UNIT-1 CEMENT

procedure:-

Portland cement:-

* In the wet process the limestone what from the quarres and it is crushed into the smaller crackers

* Then it is taken into a tube mill when it is mixed with clay or shale as a case may be and ground in a fine constistency of slurry with a addition of water

* The slurry is a liquid or cremy consistency with water content of 30-50% where in particles crush to the finess of Indian standard sieve number slurry is pumper to slurry tank or basin where it is kept in ajicated condition by means of rotating arms with chains or blowing compressed air from the bottom to prentend setting of time and clay particles

* The compaction of the slurry is tested due the requir-ed chemical composition and corrected periodically in the cube mill and also in the slurry tank. By blending slurry from different storage tank.

* finally the connected slurry is storared in a final storage tank and kept in a homogenous. condition by the adjcated way slurry.

* The corrected slurry is separated on the upper end of rotary clinker against hot heavy hanging chain

* The fuel is either powderd coal or oil are natural gas by the time the material rolls down to the lower end of the rotary kiln the dry material undergoes a series of chemical reaction. where the temperature is 1500°c about 20-30% of the material get fused lime, sillica and aluminia get recombined the fuse mass turns into modular form of size 3mm - 20mm and it is cooled under controlled condition the clinker weights about 1100 - 1300grms/m the cooled clinker is them grounded into a bulls with addition of 3-5% of gypsum in order to prevent flash setting of the cement

* The particles crushed to the required finess and cement is filled into balance to bulk supply to dams and other sites.

Dry process or semi dry process :-

Dry process or Semi dry process. In the raw material are crushed dry fed in correct proportion into a grinding mill where they are reduced to a very fine powder.

* The dry powder is called the raw mill is then blented and corrected for the right composition and mixing by means of compressed air. The aerated powdered tends to behave almost lie liquid in about 1 hour of aeration a uniform mixture is obtained a blending mill is further sieved and fed into rotating disc called granulator a quantity of water about 12% is added to make blended mill into a pellets. These is done to permits air flow for exchange of heat for further chemicals reaction and conservation of the same into ~~chemi~~ clinker further in the rotary Kiln.

* The total consumption of cool in there method is only about 100Kgs.

* The method are commonly employed for direct control of quality of clinker.

* The first method involved reflected light optical micro-scopic of polished section of clinker.

The second method is also applicable to powdered cement involves x-ray refraction of powdered cement.

* These important note that the strength and property of cement are considerable by the Cooling rate of clinker.

Types of Cement	cooling condition	compressive strength Mpa		
		3 days	7 days	28 days
Normal cement	Quick	9.9	15.3	26
	Moderate	9.7	21.0	~~24~~ 27
	slow	9.7	19.3	24
	veryslow	~~10.2~~ 8.7	18.7	~~29~~ 23
High strength cement	Quick	10.2	18.8	29
	moderate	14.2	26.7	33
	slow	10.2	21.0	29
	veryslow	9.1	18.1	28

In the moderate cooling it imployes that from about 1200°c the clinker is bought above 500°c in about 15 min and the 500°c temperature is drawn from to normal atmosphere in about 10min

* The rate of cooling influence the degree of crystalization the size of crystal and the amount of amorphous materials present in the clinkers the properties of the amorophous can be similar composition will be different from the one which is crystalline.

Chemical composition:-

* The raw material used for the manufacture of cement consist namely are lime, silica, Alumina and iron oxide.

* These oxide interact with one an another in kiln at high temp to form more complex compound

* These oxide compositions are responsible for influencing the varies properties of cement in addition to rate of cooling and finess of grinding.

Approximate oxide composition limits of ordinary portland cement.

oxides	% of content
CaO	60-67
SiO_2	17 - 25
Al_2O_3	3.0 - 8.0
Fe_2O_3	0.5 - 6.0
MgO	0.1 - 4.0
Alkalies (K_2O) (Na_2O)	0.4 - 1.3
SO_3	1.3 - 3.0

- Indian standard 33grade cement specification specified in IS 269-1989 specifies the chemical representation.

- The oxides present in the raw materials while subjected high clinkering temp combined with each other to th form complex compound.

- The identification of the major compounds is largely based on R.H Bogue's work. It is called as "Bogue's components".

Bogue's components:-

Name of the compound	formula	Abbrevated formula
Tricalcium silicate	$3CaO\,SiO_2$	C_3S
Dicalcium silicate	$2CaO(Al_2O_3)SiO_2$	C_2S
Tricalcium Aluminate	$3CaO\,Al_2O_3$	C_3A
Tetracalcium alumino ferrite	$4CaO\,Al_2O_3\,Fe_2O_3$	C_4AF

- The Equation suggested by for calculating the percentage of major components which are given below.

$\rightarrow C_3S = 4.07\,(CaO) - 7.60\,(SiO_2) - 6.72\,(Al_2O_3) - 1.43\,(Fe_2O_3) - 2.85\,(SO_3)$

$\rightarrow C_2S = 2.87\,(SiO_2) - 0.754\,(3CaSiO_2)$

→ $C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$

→ $C_4F = 3.04(Fe_2O_3)$

- The oxides shown within the brackets represents the % of the same in the raw material

Oxide composition of a tipical portland cement and corresponding calculated compound composition.

Oxide composition	percentage
CaO – 63	
SiO_2 – 20	C_3S – 54.1
Al_2O_3 – 6	C_2S – 16.6
Fe_2O_3 – 3	C_4A – 10.8
MgO – 1.5	C_4AF – 9.1
SO_3 – 2	
K_2O, Na_2O – 1.0	

* In addition to the major components they are many minor components in the kiln

* These minor components influence the properties of cement and the 2 minor components are oxide namely K_2O, Na_2O.

* Refered as alkalies in cement are of the same importance

* Tricalcium silicate & Dicalcium silicate are most important components responsible for the strength They together Constitute contribute of about 70–80% of cement.

* The average % of C_3S in moderate cement is 45% and that of C_2S 25%.

* It is necessity to control the oxide composition of the raw material.

* As increase in lime content beyond the certain values makes it difficult to combine with an another components & freely lime exist in clinker which causes Unsoundness in cement.

* As increase in silica content it contains Alumina & ferric oxide will make the cement difficult to fuse & form clinker

* Bogues component C_3S, C_3A, C_2S, C_4AF are sometimes called as aulite, betite, celite, felite

Raw material for ce → lime stone, claychale for cement

↓

component → O_2, Si, Ca, Al Fe cements.

↓ on buring — clinker formed

Compound composition → C_3S, C_2S, C_3A, C_4AF

↓

portland cement · various types

↓ on hydration

product of hydration C-S-H gel + $Ca(OH)_2$

hydration of cement [heat of hydration]:-

Un hydrus cement compounds mixed with water react with each other to form hydrate compounds of very solubility. The hydration of cement can be visualies in two ways.

1. Throughout solution, in these the cement compound disolve to produce as super saturated slution from which different hydration product get paticipated

2. The second possibility is the water attacks cement compounds into solid state coverting the compounds into hydrates products.

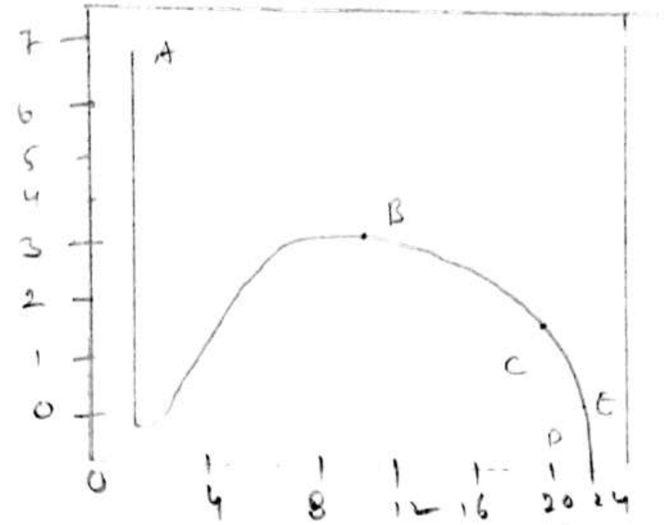
* solid state type of mechanism may be occur during the course of reaction b/w cement & water

Heat of hydration:-

The reaction of cement with water is exothermic the reaction liberates a considerable quantity of heat. These liberation of heat is called a <u>heat of</u> ~~hydration~~ <u>hydration</u>

* The study and control of heat of hydration becomes more important the construction the temperature in the interior of a large mass concrete is 50°c about the temp of the concrete mass. At the time of orginal placing fresh concrete.

* The patern of liberation of heat from setting of time and during earlier hardening period



* The ascending (A) of a peak of portion is due to reaction of aluminate & sulphate.

* Descending pick of ~~A~~ the initial heat evaluation. Causes quickly when the soluability of aluminate is dispersed by gypsum.

* heat evaluation is an account of reaction C_3S.

structure of hydrated cement:-

To understand the behaviour of concrete in necessary to analyse ourself with a structure of hydrated harden cement paste.

The concrete considerable as two faces material namely paste' aggregate phase the important of studying the structure as it influence the behave of concrete must grefer exchange.

* The strength the permeability, durability and drying shinkage the elastic property creep & volume change properties of concrete is greatly influence by the paste structure.

Water require for Hydration:-

* The component C_3S requires 24% of water by the weight of cement and C_2S require 21%

* It has been also estimated that on an average of 23% of water by the weight of cement is required for chemical reaction with portland cement components.

Types of cement:-

a) Ordinary portland cement (OPC)

i) Ordinary portland cement of 33 Grade

ii) Ordinary portland cement of 43 Grade

iii) Ordinary portland cement of 53 Grade.

b) Rapid Hardening cement (R.H.C)

c) Extra rapid hardening cement (E.R.H.C)

d) sulphate Resistant cement (S.R.C)

e) portland stage cement (P.S.C)

f) Quick Setting cement (Q.S.C)

g) super sulphate cement (S.S.C)

h) Low heat cement

i) portland pozzolana cement

j) Air entering cement.

k) coloured cement (White cement)

L) Hydrophobic cement

M) Masonry cement

N) Expensive cement

o) oil well cement

P) Rediset cement

2) concrete sleeper grade cement
4) High aluminum cement
5) very high strength cement.

ASTM classification:-

American society for testing material as per ASTM cement is classified into different types namely.

1) Type - I
2) Type - II
3) Type - III
4) Type - IV
5) Type - V

and there are minor classification also

1) Type - IS
2) Type - IP
3) Type - IA
4) Type - IIA
5) Type - IIIA

Type-I:- It is used for the general constructions where the special properties specified for type-II, type-III, type-IV (O.P.C).

Type-II:- for the use in general concrete construction exposed to moderate sulphate action (or) where moderate heat of hydration is required.

Type-III:- for use of high early strength is required (Rapid hardening cement)

Type - IV :- for the use of Low heat of hydration is required

Type-V :- for the use when high sulphate resistance is required [sulphate resistant cement).

Type - 1s :- ASTM standard also have cement of type-1s. This consist of uniform blended of portland cement of type I and find granulated slag contain is in between 25 to 70% of the weight of portland blast furines black cement.

Type-1p :- This consist of an uniform blend of portland cement (or portland blast furines black slag). and time pozzolana cement contain in between 15 to 40% of the weight of total cement.

Type - IA, IIA, IIIA :- Type-IA, IIA, IIIA cement in which air entrining agent is inter ground where air entrining in concrete.

Test on physical properties of cement :-

Testing of cement can be bought under two categories

a) field testing

b) Laboratory testing.

Field testing :- It is sufficent to subject in the cement to field test when it is used for minor works.

1) open the bag and take a good look at the cement.

2) There should not be any visible lumps.

3) The colour of cement should be grenish gray.

4) Thrust your hand into cement bag. It must give

a cool feeling there should not be any lumps.

5) Take a pinch of cement and feel b/w the finger it should give a smooth and not a gritty feeling.

6) Take a hard full of cement and throw into a bucket of water the particle should float for some time, before the sink.

7) Take about of 100grms of cement and small quantity of water and make it stiff paste. from the stiff paste. a cake with a sharpe edges put it on a glass plate and slowly take it under the water.

8) see that the shape of the cake not disturb while taking it top of the bottom of the bucket.

9) After 24 hours that cake should return in orginal shape at the same time. It should also set the same strength.

Laboratory test:-

1) fineless test
2) setting time
3) strength test
4) soundness testing
5) Heat of hydration testing
6) chemical composition testing.

Fineness test:-

-> The fineness of cement has an important baring on the rating of hydrasation and hence the rate of gain of strength and also the rate of gr revaluation of

→ finess cement of great surface area for hydration and hence faster development of strength.

→ maximum number of particles in a sample of cement should have a size less than 100 microns(μ). The smallest particle may have a size of about 1.5 μ

→ Increase in the fineness of cement is also found to be the dry shrinkage of concrete

→ The fineness of cement can be tested as two types.

1) Sieve test
2) Air permeability method.

Sieve test:-

Take a sample of cement of weight 100 grms and take it on standard sieve is No.9 (90 microns). Breakdown the air said lumps in the sample with the finger. continously see the sample giving the circular & vertical motion for period of 15 minutes.

→ Weight the reduced left on the sieve.

→ The weight of the sieve shall not exceed 10% of ordinary cement.

Air permeability Method:-

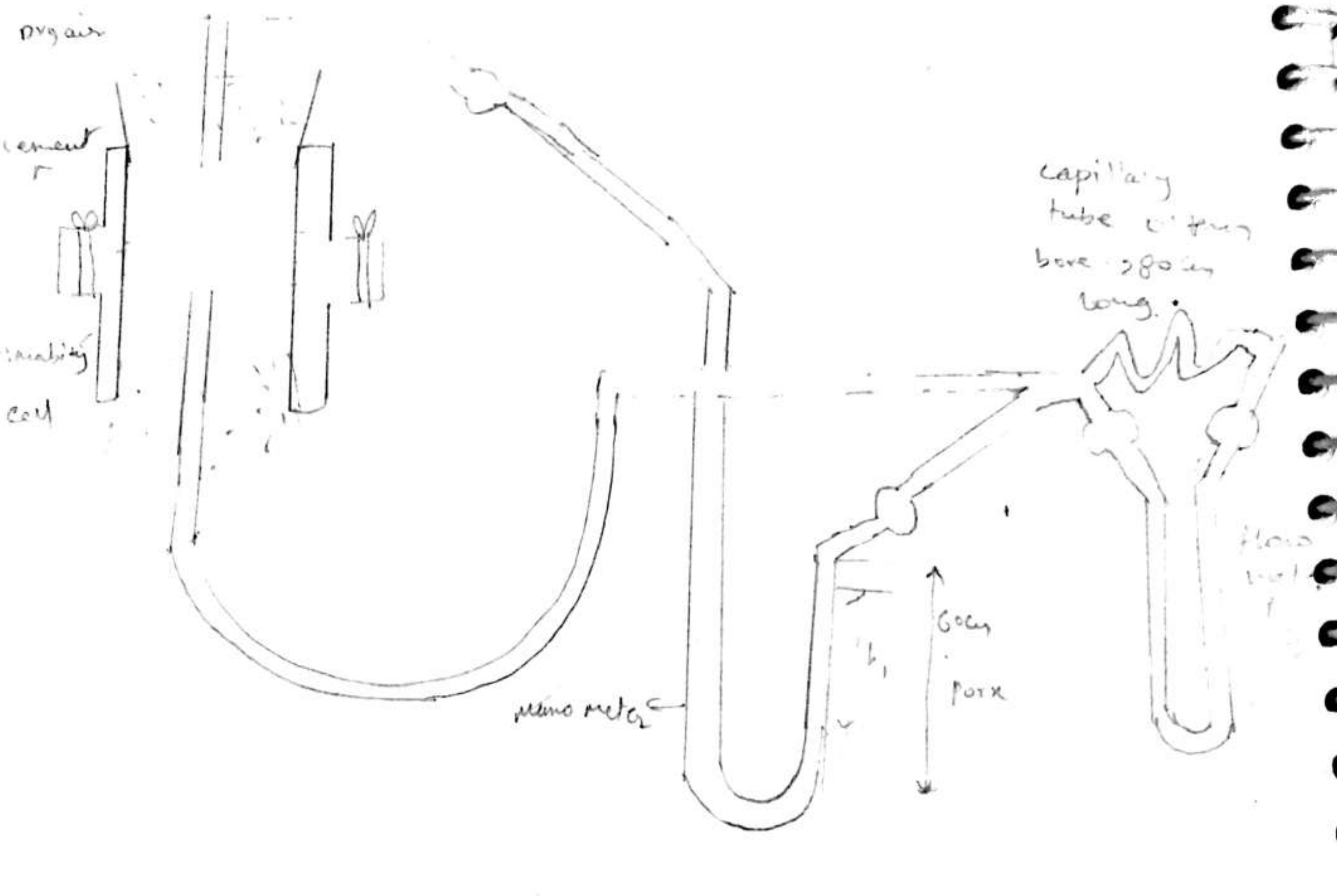


fig :- Permeability Apparatus with Manometer & flowMETER

This method of test covered the procedure for determine the finess of the cement as represent by specific surface express as total surface area in square centimeter of cement. and it also expressed as m^2/Kg.

The principle is based on the relation between the flow of air through cement bed on the surfaceare of the particle. compressing the cement bed.

-> The cement bed in the permeability cell is 1cm height and 2.5cm the density of cement of the weight required to make a cement bed of porosity of 0.475 can be calculated.

-> This quantity of cement is placed in the permeability cell in a standard manner.

-> slowly passed air through the cement bed at constant velocity adjust the rate of flow until the flow meter shows at the different levels 30-50cm

-> Read the difference level (h_1) of the manometer and the difference level as h_2.

Repeat this observations to ensure that the studying condition is obtained as shown by the constant value of h_1/h_2 then specific surface (S_w)

$$S_w = K\sqrt{h_1/h_2} \quad \text{and} \quad K = \frac{14}{d(1-x)}\sqrt{\frac{x^3 A}{CL}}$$

A is Area; c - flow meter cement. d - density of cement; l = length of cement, x - porocity.

Normal consistency & standard consistence cement:-

To findout initial setting time and strength and perimeter known as standard consistence of cement.

* The standard consistence of cement paste is defined as the consistence which will permite vicat plunger having 10ml. dia. with 50 mm height & length of 50mm to penitrate the depth of 33-35mm from the top of the bowl

Procedure:-

1) Take 500grms of cement and prepare a paste with a weight quantity of water say 24% by the weight of cement as a first trail.

2) The paste must be prepared in a standard manner and filled into a vicat mould within 3-5year. After completely filling the mould shake the mould to exhail or sperpellair

3) A standard plunger of dia 10mm & height 50mm is attached and brought the down to touch the surface of the cement paste.

4) In the test block and quickly release alone into sink into the paste by its own way.

5) Take the reading by the depth of the penetration of the plunger.

6) conduct a trail to with a percentage of 25% and find out pentration of the plunger until and unless the plunger pentration should be 33-35.

7) The percentage sho is usually is denoted by 'p'

Setting time:- [Initial & final setting time]

* The initial setting time is regarded as time ellapsed between the momentum that the water is added to the cement to that time the paste starts loosing its plasticity.

* The final setting time is the time ellaps b/w the moment the water is added to the cement and the time paste has completely loose its plasticity and

has attain sufficent firmness to resist certain different pressures.

-> The time interval for which the cement product remains in a pastic condition is known as initial setting normally the minimum 30 mins is giving for mixing & handing operation.

-> once the concrete is placed in final position they will compact and finished it should. loose its plasticity Thus the time should not be more than 10 hours which is off. refered as final setting time.

Initial setting time:-

procedure:-

Take 500grms of cement sample and it with 0.85 times the water required to produce cement paste of standard consistency and filled into a vecat mould in a speificed manner within 3-5mints starts the stop watch the moment water is added to the cement.

- The temperature should be 27°c ± 2°c
- Lower the needle, 'c' gently and bring it contact with surface of the test block.
- Allow it to penetrate into the test block But after sometime the paste start loosing its plasticity The needle may penetrated only the depth of 33-35

• The period enlapse in b/w the time the water is added to the cement and time at which the needle penetrates the test block to a depth of 33-35mm from the top of the vecat apparatus.

Final setting time:-

• Replace the needle 'c' of the vecat apparatus by a circular attachment [F] as shown in the figure

• The central needle makes a penetration while the circular cutting edges of the attachement fails to do it in other word the paste has added attendent such hardness that is centre needle does not penetrate through the paste more than 0.5 mm.

strength test:-

→ The compressive strength of harden cement is most important of all the properties of a cement. strength test are not made on neat cement paste because of the excessive shinkage and subsequent cracking.

→ The strength of cement is indirectly found by adding cement motor.

Procedure:-

* Take a cement sample of 185gms and a sand of standard "C" of weight 555grms. the ratio of (1:3) and mixed them with trovel in a dried state and then add water of quantity $P/4+3$ (p= percentage of water required to produces standard consistancy) and mix the ingradinace gently under proper colour and place the motor in a cube of the standard size 7.06 cm.

