

LECTURE NOTE
CONCRETE TECHNOLOGY
6TH SEMESTER
Diploma (Civil Engineering)



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CONCRETE TECHNOLOGY



CHAPTER-1&2

1. CONCRETE AS CONSTRUCTION MATERIAL
2. CEMENT

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1. Concrete as a construction material:

1.1 Grades of concrete.

1.2 Advantages and disadvantages of concrete.

2. Cement:

2.1 Composition, hydration of cement, water cement ratio and compressive strength, fineness of cement, setting time, soundness, types of cement.

- **CONCRETE:-**

- Cement concrete is a major building material in the world which is widely using because of its marvelous structural properties. The ingredients of cement concrete are cement, fine aggregate, coarse aggregate and water respectively.
- Due to the versatile property of concrete it is widely used in construction.



Cement



Aggregate



Sand



Water

- **Grade of Concrete:-**

- Grade of concrete is defined as the minimum **strength the concrete (compressive strength)** must posses after 28 days of construction with proper quality control. Grade of concrete is denoted by prefixing M to the desired strength in MPa.
- **For example**, for a grade of concrete with 20 MPa strength, it will be denoted by M20, where M stands for Mix.

NORMAL GRADE OF CONCRETE	STANDARD GRADE OF CONCRETE	HIGH STRENGTH CONCRETE
M5- M20	M25- M45	M50- M70



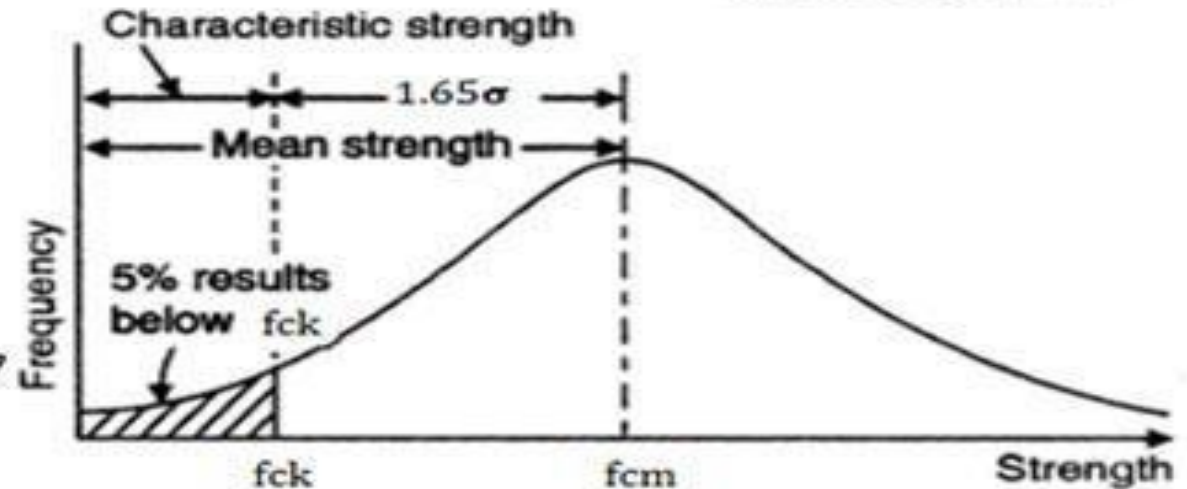
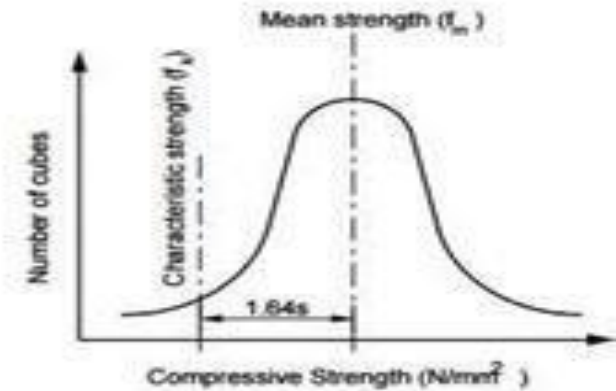
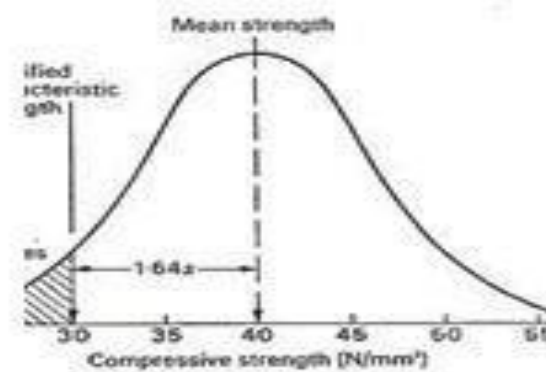
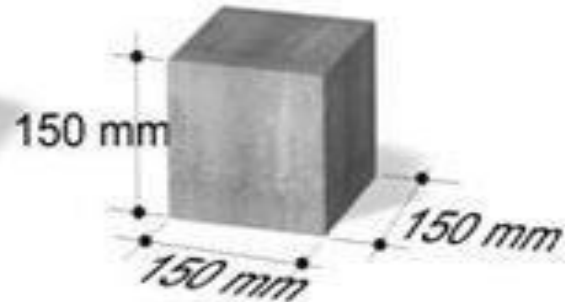
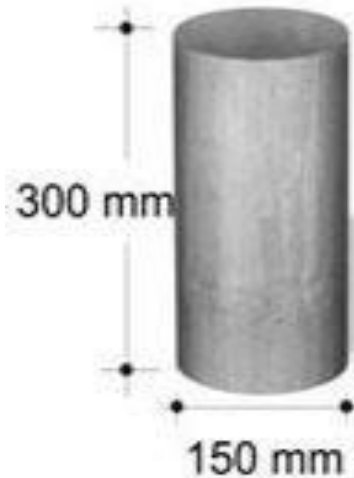
Characteristics Strength of Concrete:-

