to absence of medullary rays.
These sections are also unsuitable ~~for~~ to be used for flooring works as they cannot be polished evenly.



⑨ Radial / Rift sawing:-

In this method of sawing cuts are made in radial direction, parallel to the medullary rays.
This method of sawing induces decorative effects and leads to the formation of section having max^m strength due to the presence of entire medullary ray across its section.
Section obtained by this method proves to be costly due to high wastage



⑩ Preservation of Timber

Preservation of Timber is carried out to achieve the following:

① To increase the life of timber strength.
② To make the timber strength durable.
③ To protect the timber strength from the attack of destroying agencies such as fungi, insects etc.

Preservative used for this purpose should possess following properties.

① It should allow decorative treatment.

② It should be capable of covering large area.
③ It should be cheap and easily available.
④ It should be non-inflamable.
⑤ It should be free from unpleasant odour.
⑥ It should not affect the durability of other building components.
⑦ It should not wash away easily with water.
⑧ It should penetrate deep inside the timber section upto the depth of 6-25mm.

TYPES OF PRESERVATIVE

Following types of preservatives are commonly used for timber.

① As Cu Treatment

* It is a special type of preservative which increases the resistance of the timber against the action of white ants (TERMITES).
* It consist of the following:
* 1part by weight of $As_2O_5 \cdot 2H_2O$ (Arsenic Penta oxide)
* 3parts by weight of $CuSO_4 \cdot 5H_2O$ (copper sulphate)
* 4parts by weight of $K_2Cr_2O_7$ / $Na_2Cr_2O_7 \cdot 2H_2O$
* It is termed as 1:3:4 reagent.
* It is available in powder form, hence 6 part by of its weight are mixed with 100 parts by weight of water and solution is applied over the timber.

② Solignum Paint

These paints also increase the resistance of timber against

White ants but also impart aesthetic value to it.

③ Oil Paint

Timber surface is coated with 2-3 coats of oil paint in order to increase its resistance against penetration of water hence make it more durable.
But it should be applied over well seasoned timber or else it would lead to decay of timber due to the presence of sap in it.

④ Chemical Paints

These are water borne preservatives that are mostly salt dissolved in water ~~due~~ used to increase the durability and resistance against deforming agencies.
eg: Mercury Chloride, Sodium Fluoride, $CuSO_4$, Zinc Chloride.

⑤ Coal Tar

Timber surface is coated with tar in hot state and process is termed as TARRING.
It increases the resistance of timber against fire but gives unpleasant smell and appearance which makes timber unsuitable for paint, hence it is used for engineering works of less significance.

Note:

① Resistance of ~~fire~~ timber against fire can also be increased by application of
- Ammonium Sulphate
- Borax $[Na_2[B_4O_5(OH)_4]\cdot 8H_2O]$
- Zinc Chloride
- Boric Acid $[H_3BO_3]$
- Sodium Silicate (Sir Abel's Process)

② Same purpose can also be achieved by coating of clay sulphate and phosphate ~~cement~~ paint.

⑥ Creosote Oil :

* It is obtained from distillation of tar.
* Process of application of creosote oil is termed as "creosoting Bethels Process".
use of creosote oil almost doubles the life of time, increase the durability and resistance against deforming agencies, hence is used for major engg. works.
eg: Pipes, Poles, sleepers.

Preservatives are applied over the timber section by any of the following methods:

* Brushing
* Charring
* Dipping and steeping
* Hot and cold open tank Treatment
* Injecting under pressure

Note: Preservatives are of following types :-

Type : I : OIL TYPE PRESERVATIVE
Oil paints. Petroleum Product Paint

Type II : Organic Solvent Preservative
Benzene - hexa chloride
DDT (Dichloro Diphenyle Trichloroethane)
Penta chloro Phenol.

Type III : Water Soluble Preservative
Ascu, zinc chloride etc.

Treatment Process over Timber

① BOUCHERIE PROCESS

Sapwood of almost all green colour timber with the bark on and of bamboos in green condition, soon after felling, can be treated using any of inorganic water insoluble preservative in this process.

② Empty cell Process.

* It is also known as pressure process, and aimed at a maxm penetration of the preservative with minimum net retention.