→ The area of phase of the cube there will be equal to $50cm^2$

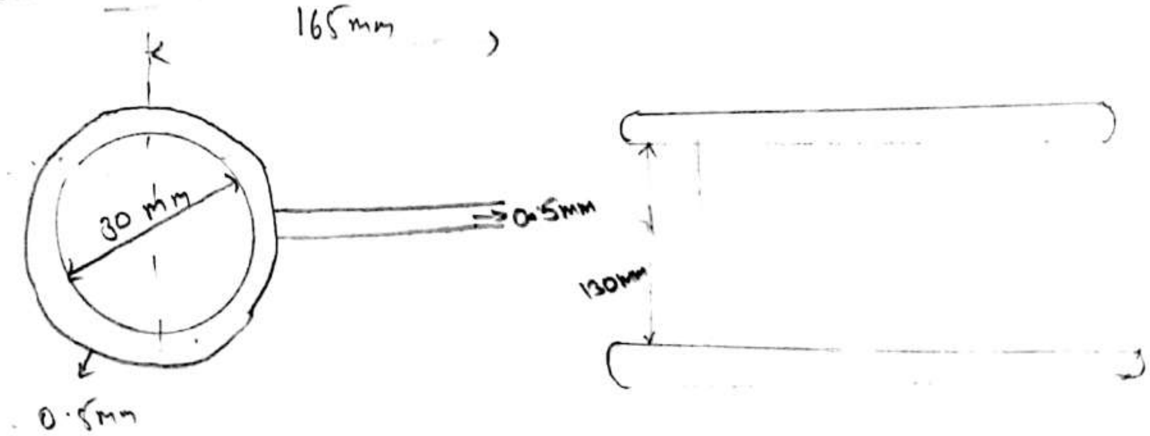
→ compact the motor either by manually or by using libvator for 2 mins.

→ After compacting place the amount at normal temperature $27^\circ \pm 2^\circ c$ over a time period of 54 hours.

→ After 24 hours the cube should be removed from the mould and place it in a fresh water a different period of time (3 days, 7 days, 28 days)

→ compressive strengthcement = $\frac{\text{maximum load at cube fails in Newton's}}{\text{average area overload applied in } mm^2}$

Soundness test:-



→ A cement has be undergo a large expansion after setting causing discraption of the set and hardmass.

→ These will cause sever difficulties for the durability of structure.

-> The testing of soundness of cement is to ensure that the cement doesn't show any approrable subsequen expansion of the price importance.

-> The unsoundness of cement is due to the presence of excess lime that which is combined acidic oxide these also due to primary inadectuate insufficient fineness of grain in proper mixing of raw materials.

-> Unsoundness in cement is due to the excess of lime.

-> unsoundness cement doesn't comes with the surface for comfortamble period therefore accelerated test are required to detected it

Le-chatelier test:-

procedure:-

* The appartus used for the finding of soundness of cement.

1) consider a small spilt cylinder with a inner dia. 30mm and thickness of 0.5mm and height of cylinder is 30mm and the two indicator.

-> on either side of the split cylinder the two indicator on either side of the split cylinder with arms to fixed as eitherside of the split cylinder with help of 165 mm, cement sample is taken and mixed with water is added in a standard consistency manners and fill the paste into the mould and place a glass plate above and below the split cylinder.

-> place a weight above the glass plate.

-> The whole assemblie is immerse in water a temperature of 27°c to 32°c. So measure the distance between the two indicator after removal of specimen from the water time period of 24hours (L)

→ Submerge the mould into the water and heat the water and bring the water to a boiling point Keeping for 3hours. Remove from the hot water allow with cool and measure the distance between the two indicators

→ Differente between the these two measurments as replacent the expansion of cement this must not exceed 10mm. for ordinary rapid, harding low heat portland cement. In the case of expansion if it is more than 10mm as tested the cement is said to be unsound.

→ The le-chatelier test undergoes free lime only.

Heat of Hydration:-

* It is a exothermic reaction occurs when a cement got in contact with water.

* It is estimated that for 1gm of cement 120 calories of heat is produced.

* A temperature rises about 60°c has been absorbed

* usually high temperature is developed at the interior portion in dams causes sevier expansion of the body of of the gap. And if the suffiquerent coolent considerable of the gap. Shinkage take these results sevier dams or sevior cracking for the concrete.

* These for heat.

* Test for heat of hydration is essentially required to be carried out by for low heat cement only.

Procodure :-

* Take a Vorrum flask take a cement sample and add water to it and a insult therometer to check the heat produced in the flask.

* for low heat cement the heat of hydration shall not be more than 65cal/grm → 7days
75cal/gm → 28days.

Chemical composition test :-

* The ratio of percentage of lime, silica, Alumina and iron oxide when calculated by formula by using.

$$\frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$$

this formula not greater than 1.02
Not lessthan 0.66

* The above is called as lime saturation factor percentage.

Ad mixture :-

Admixture is defined as the material otherthan cement and aggrates and water cement ratio that is used as ingradient to cement & added when it is added to the batch immedatly before or during mixing.

* ~~The admix~~.
* The admixture are used for modify the properties of concrete.

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Types of admixture:-

As per report there are 212 admixture has been classified into 15groups according to the type of materials considerable the as the admixture

1) plasticizer's
2) Super plasticizer's
3) Retarders and retarding plasticizers
4) Accelerators and Accelerating plasticizer
5) Air-entraining Admixture
6) pozzolanic (or) mineral admixture
7) Dam proofing and water proofing admixture.
8) Gas forming admixture
9) Alkali aggregate expansion inhabiting admixture
10) work ability admixture
11) Grouting admixture
12) corossion inhabiting admixture
13) Bonding admixture
14) colouring admixture

Plasticizer s:- (water reducer):-

Requirement of right workability if the right essential for good concrete.

→ concrete it different situation requires different types of workability. high workability is require for deep beam, thin walls of water resisting structure with high percentage of steel rein force ment

• These plasticizer can help the different condition for obtaining for high workability with less water.
• The excess water will not improve the good qualities such as conessive. & homogensious of the mix with reduces segregation and blooding.

Super plasticizers :- (High raing water reducer)

• The use of super plasticizer's is practice for self-leveling self-compacting and for the production of high strength and high performance concrete. The mechanism of super plasticizor more or less similar to normal or ordinary plasticizer.

• Super plasticizers can produce.

1) At the same water cement ratio much more workable concrete compare to ordinary concrete
2) for the same workability it permits used of water cement ratio
3) As a consequence of increasing strength with lowering the water cement ration.

Retarders and retarding plasticizers:-

A retarder's is an admixture that slower down the chemical process of hydration so that concrete remains in a plastic and workable for a longer time.

* The retarders are used in the casting and consuldating large number of porcus without formation of cold joints. These are used in grouting oils wells.

* The most commonly retarder is calcium sulphate.

Retarding:-

- These type of plasticizer extend of retardation of Setting time offer by the admixture will not be sufficient
- Instead retardard seperately these are mixed with Plastcizers or Super plasticizers at the time of chemical Composition such types of admixture are called as retarding admixture.
- These category of admixture are used in readymix concrete company for the purpose of retaring the slump loss.

Acceleration and Accelerating plasticizers:-

Acceleration admixture are added to the increase the rate of earlier strength of develop in the concrete.

Uses:-

- permits earlier remover of form work.
- It reduces curing time period.
- Advance the time that can be structure placed in service
- It retains the effects of low temperature during cold wheather concreting.
- It is used in emergency work retains
- Accelerators commonly used materials are calcium chloride soluble carbonates organi.c components. such as triethenolamine
- Accelerating material added to the plasticizer's or Super plasticizer's are used as accelerating plastrizers

Mineral Admixtures (OR) pozzolonic :-

siliceous material which are mixed with lime produces strong cementing material having hydrolic properties and such cementing materials are used in the construction of acqvaducts, Arches, dams, bridges etc.

Uses of mineral Admixtures:-

- It loads the heat of hydration
- It reduced alkaline agregrade reaction.
- Improves the resistance to attack by sulphate soil and ocenic water
- Improver extensability
- Improver workability
- chipar in cost.
- A good pozzolona will not usually increased a dry shirnkage.

Materials of pozzolona (or) Admixture :-

- pozzolonic materials are siliceous and alumineous material which them cementization process little or no cementization process values are divide from the presence of moisture chemically react with calcium hydroxide when liberated on hydration at ordinary temp to form a compound processing cementization process.

pozzolan + calcium hydroxide + water

C - S - H (Gel)

Types of mineral admixture:-

Natural	Artificial
	fly ash
clay and shales	Blast furnance slag
opaline cherts	silica fame
Diatomaceous Earth	• Rice Has
volcanic tuffs.	• Metakaoline
	• surkhi

other than these minerals finely ground marble, Quartz, gravite, powder.

Fly ash:-

It is also called as pulvanisked fuel ash. It is a cold combustion products.

* Fly ash is the nost widely used pozzolonic material
* The use of fly ash in concrete admixture not only uses for technical advantages with the property of concrete but also control the environment pollution.
* Fly ash can be used in Two ways.

1. Integrating certain percentage of fly ash with the cement clinker manufacture portland pozzolanic cement.
2) Fly ash can be used as admixture at the time of making concrete.

Classification of fly ash:-

ASTM classified flyash into two types.

i) class 'F' ii) class 'C'

Class 'F':- Fly ash normally produced by pro coal which osually have less than 5% of CaO whichosed It has pozzolanic properties.

Class 'C':-

Flyash normally produced by burning sub-bitumino-us-coal and also has cao constant up to 10% and has pazzdonic properties also

Silica fumes:-

Silica fume also required as micro silica or silica fume.

* It is a product resulting from the reduction of high purity of Quartz with coal in a electrical fornace manufacturing of silica or ferro silica alloy.

* It is extermely find with particle size less than 1 micron with an average dia of 0.1 micron

* 100 times smaller the cement particles ~~it is available~~ ~~and economical and it is used for~~

* It is avaiable and economical and it is used for the production of high perfomance of concerte and it makes easier to achieve the compressive strength in the range of 60-90 Mpa.

Available form of silica (or) Micro silica :-

1. Undensified with bulk density of 200 - 300 Kg/m^3
2. Densified form with bulk density 500 - 600 Kg/m^3
3. Micro - pelletised form with bulk density 600 - 800 Kg/m^3
4. slurry form with a bulk density 1400 Kg/m^3
5. Risehusk :-

It obtain by buring RisE husk in control manner without causing any environmental pollution it contains SiO_2 which can be used as an admixture on concrete is also have a pozzolonic characteristic and contribute high strength and impremiability of concrete.

* The rise as ash consist of silica with 90% (atmospheric silica) 5% of carbon and 2% of K_2O
* The specific surface of RHA is 40 - 100m^2/Kg

Surkhi :-

Surkhi is an artifical pozzolona made by powdering bricks on burnt clay balls.

* for a large scale production of surkhi clay balls are specially manufactured and burnt for the purpose and then powdered.
* characteristic are generally influenced by the consitute mineral composition of soil. degree of buring and finessness of grinding.

Ground Granulated Blast furnace slag (GGBS)

Ground Granulated Blast furance slag is normally consist of essiential silicate and other aluminate, calcium calcicum and other base the molton slag is rappidly chilled by the add Glassy sand like gradular material

* The chemical composition of blast-furance slag is similar to that of cement clinker.

Advantages of GGBS in fresh concrete:-

* The replacement of cement with GGBS will reduce the water containt neccessary to obtain same slump.

Advantages of GGBS in harded concrete:-

* The major advantages of recongulation are
* It redues of heat of hydration
* Refinement of pores structure
* Reduces the permeability to the external cases.
* Increase to the chemical attack.

Chemical Admixture:-

1) Damp proofing (or) water proofing
2) Grouting admixture
3) Gas-forming agence
4) Air detraining
5) Alkaline aggregrate expansion inhabitor
6) Workability agent
7) corrosion

Damp- proofing (or) Water-proofing:-

One of the most important requirment of concrete is must be imper to the water under two conditions.

1. When it is subjected to pressure of water at one side.

2. The absorption of surface water by the capilarity action.

3. Water proofing admixture may be obtained in form of powder or paste or liquid.

4. The cheif material in the pour filling class are

1. silicate of soda, Aluminum & zinc sulphate and aluminum & Calciumchloride.

* Some type of materials like soda, potash soap, calcium soap, vegitable oil, fat, wax and coretar.

Working agent:-

Workability is the one of the most important characteristic of concrete specially under some circumference

1. If the concrete to be placed around closely placed reinforcement, D-beams, thin section etc.

* Where special means of placement are required such as plumping method.

* If the concrete is harach because of poor aggregate characteristic.

* For increasing the strength of concrete when the water cement ratio is allow some admixture are used to improve the workability.

1. The workability agentesare plastic sizer & super plastisizer
2. air entaraing
3. finaely adivided material.

Gas forming agents:-

A Gas forming agent is a chemical admixture such as alumium powder reacts with hydroxide produce in the hydration of cement to produce hydrogen gas bubbles throughout the mixture.

* Aluminum powder is also used the manufactureing of light weight concrete.
* The Aluminum powder has a tendency to float on water. so, it is generally mixed with fine sand and then the mixture is added to the concrete mix

Air-detraining:

In this agents are in the case aggregate release gas into or case excess air in plastic concrete. which make to use admixture capable of removing to excess of air or gas from the concrete.

* The compounts use as admixture such as tributyl phosphate, water insoluble in ~~alel~~ alkali
* It mostly widely used admixture of tributyl phosphate.

Alkaline aggregate expansion inhabit:-

- There are some drawbacks that air entorning admixture reduces alkaline aggregate reaction straightly
- The other admixture that the osed to reduce alkaline aggregate expansion or aluminum and lithium salts.

Grouting agents:-

Grouting under different purpose would necessary different qualities of grouting mix.

* some of the grouting mix require quick setting, sometime it will have to be fluid state for longer period, or it may be little water is to be osed and at the same time it. should exhibit good workability these agents will satisfy the requirement of grounting mixture.

1. Accelerator. 2. Retorders 3. Gass forming agents
4. workability agents 5. plastisizes.

UNIT – II

Aggregates

Aggregates :-

Aggregates are the important constituents of concrete. The aggregates occupy about 70-80% of the body of the concrete and hence influence is extremely important. They should therefore meet certain requirements for the concrete to be workable, strong, durable and economical. The aggregate must be of proper shape, clean, hard and well graded. It should possess chemical stability and, in many cases, exhibit abrasion resistance and resistance to freezing and thawing.

Classification of aggregates:-

Classification based on source:- The aggregates are usually derived from natural sources of bed rocks. They are derived from Igneous, Sedimentary and metamorphic rocks.

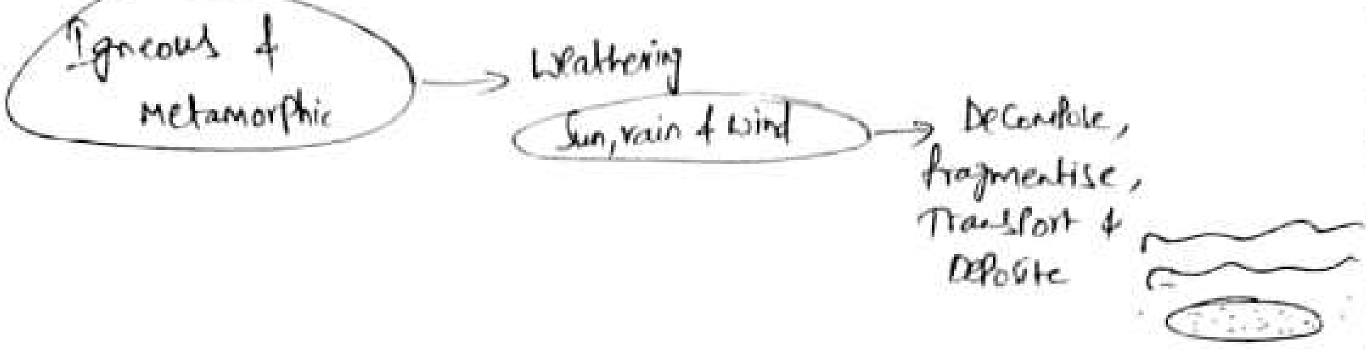
→ Igneous :- These rocks are formed from the melting & cooling of magma (or) lava.

Eg: of aggregates are :- Quartz, granite, Basalt.

→ Sedimentary:- These rocks are formed due to weathering action.

Eg:- Sandstone, limestone, shale.

→ Metamorphic :- These rocks are formed from the action of heat & pressure. Eg:- Marble, slate & schist



Classification based on size:-

Based on size aggregates are classified as (i) Fine Aggregates and (ii) Coarse aggregates.

(i) Fine Aggregates

The aggregates which passes through 4.75 mm IS sieve and retained on 75 μ (microns) sieve are termed as fine Aggregates (F.A). Eg:- Natural sand, Crushed stone sand, Crushed gravel sand.

IS: 383-1970 has divided the F.A into four grading zones. The grading zones becomes progressively finer from grading zone-I to zone-IV.

(ii) Coarse Aggregates

The aggregates which retain on 4.75 mm IS sieve and greater than 4.75mm are termed as Coarse Aggregates (C.A).

Eg:- Crushed gravel (or) stone, uncrushed gravel, Partially Crushed gravel.

The aggregate sizes of nominal size 40mm, 20mm, 12.5, 10, 6.3, 4.75 are considered as C.A.

Classification based on unit weight :-

Based on unit weight of aggregates, aggregates are classified as Normal weight, light weight & Heavy weight aggregates.

Normal weight :- Sand, gravels, crushed rocks such as granite, basalt, Quartz, Sandstone, limestone and brick basalt etc are normal weight aggregates which have specific gravities b/w 2.5 - 2.7 and unit weight ranging from 2160 - 2560 kg/m3.

Light weight :- Diotomite, Pumice, Volcanic Cinder etc ~~are~~ (or) bloated clay, sintered fly ash (or) foamed blast furnace slag are light weight aggregates whose unit weight is from 240-1440 kg/m3.

Heavy weight :- Magnetite, barytes and scrap are used in the manufacture of heavy weight aggregates. The Specific gravity of heavy weight aggregates ranges from 2.8 - 2.9 and whose unit weight is of 2800 - 6400 kg/m3. Eg :- Hematite, Barite.

Classification based on Shape :-

Based on shape aggregates are Classified as

Rounded :- The aggregates with rounded Particles (river (or) Seashore gravel) has minimum ratio of Surface area to volume, thus requiring minimum Cement Paste. The main disadvantage is that the interlocking b/w the Particles is less and hence develops Poor bond.

Irregular Aggregates:- The aggregates having Partly rounded Particles (Pit sand and gravel) requires more cement paste for a given workability. The interlocking between Particles, is better than rounded aggregates.

Angular Aggregates:- The aggregates with sharp, angular and rough Particles (Crushed rock) has a maximum Percentage of voids. Thus interlocking between Particles is good thereby Providing good bond. These aggregates are suitable for high strength Concrete and Pavements Subjected to tension.

Flaky and elongated aggregates:- An aggregate is termed as Flaky when its least dimension (thickness) is than 3/5th of its mean dimension. The Presence of these particles is limited to 10-15%. This type of aggregates Contain bond Partly due to the interlocking of the aggregate & Paste. A rough Surface results in a better bond.

Classification based on Production methods:-

Based on Production methods, aggregates are classified as Natural and artificial aggregates.

Natural aggregates are formed naturally. Eg:- Sand, gravel, Granite, Quartzite, Basalt, Sand Stone.

Artificial aggregates are obtained by Crushing, breaking, (or) making them into Powdered form.

Eg:- Broken brick, Air cooled slag, Sintered (Powdered) Fly ash, Bloated (Expanded) Clay

Characteristics of Aggregates:-

The Properties and Performance of Concrete are dependant to a large extent on the characteristics and Properties of the aggregates themselves. The Properties of aggregate for Concrete are discussed below:

1) Strength of Aggregate:- Strength of the Concrete depends on the Strength of aggregates. Generally, three tests are Conducted to determine the strength of aggregate

a) Aggregate Crushing value test:-

* Steel Cylinder with open ends and internal dia 152 mm, Square base Plate, Plunger having a Piston of dia 150MM with a hole Provided across the stem of the Plunger so that a rod Could be inserted for lifting (or) Placing the Plunger.
* Cylindrical measure having internal dia of 115 mm & height 180MM
* The aggregates passing 12.5mm & retained on 10mm IS Sieve are selected and filled in the Cylindrical measure in 3 layers by giving 25 tampings. Weight of the Cylinder is Measured (W_1)
* The Cylinder is then Placed in Position on the base Plate.
* Load is then applied at a uniform rate of 4 tonnes/minute until the total load is 40 tonnes and then the load is released.
* Aggregates including the Crushed Portion are removed from the Cylinder and sieved on a 2.36MM Sieve. The material which Passes the sieve is Collected and weighed (W_2)

$$\text{Aggregate Crushing value} = \frac{100 W_2}{W_1}$$

W_1 = Total Wt of dry sample

W_2 = Wt of Crushed aggregate.

b) Aggregate impact value test :-

* Aggregates passing through 12.5 mm & retained on 10mm IS sieve are collected and filled in the impact value test cylinder and weigh the weight as W_1

* Fix the cup firmly in position on the base of machine and place whole test sample in it. Raise the hammer (Hammer weight 14 kgs) until its lower face is 380 mm above the surface of sample and allow it to fall freely on the aggregate sample.

* Give 15 such blows at an interval of not less than one second between successive falls.

* Remove crushed aggregate from the cup and sieve it through 2.36 mm IS sieve and weigh it as W_2

$$\text{Aggregate impact value} = \frac{W_2}{W_1} \times 100$$

Aggregate impact values

<20%	Exceptionally strong
10-20%	Strong
20-30%	Satisfactory
>35%	Weak

C) Ten Percent fine value test :-

Ten percent fine value test gives the load required to produce 10% fines from 12.5 mm to 10mm particles. This test is reliable among the 3 tests.