- The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

C 30 / 37

cylinder's strength
 $f_{ck} = 30 \text{ MPa}$

cube's strength
 $f_{ck} = 37 \text{ MPa}$



NORMAL GRADE OF CONCRETE	STANDARD GRADE OF CONCRETE	HIGH STRENGTH CONCRETE
M5- 1:5:10 COMP. STRENGTH 5MPA	M25 1:1:2 COMP. STRENGTH 25MPA	M50- M70
M10 – 1:3:6 COMP. STRENGTH 10MPA	M30 ONWARDS DESIGN MIX	
M15- 1:2:4 COMP. STRENGTH 15MPA		
M20- 1:1.5:3 COMP. STRENGTH 20MPA		

- Regular grades of concrete are M15, M20, M25 etc. For plain cement concrete works, generally M15 is used.
- For ***reinforced concrete construction minimum M20 grade of concrete are used.***
- ***Design mix concrete*** are those for which mix proportions are obtained from various lab tests. Use of design mix concrete requires good quality control during material selection, mixing, transportation and placement of concrete.
 - This concrete offers mix proportions based on locally available material and offers economy in construction if large scale concrete construction is carried out.
 - Thus, large concrete construction projects uses design mix concrete.

ADVANTAGES OF CONCRETE

- Ingredients of concrete are easily available in most of the places.
- Unlike natural stones, concrete is free from defects and flaws.
- Concrete can be manufactured to the desired strength with an economy.
- The durability of concrete is very high.
- It can be cast to any desired shape.
- The casting of concrete can be done in the working site which makes it economical.
- The maintenance cost of concrete is almost negligible.
- The deterioration of concrete is not appreciable with age.
- Concrete makes a building fire-safe due to its noncombustible nature.
- Concrete can withstand high temperatures.
- Concrete is resistant to wind and water. Therefore, it is very useful in storm shelters.
- As a soundproofing material cinder concrete could be used.