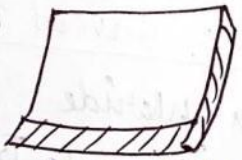
→ These are further of two types.
- Lowry Process
- Rueping Process

Defects in Timber

Defects occuring in timber can be categorised as follows:
① Defects due to seasoning.
② Defects due to conversion.
③ Defects due to Natural forces
④ Defects due to fungi

① Defect due to seasoning:-

① **Bow:** It is indicated by curvature formed in the direction of length in timber.



② **Cup:** This defect is indicated by curvature formed in the transverse direction in timber.

③ Warp

when a piece of timber is twisted out of shape it is said to be warped

④ Twist :

when a piece of timber has spirally distorted along its lengths is said to be twisted.

② Defect due to conversion

① Chip Mark.

This defect is indicated by the mark or signs placed by chips on finished surface of timber
This defects are induced by pointed parts of sawing machine.

② Diagonal Grain

The defect is formed due to improper sawing of timber.
It is indicated by diagonal mark on straight grained surface of timber.

③ Toon Grain

This defect is formed by improper sawing of timber.
It is indicated by dispersion / void over the surface of the timber which is formed by falling of some tool.

④ Wane :

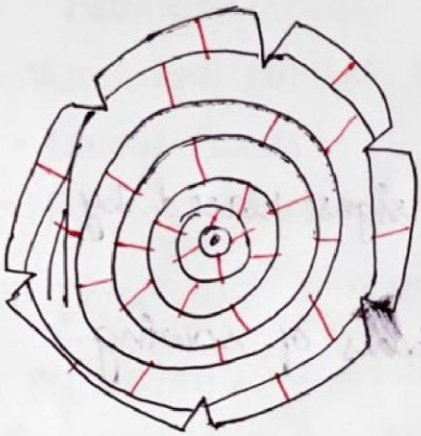
This defect is identified by presence of original rounded surface of the manufacturer price of timber.

③ Defect due to Natural Forces

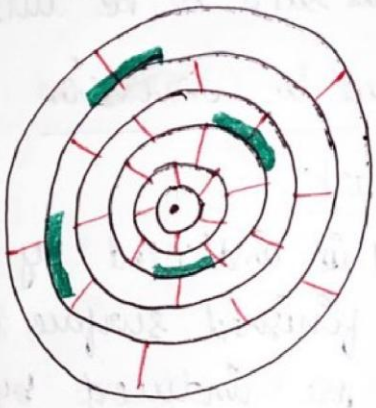
① Shakes:

These are cracks which are partly or completely separate the fibre of wood, these are of following.

* Cup shakes
* Heart shakes
* Ring shakes
* Star shakes
* Radial shakes



Star shakes.



Ring shakes.

Heart shakes.

② Twisted Fibre:

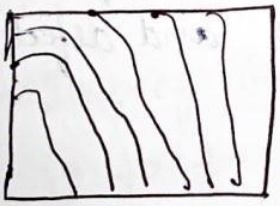
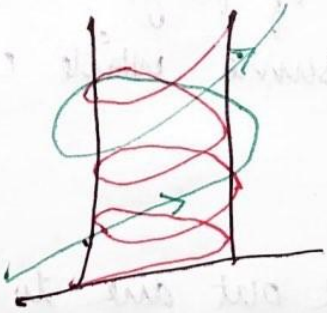
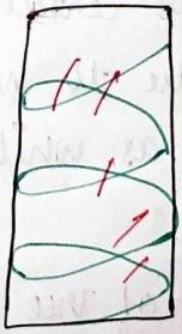
It is also termed as wondering fibres as they are caused by twisting of young trees by fast blowing wind.

The fibres of the wood are twisted in one direction making it unsuitable for sawing.
Hence, in this case the entire section is used as post or pole.

③ Druiness:
This defect is indicated by white decayed spots which are concealed by healthy wood.

④ Knot:
If the branch of the tree falls out, the position from which it is removed continues to receive the nourishment up to an extent a dark knot is formed across it section, which induces non homogenity in it and reduces its strength.
These are further classified as

- Loose knot
- Decayed knot
- Tight knot
- Dead knot
- Round knot
- Live knot

④ Defects of Fungi

* Fungi are minute microscopic plant which feed over the timber section and leads to its decay.
* Attack of Fungi over the timber takes place only if
① Moisture content of timber is above 20%.
② There is presence of air and warmth around the timber.
③ Defects due to fungi in timber are as follows:

① Blue Stain | Sap Stain

There are certain types of fungi which feeds over the sapwood due to which it assumes blue colour.