2) <u>Particle Shape & Texture</u> :-

Shape, texture & roughness influences the workability

* Rounded aggregates are obtained from river (or) seashore gravel are completely shaped by attrition useful for rigid (Concrete) Pavements.
* Irregular → Pit sand & gravel → Partly shaped by attrition & have rounded edges.
* Angular → well defined edges → used for flexible pavements
* Flaky → Thickness < width (or) length

Use of Crushed / irregular aggregates increases the Compressive strength by 10-20%. because of stronger aggregate-mortar bond.

Flakiness Index = $\frac{\%}{\text{Wt of Flaky Particles in Sample}}$

* Angular aggregates are more Preferable among all because they assure high Compressive strength.

<u>Texture</u>

↳ It is the measure of smoothness (or) roughness of aggregate

Texture of aggregates are Glassy, Smoothy, granular, Rough, Crystallene, Porous and Honeycombed.

Among these, aggregates having rough, crystalline & Porous nature texture increases the aggregate cement bond by 75% and gives 20% more Compressive & flexural strengths.

3) <u>Specific gravity</u> :-

$$S.G = \frac{\text{Mass of Solid in a given Sample}}{\text{Mass of Equal vol. of Standard fluid}}$$

Absolute specific gravity → Excluding voids
Apparent " " → Including voids

Higher specific gravity indicates that aggregates are stronger & harder.

4) Bulk density (or) unit weight :-

It is the mass of material in a given volume. It is measured in kg/litre. It indicates how densely aggregates are packed in the measure. Factors affecting the bulk density of aggregates are particle shape, size, grading & moisture content.

5) Porosity :-

Minute holes (or) cavities formed during formation of rocks ~~are~~ is known as porosity.

Porosity of commonly used rocks varies from 0-20%.

6) Absorption :-

Due to pores present on the aggregates, free moisture can be penetrated into the aggregates and absorption is the percentage of water absorbed by an aggregate when immersed in water.

7) Moisture Content :-

Moisture content present in the aggregates is measured by bulking of aggregates test. Bulking of F.A i.e., sand is the measure of free moisture content. Due to the surface tension phenomenon the moisture content ~~occupy~~ around the aggregate particles gets repelled with each other and a layer of moisture content will form between the particles. This results in the appearance of bulking of sand.

It can be measured by,

$$\% \text{ bulking} = \frac{h_1 - h_2}{h_2} \times 100$$

The other mechanical properties that characterize the aggregates are

Toughness :- Resistance of aggregates to failure by impact.

Hardness :- Resistance to wear aggregate abrasion value. This can be obtained by conducting Los Angles abrasion test. If abrasion value is not > 30% → wearing

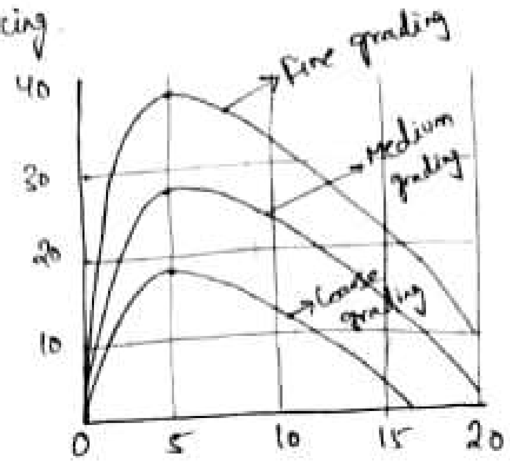
> 50% → Non wearing.

Bulking of Sand (F.A)

The increase in volume of a given mass of fine aggregate caused by the presence of water is known as bulking. The bulking of F.A is caused by the films of water which push the particles apart.

The extent of bulking depends upon percentage of moisture present in the sand and its fineness. Free moisture forms a film around each particle. This film exerts a phenomenon called surface tension due to which neighbouring particles move away from it. Due to this, every particle moves away from each other which results in bulking (or) increase of volume.

The bulking increases with the increase in moisture content upto a certain limit and beyond that the further increase in moisture content results in decrease in volume and later F.A shows no bulking.



Percentage of bulking can be determined by conducting a test i.e., Take a sample of moist F.A & fill it into measuring cylinder Note down the level as h_1. Pour water into the cylinder & shake it. Due to the bulking effect there will be increase in level & note it as h_2.

Deleterious substance in aggregates:

$$\text{Percentage of bulking} = \frac{h_1 - h_2}{h_2} \times 100$$

* For ordinary sands, bulking usually varies from 15-30%.
* For extremely fine sand, bulking may be of 40% at a moisture content of 10% but such a sand is unsuitable for concrete.

Deleterious Substance in Aggregate :-

The materials whose presence may adversely affect the strength, workability & long-term performance of the concrete are termed as deleterious materials. These are considered undesirable for the construction because of their weakness, softness, fineness (or) other physical (or) chemical characteristics harmful to the concrete behaviour.

Deleterious substances in the aggregates are divided into 3 categories based on their action.

a) organic impurities
b) Clay and other fine materials & salts as coatings
c) Unsound Particles

a) Organic impurities :- The impurities in the form of organic matter interfere with the chemical reactions & hydration. Organic matter generally consists of decayed vegetable matter & appears in the form of humus. These are likely to be present in F.A. than in C.A. which is easily washed. (This contains Tannic acid which affects the hydration process)

b) Coatings of Clay & other fine materials & Salts :-

A thin coating of clay on aggregates interferes with the bond between aggregate & cement paste. This may leads to the reduction of strength & durability of Concrete.

Other fine materials such as silt & dust particles because of their extreme fineness have more specific surface area and therefore increase the amount of water necessary to wet all the particles in mix. Thus results in high water content in the mix which is not desirable for the construction.

Note:- Specific Surface Area:- The surface area per unit weight of the material is known as specific surface area. Specific surface area increases with the reduction in particle size.

Salts:- Sand from seashores, river estuaries & deserts contains salt. Little amounts of salts can be removed by washing the aggregates with fresh water. But if the salts are not removed by washing, their presence can cause corrosion of reinforcement bars and also absorbs the moisture content from the air thereby causing efflorescence. Efflorescence is the phenomenon of formation of crystals of salts on the surface of the concrete.

c) Unsound Particles:- Shale & low density particles such as clay lumps, wool, coal are considered as unsound particles. These contains mica, gypsum & iron pyrates etc. Presence of excess of mica reduces the strength and gypsum & iron pyrates leads to expansion of concrete.

Soundness of Aggregate

The ability of aggregates to resist the excessive Changes in volume as a result of changes in Physical Conditions is known as Soundness of aggregate. The Physical Conditions may be freezing, thawing, variation in temperatures. Aggregates which undergo excessive volume changes are unsound for the construction.

Soundness of Aggregates can be tested by following Procedure :

* Aggregates Passing through 10mm IS sieve and retained on 300 μ IS sieve are collected.
* For fine Aggregates, collect 100 gms of sample from Each Combination as follows.

Passing	Retained	Sample weight
10 mm	4.75 mm	100 gms
4.75 mm	2.36 mm	100 gms
2.36 mm	1.18 mm	100 gms
1.18 mm	600 μ	100 gms
600 μ	300 μ	100 gms

* For Coarse Aggregates collect different weights of aggregate samples as follows:

Passing	Retained	Wt of sample
80mm	63mm	3000 gms
63mm	40mm	3000 gms
40mm	20mm	1500 gms
20mm	10mm	1000 gms
10mm	4.75mm	300 gms

* Take Proper weights of samples from each fraction and place it in seperate containers for the test.
* Take individual samples in a wire mesh basket and immerse it in the solution of Sodium Sulphate (or) Magnesium Sulphate for not less than 16 hrs nor more than 18 hrs.
* After completion of immersion period, remove the samples from solution and allow it to drain for 15 mins & place it in dry oven.
* After drying, remove the sample from oven and cool it to room temperature.
* After cooling, again immerse it in the solution in the above manner.
* Repeat the above procedure for 10 times.
* After completion of the final cycle, wash it to free from Na_2SO_4 & $MgSO_4$ solution.

* Then dry each sample to constant temp of 105°c - 110°c and weigh it.
* Sieve both the F.A & C.A over the same sieve on which it was retained before test.
* Weigh the samples and calculate loss of weight.
* The Average loss of weight after 10 cycles should not be less than 12% and greater than 18% i.e., (≤ 12-18%).

Alkali- Aggregate Reaction (AAR) (or) Alkali - Silica Reactivity (ASR):-

Alkali-Aggregate Reaction is the reaction between active silica constituents of the aggregates and alkalies i.e., Na_2O and K_2O present in the cement. The reactive silica generally occur in the aggregates obtained from traps, opaline, andesites, rhyolites, siliceous limestones and certain types of sandstones.

Mechanism of AAR:- The soluble alkalies present in the cement dissolve in the mixing water turning it into a highly caustic liquid which reacts with the reactive silica present in the reactive aggregates to form expansive alkali- silica gel. The expansive growth due to continuous supply of water and correct temperature results from excessive formation of silica gel. As the silica gel is confined by the surrounding paste the continuous growth of silica gel exerts internal hydraulic pressure generates through osmosis on the surrounding set-cement gel to cause pattern cracks which leads to subsequent loss in strength and elasticity. The formation of cracks due to alkali-aggregate reaction accelerates the deterioration of the structure.

Factors Promoting alkali-aggregate Reaction:-

Factors promoting the alkali-aggregate reaction are

1) Reactivity of the aggregate.
2) Alkali content in cement
3) Availability of moisture
4) Temperature conditions.

1) Reactivity of the aggregate:-

Potential reactivity of the aggregates can be determined by Petrographic examination of thin rock sections. According to IS:2386 (Part-VII)-1963, there are 2 methods namely mortar bar test and the chemical test for the determination of the potential reactivity of the aggregate.

→ Mortar bar expansion test:- A specimen of size 25mm x 25mm and 250mm length is cast, cured and stored in a standard manner. Measure the length of the specimen periodically at the ages of 1, 2, 3, 6, 9 & 12 months. Find out the nearest difference in length of the specimen to the nearest 0.001 percent and record the expansion of the specimen. The aggregate under test is considered harmful if it expands more than 0.05 % after 3 months (or) more than 0.1 % after 6 months.

→ Chemical method :- The potential reactivity of aggregate can also be found out by chemical method. In this method, the potential reactivity of an aggregate with alkalies in Portland cement is indicated by the amount of reaction taking place during 24 hrs at 80°c b/w sodium hydroxide ($Na(OH)_2$) solution and the aggregates that are passed through 300 μ IS sieve and retained on 150 μ sieve. After 24 hrs, the solution is analysed for silica dissolved and reduction in alkalinity, expressed as millimoles per litre.

2) High alkali content in cement :- The high alkali content in cement is one of the most important factors contributing to the alkali-aggregate reaction. The alkali content should be less than 0.6 %. Their total amount is expressed as Na_2O equivalent ($Na_2O + 0.658\, K_2O$). A cement meeting this specification is considered as a low alkali cement. However, cement with even lower alkali content have caused objectionable expansion. Generally, indian cements do not contain high alkalies compared to U.S & U.K.

3) Availability of moisture :- Every chemical reaction requires the presence of water. Alkali-aggregate reaction gets increased with the presence of water. Lack of water greatly reduces this kind of deterioration. Therefore, it is clear that deterioration due to alkali-aggregate reaction will not occur in the interior of Mass Concrete. The deterioration will be more on surface. This can be reduced by the application of water proofing agents to the surface of the Concrete to prevent additional penetration of water into the structure.

4) Temperature Conditions :- The ideal temperature for the promotion of alkali-aggregate reaction is in the range of 10 – 38°c. If the temperatures are more than (or) less than the 10-38°c, it may not provide an ideal situation for alkali-aggregate reaction.

Control of alkali-aggregate Reaction :-

Alkali-aggregate reaction can be controlled by:

(i) Selection of non-reactive aggregates
(ii) Use of low alkali cement (0.4% — 0.6%)
(iii) Controlling moisture condition & temperature
(iv) Air-Entraining agents (To absorb osmotic pressure)
(v) Use of crushed stone dust, fly ash, surkhi etc.

Thermal Properties of aggregates

The thermal Properties of the aggregates affect the durability of Concrete. The Principal thermal Properties of the aggregate are:

1) Coefficient of thermal expansion
2) Specific heat and
3) Thermal Conductivity

1) Coefficient of thermal expansion:- The coefficient of thermal expansion of the Concrete increases with the Coefficient of thermal expansion of aggregate. If the Coefficient of expansion of Coarse aggregate and cement paste differs too much, a large change in temperature may introduce differential movement which may break the bond between the aggregate and Paste.

Note:- Coefficient of thermal expansion (CTE) (or) Thermal expansion (CTE) of a material is the change in shape, area & volume in response to change in temperature

$$CTE = \frac{\text{Relative expansion}}{\text{Change in temp}}$$

If the CTE of C.A & Cement paste differs by more than $5.4 \times 10^{-6} / °c$ then the Concrete is subjected to freezing & Thawing which affects the durability. CTE of aggregates depends on Parent rock.

→ For majority of the aggregates, CTE lies between $5.4 \times 10^{-6} - 12.6 \times 10^{-6}/°C$.

→ For hydrated Portland cement → CTE varies from $10.8 \times 10^{-6}/°C$ to $16.2 \times 10^{-6}/°C$.

→ For linear CTE of aggregates varies from $5.8 \times 10^{-6}/°C$ to $14 \times 10^{-6}/°C$.

It can be measured by verbect's dilatometer test. Thermal incompatibility causes severe stresses affecting durability and integrity of concrete. It also affects the fire resistance of concrete.

2) <u>Specific heat</u>:- The specific heat of the aggregate is a measure of its heat capacity. It can be measured by calorimeter method. Specific heat depends upon mixing ratio and mineral properties of rock. Specific heat increases with increase in moisture content and temperature. If density of concrete increases, it represents less voids thereby contains little area to enter the heat. Thus, as density of concrete increases, specific heat decreases.

3) <u>Thermal Conductivity</u>:- Thermal conductivity is the ability of aggregate to conduct (or) pass the heat. It depends on crystallinity of the aggregates (i.e., direction of arrangement of crystals). It affects the direction of flow of heat.

Trachyte & Basalt → Low Conductivity
Limestone + Dolomite → Medium "
Quartz → High "

Sieve analysis

It is dividing a sample of aggregates into various fractions each consisting of particles of same size. This is done by sieving the aggregates as per IS : 2386 (Part I)-1963. It is used to determine particle size distribution i.e., gradation. In this, we use different sieves as standardized by IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

Procedure :-

* The test sample is dried to a constant weight at a temp of 110 + 5°c and weighed.
* The sample is sieved by using a set of IS sieves i.e., 80mm, 63mm, 50mm, 40mm, 31.5 mm, 25 mm, 20mm, 16mm, 12.5 mm, 10mm, 6.3mm, 4.75mm, 3.35 mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and 75μm.
* On completion of sieving, material on each sieve is weighed.
* Cumulative weight passing through each sieve is calculated as a percentage of total sample weight.
* The particles of size 80mm − 4.75mm are considered as coarse aggregates and of size 4.75 mm − 150μ are considered as fine aggregates.
* 4.75 mm is the common fraction in both C.A & F.A
* Sieving can be done manually (or) mechanically in all possible directions. Machine sieving is efficient than hand sieving.

Grading of aggregates

As aggregates constitutes 85-90% of volume of Concrete, grading of aggregates plays a major role on properties of concrete. The particle size distribution of an aggregate as determined by sieve analysis is termed as grading of the aggregate. Aggregate gradation determines the void content within the structure of aggregate & consequently amount of cement paste i.e., required to fill the void space and ensure a workable concrete.

Proper gradation not only ensures a workable concrete but also reduces problems of segregation, bleeding and shrinkage cracking.

There are three typical range categories of aggregate grading:

1) Well graded
2) Poor graded
3) Gap graded

1) Well graded:- Well graded aggregate has a gradation of particle size that fairly evenly spans the size from the finest to the coarsest. Well graded aggregate sample contains all standard fractions of aggregate in required proportion, thus results in minimum voids. This requires minimum paste to fill the voids. Minimum paste represents less quantity of cement & water thereby results in more economical

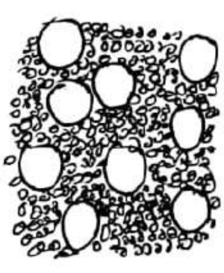
Construction and gives higher strength, lower shrinkage & greater workability. A slice of a core of well-graded aggregate concrete shows a packed field of many different particle sizes. It is characterized by the S-shaped curve in gradation curve.

Well-graded

2) Poor-graded :- (or) uniform graded :- Poor-graded aggregate is characterized by small variation in size. It contains aggregate particles that are almost of the same size. This means that particles pack together, leaving relatively large voids in the concrete. It is also called "uniform-graded". It is characterized by steep curve.

Poorly-graded

3) Gap-graded (or) skip-graded :- Gap-graded aggregate consists of aggregate particles in which some intermediate size particles are missing. A core slice of gap graded, (or) skip grade, concrete shows a field of small-sized aggregate with slightly



Gap-graded

UNIT - III

FRESH CONCRETE

~~Workability~~:- The Performance requirements of hardened Concrete are defined with respect to shape, finish, strength, durability, Shrinkage and creep. To achieve these objectives, in addition to have suitable Composition in terms of quality & quantity of Cement, admixtures & aggregates, there are some other requirements from the mixing stage till it is transported, Placed in formwork and Compacted. They are:

→ Mixability

→ Stability

→ Flowability (or) Mobility

→ Compactability

→ finishability

Mixability:- The mix should be able to Produce a homogeneous fresh Concrete from the Constituents materials of the batch under the action of mixing forces. Mixability is the Property of attaining a homogeneous and uniform mix. A less mixable concrete mix requires more time to Produce a homogeneous mix.

Stability:- Stability is the Property of Concrete mix not getting seperated (or) segregated during transportation and placing when it is subjected to forces during handling operations. The tendency of bleeding should also be minimized.

Flowability (or) Mobility :- The mix should be cohesive enough and sufficiently mobile to be placed in the form around the reinforcement and should be able to caste into the required shape without losing continuity (or) homogeneity. This property is known as flowability (or) mobility.

Compactability :- A best mix of well compacted concrete reduces the original voids upto 99%. The mix should be amenable to proper and thorough compaction into a dense, compact concrete with minimum voids

Finishability :- The mix should be possible to obtain a satisfactory surface finish without honeycombing (or) blowing holes on free surface by trowelling and other processes. This capability is termed as finishability.

Workability :-

The property of freshly mixed concrete (or) mortar which determines the ease and homogeneity with which it can be mixed, placed compacted and finished.

Ease is related to rheology of fresh concrete which includes performance parameters of stability, mobility and compactability.

Rheology is the study of flow and deformation of materials under applied forces.

Workability of fresh concrete is a complex system of two critical parameters i.e., consistency and homogeneity.

Consistency is the relative ability of a freshly mixed concrete to flow. factors affecting consistency are: water content; cement content and its characteristics i.e., plasticity of the cement paste; aggregate content and its characteristics, air content, temperature etc.,

Homogeneity means the uniform and stable distribution of cement, aggregate and water, and resistance to segregation.

Factors affecting workability :- Factors affecting the workability of concrete are materials such as water content, cement concrete, sand and aggregate properties such as size, shape, grading, mix design ratio and use of admixtures. Each and every process and materials involved in concrete mixing affects the workability of concrete.

Workability and strength of Concrete are inversely Proportional. Strength of Concrete decreases with increase in workability of normal Concrete affecting the durability of Concrete.

The Primary materials of Concrete are cement, F.A, C.A and water. Many times admixtures are used in concrete to enhance its Properties. Therefore, Properties of these materials and their content affect the workability of Concrete.

Following are the general factors affecting Concrete workability:

Cement Content of Concrete:- Cement Content affects the workability of Concrete in good measure. More the quantity of Cement, the more will be the Paste available to coat the Surface of aggregates and fill the voids between them. This will help to reduce the friction between aggregates and Smooth movement of aggregates during mixing, transporting, Placing and Compacting of concrete. For a given water-Cement ratio, the increase in Cement content will also increase the water Content Per unit volume of Concrete increasing the workability of Concrete. Generally, a w/c ratio of 0.45 to 0.6 is used for good workable Concrete without the use of admixture.

Water Content of Concrete:- Higher the w/c ratio, higher will be the water Content Per volume of Concrete and Concrete will be more workable.

Higher w/c ratio is generally used for manual Concrete Mixing to make the mixing Process easier. For machine Mixing, w/c ratio can be reduced. This is for nominal mix. For designed mix Concrete, the strength and durability of Concrete is of utmost importance and hence w/c ratio is mentioned with the design. Generally, design Concrete uses low water/cement ratio so that desired strength and durability of Concrete can be achieved.

Mix Proportions of Concrete:- Mix Proportion of Concrete tells us about the ratio of F.A & C.A w.r.t Cement quantity. If more cement is used, Concrete becomes richer and aggregates will have proper lubrications for easy mobility (or) flow of aggregates. The low quantity of Cement w.r.t aggregates will make the less paste available for aggregates and mobility of aggregates is restrained (i.e, under Control).

Size of aggregates:- Surface area of aggregates depends on the size of aggregates. For a unit volume of aggregates, with large size, the surface area is less Compared to same Volume of aggregates with small sizes. when the surface area increases, the requirement of cement quantity also increases to cover up the entire surface of aggregates with paste. This will make more use of water lubricate each aggregate Hence, lower sizes of aggregates with same water Content are less workable than the large size aggregates.

Shape of aggregates:- The shape of aggregates affects the workability of concrete. It is easy to understand that rounded aggregates will be easy to mix than elongated, angular and flaky aggregates due to less frictional resistance. But it is not preferable to use rounded aggregates in constructions.