DISADVANTAGES OF CONCRETE

- Compared to other binding materials, the tensile strength of concrete is relatively low.
- Concrete is less ductile.
- The weight of concrete is high compared to its strength.
- Concrete may contain soluble salts. Soluble salts cause efflorescence.

- **CEMENT:-**

- A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together.
- Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete.

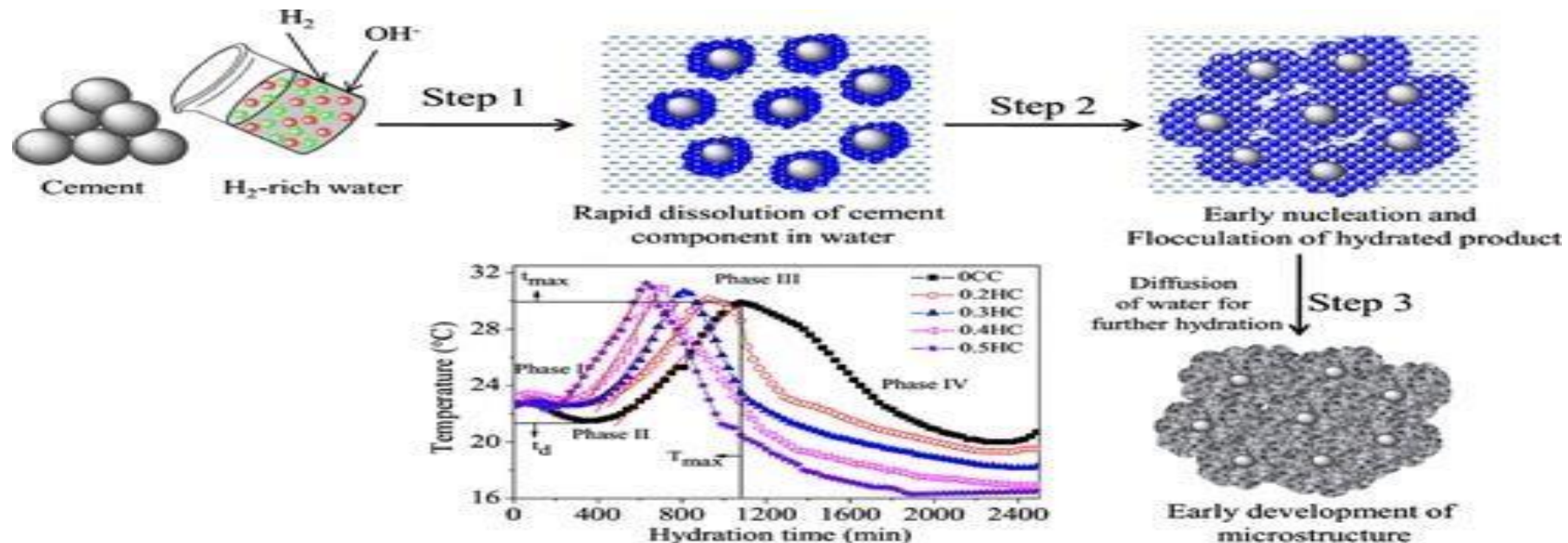
- **Composition of Cement:-**

- Lime:- (60-65%) controls strength and soundness properties, excess causes unsoundness of cement, deficiency causes less strength.
- Silica:- (17-25%) imparts strength to cement, by forming C2S & C3S. Excess Strength of cement increases and setting time prolonged.
- Alumina:- (3-8%) it acts as a flux and reduces the temperature of clinker and imparts quick setting property.
- Calcium sulphate:- it is in the form of Gypsum and increase setting time of cement.
- Iron oxide:- (0.5-6%) imparts colour and act as a catalyst in fusion of different ingredients of cement.
- Magnesia:- (0.1-4%) imparts hardness and colour, excess causes unsoundness.
- Alkalies :- present a small amount.