② Brown Rot:

* Here rot is used to indicate decay or desease of timber.
* Certain type of fungi remove cellulose compound from wood due to which it assumes brown colour and defect is termed as brown rot.

③ White Rot:

This defect is just opposite of brown rot.
In this case certain type of fungi attack lignin (fibres) of wood due to which assume white colour and defect is termed as white rot.

④ Heart Rot:

If branch of tree of fall out due to any reason it exposes the heartwood to the attack of fungi, which consumes it over the period of time, and reduces its strength.

⑤ Dry Rot:

certain type of fungi feed over the wood and ~~concrete~~ convert it into dry powder from termed as dry rot.

① where there is no free circulation of air
② unseasoned softwood is used
③ Timber is not store properly after felling.

⑥ Wet Rot:

Some varieties of fungi carries out chemical decomposition of timber, due to which it assumes greyish ~~colo~~ brown colour and defect is termed as wet rot.

Its tendency increases when timber is exposed to alternate wetting and drying or in unseasoned timber.

Industrial Timber:

Timber which is prepared scientifically in a factory is termed as industrial timber and such timber passess desired shape, appearance, strength, etc.

Following are the varities of the industrial timber.

① Veneers
② Plywoods
③ Impreg Timber
④ compreg

① Veneers:

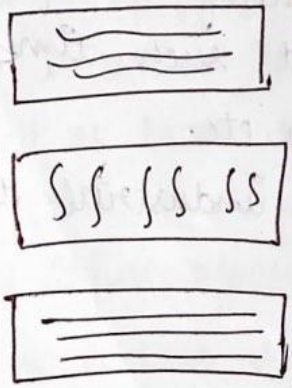
* These are thin sheets or slices of wood of superior quality
* Thickness of veneers from 0.4mm - 6mm or more.
* They are obtained by rotating a log of wood against a

Sharp knife of rotatory cutter.

* Veneers after being removed are dried in Kilns to remove moisture.
* Veneers are further used to produce plywoods battenboards, and lamin boards.

② Plywoods.

* These are boards which are prepared from thin layers of woods or veneers.
* Three or more veneers are placed one above the other with the direction of grains of successive layers at right angles to each other.
* They are held in position by application of suitable adhesive.
* The placing of veneers normal to each other increases the longitudinal and transverse strength of plywoods.



③ Fibre Board:

* These are rigid boards and they are also known as pressed or reconstructed wood.
* The thickness varies from 3mm to 12mm
* They are available in length varying from 3m - 4.5m and width in range of 1.2 - 1.8m.

The pieces of wood, cane or other vegetable fibre are collected and they are heated in hot water boiler.

* wood fibres separated by heat are put in a vessel.
* Steam under pressure is admitted in the vessel.
* Now the valve located at the bottom of vessel is opened, which releases the pressure and leads to the explosion of wood fibres.
* These fibres are collected, cleaned and then further used for making fibre board.

(4) IMPREG TIMBER.

* Timber which is fully or partly covered with resin is known as impreg timber.
* The usual resin employed is phenol formaldehyde (soluble in water).
* Veneers or thin strip of wood are taken and they are immersed in resin.
* The resin fills the space b/w wood cells and by chemical reaction, consolidated mass is formed.
* It is then cured at temperature of 150-600°C.

(5) Compreg Timber

The process of preparing compreg timber is same as that of impreg timber except that curing is carried out under pressure.

The strength and durability of compreg timber are more as compared to impreg timber.

STEEL

* Steel is most suitable building material amongst all the metallic materials.
* This is due to wide range and combination of physical and mechanical properties that steel can have.
* By suitably controlling the carbon content alloying elements and heat treatment.
* A desired combination of properties can be attained in steel.
* On the basis of carbon content steel can be classified as under:

Type of Steel	Carbon Content (%)
Dead Mild Steel	< 0.15
Mild Steel.	0.15 - 0.3
Medium carbon Steel	0.3 - 0.8
High Carbon Steel.	0.8 - 1.5

① MILD Steel:

* It is also known as low carbon/soft steel.
* It is ductile, malleable, tougher, more elastic than wrought iron.
* It can be easily welded and forged.
* It rust quickly and can be magnetised permanently.
* If $G = 7.3$, ultimate comp. strength is in range 800-1200 N/mm^2. and tensile strength is approx, 600-800 N/mm^2.
* It is used in rolled section, reinforcing bars, roof coverage sheet pile walls, railway tracks.