Grading of aggregates:- Grading of aggregates have the maximum effect on workability of concrete. A well graded aggregates have all sizes in required percentages. This helps in reducing the voids in a given volume of aggregates. The less voids makes the cement paste available for aggregate surfaces to provide better lubrication to the aggregates. Thus low w/c ratio is sufficient for properly graded aggregates.

Surface texture of aggregates:- Surface textures such as rough & smooth surface of aggregates affects the workability of concrete in the same way as the shape of aggregates. Rough textured aggregates have more surface area than smooth textured aggregates. Thus, concretes with smooth surfaces are more workable than with rough textured aggregates.

Use of admixtures in concrete:- There are different types of admixtures in concrete which enhances the workability such as plasticizers and superplasticizers with low w/c ratio. And also there are some water reducing admixtures and air entraining

Concrete admixtures to increase its workability.

Measurement of workability by different tests:-

The main aim of measuring workability is to Assess the Concrete whether it is having high workability (or) Low workability (or) Semi-dry (Plastic) workability etc. It Can be determined by Conducting the following tests in the laboratory.

1) Slump - test
2) Compaction factor test
3) Vee- Bee Consistency test
4) Flow-test.

1) **Slump test:-** It is the most Common method for measuring the workability of freshly mixed Concrete. Uniformity of the Concrete regarding workability and quality aspects Can be assessed from batch to batch by observing the nature in which the Concrete slumps. It is not very Suitable for very wet (or) very dry Concrete.

→ A Steel mould in the form of frustrum of Cone is used in slump test which has the top diameter of 100mm, bottom diameter of 200mm and the height is 300mm. According to IS Specification, Maximum size of the aggregate in Concrete that Can be used to Perform slump test is restricted to 38 mm.

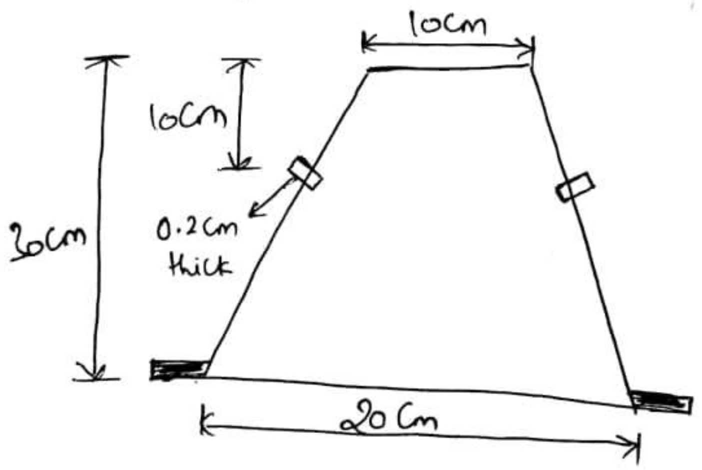
→ The mould is freed and cleaned from any Surface moistures and then Concrete is Placed in 3 layers.

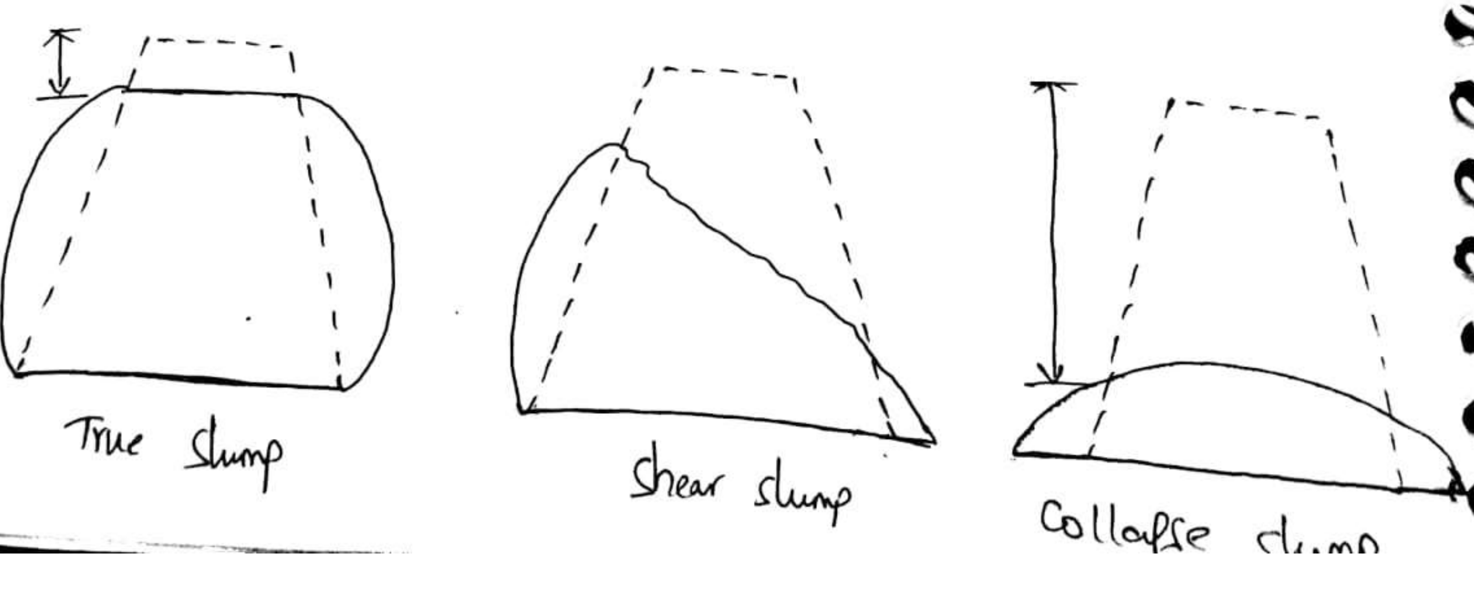
→ Each layer is tamped 25 times with a standard tamping rod (16mm dia, 0.6m length).

→ After filling, the Cone is slowly lifted and the Concrete is allowed to Subside.

→ The decrease in height of the center of the Slumped Concrete is called slump and is measured to the nearest 5mm.

→ If the Concrete Subsides Evenly all round, the slump measured is true slump. If one half of the Cone slides down an inclined Plane, it is a Shear slump. Too wet mix shows Collapse slump.





Standard slump values

Type of Construction	slump in mm	w/c ratio
Roads & mass Concrete works	25-50	0.7
RCC beams & slabs	50 - 100	0.55
Columns & retaining walls	75-125	0.45
Foundation works	25 - 50	0.7

2) Compaction factor test:-

This test is useful for concrete mixes of very low workability (or very dry concrete). This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.

Container	Top dia (mm)	Bottom dia (mm)	Height (mm)
upper hopper	254	127	279
Lower hopper	229	127	229
Cylinder	152	152	305

Distance b/w bottom of upper hopper & top of lower hopper = 203 mm

Distance b/w bottom of lower hopper & top of cylinder = 203 mm

The Concrete is Placed in the upper hopper gently so that no effort is applied to Produce Compaction. The bottom door is opened so that the concrete falls on the lower hopper. Again the bottom door of the lower hopper is opened and the Concrete falls on the cylinder. After removing the excess Concrete by the help of blades, the weight of the cylinder is taken. This weight is known as weight of "Partially Compacted Concrete (W_1)". The cylinder is emptied and then filled with the same Sample rammed heavily so as to obtain full Compaction. The cylinder is weighed to nearest 10 gms and is known as "weight of fully Compacted concrete (W_2)".

$$\text{Compacting factor} = \frac{\text{Weight of Partially Compacted Concrete } (W_1)}{\text{Weight of fully compacted Concrete } (W_2)}$$

Degree of workability	Compaction factor
Very low	0.78
Low	0.85
Medium	0.92
High	0.95

Dry Concrete

3) Vee-Bee test:- This test is suitable for stiff Concrete mixes having low and very low workability. It Consists of vibrating table, a metal pot, a sheet of metal cone and a standard iron rod.

→ In this test, slump test as mentioned earlier is performed by placing the slump cone inside the sheet metal cylindrical pot.

→ Then the vibration is started and the time on a stop watch is noted.

→ The time taken by the concrete to take cylindrical shape after the conical shape disappears is noted.

→ This recorded time is known as Vee-Bee Degree (or) Vee-Bee seconds.

Standard values

Degree of workability	Vee-Bee seconds
Extremely dry	32-18
very stiff	18-10
Stiff	10-5
Stiff Plastic	5-3
Plastic	3
Flowing	—

4) <u>Flow test</u> :- It gives an indication of the quality of the concrete with respect to consistency, cohesiveness and proneness to segregation.

→ A flow table with 70cm × 70cm is used to conduct the test.

> Note :- In American version of this test, a round table of top 76.2 cm dia is used.

→ Abram's cone of measurements 30cm Height, 17cm top diameter and 25cm bottom diameter is used.

→ The cone is placed in the center of the flow table and filled with fresh concrete in two equal layers. Each layer is tamped 10 times with a tamping rod.

→ After waiting for 30 seconds, the cone is lifted immediately allowing the concrete to flow.

→ The flow table is then lifted up 40mm and then dropped 15 times causing the concrete to flow.

→ After this, the diameter of flow of the concrete is measured by taking 3 average diameters. Using scale.

→ % flow is measured by,

$$\% \text{ Flow} = \frac{\text{Dia of flow} - 25}{25} \times 100$$

Standard values

% Flow	Consistency
0 – 20	Dry
20 – 60	Stiff
60 – 100	Plastic
100 – 120	Wet
120 – 150	Sloppy

Setting times of Concrete :-

According to ASTM C403 setting time of concrete is defined as the elapsed time from the addition of mixing water to a cementitious mixture until the mixture reaches a specified degree of rigidity.

Generally,

Cement Paste / Mortar Paste / Concrete mix (Cement + mortar = Paste)

Paste + F.A = Mortar

Mortar + C.A = Concrete

Time is required for mixing, transporting, placing, compacting and finishing. The paste gets rigid based on hydration process. As hydration is an irreversible process, the reaction is gradual which first causes stiffening & then leads to

Strength development. Setting of Concrete is transition of fresh Concrete from liquid state to Solid state. The time of setting of hydraulic cement Paste is determined based on the Penetration resistance using a Vicat apparatus whereas time of setting of Concrete is determined by Conducting Standard Penetration resistance test. The apparatus Consists of standard size of needles used are 28.66 mm, 20.28 mm, 14.32 mm, 9.1 mm, 6.38 mm, 4.52 mm. and mould of size 150mm x 150mm and a pippet.

→ A Concrete mix is Prepared with Proper Proportions. After mixing it Properly, the mix is sieved through 4.75 mm size sieve and a mix of (F.A + Cement + water) is Collected.

→ The Collected Paste is filled in mould and bleeded water is removed by using Pippet and Standard needle is Penetrated through the Paste according to the Consistency of the Paste.

→ The needle is Penetrated into the Paste in such a way that for every 10 sec 1 inch Penetration is to be given, by applying vertical force.

→ The dial gauge reading is to be noted and using Calibration chart, dial gauge reading was Converted to force.

→ A graph is Plotted between force and time.

→ The time taken to achieve a penetration resistance of 3.5 MPa (500 Psi) is noted and is taken as initial setting time of concrete.

→ The time taken to achieve a penetration resistance of 28 M.Pa (4000 Psi) is noted and is taken as final setting time of concrete.

Note:- Psi → Pound Force Per Square Inch

Effect of Time & Temperature on workability:-

Time:- Freshly mixed concrete stiffens with time. It is simply observed that some water from the mix is absorbed by the aggregate if not saturated, some is lost by evaporation, particularly if the concrete is exposed to sun (or) wind, and some is removed by the initial chemical reactions. The exact value of loss in workability depends on several factors. The change in workability with time depends on moisture condition of aggregate, The loss is greater with dry aggregate due to the absorption of water by aggregate.

Temperature:- The workability of a mix is also affected by the ambient temperature of the concrete. It is observed that on a hot day the water content of the mix would have to be increased for a constant early workability to be maintained. The loss of slump in stiff mixes is less influenced by temperature because such mixes are less affected by changes in water content. Several experiments stated that as the concrete temperature increases, the percentage increase in water required to effect a minimum change in slump also increases.

→ A rise in the curing temperature speeds up the chemical reactions of hydration and thus effects the early strength of concrete without any ill-effects on the later strength.

→ A higher temperature during placing and setting increases the very early strength, it may adversely affect the strength from about 7 days onwards.

→ It is concluded that, when temperature increases, then workability of fresh concrete decreases in the same proportion. This is because, when the temperature increases, then evaporation rate also increases due to that hydration rate decreases and hence, concrete will gain early strength.

Segregation:- The stability of a Concrete mix requires that it should not get segregated during transportation and placing. Segregation can be defined as Seperating out of the ingredients of Concrete mix so that the mix is no longer in a homogereous condition. only a stable homogeneous mix can be fully compacted.

Two types of segregation can occur:

1) The seperating out of coarser particles in a dry mix, termed segregation and

2) Seperation of cement paste from the mix in the case of lean and wet mixes, termed as bleeding.

Segregation depends upon handling & placing operations. The tendency to segregate increases with the maximum size of the aggregate, amount of C.A, and with the increased slump. Segregation can be minimized by:

→ Reducing the height of drop of concrete

→ Not using vibration as a means of spreading a heap of concrete into a level mass over a large area, and

→ Reducing the continued vibration over a longer time, as the C.A tends to settle to the bottom and the scum raises to the surface.

Scum ↓ layer of dirt on Surface

Bleeding :- Bleeding is due to rise of water in the mix to the surface because of the inability of the solid particles in the mix to hold all the mixing water during the settling of the particles under the effect of compaction. Bleeding causes the formation of a porous, weak and nondurable concrete layer at the top of placed concrete. Bleeding may also result in a plane of weakness between two layers.

Mixing and Vibration of Concrete :-

Mixing :- The process of rolling, folding and spreading of particles is known as mixing of concrete. The materials of concrete should be mixed thoroughly so that there is uniform distribution of materials in the mass of concrete. The thorough mixing also ensures that cement water paste completely covers the surfaces of aggregates. The mixing of materials of concrete can be done either with hand (or) with the help of a cement mixer machine.

Hand mixing :- For hand mixing, the materials are stacked on a water-tight platform, which may be either of wood, brick (or) steel. The materials should be thoroughly mixed, atleast 3 times, in dry condition before water is added. The prepared mix should be consumed in 30 minutes after adding water. The mixing by hand is allowed in case of small works of unimportant works where small quantity of concrete is required. For important works, if hand mixing is to be adopted, it is advisable to use 10% more cement than specified.

Machine mixing :- For machine mixing, all the materials of concrete, including water, are collected in a revolving drum and then the drum is rotated for a certain period. The resulting mix is then taken out of the drum. The features of machine mixing of concrete are as follows:

→ It is found that mixing of concrete materials with the help of machines is more efficient and it produces concrete of better quality in a short time.

→ The mixes of various types and capacities are available in the market. They may either be of tilting type (or) non-tilting type. They are generally provided with power-operated loading hoppers. For smaller works, a mixer capable of producing concrete of one bag of cement is used. For works such as roads, aerodromes, dams etc., special types of mixers are used.

→ The water should enter the mixer at the same time (or) before other materials are placed. This ensures even distribution of water.

→ The concrete mixer should be thoroughly washed and cleaned after use. If the Precaution is not taken, the lumps of hardened concrete will be formed inside the mixer. These lumps are not only difficult to remove at a later stage, but they considerably affect the efficiency of the mixer.

→ The inside Portion of the mixer should be inspected carefully at regular intervals. The damaged (or) broken should be replaced.

→ The time of mixing concrete materials in the mixer and the speed of mixer are very important factors in deciding the strength of concrete which is formed. The mixing time should be rotated at a speed as recommended by the manufacturers of the mixer.

→ The concrete discharged by the mixer, after thoroughly mixing concrete materials, should be consumed within 30 minutes.

<u>Vibration</u>:- Where high strength is required, it is necessary that stiff concrete, with low water/cement ratio be used. To compact such concrete, mechanically operated vibratory equipment, must be used.

→ The action of vibration is to set the particles of fresh concrete in motion, reducing the friction between them and affecting a temporary liquefaction of Concrete which enables Easy Settlement.

→ The vibration of Concrete is done for the better Compaction of concrete. There are different vibrating techniques used at the site.

Internal vibrator: of all the vibrators, the internal vibrator is most commonly used. This is also called, "Needle vibrator" (or) "Poker vibrator". This essentially consists of a Power unit, a flexible shaft and a needle. (30 sec - 2 min)

Formwork vibrator (External vibrator) :- Formwork vibrators are used for concreting columns, thin walls (or) in the casting of Precast units. The machine is clamped on to the external walls surface of the formwork. (1 min - 2 min)

Table Vibrator :- This is the special case of formwork vibrator, where the vibrator is clamped to the table. They are commonly used for vibrating concrete cubes.

Platform vibrator :- It is nothing but a table vibrator, but it is larger in size. This is used in the manufacture of large Prefabricated concrete Elements such as electric poles, railway sleepers, Prefabricated roofing Elements etc.

Surface Vibrator:- Surface vibrators are sometimes known as 'screed Board vibrators'. A small vibrator placed on the screed board gives an effective method of compacting and leveling of thin concrete members, such as floor slabs, roof slabs and road surface.

Vibratory roller:- one of the recent developments of compacting very dry and lean concrete is the use of vibratory roller. Such concrete is known as roller compacted concrete.

Steps in manufacture of concrete:-

Various stages of manufacturing of concrete are:

* Batching
* Mixing
* Transporting
* Placing
* Compacting
* Curing
* Finishing

Batching:- Batching is the process of measuring concrete mix ingredients by either mass (or) volume and introducing them into the mixer. To produce concrete of uniform quality, the ingredients must be measured accurately for each batch

Batching Can be done in 2 ways
→ Volume batching and → Weigh batching

<u>Volume batching</u>:- This method is generally adopted for Small jobs. Gauge boxes are used for measuring F.A & C.A. The volume of one gauge box is Equal to the volume of one bag of cement. Gauge boxes are also known as 'FARMAS'. They Can be made of timber (or) Steel. They are made generally deep and narrow. No compaction is allowed while filling the gauge boxes.

<u>Weigh batching</u>:- Batching by weight is more Preferrable than Volume batching as it is more accurate and leads to more uniform Proportioning. weigh batching Can be done in 3 ways
(i) Manual (ii) semi automatic and (iii) fully automatic.

In Case of manual batching, all weighing and batching of Concrete are done manually. It is used for Small jobs.

In Case of semi-automatic batching, the aggregate bin gates are opened by manually operated Switches and are Closed automatically when the material has been delivered.

In Case of fully automatic batching, the material is Electrically activated by a single Switch and Complete autographic records are made of the weight of Each material. The batching Plant Comprises 2,3,4 (or) 6 Compartments bins of several capacities.

<u>Mixing</u>:- The mixing should be ensured in such a way that the mass becomes homogeneous, uniform in Colour and Consistency. Mixing Can be done in 3 ways

→ Hand mixing

→ Stationary mixers

→ Ready Mix Concrete

Hand mixing includes mixing ingredients of concrete by hands using ordinary tools like hand shovels etc. This type of mixing is done for less output of Concrete.

Concrete is sometimes mixed at jobsite in a Stationary mixer having a size of 9 m³. These mixers may be of Tilting type and Non-tilting type. <u>Tilting type</u> mixer Consists a Conical drum which rotates on an inclinable axis. It has only one opening. The drum charged directly and discharged by tilting and reversing the drum. Non-tilting type mixing drum is Cylindrical in shape & revolves on two-horizontal axis. It has opening on both sides. The ingredients are charged in from one opening. and discharged from other opening.

Ready Mixed concrete (RMC) is Proportioned and mixed off at the Project site and is delivered to the Construction area in a freshly mixed and unhardened state. It Can be manufactured by 2 methods.

* Central mixed Concrete
* Truck-mixed Concrete

Central mixed concrete is mixed completely in a stationary mixer and delivered in Agitating trucks & Non-Agitating trucks.

Agitator trucks → A vehicle carrying a drum in which freshly mixed concrete can be conveyed from point of mixing to that of placing where drum is being rotated continuously. In this, concrete is to be discharged within 1½ hr.

Non-Agitator trucks → which transports concrete for small distances over smooth roadways.

Truck mixed concrete mixers are used for intermittent production of concrete at jobsite, (or) small quantities. This is completely under one-man operation. This is a combined materials transporter, batching & mixing system.

Transporting:- Concrete can be transported by mortar pans when it is in small quantity. It is of 2.5 ft^3 and 25" x 17" x 6" size. It can also be transported by wheel barrows and buggies which are used in places of onsite concrete constructions. In places of conveying the concrete horizontally (or) higher | lower level belt conveyors are used. Cranes and buckets are used for work above ground level with cranes, cableways and helicopters. Concrete can be transported through pumps to convey concrete from central discharge point to formwork. Transit mixers are used for transporting the concrete over long distance particularly in RMC plant.

Placing :- Concrete must be placed in a systematic manner to yield optimum results. The placing sequence, rate and layer thickness must be controlled to ensure that consolidation is effective and complete. Most surface defects are related to incorrect placement. The concrete shall be placed and compacted before initial setting of concrete commences and should not be subsequently disturbed. Methods of placing should be such as to avoid segregation. Care should be taken to avoid displacement of reinforcement (or) movement of formwork. As a general guidance, the maximum permissible free fall of concrete may be taken as 1.5m.