- HYDRATION OF CEMENT:-

- The chemical reaction takes place between Cement and Water is known as hydration of cement. In this reaction process a large amount of heat liberated which initiate setting of cement.
- If cement is grounded very finely, then heat of hydration will more and cement sets quickly which leads flash setting of cement.



WATER CEMENT RATIO:-

- Water Cement Ratio means the ratio between the weight of water to the weight of cement used in concrete mix.
- Normally water cement ratio falls under 0.4 to 0.6 as per IS Code 10262 (2009) for nominal mix (M10, M15 M25)
- We all know that water cement ratio will directly affect the strength of concrete. Either it increases the strength if used in correct proportion or decrease it.

Role of water in Concrete:-

- It contains micro ingredients such as cement, sand, fine aggregate & Coarse aggregate. In order to acquire high strength concrete which withstands up to our desired compressive strength, We need correct proportion of admixture to combine these materials.
- Here comes the Water which will initiate this chemical *process by adding 23%-25% of the cement volume. This initiates the chemical process and makes 15% of water cement paste also known as a gel to fill the voids in the concrete.*

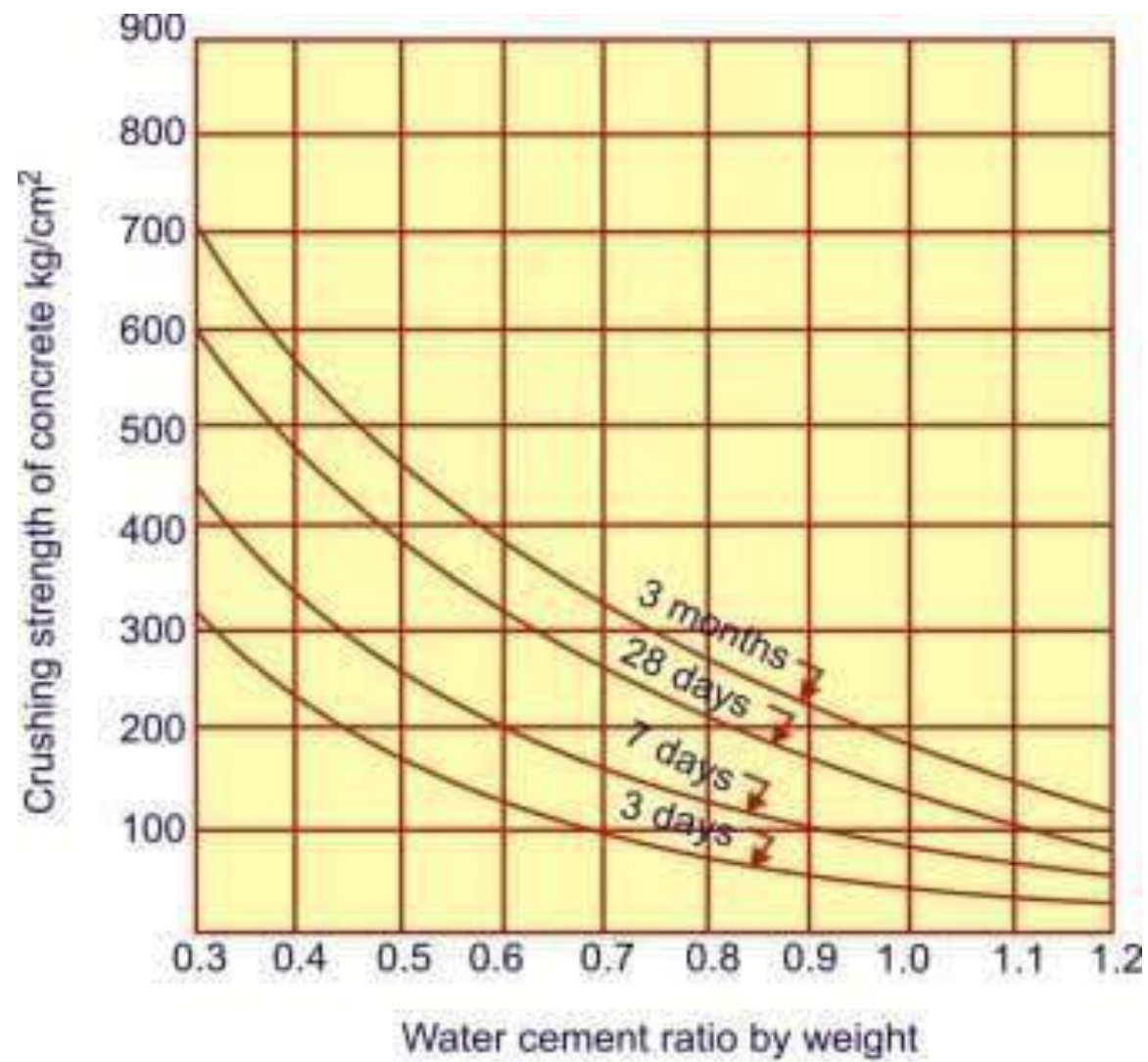
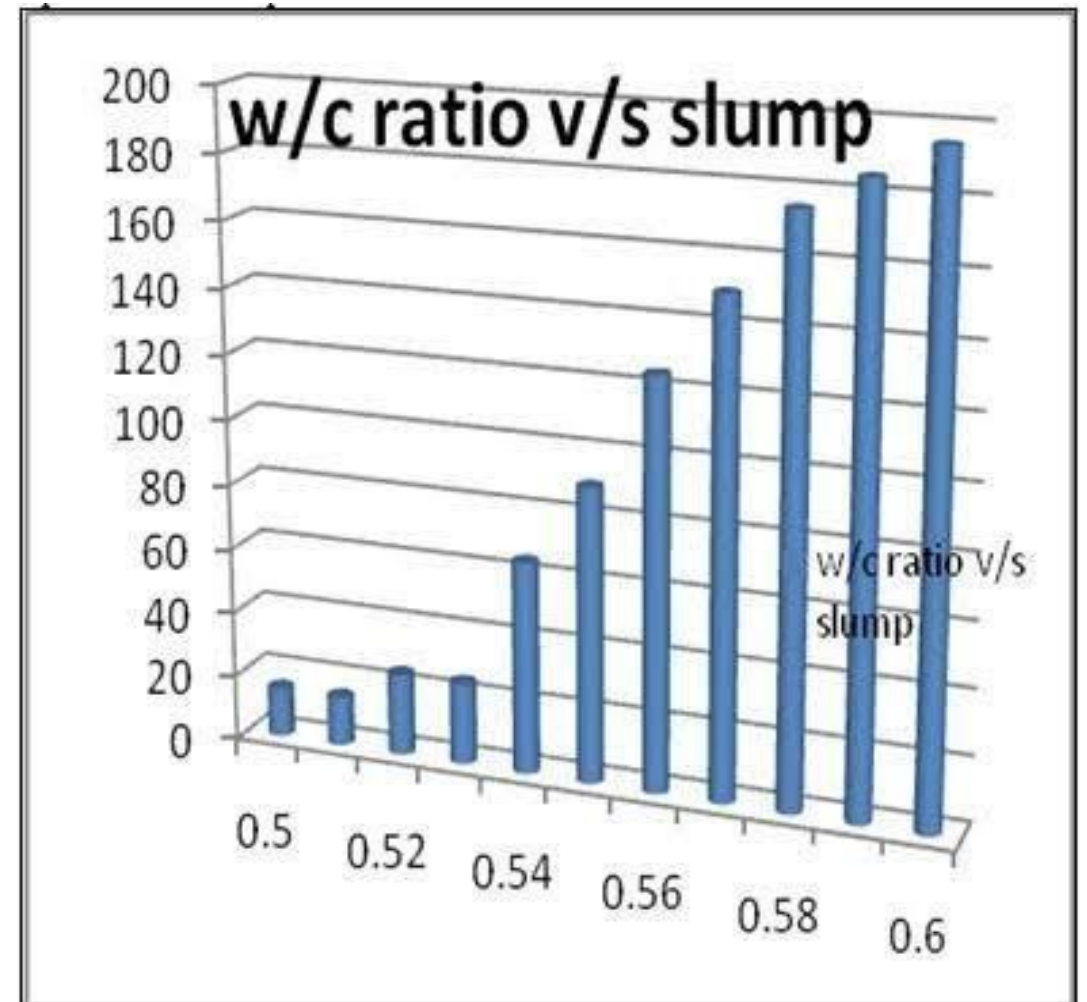
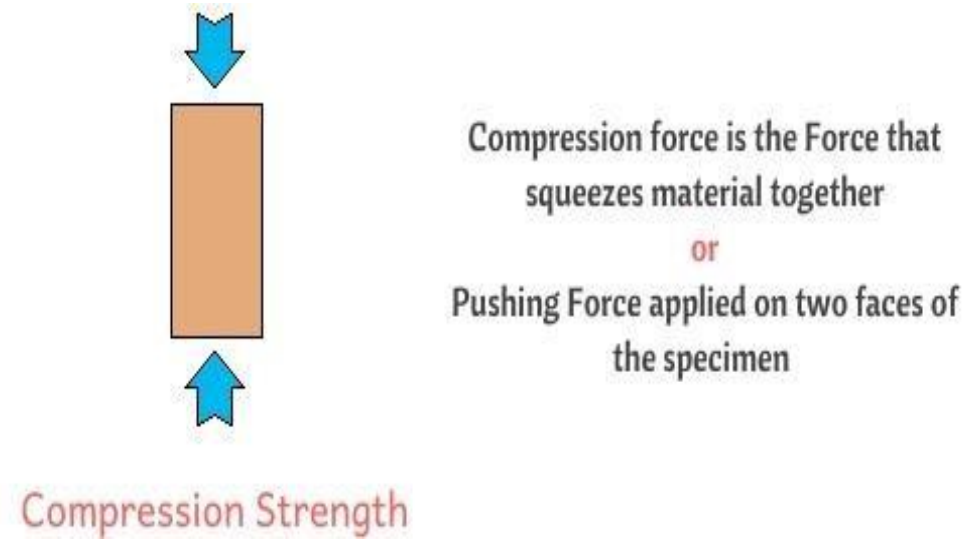