② HIGH Carbon Steel

* It is also termed as hard steel.
* It is tougher or more elastic than mild steel.
* It can be forged and welded with difficulty
* Its ultimate compressive strength is 1350 N/mm² and tensile strength is 1400-2000 N/mm².
* Its G = 7.9.
* Its find its application in RCC work, pre stress concrete, machine tools, and machine parts.

③ Medium Carbon Steel.

* It is also termed as high tensile steel.
* Its ultimate strength is approx 2000 N/mm² and compressive strength is 1200-1350 N/mm².
* It is also used in prestressed concrete strength

Manufacturing of steel

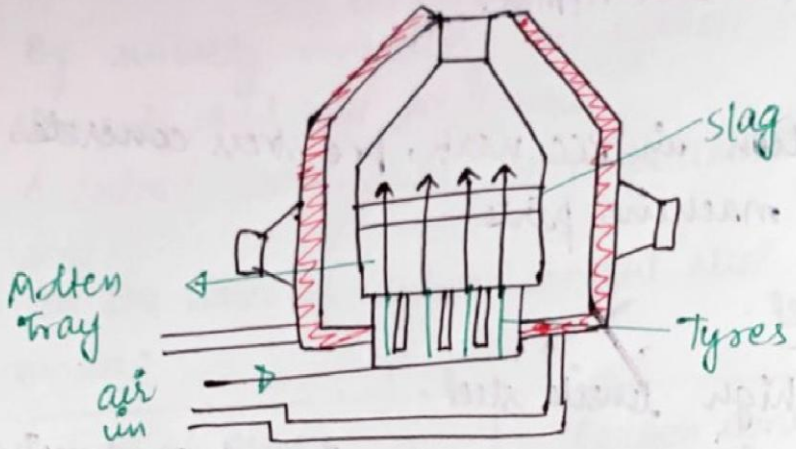
Steel can be manufactured by any of the following method:

① Bessemer Process
② Cementation
③ Crucible
④ Open Hearth
⑤ Electric Smelting
⑥ Duplex Process

① Bessemer Process

* Bessemer process is most prominent method used for manufacturing of steel.
* In this pig iron is first melted in furnace and sent to Bessemer converter.

* Blast of hot air is given to oxidise the carbon.
* Depending upon the requirement, some carbon and mangnese is added to the converter.
* The molten matter is then powred into moulds to form ingots



Heat Treatment of Steel

* It is carried out to develop desired properties in it.
* The properties of steel can be controlled and changed by various heat treatment.
* Two same type of steel having same composition can be given different properties by subjecting it to different types of heat treatment as follows.

① Hardening :-

It consist of heating the steel above the critical temp and holding it there for some time and then rapidly cooling it by immersing it in solution of salt, water or oil (depending upon the desired Hardness and cooling rate) to induce desired Hardness.

② Tempering:
In this process hardened steel is reheated to relieve the excess surface strains induced in it during hardening process.

③ Annealing:
It is the term used for the treatment of any metal in which it is heated below critical temp. (b/w 500-600°C) to induce the following properties.

* It removes excess strains
* It modifies electrical and mechanical properties
* It removes gases.

④ Normalizing:
It consists of heating steel above critical temp. and rapidly cooling in air in order to modify the deformities impacted during manufacturing process.

III ALLOY STEEL

In order to impart the desired properties in the steel required for construction, combination of metals, or metallic substances is done that is termed as "ALLOY."