Compacting :- The process of removal of entrapped air and of uniform placement of concrete to form a homogeneous dense mass is termed as compaction. The density and consequently the strength and durability of concrete depend upon the quality of compaction. Compaction is necessary for the following reasons:

1) The internal friction between the particles forming the concrete, between concrete & R/F, and b/w concrete

and formwork, makes it difficult to spread the concrete in the forms. The friction also prevents the concrete from coming in close contact with the r/f, thereby leading to poor bond b/w the r/f and surrounding concrete. The compaction helps to overcome these frictional forces.

2) Friction can also be reduced by adding more water than can combine with cement. The water in excess to that required to hydrate the cement fully forms water voids which have as harmful an effect in reducing strength as air voids. The compaction reduces the voids to minimum.

Compaction of the concrete can be achieved in 4 ways,
(i) Hand rodding (ii) Mechanical vibrations
(iii) centrifugation (or) spinning and (iv) High pressure & shock.

(i) Rodding is the process of ramming the concrete manually with a heavy flat-faced tool in an effort to work it around the reinforcement, the embedded fixtures and corners of the form work. The main disadvantage of rodding is that it produces large pressures on the form work. However, such a system though better than no compaction, cannot assure a thoroughly dense and compacted concrete free of air pockets.

(ii) Vibration is the commonly used method of compaction of concrete, which reduces the internal friction between the different particles of concrete by imparting oscillations to the Particles and thus Consolidates the Concrete into a dense and Compact mass. The oscillations are in the form of simple harmonic motion. The mechanical vibrations can be imparted by means of vibrators which are operated with the help of an electric motor (or) diesel engine (or) Pneumatic Pressure. The Period of vibration required for a mix depends upon the workability of the mix.

Different vibratory techniques were discussed in Vibration Process

(iii) Centrifugation (or) spinning method is used in the Production of Elements which are circular in c/s such as concrete Pipes, Concrete lamp Posts etc. It comprises, feeding the Concrete into the horizontal mould spinning at a low speed. After the Predetermined amount of concrete is fed into the mould, the spinning speed is increased to a high value. The water is forced out of the mix which flows out of the mould. At the end of the spinning Process, the speed is slowly reduced and dry cement is sprinkled in small quantity such that any free water on the surface does not increase the w/c ratio. The Centrifugation results in a watertight Product and hence is used in the manufacture of both Pressure Pipes for water-supply and non-Pressure Pipes for Sewerage disposal and storm water drains.

(iv) Vibropressing (or) giving external Pressures and shocks, this method comprises applying external Pressure from the top and vibration from below the mould. the vibration tables can be used for this Purpose. The excess water added during the mixing is forced out due to large Pressure. The Product obtained by this Process is of extremely good quality and durability. The technique has been successfully used for mass manufacturing of Concrete kerbs, etc.

<u>Curing</u>:- Hydration of Cement results in getting ultimate strengths in concrete. 80-85 % of the eventual strength is attained in the first 28 days and this is considered to be the characteristic strength. The Concrete Continues in gaining strength with time Provided sufficient moisture is available for the hydration of Cement which Can be assured only by creation of favourable Conditions of temp & humidity. This Process of Creation of an environment during a relatively short Period immediately after the Placing and Compaction of the Concrete, favourable to the setting and the hardening of Concrete is known as Curing. The Curing increases Compressive strength, improves durability, impermeability and abrasion resistance. Proper Curing is one of the important steps in making high quality Concrete. To develop design strength, the Concrete has to be Cured for upto 28 days.

Curing can be done in many different ways:

-> Ponding of water over the Concrete Surface after it has set.

-> Covering the Concrete with wet straw (or) Damp Earth.

-> Covering the concrete with wet Burlap (Jute)

-> Sprinkling of water

-> Covering the Surface with water proof Paper

-> Membrane Curing of Concrete

-> Chemical curing

-> steam curing

-> Electrical Curing

Finishing :- The Process of leveling, Smoothing, Compacting and Otherwise treating Surface of fresh Concrete to Produce desired appearance is known as finishing.

Finishing concrete involves 3 steps:

* Screeding
* Floating
* Trowelling

Screeding is the Process of striking off the excess Concrete to bring the top Surface to Proper grade. While depositing concrete its thickness is kept slightly more than final finish. It is then moved by a strike off board known as screed.

Floating consists of removing the irregularities on the surface of concrete which are left after screeding. This is done with a wooden float. It is about 1.5m long and 20cm wide, attached with a handle. Finishing is done with the forward and backward motion of the float.

Trowelling is the final operation of finishing. It provides a smoother finish which is hard and abrasion resistant. Trowelling may be necessary to finish points not finished in a satisfactory manner by floating. Trowelling with a steel float when the concrete is almost dry gives a very smooth finish. The trowel is 25-50cm long and 8-12 cm wide. The blades give better service after they have been used enough.

Quality of Mixing water:-

Concrete is a mixture of binding materials, inert materials and water. Water plays a major role in getting concrete hardening w.r.t time. The purpose of water in concrete is as follows:

→ To wet the surface of aggregates to develop adhesion because the cement paste adheres quickly & satisfactory to the wet surface of the aggregates than to a dry surface.

→ To prepare a plastic mixture of the various ingredients and to impart workability to Concrete to facilitate Placing in the desired Position and

→ Water is also needed for the hydration of the Cementing materials to set and harden during the Period of Curing.

The quality of water in the mix Plays a vital role on the strength of the Concrete. Some water adversely effect on hardened Concrete. Sometimes may not be harmless (or) Even beneficial during mixing. So clear distinction should be made between the effect on hardened Concrete and the quality of mixing water.

Potable water as mixing water:-

The Common specifications regarding quality of mixing water is water should be fit for drinking. Such water Should have inorganic solids less than 1000 PPM. The Content lead to a Solid quantity 0.05% of Mass of Cement when w/c ratio is Provided 0.5 resulting small effect on strength. But Some water which are not Potable may be used in making Concrete with any Significant effect. Dark Colour (or) bad Smell water may be used if they do not Posses deleterious substances. pH of water to Even 9 is allowed if it not tastes brackish. In Coastal areas where local water is saline and have no alternate sources, the chloride concentration upto 1000 ppm is even allowed for drinking. But this excessive amounts of alkali carbonates and bicarbonates, in some natural mineral water may cause alkali-silica-reaction.

Quality Parameters	Max. limit (ppm)
Chlorides	500
SO_3	1000
Alkali Carbonates & Bicarbonates	1000
Turbidity	2000

The effect of different types of contaminations & impurities on concrete is as follows:

Suspended solids :- Mixing water with a high content of suspended solids should be allowed to stand in a setting basing before use as it is undesirable to introduce large quantities of clay and silt into the concrete.

Acidity and alkalinity :- Natural water that are slightly acidic are harmless, but presence of humic (or) other organic solids may result in adverse affects over the hardening of concrete. Water which are highly alkaline should also be tested.

Algae :- The Presence of algae in mixing water Causes air entrainments with a Consequent loss of strength. The green (or) brown slime forming algae should be regarded with Suspicion and such water should be tested Carefully.

Sea water :- Seawater contains a total salinity of about 3.5% (78% of Dissolved solids being NaCl and 15% $MgCl_2$ + $MgSO_4$) which Produces a slightly higher early strength but a lower long-term strength. The loss of strength is usually limited to 15% and can be tolerated. Sea water reduces the initial setting time of Cement but donot effect final setting time.

Chloride :- water Containing large amount of chlorides tends to Cause Persistent dampness and Surface efflorescence. The Presence of chlorides in Concrete Containing embedded steel can lead to its Corrosion.

UNIT - IV

Hardened Concrete

Hardened Concrete is the concrete which must be strong enough to withstand the structural and service loads which will be applied to it and must be durable enough to the environmental exposure for which it is designed.

Water/Cement ratio :- The water-cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. The strength of concrete at a given age under given curing conditions is assumed to depend mainly on water-cement ratio and degree of compaction. Water-cement ratio was first developed by Duff A. Abrams. A w/c ratio of 0.4 means that for every 100 lbs of cement used in concrete, 40 lbs of water is used.

The practical range of the w/c ratio is from about 0.3 to over 0.8. A ratio of 0.3 is very stiff and a ratio of 0.8 makes a wet and fairly weak concrete. For reference, a 0.4 w/c ratio is generally expected to make a concrete with a compressive strength of about 5600 psi when it is properly cured. On the other hand, a ratio of 0.8 will make a weak concrete of about 2000 psi.

The greater the ~~abov~~ amount of water in a concrete mix, the more dilute the cement paste will be. This not only affects the compressive strength, it also affects the tensile and flexural strengths, the porosity, the shrinkage and the color. The more the w/c ratio is increased, the more the strength of the resulting concrete is reduced. This is because, ~~the~~ adding more water creates a diluted paste that is weaker and more susceptible to cracking and shrinkage.

Using a low w/c ratio is the usual way to achieve a high strength and a high quality concrete, but it does not guarantee that the resulting concrete is always appropriate for countertops. Good concrete results from good mix design, and a low w/c ratio is just one part of a good mix design.

Abram's law:- Abram's law states that the strength of a concrete mix is inversely related to the mass ratio of water to cement. As the water content increases, the strength of concrete decreases. It is indicated as,

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

where S = strength of concrete

A & B are Constants

and x is water/cement ratio by volume. Which varies from 0.3 - 1.2

Gel - Space ratio:- Since, Concrete is a brittle material, its Porosity Primarily governs its strength. The Compressive strength is found to be severely decreasing with increase in the Porosity.

* The Porosity of Concrete which governs the strength of Concrete is affected by the gel/space ratio in Concrete.
* The gel/space ratio is the ratio of the Solid Products of hydration to the Space available for these hydration Products.
* A higher gel/space ratio reduces the Porosity and therefore increases the Strength of Concrete.
* The gel/space ratio, which governs the Porosity of Concrete affecting its strength, is affected by the w/c ratio of Concrete.
* A higher w/c ratio decreases the gel/space ratio increasing the Porosity thereby decreases the strength of concrete.

* Power's experiment showed that the strength of Concrete bears a specific relationship with the gel/space ratio.

* He found the relationship to be $S = 240x^3$

where, x is the gel/space ratio

240 is intrinsic strength of the gel in MPa for the type of Cement & Specimen used

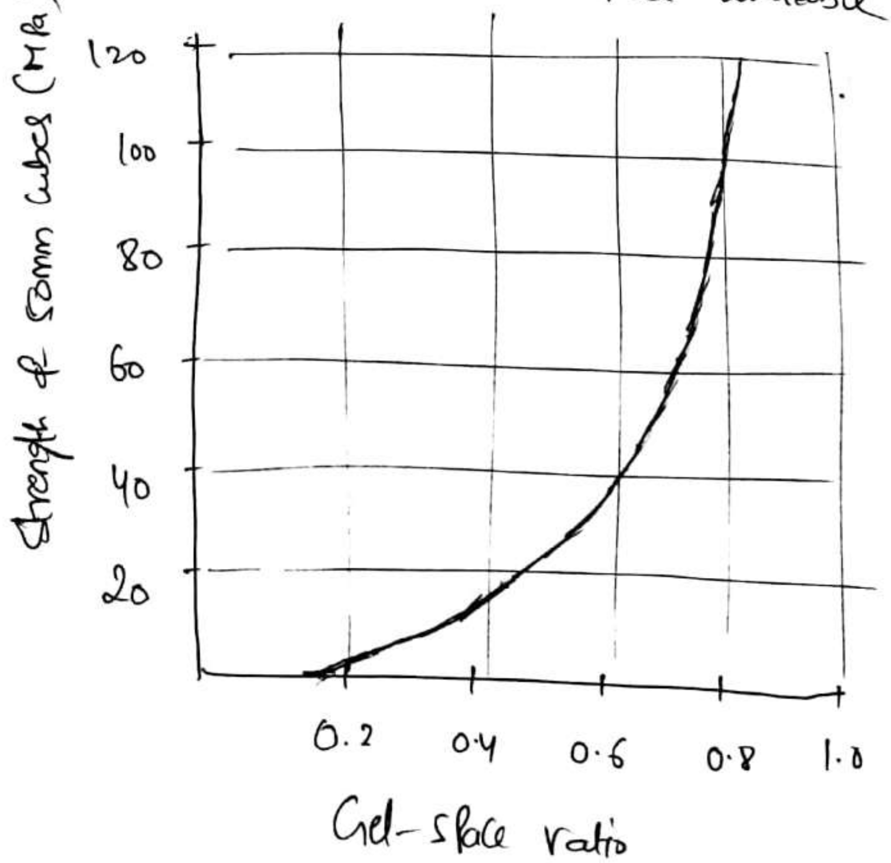
S = strength of Concrete

* Calculation of gel/space ratio for Complete hydration

$$\text{Gel/space ratio} = \frac{\text{Volume of gel}}{\text{Space available}}$$

* Calculation of gel/space ratio for Partial hydration,

$$\text{Gel/space ratio} = \frac{\text{Volume of gel}}{\text{Space available}}$$

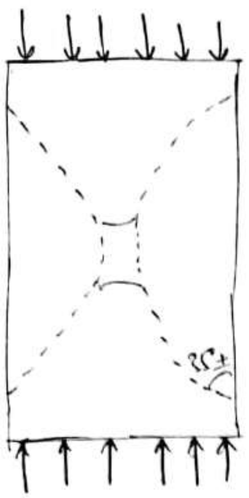


Nature of Strength of Concrete:-

Strength of Concrete is commonly considered its most valuable property, other characteristics such as durability and permeability may infact be more important. Strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste.

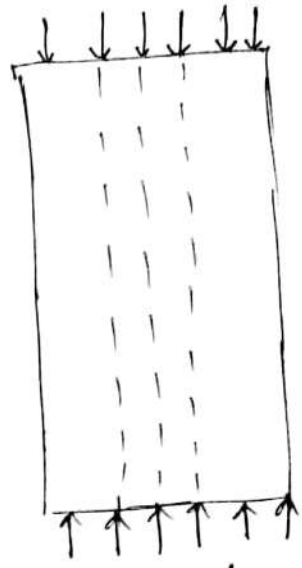
Strength of concrete could be defined as the ultimate load that causes failure (or its resistance to rupture) and its units are N/mm^2 (or) kN/mm^2.

The paramount influence of voids in concrete on its strength has been repeatedly mentioned, and it should be possible to relate this factor to the actual mechanism of failure. Rupture of concrete may be caused by applied tensile stress, shear stress (or) by compressive stress (or) a combination of two of the above stresses. ~~Rupture of Concrete may be caused by applied tensile stress~~ Concrete being a brittle material is much weaker in tension and shear than compression and failures of concrete specimens under compressive load are essentially shear failures on oblique planes.



Shear (or) Cone failure

Combination of Compressive, tensile and Shear



Columnar fracture

Strength may be classified as :

1) Compressive strength
2) Tensile strength
3) Shear strength and
4) Bond strength

1) Compressive strength :- For structural design the Compressive strength is taken as the criterion of quality of Concrete and the working stresses are prescribed as per codes in terms of percentages of Compressive strength.

2) Tensile strength :- Concrete being a brittle material is not expected to resist direct tensile ~~str~~ forces. Tension is of importance with regard to cracking, which is a tensile

failure. Most of the cracking is due to the restraint of contraction induced by drying shrinkage (or) lowering of temperature. The maximum tensile strength of concrete has been found of the order of 42 kg/cm². Some researchers have observed that the type of C.A has a greater relative effect on tensile strength than on compressive strength.

3) <u>Shear strength</u>:- Shear is the action of two equal and opposite parallel forces applied in planes a short distance apart. Shear stress cannot exist without accompanying tensile and compressive stresses. As the concrete is weaker in tension than in shear, failure in tension invariably occurs in diagonal tension.

4) <u>Bond strength</u>:- It can be defined as the resistance to slipping of the steel reinforcing bars which are embedded in concrete. This resistance is provided by the friction between concrete and steel and the friction between concrete and the lugs of deformed bars. In general, bond strength is approximately proportional to the compressive strength of concrete upto about 200 kg/cm². Bond strength varies considerably with the type of cement, admixtures and water cement ratio i.e., on quality of paste. It is not affected by air entrainment.

Relation between Compressive & Tensile strength:-

Tensile strength of Concrete is Proportional to the Square root of the Compressive strength.

* The Proportionality Constant depends on many factors, Such as the Concrete strength and the test method Used to determine the tensile strength.

The following are the relations :

Direct tensile strength $f_{ct} = 0.35\sqrt{f_c}$

Split tensile strength $f_{cts} = 0.50\sqrt{f_c}$

Flexural tensile strength $f_{ct} = 0.64\sqrt{f_c}$

} f_c in MPa

The tensile strength of Concrete is much lower than the compressive strength, largerly because of the Ease with which Cracks Can Propogate under tensile loads. The tensile strength of Concrete varies from 7% to 11% of the Compressive strength but on average it is taken as 10% of Compressive strength. further it has been observed that the higher the Compressive Strength, lower the relative tensile strength.

IS Code provides relationship as,

$$\text{Flexural strength} = 0.7\sqrt{f_{ck}}$$

Curing:- Concrete derives its strength by the hydration of Cement particles. The hydration of cement is not a momentary action but a process continuing for long time. The rate of hydration is fast to start with, but continues over a long time at a decreasing rate.

* Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. As long as free moisture and unhydrated cement exist inside the concrete, the strength, hardness and density will gradually increase.
* Curing is simply the process of keeping the hardened concrete moist so that it can continue to gain strength.
* If the concrete dries out, it stops gaining strength. This is why it is so important to cover your concrete right after casting and keep it moist.

Curing can be done in many different methods:

→ Water Curing

→ Steam Curing

→ Application of heat

→ Membrane Curing

→ Electrical Curing

Maturity Concept :-

Concrete maturity indicates how far curing has progressed. Maturity is the relationship between concrete temperature, time and strength gain. It is represented by an index value that can be measured in real time in the field.

Maturity of concrete is defined as the summation of the product of time (↳ Age) and temperature

$$\text{Maturity} = \Sigma(\text{Time} \times \text{temperature})$$

Its units are °C hr (or) °C days

Ex:- Concrete cured under 18°C for 28 days. Find Maturity.

$$\text{Maturity} = 28 \times 24\,[18 - (-11)]$$

$$= 19800\,°C\ hr$$

Note:- Hydration can take place at minimum of −11°C. Below this, water crystals (ice) do not react with cement.

Concrete is fully matured when it is cured at 18°C till 28 days. For an ordinary concrete maturity should not be less than 19800°C hr.

Factors affecting strength of Concrete:-

Factors affecting the strength of Concrete are:

1) Type of Cement
2) Type of aggregate
3) Richness of the mix
4) Curing temperature
5) Age of Concrete
6) Effect of Compaction
7) Aggregate - Cement ratio
8) Temperature at the time of Placing
9) Effect of loading Condition.

1) Type of Cement:- Type of Cement influences the strength development in Concrete to a great extent depending upon its chemical composition and fineness of grinding. The Percentage of C_3S in Concrete is responsible for the higher strength development upto 28 days, while C_2S Contributes to strength development after 28 days. In a well burnt modern Cement Clinker the C_3S Content is about 45% and that of C_2S is 25%. Their sum in most of the Cements Varies from 70%-80%. Thus in general the early strength say upto 28 days of Port-land Cement will be higher with high % of C_3S.

Scanned by CamScanner

and after that % of C_2S will affect the strength development of concrete. The presence of alkalis in cement also affects concrete strength after 28 days to a great extent. The greater the amount of alkalis present, lower the gain in strength. The finer the cement, rapid and greater the strength development.

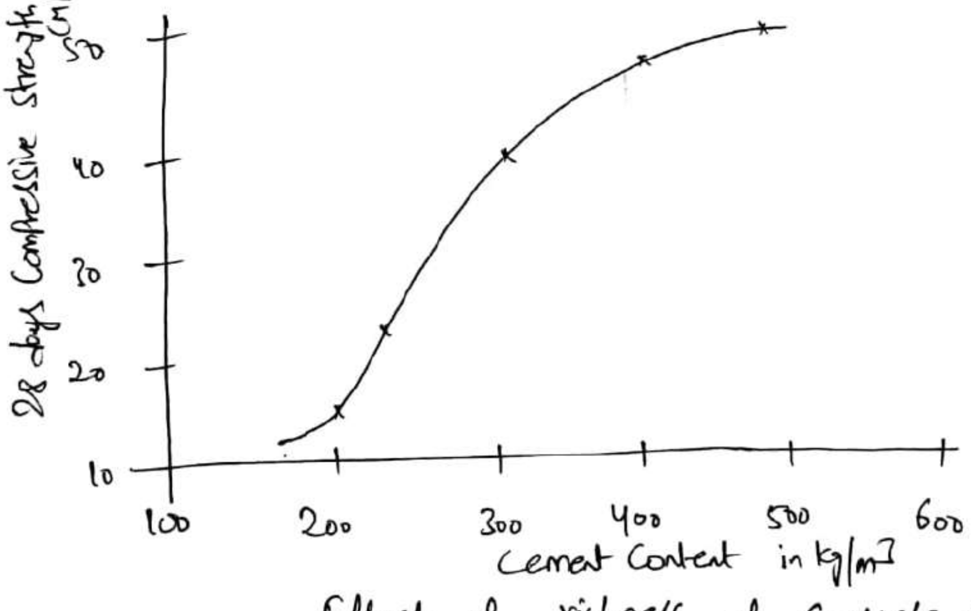
2) Type of aggregate :-

(a) Shape and texture of aggregates also affect the strength of concrete. Crushed rock aggregate with rough surface and angular particles develop about 15% higher strength in comparison of natural smooth surfaced gravel due to better bond between the aggregate and cement paste.