FIG. 8.1.



COMPRESSIVE STRENGTH OF CEMENT:

- Compressive strength is the capacity of material or structure to resist or withstand under compression. The Compressive strength of a material is determined by the ability of the material to resist failure in the form of cracks and fissure.
- In this test, the impact force applied on both faces of Mortar specimen made with Cement and the maximum compression that cement specimen bears without failure recorded.



Steel Cube 7.06cm x 7.06cm x 7.06cm

$$\text{Compressive Strength of Concrete} = \frac{\text{Max Load Carried by Specimen}}{\text{Top Surface Area of Specimen}}$$

FINENESS OF CEMENT:-

- The fineness of cement is property of cement which indicate the particle size of cement and specific surface area and thus indirectly effect heat of hydration.
- Importance/effect of fineness of cement;
 1. Fineness of cement affects hydration rate hence the rate of strength gain.
 2. Bleeding can be reduced by increasing fineness. However, increased fineness can also lead to the requirement of more water for the workability, resulting in a higher possibility of dry shrinkage.
 3. Fineness test is used to change the proper grinding of cement and measures the surface area of the cement particles per unit mass.
 4. Therefore finer cement react faster with water and the rate of development of strength and corresponding heat of hydration is high.
 - Fineness limit;
It should not exceed following percentage by weight for different types of cement;
 1. Ordinary portland cement = 10%
 2. Rapid hardening cement = 5%
 3. Low heat cement = 5%



INITIAL AND FINAL SETTING TIME :-

Initial Setting Time of Cement

- It is the time elapsed between the moments that the water is added to the cement, to the time that the paste starts losing its plasticity.