* Different types of alloy steel used in construction are as follows:

Alloy steel	Composition (%)	Properties	Uses
Stainless	Chromium: 16	Very hard, tough, Elastic, acid and corrosion resistance	Utensils, Ball Bearing, Razors
Nickel	Nickel: 3.5	More Elastic, High tensile strength, Hardness, less weight	Automobiles and Air plane parts

Invar	Nickel · 30-45%	Low coefficient of thermal expansion	Measuring tape, Precise instruments
Vanadium	Vanadium (0.1-2%)	High Tensile Strength	Spacecraft, Delicate Instrument
Tungsten	Tungsten (4-20%)	High cutting resistance Hardness	Bulb filaments, Blade cutter, High speed tool.
Manganese	Manganese (12-15%)	Hard, Tough, Strength, High Electrical Resistance	Drilling m/c, Railway Crossing crushers
Molybednum	Molybednum (0.2-0.3%)	High Tensile Strength at high temp	Gear, Axle, shaft.

PAINTS:

Paint is a liquid surface coating, on drying which forms a thin film (60-150 μ) on painted surface.

Paints are classified as

1. Oil Paints
2. water Paints
3. Cement
4. Bituminous
5. special Paints
   - → Fire Proof Paints
   - → Luminous Paints
   - → Chlorinated Rubber Paint.

composition of Oil Paint

(1) Base:

The base, usually a metallic oxide, is the principal constituent of paint.

It makes the paint film opaque and possess binding property which reduces shrinkage crack in the film of paint on drying.

eg: White lead, zinc white, Aluminium Powder, Titanium white

(2) Vehicle: It is also known as binder. Vehicle is an oil to which base is mixed.

It holds the constituents of paints in suspension and helps us spread it over the surface of painted parts.

It imparts durability, toughness and water proofness.

to the paint film and resistance to weathering.
eg: Linseed Oil, Nut oil.

③ Pigments:

These are used to hide the surface imperfection and to impart the desired colour.
They protect the paint film by reflecting the destructive UV rays (which acts as a catalyst for oxidation of film).
They also improve the impermeability of the paint and enhance the resistance do weathering.
Pigment can either be natural or artificial.
Natural Pigments includes clay, limestone, chalk etc.
whereas Artificial Pigment includes gold dust, chrome oxide, metallic Powders etc.

④ Solvent:

These are the oils used to thin the paints and increase its spread.
They are also known as thinners
They make the paint of workable consistency, evaporate during drying of the film.
The common thinning agents used as petroleum spirits, napthalene, turpentine oil.

⑤ Driers:

It is also known as plasticizers, which are added to paint for specific purposes like.

① catalyst (accelerate the drying of vehicle for oxidation)
② Polymerisation and condensation of the vehicle on point.