(b) Size of aggregate :- For the structural concrete, the maximum size of aggregate upto 38 mm has produced highest strength after which strength started declining. It may be due to the fact that larger the aggregate size, the smaller the surface area to be wetted per unit weight of aggregate. Above 38 mm (or) 40mm size aggregate, the gain of w/c is off set by the effect of lower bond area b/w aggregate & cement paste.

(C) Grading of Aggregate :- A well graded aggregate will produce a denser concrete resulting in higher strength. The influence of type of aggregate on the strength varies in magnitude and depends on w/c ratio of the mix. For w/c ratio less than 0.4, the use of crushed aggregate has been found to give higher strength more than 38% than with the use of natural gravel.

3) Richness of the mix :- for a particular workability, higher the cement content, lesser the amount of water required, resulting in higher strength.



Effect of richness of Concrete on its strength

4) Curing Temperature :- The strength development of concrete is based on maturity of concrete i.e, function of Time and temperature. Thus, the rise in temperature accelerates the chemical reaction of hydration and affects the Early strength of concrete.

5) Age of Concrete:- The strength in concrete is developed due to the hydration of cement. Different types of cement hydrate at different rate. Thus, the strength development in concrete continues. It was assumed that after 28 days, the rate of hydration is very small, nearly negligible, but recent studies have shown that rate of hydration continues upto 1 year. Strength after 1 year has been found 24% higher than the strength at 1 month.

6) Effect of Compaction:- It has been observed that each 1% of deficiency in compaction, results 5% reduction in compressive strength of concrete.

7) Aggregate - Cement ratio:- For a particular w/c ratio, higher strength is produced by a leaner mix. The leaner mix means greater aggregate/cement ratio. In lean mix having large amount of aggregate, obviously aggregate absorb significant amount of water from mix reducing effective w/c ratio.

8) Temperature at the time of Placing:- If the temperature is below 20°c the rate of hydration of cement will be very low resulting slow development of strength. on the other hand higher temperature during placing and setting will accelerate the process of hydration, but the quality of the

gel formed will be poor, resulting in low strength.

9) Effect of loading Condition:- several experiments Concluded that with variation of rate of loading on Concrete specimen, the strength varies proportionately.

→ At a higher rate of loading, the compressive strength increases.

→ The increment is from 30% to almost 50% of the original strength.

→ At lower rate of loading, the reduction in strength of Concrete Cube Compared to its true is insignificant.

Testing of Hardened Concrete

Strength of hardened concrete can be tested by Conducting compression tests, tensile tests, flexural tests and split-tensile tests.

Compression tests:- Determination of compressive strength plays a major role among all the other tests because the Concrete is primarily meant to withstand compressive stresses. Test for compressive strength is carried out either on cube (or) cylinder.

* For cube test two types of specimens either cubes of 15cm x 15cm x 15cm (or) 10cm x 10cm x 10cm depending upon the size of aggregate are used

* For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.
* Concrete is poured into the mould and tampered properly so as not to have any voids.
* After 24 hrs these moulds are removed and test specimens are put in water for curing at 27 ± 2°C.
* The top surface of these specimen should be made even and smooth.
* These specimens are cured for 7 days (or) 28 days and tested by compression testing machine.
* Load should be applied gradually at the rate of 140 kg/cm² per minute till the specimens fails.
* Compressive strength of concrete is obtained by dividing load at the failure by area of specimen.
* Average compressive strength of the concrete cube at 7 days & 28 days is calculated in N/mm².

Tension tests :- The tensile strength of the Concrete is determined by indirect test methods :

1) Split Cylinder test 2) Flexure test.

1) Split cylinder test :- It is the standard test to determine the tensile strength of Concrete in an indirect way.

* A standard test cylinder of Concrete specimen (300mm × 150mm Dia) is placed horizontally between the loading surfaces of Compression testing machine.

* The Compression load is applied diametrically and uniformly along the length of cylinder until the failure of the Cylinder along the vertical diameter.

* To allow the uniform distribution of this applied load and to reduce the magnitude of the high Compressive stresses near the points of application of this load, strips of Plywood are placed between the specimen and loading Platens of the testing machine.

* Concrete cylinders split into two halves along the vertical plane due to indirect tensile stresses generated by Poisson's effect. Due to this Compressive loading, an element lying along the vertical diameter of the cylinder is subjected to a vertical compressive stress and a horizontal stress.

* The loading condition produces a high compressive stress immediately below the loading points. But the larger portion of cylinder, corresponding to its depth is subjected to uniform tensile stress acting horizontally.

* It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension due to Poisson's effect.

Assuming concrete specimen behaves as an elastic body, a uniform lateral tensile stress of f_t acting along the vertical plane causes the failure of the specimen, which can be calculated as,

$$f_t = \frac{2P}{\pi DL}$$

P = Compressive load at failure

L = Length of cylinder

D = Diameter of cylinder.

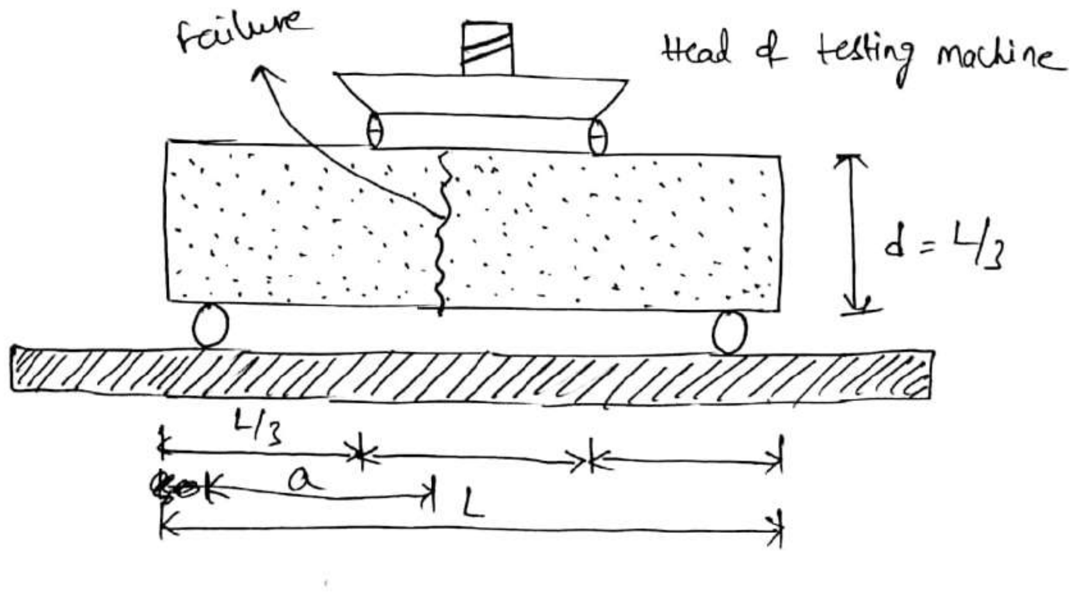
2) Flexure test :- Another common test performed for determination of tensile strength is the flexure test.

Apparatus:- Beam mould of size 15cm x 15cm x 70cm (when size of aggregate is less than 38mm) (or) of size 10x10x50cm (when size of aggregate is less than 19 mm), Tamping bar, Flexural test machine.

Procedure:-

* Prepare the test specimen by filling the Concrete into the Mould in 2 layers of approximately Equal thickness. Tamp Each layer 25 times using the tamping bar.
* Clean the bearing Surfaces of the Supporting and loading rollers, and remove any loose Sand (or) other material from the Surfaces of the Specimen.
* The test specimen after Curing shall be tested immediately on removal from water.
* The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers.

Third-Point loading



Flexural Strength test arrangement

* The load shall be applied at a rate of loading of 400 kg/min for the 15cm specimens and at a rate of 180 kg/min for the 10cm specimens.

The flexural strength (or) Modulus of rupture (f_b) is given by,

$$f_b = \frac{Pl}{bd^2} \quad (or) \quad f_b = \frac{3Pa}{bd^2}$$

If $a > 200$ mm for 150 mm specimen, $a > 133$ mm for 100 mm specimen → $f_b = \frac{Pl}{bd^2}$

If $a < 200$ & $a > 170$ for 150 mm specimen; If $a < 133$ mm & $a > 110$ mm for 100 mm specimen → $f_b = \frac{3Pa}{bd^2}$

a = Distance b/w the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = Width of specimen (Cm)

d = failure point depth (Cm)

l = Supported length (Cm)

P = max. load (Kg)

Pull-out tests :- A Pull-out test measures the force required to pull a specifically shaped steel rod (or) disc out of the hardened concrete into which it has been cast. The concrete pull out test is done by

1) LOK Test method and
2) CAPO test method

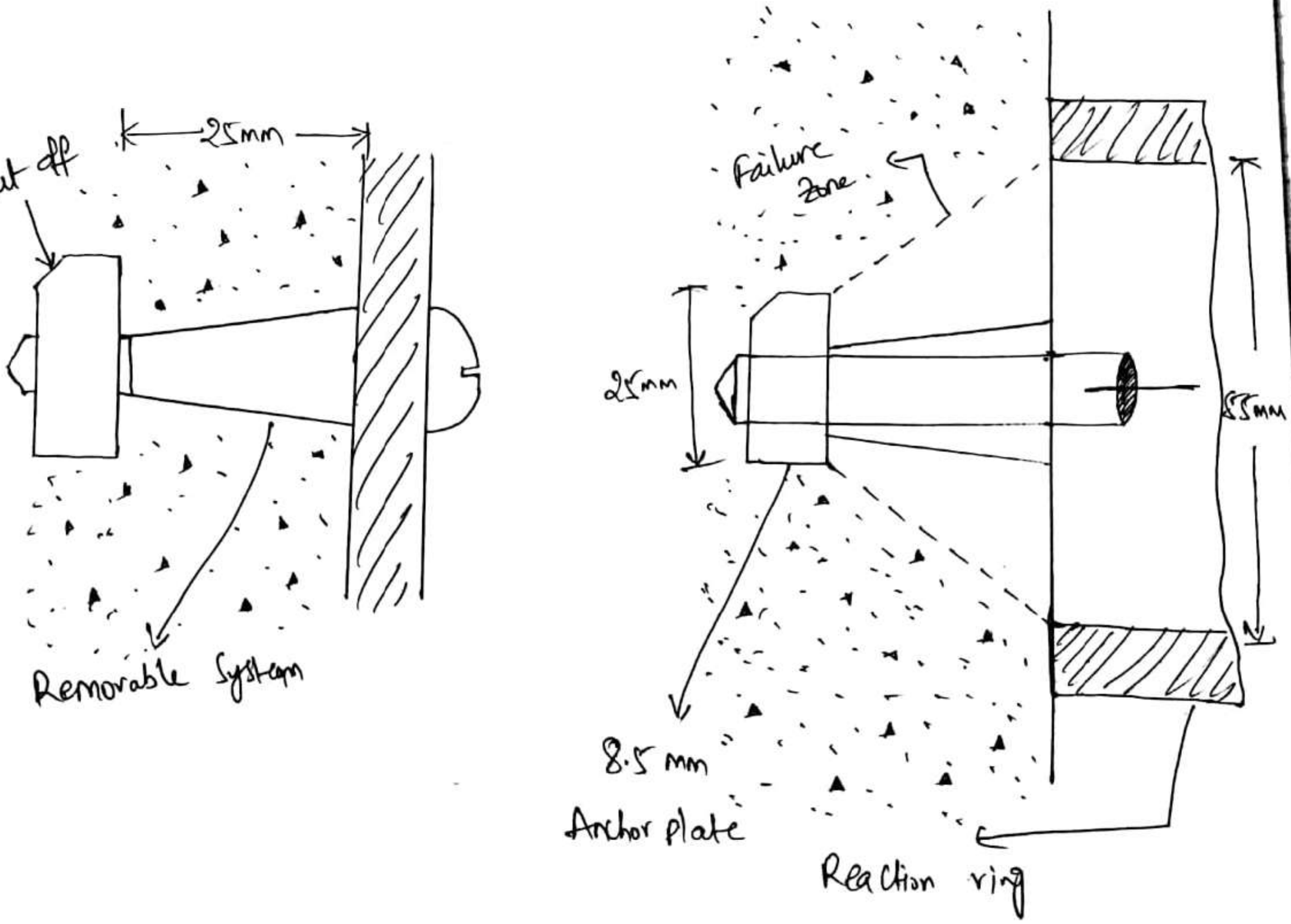
1) **Lok Test :-**

Principle :- It is the measure of force required to pull a 25mm diameter cast in steel disc.

Procedure :-

* steel disc is embedded to 25mm depth in fresh concrete at the time of concreting.

* The steel disc is Precisely embedded in Concrete so that air voids are not formed below the steel disc.
* Pull bolt is attached to the steel disc and after the Curing Period, the 25mm steel disc is Pulled until failure of the Concrete occurs.
* As the Lok test insert (steel disc) is Pulled out, a roughly cone shaped fragment of the Concrete is extracted and the Pull out force is measured.
* This test is Carried out for early age strength estimation, to find out the Compressive strength with the help of Calibration Curve.



Lok Test insert

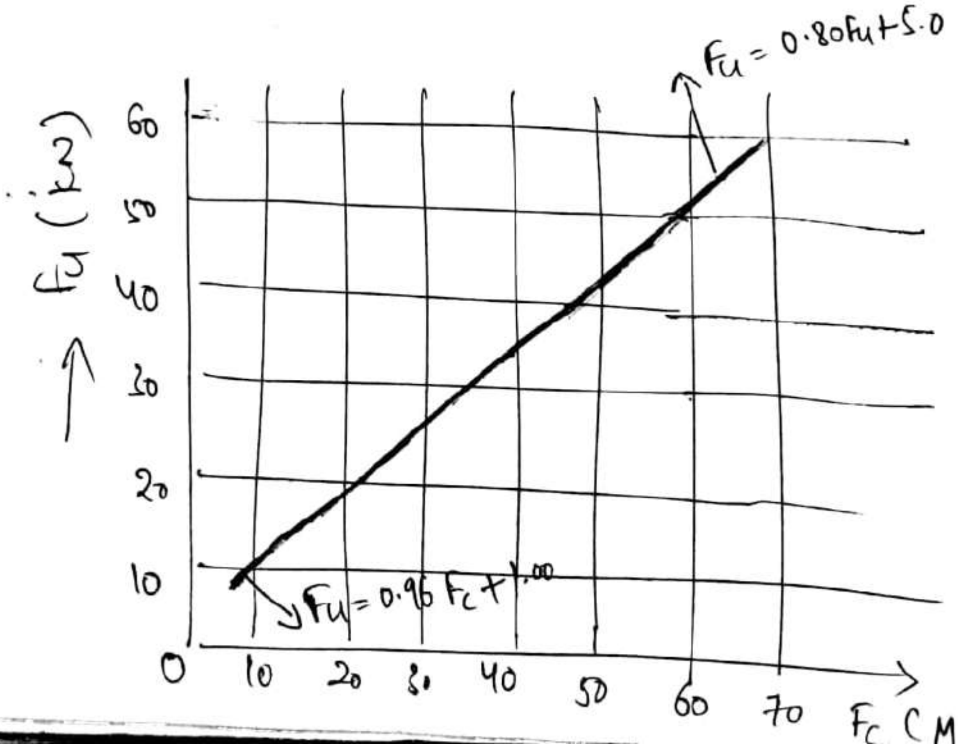
2) CAPO Test:-

Principle:- It is allo known as Cut And Pull out test.
Principle is Same as Pull out test.

Equipment:- Pull Machine, Drill machine, Preparation kit, Suction Plate

Procedure:-

* A steel ring is Used and expanded into a recessed groove at a depth of 25mm and is pulled against a Counter Pressure as with Lok test.
* A ring is split by sideward cutting at one location, Compressed and governed through a Centre hole into a 25mm groove, 25mm deep, where it is expanded.
* The groove is recessed in CAPO test through a Centre hole by a diamond drill with the drill bit which is large at the tip.
* Measure the pull force from the Equipment and find out the Compressive strength with the help of typical Pull force Calibration chart.



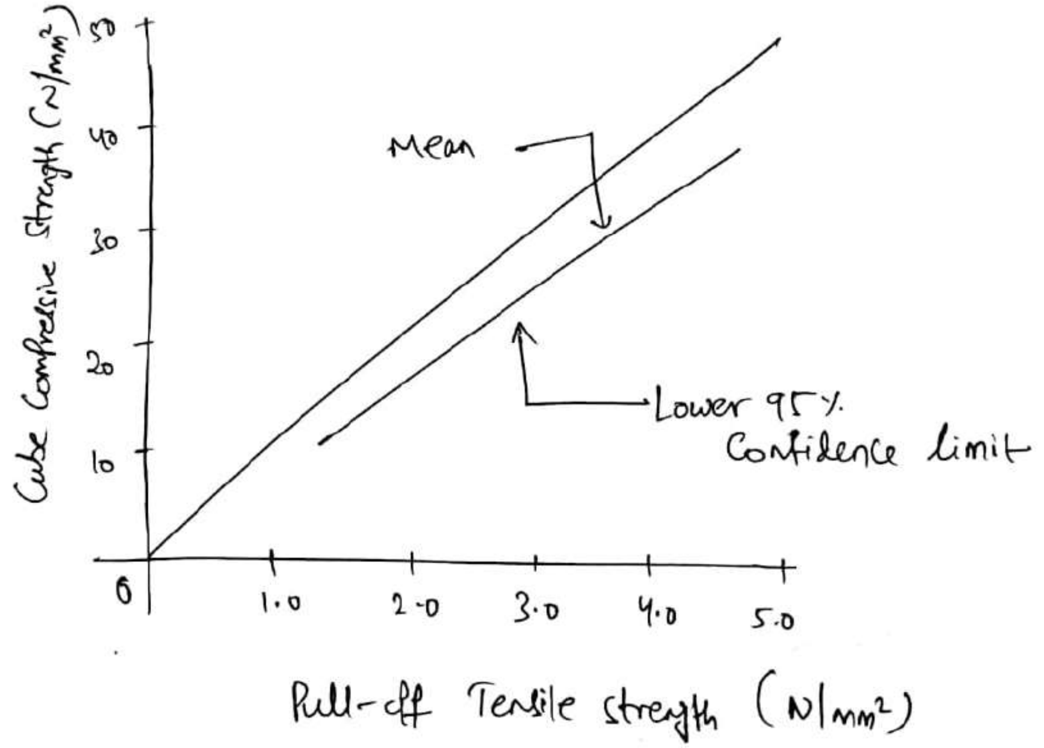
Max. Aggregate size = 38mm

* The CAPO test method offers greater flexibility for conducting the in-situ concrete test on the hardened concrete of existing structures.
* The compressive strength can be considered as proportional to the ultimate pull force.
* Concrete volumes of greater depth can be tested by using this pull-out test methods.

Pull off Test :-

* In pull off test, the traction force (pull force) required to pull off a metallic disc bonded to a surface of the concrete is related to the compressive strength of the material.
* The traction is axially transmitted to the disc previously bonded to the concrete with the help of resin (or) adhesive.
* After a period of time enough to cure the resin (or) adhesive, a traction force (pull force) is applied to the disc by potable mechanical equipment.
* The gradual increase of force in MPa can be measured in equipment that has an integrated digital manometer.
* The gradual increase in pull force cause breakage and can directly record on a scale and maximum tension is logged, as soon as the pull off of concrete happens.

* Relate the Pull off force with the Calibration Curves and estimate the compressive strength.
* The test was conducted with a surface cut of 5mm deep according to the dimension of the metallic disc. The surface cut is necessary for the surface which is affected by carbonation effect.
* The surface needs to be clean before the bonding of metallic disc with concrete.

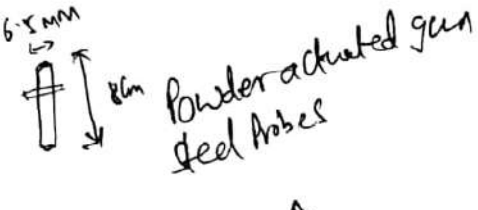


Non-Destructive Test Methods (NDT)

Non-Destructive testing of Concrete is a method to obtain the Compressive strength and other Properties of Concrete from the existing structures. This test Provides immediate results and actual strength and Properties of Concrete structures. The standard method of Evaluating the quality of Concrete in buildings (or) structures is to test specimens Cast simultaneously for Compressive, flexural and tensile strengths. These test methods depend on the fact that certain physical Properties of Concrete Can be related to strength and Can be measured by non-destructive methods. Such Properties include hardness, resistance to Penetration by Projectiles, rebound Capacity and ability to transmit ultrasonic Pulses and x-rays and γ-rays.

Following are different methods of NDT on Concrete.

1) Penetration method
2) Rebound hammer method
3) Ultrasonic Pulse velocity method
4) Radioactive methods



1) Penetration tests :-

* The Equipment used for Penetration test is Windsor Probe.
* The Equipment Consists of a Powder-actuated gun (or) driver, hardened alloy Probes, loaded Cartridges, a depth gauge for measuring Penetration of Probes etc

* A Probe of diameter 6.5 mm and length 8cm is driven into the Concrete by means of a Precision Powder Charge.
* The instrument should be Calibrated for type of Concrete and type and size of aggregate used.
* Depth of Penetration should be noted and by using Calibration charts and Penetration depth, Compressive strength of Concrete is calculated.
* The Probe test Produces quite variable results and should not be expected to give accurate values of Concrete strength.
* It has the Potential for Providing quick means of Checking quality and maturity of in-situ Concrete.
* It also Provides a means of assessing strength development with Curing.
* The test is essentially Non-destructive, since Concrete and structural members Can be tested in-situ, with only minor Patching of holes on exposed faces.