Final Setting Time of Cement

- It is the time elapsed between the moment the water is added to the cement and the time when cement paste loses its plasticity completely and has attained sufficient firmness to resist certain definite pressure.



Significance of Initial and Final Setting Time of Cement

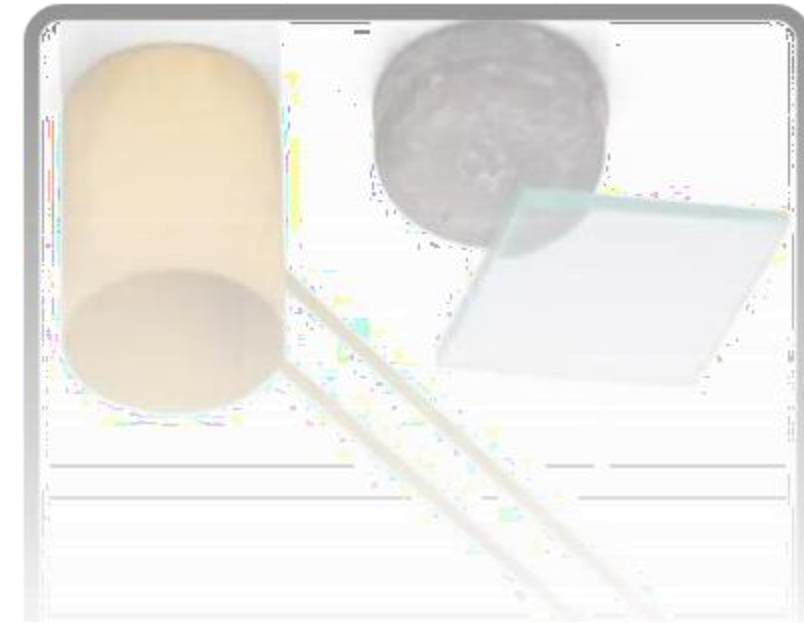
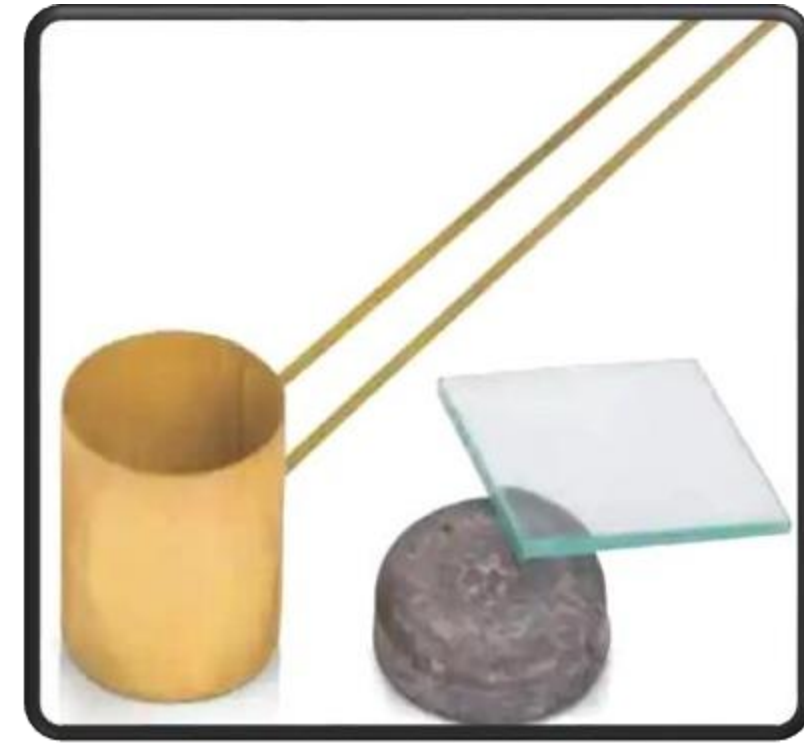
- It is **required** that cement does not **lose** its **plasticity** too **early** or too late. If **cement** set too early, there is **insufficient** time for **transportation** and **place concrete**.
- If **cement** set too late then **there** is a **delay** in **construction work**. Also, **concrete** will not get **sufficient** strength early and the **formwork** removal process **delayed**.
- The **proper setting** time required for the **stiffening** of **cement paste** to a defined consistency.
- It is **indirectly** related to the **chemical reaction** of **cement** with **water** to form an **aluminum–silicate compound**.
- Initial setting time is an **important** time to know for **concrete transportation, placing, and curing**.
- **Initial setting** time also **utilized** to delay the **process** of **hydration** or **hardening**.
- The **final setting time** utilized for the **safe removal** of **scaffolding** or **form**.