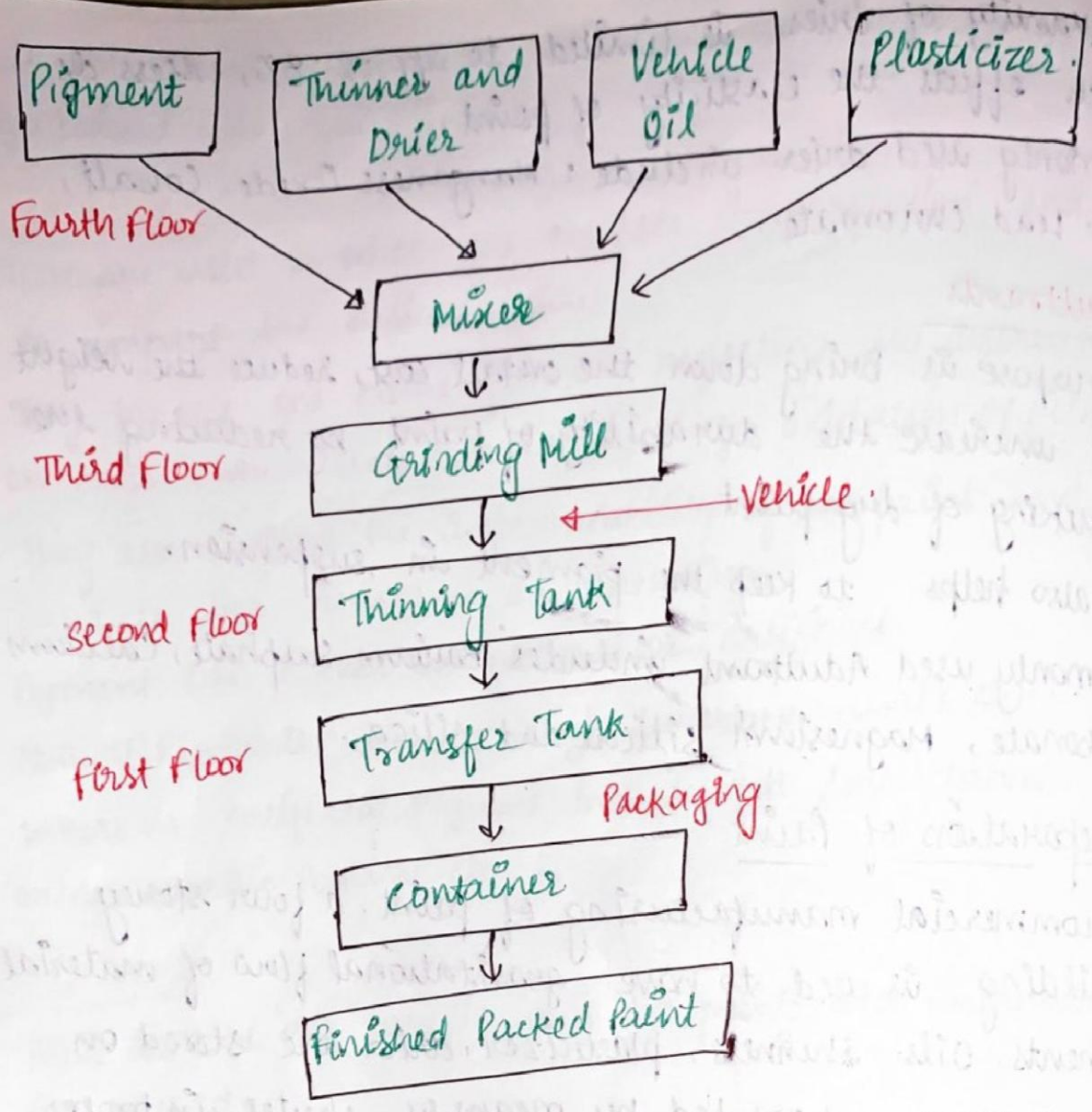
The quantity of drier is limited to approx 8%, excess of which effects the elasticity of paint.
commonly used drier include: Manganese Oxide, Cobalt, zinc, Lead Chromate.

⑥ Adultrants

If purpose is bring down the overall cost, reduce the weight and increase the durability of paint by reducing the cracking of dry paint.
It also helps to keep the pigment in suspension.
commonly used Adultrant includes Barium sulphate, Calcium carbonate, Magnesium silicate and silica.

Preparation of Paint

For commercial manufacturing of paint. a four storey building is used to have gravitational flow of material. Pigments, Oils, thinners, plasticizer, drier are stored on fourth floor and are fed by means of chutes in proper proportion to the grinding mill place on third floor and are grounded.
The thoroughly grinded material are then sent to storage tank on the next floor.
An additional quantity of vehicle is added here to get the desired composition
The batch is then test for quality control.



Covering Power of Paints

The covering power is the capacity of a given quantity of paint of the suitable consistency for application, to cover the extent of area.

The covering power also termed as SPREADING CAPACITY OF PAINT, depends upon the type of paint and its constituents type of surface to be painted and number of coats to be applied.

The area covered by different paints are as follows:

Type of Paint or Varnish	Type of surface	Area (m^2/lt)
Lead Priming coat	Wood Work	10
Under Coat	Flat surface	11
Glass Paint	Flat surface	11
Enamel	Flat surface	11
Varnish (First Coat)	Flat surface	12
Varnish (second coat)	Flat surface	15

PIGMENT VOLUME CONCENTRATION

It is the concentration by volume of the pigments expressed as a % of total volume of non volatile constituents (pigments + vehicle) of the paint.

$$PVC = \frac{\text{Vol. of pigment in paint}}{\text{Vol. of non volatile constituents of paint}}$$

It helps in determining the amount of a particular pigment that can be added to the polymer of coating.

The point where there is just sufficient polymer to wet the pigment particles is known as critical pigment volume concentration (CPVC)

Below CPVC there is sufficient polymer for pigment wetting and above CPVC it is not.

At CPVC many physical and optical properties of paint change abruptly.

PVC largely controls factors such as glass washability,

adhesion, undertone, hiding power, permeability and durability of the paint.

Different finisher of paint and PVC is as follows:

Type of Paint	PVC
Flat	50-75
Semi-Gloss	35-45
Gloss	25-35

Enamel.