2) Rebound - hammer Method :-

* The Rebound hammer is a surface hardness tester for which an empirical correlation has been established between strength and rebound number.
* The instrument used for testing concrete to make use of rebound principle is Schmidt hammer. Its weight is about 1.8 kg and is suitable for both laboratory and field work.
* It consists of a spring-controlled hammer mass that slides on a plunger within a tubular housing.
* The hammer is forced against the surface of the concrete by the spring and the distance of rebound is measured on a scale.
* The test surface can be horizontal, vertical (or) at any angle but the instrument must be calibrated in this position.
* By using the calibration charts and taking several readings, the average value representing the rebound number is calculated.

>40	very good hard layer
30-40	Good
20-30	fair
<20	Poor
0	Delaminated

* The Schmidt hammer provides an inexpensive, simple and quick method of obtaining an indication of strength, but accuracy of ±15 to ±20 % is possible only for specimens cast cured and tested under conditions for which calibration curves have been established.

* The results are affected by factors such as smoothness of surface, size and shape of specimen, moisture condition of the concrete, type of C.A & extent of carbonation of surface.

3) Ultrasonic Pulse velocity method :- Transducers

* This is a ~~more~~ Dynamic Non-Destructive test method conducted on concrete.
* This method is the only one of this type which shows potential for testing concrete strength in-situ.
* It measures the time of travel of an ultrasonic pulse passing through the concrete.
* The instrument consists of a pulse generator and a pulse receiver.
* Pulses are generated by shock-exciting piezo-electric crystals, with similar crystals used in the receiver.
* The time taken ~~by~~ for the pulse to pass through the concrete is measured by electronic measuring circuits.
* Pulse velocity tests can be carried out on both laboratory-sized specimens and completed concrete structures.
* If large differences in pulse velocity are found within a structure, it indicates that defective (or) deteriorated concrete is present.

* High Pulse velocity readings are generally indicative of good quality concrete.

direct
Semi - direct
Indirect

Quality of Concrete & Pulse velocity

General Conditions	Pulse velocity ft/sec
Excellent	Above 15,000
Good	12,000 - 15,000
Questionable	10,000 - 12,000
Poor	7,000 - 10,000
very Poor	7000

* The Pulse velocity method has been used to study the effects on Concrete of freeze-thaw action, Sulphate attack, and acidic waters.
* The degree of damage is related to a reduction in Pulse velocity. Cracks can also be detected.
* This method can also be uced to estimate the rate of hardening and strength development of concrete in the early stages to determine when to remove formwork.
* Ultrasonic Pulse velocity tests have a great Potential for Concrete Control, Particularly for establishing uniformity and detecting cracks (or) defects.
* The Presence of r/f steel in Concrete has an appreciable effect on Pulse velocity.

4) Radioactive method :-

* Radioactive methods of testing Concrete can be used to detect the location of reinforcement, measure density and perhaps establish whether honeycombing has occured in structural concrete units.

* These include the X-ray and Gamma ray Penetration for measurement of density and thickness of Concrete.

* Also, the neutron scattering and neutron activation methods are used for moisture and cement content determination.

* Gamma radiation of known intensity is made to pass and penetrate through concrete and the intensity at other face is measured and from this the thickness of member is calculated.

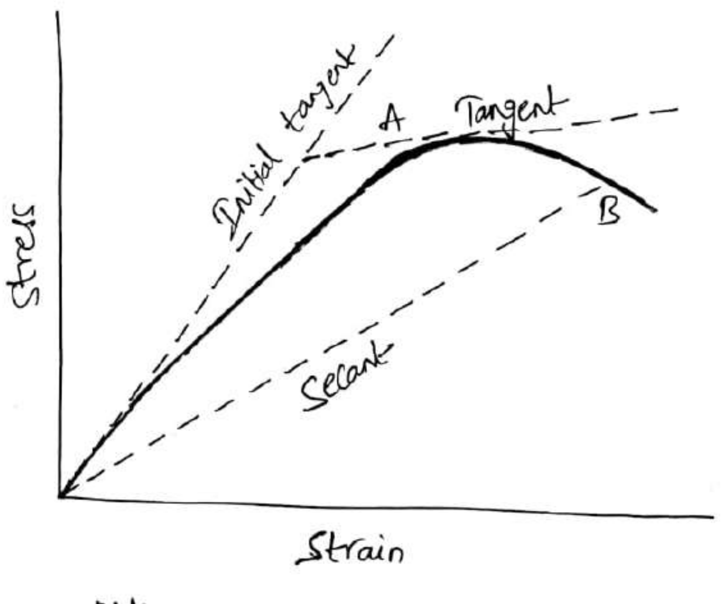
* The detectors for the radiometry techniques absorb a portion of the radiation and turn it into electrical pulses (or) currents, which can be counted (or) analyzed.

* Geiger - Muller tubes were used widely in nuclear density gauges. Gamma rays ionize some of the gas in the tube. When the amount of ionization is then multiplied by a high voltage applied across the tube, it produces an electrical pulse, which indicates the radiation.

Elasticity, Creep & shrinkage:-

Modulus of Elasticity

The modulus of Elasticity of concrete would be a Property for the Case when the material is treated as elastic. The modulus of Elasticity of Concrete is a function of the modulus of Elasticity of the aggregates and the Cement matrix and their relative Proportions. If we Consider the stress-strain Curve of the first cycle, the modulus Could be defined as initial tangent modulus, Secant modulus, tangent modulus (or) Chord modulus.



Different Modulii of Elasticity

For the determination of the modulus of Elasticity of Concrete, a cylinder is loaded and unloaded for 3 (or) 4 cycles, the stress-strain Curve is plotted after residual strain has become almost negligible and the average slope of stress-strain Curve is taken.

The indian Code of Practice recommends, $E_c = 5000\sqrt{f_{ck}}$

* As the elastic modulus increases, the material becomes stiffer and brittle. As the concrete is more brittle, the modulus of elasticity of concrete is b/w 25-50 GPa (whereas steel is, 200 GPa)

Factors affecting elastic modulus of concrete are:

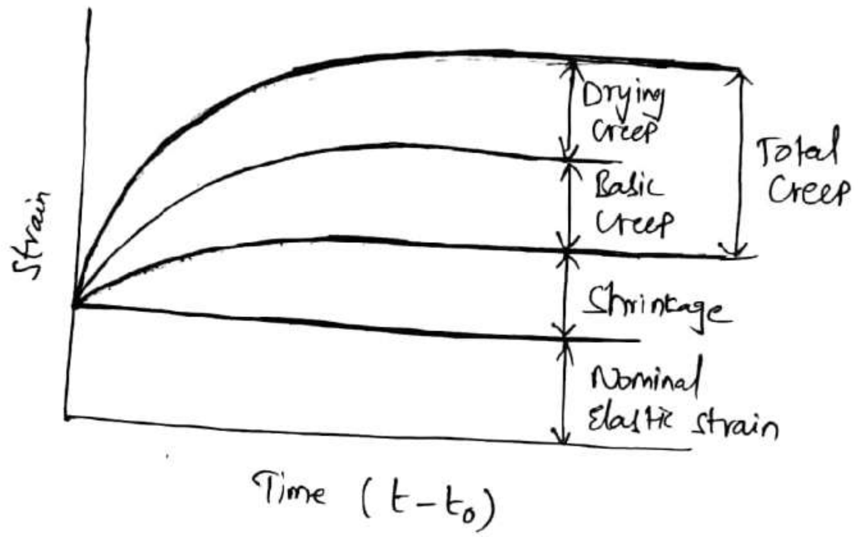
* Coarse aggregate properties → The higher the volume of aggregate in the mix, the higher the elastic modulus.
* Mix design → which includes total cementitious content and w/c ratio. Less paste is good for higher elastic modulus.
* Curing conditions → Moist cured specimen showed better results than that of dry cured, due to shrinkage and associated cracks.
* Loading rate → High loading rate will result in higher compressive strength and higher elastic modulus.

The most important factor influencing the elastic modulus of concrete is the aggregate used. It is also affected by the aggregate/cement ratio and the age of concrete.

Creep:-

Creep is time dependent deformation of concrete under permanant loads (self weight). When concrete is subjected to compressive loading it deforms instantaneously. If the load is maintained for a considerable period of time, concrete undergoes additional deformations even without any increase in load.

This time-dependent strain is termed as creep. In R/f concrete beams, creep increases the deflection with time and may be a critical consideration is given in design. In eccentrically loaded columns, creep increases the deflection and can lead to buckling. In Mass concrete structures such as dams, on account of differential temperature conditions at the interior and surface, creep is harmful and by itself may be a cause of cracking in the interior of dams.



Relationship between creep and elastic deformations,

$$\varepsilon_{cr} = \varepsilon_{el}\,\phi$$

$$= \frac{\sigma}{E_{28}}\,\phi$$

Where ε_{cr} = Creep strain

ε_{el} = Elastic strain

σ = Stress

E_{28} = Elastic modulus of concrete at 28 days

ϕ = Creep factor

Factors affecting Creep :-

* Concrete mix Proportion → A Poorer Paste structure undergoes a higher creep. Creep increases with increase in w/c ratio.
* Aggregate Properties → light weight aggregate shows Substantially higher Creep than normal weight aggregate.
* Age at loading → Age at which a Concrete member is loaded will have a Predominant effect on the magnitude of Creep.
* Curing Condition → larger the curing smaller the Creep.
* Cement Properties → The type of Cement effects creep in So far as it influence the strength of the Concrete at the time of application of load. Fineness of cement affects the strength development at early ages and thus influence Creep. The finer the cement the higher its gypsum requirement so that re grinding of cement in laboratory without the addition of gypsum Produces an improperly retarded Cement, which exhibits high Creep.
* Temperature → The rate of Creep increases with temperature upto about 70°c. It is approximately 3.5 times higher than 21°c.
* Stress level → There is a direct Proportion b/w Creep and applied stress. Higher the stress higher will be the Creep.

Shrinkage:-

The volumetric changes of concrete structures due to the loss of moisture by evaporation is known as concrete shrinkage (or) shrinkage of concrete. It is a time-dependant deformation which reduces the volume of concrete without the impact of internal forces.

Types of shrinkage:-

1) Plastic Shrinkage:- Plastic shrinkage occurs very ~~soon after~~ soon after pouring the concrete in the forms. The hydration of cement results in a reduction in the volume of concrete due to evaporation from the surface of concrete, which leads to cracking.

~~2) Drying shrinkage:- It occurs very soon after pouring the concrete in the forms. The hydration of cement results in a reduction in the volume of concrete due to evaporation from the surface of concrete~~

2) Drying Shrinkage:- The shrinkage that appears after the setting and hardening of the concrete mixture due to loss of capillary water is known as drying shrinkage. Drying shrinkage generally occurs in the first few months and decreases with time.

3) Carbonation Shrinkage:- It occurs due to the reaction of CO_2 with the hydrated cement materials, carbonating $Ca(OH)_2$ to $CaCO_3$. The carbonation slowly penetrates

the outer surface of the Concrete. This type of shrinkage mainly occurs at medium humidities and results in increased strength and reduced permeability.

4) Autogenous shrinkage:- It occurs due to no moisture movement from concrete paste under constant temperature. It is a minor problem in concrete and can be ignored.

Factors Affecting shrinkage:-

* Water-cement ratio → Shrinkage increases with the increase in w/c ratio.

* Environmental Condition → It is one of the major factors that affect the total volume of shrinkage. Shrinkage is mostly occured due to the drying condition of the atmosphere. It increases with the decrease in the humidity.

* Time → The rate of shrinkage rapidly decreases with time. It is found that 14-34% of the 20 yrs shrinkage occurs in two weeks, 40-80% shrinkage occurs in three months and the rest 66-85% shrinkage occurs in one year.

* Type of Aggregate → Aggregates with moisture movement and low elastic modulus cause large shrinkage. The rate of shrinkage generally decreases with the increase of the size of aggregates. It is found that concrete made from sandstone shrinks twice than the concrete of limestone.

Other factors that affect the shrinkage of Concrete are the type and quantity of cement, Granular and micro biological Composition of aggregates, the strength of Concrete, the method of Curing and the dimensions of elements etc.

Effects of shrinkage:-

* Shrinkage of Concrete between movement joints causes joints to open (or) makes it wider. Therefore joints must be designed to accommodate the widening caused by shrinkage.
* Shrinkage causes relative movement between ceramic tiles which are fixed on top of Concrete surface. The resulting stresses can causes failures at the interface.
* Shrinkage of the concrete causes the Concrete to grip r/f bars more tightly. This increases friction b/w Concrete & steel and so improves bond strength.

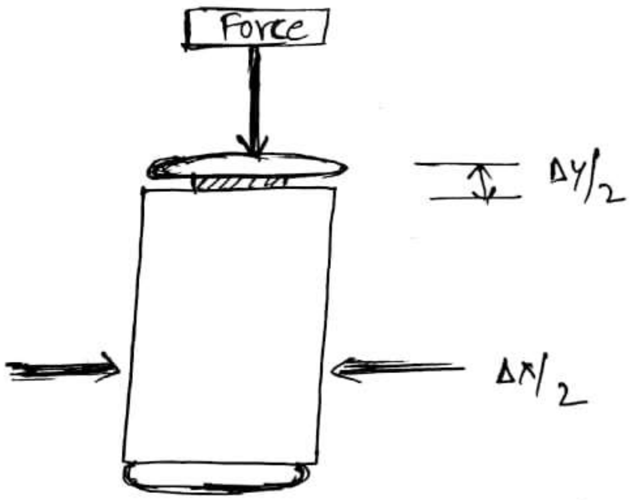
⇒ Poisson's Ratio:-

Poisson's Ratio is the ratio of lateral strain to longitudinal strains. It is represented by:

$$= \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

When compressive force acts on a specimen, then with the increase in force. Two types of strains that will crop in the specimen of concrete. Both strains are opposite in direction, one is along x-axis that we call as longitudinal strain and second is in vertical direction, that is produced due to reduction in volume (when compressive load acts on specimen). These strains are named as:

1) Lateral strains (vertical strains)
2) Longitudinal strains (horizontal strains)



$$\text{Poisson's ratio} \Rightarrow V = \frac{(\Delta X/2)}{(\Delta Y/2)}$$

Practically it ranges from 0 to 0.5. Poisson's ratio of concrete is generally 0.15 and for high strength concretes it varies from 0.15 – 0.2.

→ Problem on Maturity concept of concrete

Table 6 plowman's coefficients for Maturity Equation

Strength after 28 days at 18°c (Maturity of 19,800°ch), MPa	Co-efficient	
	A	B
less than 17.5	10	68
17.5 – 35.0	21	61
35.0 – 52.5	32	54
52.5 – 70.0	42	46.5

[Strength at any maturity as a Percentage of Strength at maturity of]

The Percentage strength of concrete at maturity

$$= A + B \log_{10} \frac{(\text{Maturity})}{1000}$$

The values of coefficients A and B depends on the Strength level of Concrete. These values are given in Table

Problem :-

Q!- The strength of a Sample of fully matured Concrete is found to be 40.00 Mpa. find the strength of identical concrete at the age of 7 days. when Cured at an avg. temparature during day time at 20°c, and night time at 10°c ?

Sol :-

Maturity of concrete at the age of 7 days

$$= \Sigma (\text{time} \times \text{temparature})$$

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

$$= 7 \times 12 \times 31 + 7 \times 12 \times 21$$

$$= 4368\,^\circ ch.$$

The strength range of this Concrete falls in zone III for which the constants

$A = 32$ and

$B = 54$.

∴ The Percentage strength of Concrete at maturity of

$$4368\,^\circ ch = A + B \log_{10} \frac{(\text{maturity})}{1000}$$

$$4368\,^\circ ch = 32 + 54 \log_{10} \frac{4368}{1000}$$

$$= 32 + 54 \times 0.6403$$

$$= 66.5$$

∴ The strength at 7 days $= 40.00 \times \frac{66.5}{100}$

$$S = 26.5 \text{ Mpa}$$

UNIT - V

MIX DESIGN & SPECIAL CONCRETES

Mix Design:-

Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as concrete mix = cement : sand : aggregates.

The concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions. This process is usually adopted for structures which requires higher grades of concrete such as M_{25} and above and large construction projects where quantity of concrete consumption is huge. Mix design provides the right proportions of materials, thus making the concrete construction economical in achieving required strength of structural members. As, the quantity of concrete required for large constructions are huge, economy in quantity of materials such as cement makes the project construction economical.

Generally, M_{10}, M_{15}, M_{20} → ordinary concrete

$M_{25} - M_{55}$ → standard concrete

$M_{60} - M_{80}$ → High strength concrete

Factors influencing the Choice of Mix Proportions:-

According to IS:456-2000 and IS:1343-1980, the design of Concrete Mix should be based on:

(i) Grade designation:- The grade designation gives Characteristic Compressive strength requirements of the Concrete. As per IS:456-2000, the Characteristic Compressive strength is defined as that value below which not more than 5% of the test results are expected to fall. It is the Major factor influencing the mix design. Depending upon the degree of Control available at the site, the Concrete mix has to be designed for a target mean Compressive strength which is somewhat higher than the Characteristic strength.

(ii) Type & Grade of Cement:- The type of cement is important mainly through its influence on the rate of development of Compressive strength of Concrete. The higher the strength of Cement used in Concrete, lesser will be the Cement Content. The use of 43 & 53 grade of Cement, gives Saving in cement consumption as much as 15% & 25% respectively, as compared to 33 grade of cement. For Concrete of M_{25} grade, it is advisable to use 43 & 53 grade of cement.

(iii) Maximum Nominal size of aggregates:- The maximum size of C.A should not be more than 1/4 th of minimum thickness of the member. The workability of concrete increases with an increase in the maximum size of aggregate. But the smaller size of aggregates provide larger surface area for bonding with the mortar matrix which gives higher strength.

(iv) Grading of Combined aggregates:- The relative proportions of F.A & C.A in a concrete mix is one of the important factors affecting the strength of concrete. For dense concrete, it is essential that the F.A & C.A be well graded.

(v) Maximum w/c ratio:- Abram's w/c ratio states that for any given condition of test, the strength of a workability concrete mix is dependent only on w/c ratio. The lower the w/c ratio, the greater is the compressive strength.

(vi) Workability:- Workability of fresh concrete determines the ease with which a concrete mixture can be mixed, transported placed, compacted & finished without harmful segregation & bleeding.

(vii) Durability:- Durability requires low w/c ratio. It is usually achieved not by increasing the cement content, but by lowering the water demand at a given cement content. Water demand can be lowered by thorough control of the aggregate grading and by using water reducing admixtures.

Methods of Concrete Mix design:-

Some of the Commonly used mix design methods are:

* IS method
* A.C.I Method
* Road Note 4 method (U'K Method)
* IRC 44 Method
* Arbitrary method
* Maximum Density Method
* Fineness Modulus Method
* Surface area Method
* Mix design for high strength Concrete
* Mix design for Pumpable Concrete
* DOE mix design method (British)

IS Method of Mix design:-

* The Bureau of Indian Standards, recommended a set of Procedure for design of Concrete mix. The Procedure is based on the research work Carried out at national laboratories.
* Data required for mix design: (IS 456 : 2000)

→ Characteristic Compressive strength only a few Specified Proportions of test results are expected to fall of Concrete at 28 days (f_{ck}).

→ Degree of workability desired.

→ Limitation on w/c ratio with the minimum Cement to ensure adequate durability.

→ Type and Maximum size of aggregate to be used.

→ Standard deviation of Compressive strength of Concrete.

The following is an example for mix design by I.S Method.

Generally, M_5, $M_{7.5}$, M_{10}, M_{15}, M_{20} → ordinary concrete

$M_{25} - M_{55}$ → standard Concrete

$M_{60} - M_{80}$ → High Strength concrete

for ordinary concretes Mix Proportions were

$M_5 = 1:5:10$

$M_{7.5} = 1:4:8$

$M_{10} = 1:3:6$

$M_{15} = 1:2:4$

$M_{20} = 1:1.5:3$

For Grades of Concretes of greater than M_{20}, we go for mix design Procedure ~~for~~ by I.S Method.

⇒ <u>Standard Deviation</u>:- As with all Construction Materials, Concrete quality can vary depending on batching, mixing & placing processes site Supervision & Control. Not every portion of batched volume will have strength same as targeted value. Inorder to take this non-uniformity standard deviation is adopted. Standard deviation values for given in IS:456 2000 Table 8 Page: 23 (or) 10262 : 2009.