* It consist of base like zinc oxide, grounded in Varnish.
* If desired colouring pigment is added, it imparts colour to it also
* They dry quickly and furnish a hard glossy surface.
* It can be used for internal as well as external work and are generally recommended for application on wood work.
* These are acid resistant, not affected by alkali, gases and are water proof.

Distemper

* It is made with base as well as white chalk and thinner as water.
* Some colouring pigment and glue is also added in it.
* It is available in powder as well as in paste form and hence are cheaper than paint.
* They are most suitable for plastered surface as white washed surface.

Varnish:

It is a nearly homogenous solution of resin in oil, alcohol or turpentine.

This type of solvent to be used depends upon the type of resin.

The oil dries with time and the solvent evaporates leaving behind a solid transparent resin film over the surface.

Note: For rapid drying, driers such as lead acetate can be used.

* Varnish provides a protected coating and gloss to the surface and intensify the wood grains.
* It brightens the appearance, renders brilliancy to the painted surface, protect painted surface from atmospheric action.

GLASS.

Glass is an amorphous substance having homogenous structure.

It is hard, brittle, transparent (or translucent in some cases)

It is the most common material glazed into frames for doors, windows and certain walls.

The most common type of glass used in building construction are sheet, plate, laminated, insulating, tempered, wired, patterned glass.

The most ordinary glass are alkali-lime silicate and alkali-lead silicate glass.

Compressive strength of glass is in range of 700-1000 N/mm^2

Tensile strength of glass is in range of 30-60 N/mm^2

Modulus of Elasticity is in range of 0.45×10^5 – 0.8×10^5 N/mm^2.

Constituents of Glass.

The raw materials used in manufacturing of glass are sand, lime, potash, lead borax.

① **Silica**: It imparts strength and compactness to the glass. It is added in the form of pure Quartz, crushed sandstone.

② **Lime**: It is used in the form of limestone The addition of lime makes the glass fluid and suitable for rolling, pressing or spinning.

③ **Soda**: It acts as an accelerator. for fusion of glass.

④ Potash: It renders glass infusible and make it fire resistant.

⑤ Lead Oxide: It imparts colour, brightness and shine to the glass.

Manufacturing of Glass:

Manufacturing of glass is carried out in following sequence of operation.

① Melting:

In this process, the raw materials, lime and soda sand are separated cleaned, grounded, sieved in definite proportion and mixed with water in continuous type furnace and heated to fuse all these ingredients.

At temp. of (1100-1200°C) it converts into liquid form and the bubbles rises to the surface due to the evolution of carbon dioxide

$$CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2\uparrow$$

$$Na_2CO_3 + SiO_2 \longrightarrow Na_2SiO_2 + CO_2\uparrow$$

② Forming and shaping:

The molten glass can be fabricated to desired shape and size by any of the following method.

① Spinning
② Finishing
③ Rolling
④ Annealing
⑤ Compression Moulding
⑥ Flat Drawing
⑦ Blowing

Plastic

It is made from resin with or without fillers, Plasticizers and pigments.
These are organic material of high molecular weight which can be moulded to any desired shape and size which subjected to heat and pressure in the presence of catalyst.

Plastic can be classified as:

① Thermo plastic ② Thermosetting.

① **Thermo plastic:**
It softens on heating and hardness on cooling, i.e their hardness is a temporary property subjected to change with rise or fall of temp. and can be brought again to plastic stage on heating.

② **Thermosetting:**
It can be reused as it requires great pressure and momentary heat during moulding and finally get hardend on cooling.
The chemical reaction in the process cannot be reversed hence over solidified can't be softend.

Constituents of Plastic

① **Resin:** It acts as a binder for holding different constituents together.
Thermosetting resin are usually linear polymer of low molecular weight being fusible and mouldable.

② Plasticizers

It modifies plastic to impart desirable combination of strength, flexibility and toughness.

③ Filler

It is added upto 50% of the moulding mixture to increase the hardness, strength, finish, workability reducing the cost, shrinkage on setting and brittleness of final product.

④ Pigment:

It is added to achieve desired colour.

⑤ Lubricant:

It is used to make the ~~loading~~ moulding of plastic easier and to prevent sticking of materials to the mould.