Calculate mix Proportion for M_{25} grade of Concrete

Data required (M_{25})

1) Concrete Mix design stipulation

(a) Characteristic Compressive strength = M_{25}

(b) Nominal Max. size of aggregate = 20mm

(c) Shape of C.A = Angular

(d) Degree of workability = 50-75 mm (slump)

(e) Degree of Quality Control = As Per IS:456

(f) Type of exposure = Mild

(g) Type of Cement = OPC

(h) Method of Concrete Placing = Pumpable

2) Test data of material (In laboratory)

(a) Specific gravity of Cement - 3.15

(b) S.G of F.A - 2.64

(c) S.G of C.A - 2.84

(d) Aggregate - Saturated Surface dry Condition

(e) Fine Aggregate Confirming to Zone - II of IS-383

Procedure

Step 1:- Target strength

$$f_{ck}' = f_{ck} + 1.65 \times S$$

$$= 25 + 1.65 \times 4 = 31.6 \text{ N/mm}^2$$

where S = Standard Deviation according to IS 456 : 2000
Table 8, Pg: 23 (or) IS: 10262 - 2009

Step 2:- w/c ratio depends on exposure

from table 5 of IS 456, (Pg No: 20)

Max. w/c ratio for Mild exposure (0.55)

Based on experiments conducted, adopted w/c ratio as 0.5

[Trial & error method, By using admixture our aim is to decrease the water content so that gaining higher strength, so adopt a value of 0.05 substracting from the chosen w/c ratio. Thus, 0.55 − 0.05
= 0.5]

0.5 < 0.55 ⇒ Hence OK ✓

Step 3:- Selection of water content

A/c to Table 2 of IS 10262-2009, Page : 3

Maximum water content = 186 kg (for 20mm Agg)

→ 186 is for 25-50mm slump

we can increase 3% for every 25mm increase in slump

Pg: 2 IS 10262 : 2009; Clause 4.2

25–50 ↑ 75 → 3% ⇒ $186 + \left(\frac{3}{100} \times 186\right)$

Corrected water content = 191.6 kg/m³ (or) 191.6 ltrs

Note:- When admixture used w.c is reduced by 15% ⇒ $191.6 - \left(\frac{15}{100} \times 191.6\right)$

=

Step 4:- Selection of Cement Content

W/C = 0.5

Corrected W.C = 191.6 kg/m³

Cement Content = As per IS 456 : 2000 Pg: 20

Cement = 300 kg/m³

W/C ratio = 0.5.

Water Used = 191.6 lt

$$\text{Cement Content} = \frac{W.C}{W/C \text{ ratio}}$$

$$= \frac{191.6}{0.5} = 383.2 > 300$$

= Hence ok

Step 5:- Volume of C.A & F.A Content

A/C to IS 10262 : 2009 Pg: 3

20mm Size - Zone II - W/C = 0.5 ⇒ Vol of C.A = 0.62

If it is 0.4 ⇒ 0.5 - 0.4 = 0.1   0.05 → 0.01
0.05 → 0.01
0.02

Increased by 2% ⇒ 0.02 (±0.01 for every 0.05 change in W/C)

For Pumpable Concrete, these values are reduced by 10%

Vol. of C.A = 0.62 × 0.9 = 0.56

Vol. of F.A = 1 - 0.56 = 0.44

Step 6:- Mix Calculations

a) Volume of Concrete = 1 M^3

b) Volume of Cement = $\frac{\text{Mass of Cement}}{\text{S.G of Cement}} \times \frac{1}{1000}$

$= \frac{383.2}{3.15} \times \frac{1}{1000}$

$= 0.1216\ m^3$

c) Volume of Water = $\frac{\text{Mass of water}}{\text{S.G of water}} \times \frac{1}{1000}$

$= \frac{191.6}{1} \times \frac{1}{1000}$

$= 0.191\ M^3$

d) Vol. of Chemical admixture = $\frac{\text{Mass of admixture}}{\text{S.G of admixture}} \times \frac{1}{1000}$

$= \frac{7.664}{1.145} \times \frac{1}{1000}$

$= 0.0066$

e) Vol. of all in aggregate = $[a - (b+c+d)]$

$= [1 - (0.1216 + 0.191 + 0.0066)]$

$= 1 - 0.3192 = 0.6808\ M^3$

f) Mass of F.A = e × vol of C.A × S.G of C.A × 1000

$= 0.6808 \times 2.84 \times 0.56 \times 1000$

$= 1082.744$ kg

9) Mass of F.A = e × vol. of F.A × S.G of F.A × 1000

= 0.6808 × 0.44 × 2.64 × 1000

= 790.81 kg

Step 7:- Mix Proportions

Cement = 382.2 kg/m³

Water = 191 kg/m³

F.A = 790.81 kg/m³

C.A = 1082.744 kg/m³

By adjusting w/c ratio we have to design mix for 3 trial mixes

ACI Method of mix design:-

* In the USA the method suggested by ACI is widely used. It has the advantages of simplicity in that it applies equally well and with more (or) less identical procedure to rounded (or) angular aggregate to normal (or) lightweight aggregate and to air-entrained (or) non-air-entrained concretes.
* The ACI Method is based on the fact that for a given size of well graded aggregates water content is largely independent of mix proportions, i.e., water content regardless of variation in w/c ratio and cement content.

* This method assumes that the optimum ratio of the bulk volume of C.A and on the grading of fine Aggregates regardless of shape of Particles. This method also assumes that even after complete compaction is done, a definite percentage of air remains which is inversely proportional to the maximum size of aggregate.

Eg:- Design a concrete mix using ACI method for a multi-storeyed building for the following data

* 28 days characteristic compressive strength - 30 MPa
* Type of cement - OPC
* Desired slump - 80-100 mm
* Max. size of aggregate - 20 mm
* S.D - 4.5 MPa
* Specific gravity of F.A - 2.65
* Specific gravity of C.A - 2.7
* S.G of Cement - 3.15
* Bulk density of C.A = 1600 kg/m^3
* Fineness Modulus of F.A = 2.8
* C.A absorbed 1 % moisture & sand contains 1.5% free moisture
* Assume any other data

Step - I Mean design strength $f_M = f_{min} + k.s$

$= 30 + 1.65 \times 4.5$

$= 37.425$ MPa

From Table 9.4, Assume 5% test results are expected to fall

$K = 1.65$

Step II :-

From table 9.1 for mean design strength of 37.425 MPa, the estimated w/c ratio is 0.45

* From table 9.11 for exposure condition "Concrete intended to be watertight and exposed to fresh water", the maximum w/c ratio is 0.5

* Hence adopted w/c ratio is 0.45

Step III :-

* Maximum size of aggregates = 20mm

* Desired slump = 80-100 mm

From table 9.13, for 20mm size of aggregates

Mixing water content = 200 kg/m³ of concrete

Entrapped air content = 2%

Step IV :- ~~Cement~~ Water content = ~~Cement content / W/C ratio~~

~~C = 200 / 0.45~~

$$\text{W/C ratio} = \frac{\text{Water Content}}{\text{Cement Content}}$$

$$0.45 = \frac{\text{Water Content } 200}{\text{Cement Content}}$$

$$\text{Cement Content} = \frac{200}{0.45}$$

$$C = 445 \ kg/m^3$$

Step V :- Maximum size of C.A = 20 mm & fineness modulus of F.A = 2.8

from table 9.14,

The bulk volume of dry rolled C.A is 0.62 per unit volume of Concrete

Step VI :- Weight of C.A = 0.62×1600

$= 992 \ kg/m^3$

Density of C.A = $1600 \ kg/m^3$

Step VII :- Dry density of fresh Concrete

For maximum size of C.A = 20 mm & non-air entrained Concrete

From table 9.15, dry density of fresh Concrete = $2355 \ kg/m^3$

Step VIII :- Mass of water = $200 \ kg/m^3$

Mass of cement = $445 \ kg/m^3$

Mass of C.A = $992 \ kg/m^3$

Mass of F.A = $2355 - [200 + 445 + 992]$

$= 718 \ kg/m^3$

Absolute volume of Cement = $\frac{445}{3.15 \times 1000} = 0.141\ M^3$

Absolute volume of water = $\frac{200}{1 \times 1000} = 0.2\ M^3$

Absolute volume of C.A = $\frac{992}{2.7 \times 1000} = 0.367\ M^3$

Entrapped air = $\frac{2 \times 1}{100} = 0.02\ \%$.

Total absolute volume = $0.728\ M^3$

Hence volume of F.A required = $1 - 0.728$
$= 0.272\ M^3$

Mass of F.A = $0.272 \times 2.65 \times 1000$
$= 720.8\ kg/M^3 \simeq 721\ kg/M^3$

Estimated quantities of material per Cubic metre of Concrete are :

Cement = 445 kg
F.A = 721 kg
C.A = 992 kg
Water = 200 kg
Total 2358 kg/M^3 of Concrete

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British Method

* The traditional British method has been replaced by the department of the environment for nominal mixes. Now it is known as DOE (British) mix design method.

Eg:- Design a Concrete mix using DOE Method for a R/F concrete work for the following data:

* Required characteristic Compressive strength = 35 MPa at 28 days
* Type of Cement - Sulphate resisting Portland cement
* Desired slump - 50 mm
* Maximum size of aggregate = 20mm
* Type of aggregate - Uncrushed
* Specific gravity - 2.65
* F.A Confirmed to zone-III with % Passing 600 μ Sieve of 70%.
* Exposure Condition - Moderate
* Standard deviation - 5.0 Defective rate = 5%

Step-I :- Mix design without fly ash

Target Mean strength $f_t = f_{ck} + ks$

$$= 35 + 1.65 \times 5$$
$$= 43.25 \text{ N/mm}^2$$

Step 2:- Determination of free w/c ratio

From table 9.16, for sulphate resisting Portland Cement and uncrushed aggregate 28 days, Compressive strength = 42 MPa

* For Compressive Strength of 42 MPa and w/c ratio 0.5, Mark 'P' in fig. and draw a dotted curve parallel to the neighbouring curve using this new curve again $f_t = 42.25\ N/mm^2$ the w/c ratio is read as 0.48.

* from table 9.17 from durability point of view the Max. w/c ratio is 0.6. Hence adopt w/c ratio as 0.48.

Step 3:- Determination of water content.

For desired slump = 50 mm & max size of C.A = 20 mm

from table 9.18 water content is 180 kg/m³.

Step 4:- Determination of Cement Content

w/c ratio as obtained from step 2 is 0.48 & water is 180 kg/m³

$$\frac{180}{C} = 0.48 \Rightarrow C = 375\ kg/m^3 > 300\ kg/m^3$$

(min Cement Content)

Hence adoptable — ✓

Step 5:- Aggregate - Cement ratio

Specific gravity of aggregate is 2.65

Wet density of Concrete is 2400 kg/m³

Mass of total aggregate = 2400 − 180 − ~~275~~

= 1845 kg/m³

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Volume occupied by aggregate $= 1 - \frac{375}{1000 \times 3.15} \times \frac{180}{1000 \times 1}$

$= 0.7009 \ m^3$

$\therefore$ Total aggregate content $= 0.7009 \times 1000 \times 2.65$

$= 1875 \ kg/m^3$

Step 6:- Determination of F.A & C.A content

For max. size of aggregate = 20mm & slump = 50 mm

Free w/c ratio = 0.48

Percentage aggregate passing 600 μ sieve = 70%

From fig. 9.5(b) the proportion of F.A is 30%

Mass of F.A $= \frac{30 \times 1875}{100} = 557 \ kg/m^3$

Mass of C.A $= 1875 - 557.1$

$= 1299.9 \ kg/m^3 \simeq 1300 \ kg/m^3$

Step 7:- Estimated quantities are

Water = 180 kg

Cement = 375 kg

F.A = 557 kg

C.A = 1300 kg

Cement : F.A : C.A = 1 : 1.485 : 3.46

Road Note No: 4 Method of Mix design:-

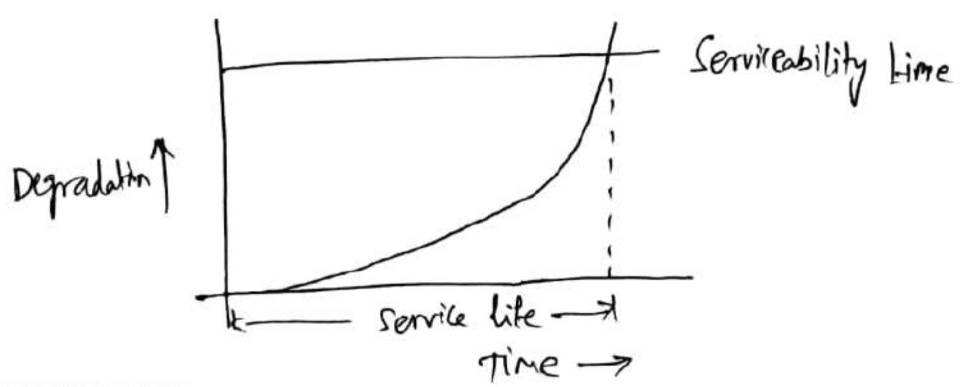
This was Proposed by Road Research Laboratory, UK in 1950.

In this method, the aggregate to Cement ratios are worked out on the basis of type of aggregate, max. size of aggregate and different levels of workability. The relative Proportion of aggregates is worked on the basis of Combined grading curves. This method facilitates the use of different types of fine and Coarse aggregates in the same mix. The relative Proportions of these Can be easily Calculated from Combined grading Curves. The values of aggregate to Cement ratios are available for angular, rounded (or) irregular Coarse aggregate.

Durability of Concrete:-

Durability of Structure, Component etc is its Capability to maintain a minimum performance level over a specified time when exposed to degradation environment.

Performance varies with time & degradation is gradual decrease of Performance with time. Concrete degrades with time.



Degradation & Chemical attack on Concrete

* Sulphate attack, sea water attack & acid attack

Sulphate reacts with $Ca(OH)_2$ & C_3A and forms Ettringite & gypsum.

$$Ca(OH)_2 + Na_2SO_4 \rightarrow CaSO_4 + 2NaOH$$

$$C_3AH_{13} + 3C\bar{S} \rightarrow C_3A \cdot 3C\bar{S} \cdot 31H + CH$$

$$C \rightarrow CaO \ \& \ \bar{S} \rightarrow SO_3$$

This $C_3A \cdot 3C\bar{S} \cdot 31H$ occupies more volume by expanding which leads to cracking.

$$Ca(OH)_2 + MgSO_4 \rightarrow CaSO_4 + Mg(OH)_2$$

$CaSO_4$ leads to formation of Ettringite. C-S-H is unstable in $Mg(OH)_2$, C-S-H decomposes and Mg-S-H formed has no binding property. This leads to formation of white crystals of gypsum, cracking and spalling.

→ This sulphate attack can be observed by formation of white powder of gypsum on scratching.

→ Lower w/c ratio improves sulphate resistance & is primary protection measure.

→ Low C_3A cement & well blended cement improves sulphate resistance.

* Sea water attack is similar to Sulphate attack as sea water Contains Sulphates in addition to Chloride.

Ettringite & gypsum are soluble in Chloride Solution, thus no expansion and Cracking but results in leaching. Leaching is severe due to de-solution of gypsum & ettringite. Leaching Can Cause Rebar corrosion.

→ Blended Cement Performs best in sea water. lower w/c & quality Concrete is other measures of Protection.

* Portland Cement is alkaline & Easily attacked by acid.

SO_2 & CO_2 reacts with water to forms sulphurous acid & carbonous acid leads to alkaline reactions.

→ pH < 6.5 attack initiates & is severe in pH < 4.5 this results in removal of several Materials from Concrete. Makes weak mass of concrete.

→ It can be reduced by treatment with sodium silicate which helps in formation of Calcium silicate & reduction of $Ca(OH)_2$.

⇒ Carbonation reaction

CO_2 from the air reacts with $Ca(OH)_2$ to form $CaCO_3$. In the Presence of moisture, Carbonic acid is formed which reduces the alkalinity of Concrete. pH value of Concrete reduces from 12.5 to 9, thus destroying the

Protective layer and exposing the steel to Corrosion.

→ Rate of Carbonation depends upon relative humidity, grade of Concrete, permeability and time.

→ For Normal M_{20} grade of concrete, nearly 1mm Carbonation is reported per year.

→ In Carbonation Process, CO_2 from the air Penetrates into Concrete and reacts with CaOH to form $CaCO_3$. In actual Practice, CO_2 Present in atmosphere Penetrates into Concrete and after Carbonation and pH value will reduced upto 8.3. In such a low pH value, the Protective layer gets destroyed and the steel is exposed to Corrosion.

→ The highest rate of ~~hy~~ Carbonation occurs at a relative humidity between 50-70%.

→ Protective Coating is required to be given for long Span bridge girders, flyovers, Industrial Structures and Chimneys. Such as Plastic Paints.

<u>Acid attack</u>

→ Concrete is not fully resistant to acids depending upon the type and concentration of acid.

→ Oxalic acid and Phosphoric acids are harmless.

→ The most vulnarable Part of the cement hydrate is $Ca(OH)_2$, but C-S-H gel can also be attacked.

→ Concrete Can be attacked by liquids with pH value less than 6.5

→ But the attack is severe only at a pH value below 5.5. At a pH value below 4.5, the attack is very severe. Cement compounds are eventually broken down and leached away. If the acids are able to reach the reinforcing steel through cracks, corrosion can occur leading to further cracking.

Corrosion:-

→ Corrosion is an electro-chemical reaction process.

Mechanism – Different areas of the same steel bar become anode and cathode. The electrical connection being maintained by pore water, which acts as electrolyte.

At the anode, steel releases electron and takes the ionic form.

$$Fe \rightarrow 2e + Fe^{2+}$$

At the cathode, water in the presence of oxygen and the released electron forms hydroxyl ions (OH)-

$$2O_2 + H_2O + 2e^- \rightarrow 2(OH)$$

$$2H_2O + O_2\,4e^- = 4(OH^-)$$

→ Corrosion can be controlled by limiting the chlorides in water, cement, superplasticizers etc to acceptable levels, providing proper cover as per IS code norms, proper compacting etc.

Alkali – Aggregate Reaction :-

Alkali from cement reacts with reactive silica from aggregates to form alkali - silica gel of unlimited swelling type. The continuous growth of silica gel exerts osmotic pressure within the concrete which leads to cracking and bulging of concrete.

→ This is due to high alkali content in cement (more than 0.6%)

→ Reactive silica in aggregate & availability of moisture.

⇒ This can be controlled by use of non-reactive aggregates from alternate sources.

→ Use of low-alkali cement

→ Reducing cement content in concrete

→ Use of pozzolana, slag (or) silica fumes

→ Controlling service condition and by limiting degree of saturation of concrete.

Quality Control of Concrete :-

For the building structure to be durable, more strength and also for aestatic view purpose, quality of concrete is of supreme importance. The quality of service may be rated based on the degree of satisfaction by the customer receiving the service. The exact meaning of quality is "The degree of excellence".

Quality of concrete construction on site can be accomplished by 3 distinct stages as follows :

1) Quality Control before Concreting.
2) Quality Control during Concreting.
3) Quality control after Construction.

1) Quality Control before Concreting :-

This stage of quality control consists of 2 steps.

a) Checking of specification requirements regarding excavation, formworks, reinforcement and embedded fixtures etc.

b) Control test on concrete ingredients (i.e, on cement, aggregate & water).

Cement

Quality of Cement is obtained by making Compressive strength tests on Cement Cubes. However, for effective Control of Cement :

* Should be tested initially once for Each Source and Subsequently once for every 2 months.
* Should be Protected from Moisture.
* Should be retested after 3 months of Storage, if long Storage is unavoidable.
* Should be rejected if large lumps are found in Cement bags.

Aggregate

Concrete aggregates Should confirm to Specified values as per standard specification. The quality of Concrete is affected by different Physical and Mechanical Properties of aggregate i.e., Shape, grading, durability, Specific gravity and water absorption etc. These properties of aggregates Should be tested before using it for Concrete Production.

Water

The quality of water should be checked for the requirements as specified in respective standard. Chemical analysis shall be conducted for approval of Source. In Case of Suspended impurities, it is necessary to Store water for some time to allow them to settle down. In case of doubt, concrete cubes made with this water are tested. Average 28 days compressive strength of atleast 3 cubes (or) cylinders (or) specified size, prepared with water proposed to be used shall not be less than 90% of the average strength of 3 similar concrete cubes prepared with distilled water.

2) Quality Control during concreting

Careful supervision during concrete manufacture is necessary for all concreting operations such as batching, mixing, transporting, laying, compacting and curing.

Precautions to be taken during concreting operation are:

→ As far as possible concrete should be batched by weight. If weight batching is not possible, then volume batching may be permitted through proper supervision in the presence of engineer incharge.

→ During mixing, the mixed should be charged to its full capacity. The materials should be fed in proper sequence. The speed of mixer should be in the range of 15-20 revolutions per minute. The mixing time should not be less than 2 minutes.

→ Workability of Concrete is an important Property of Concrete. Therefore slump test (or) Compaction factor test should be performed to check workability of Concrete.

→ Concrete should not be dropped from the height of more than 1m. If it exceeds 1m chutes should be used.

→ Vibrators should be used for compacting concrete. The frequency of vibrators should not be less than 7000 cycles/min.

→ Curing should be done for a specified Period so that concrete develops requisite strength.

→ Concrete should be protected from hot and cold weather at early ages. Concreting should not be done at temperature below 4.5°c and above 40°c.

3) Quality control after Construction

Once the concrete is laid and compacted, compression tests are made on the cubes made out of this concrete. The hardened concrete has to be checked for trueness in dimensions, shape and sizes as per design specification. General surface appearance of concrete should also be checked. Reinforcement should have adequate concrete cover and if the reinforcement is visible in part of a structure, the part should be rejected (or) necessary actions should be taken accordingly.

Concrete strength is normally to be obtained from Cube (or) Cylinder samples tested at 28 days. In Case, the strength obtained is less than the minimum specific, one (or) more of following steps may be taken.

* Load test and measurement of deflection and/or strain (the quality of the structure can then be obtained by calculating back the concrete strength).
* Cutting cores from the structures and testing them for strength.
* NDT tests like Schmidt rebound hammer (or) UPV test give only a very rough idea and are used to obtain the uniformity of construction.
* Chemical analysis of hardened concrete.