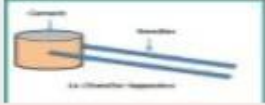
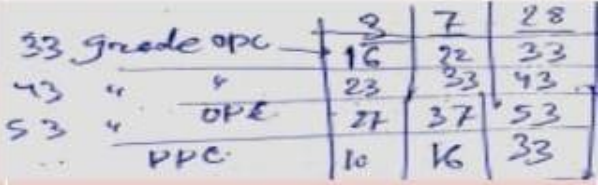
Factors Affecting Initial and Final Setting Time of Cement

- The **fineness of cement**, the **presence** of salts in **sand**, **atmospheric conditions**. For example, **cement** requires a **temperature of 27°C** to complete **Hydration**, during winters **the climate** is low which stops the **hydration** and **takes** a longer time to **set harden**.

SOUNDNESS TEST OF CEMENT:-

- Soundness of cement can be defined as its ability to retain its volume after it gets hardened. This means that a properly sound cement will undergo minimum volume change after it converts into the hardened state.
- In the soundness test of cement, we determine the amount of excess lime. This test can be conducted by Le-chatelier method and Autoclave Method
- **Significance of Soundness Test on Cement**
- Cement is a composition of lime, silica, alumina, magnesia, alkaline, sulfur trioxide, iron oxide, and calcium sulfate. Among which, lime constitutes 60 to 70%. Hence, a cement deficient in lime will set quickly and will affect the property of the cement. Lime content in higher amount will make the cement unsound. An unsound cement will affect the quality of the cement work performed.
- This demands of soundness test of cement before using it. Through this test, it is ensured that the cement won't undergo any sort of expansion due to the presence of excess amount of lime.



TEST NAME	Apparatus Required	Water to be added	IS value
Fineness Test	IS SIEVE 90micron size 		Residues left on sieve not more than 10% by weight of cement
Soundness Test	LeChartliers apparatus 	0.78 times consistency of Cement	Expansion between the legs should not exceed 5mm
Consistency of Cement	Vicat Apparatus with plunger 	Approximately to make a cement paste (25 to 33% by weight of cement)	The standard consistency of cement is that water content which permit the vicat plunger to penetrate to a point 5 to 7mm from the bottom of the vicat mould when tested
Initial setting Time	Vicat apparatus With needle	85%(0.85) of standard consistency of cement	Not less than 30min
Final Setting time	Vicat apparatus Needle with annular collar 	Further process from initial setting time (no more water to be added)	Between 6 to 10 hour
Specific Gravity	Density bottle 	As per definition	
Compressive strength (Determines grade of	Compression testing machines and 70.6mm size	(P/4 +0.3) P= % of consistency	

Types Of Cement

1. Ordinary Portland Cement (OPC)

- Ordinary Portland Cement also known as OPC is a type of cement that is manufactured and used worldwide. It is widely used for all purposes including:
 - Concrete: When OPC is mixed with aggregates and water, it makes concrete, which is widely used in the construction of buildings
 - Mortar: For joining masonry
 - Plaster: To give a perfect finish to the walls
- Cement companies in Malaysia offer OPC in three different grades, namely grades 33, 43, and 53.
- Besides the aforementioned purposes, Ordinary Portland cement is also used to manufacture grout, wall putty, solid concrete blocks, AAC blocks, and different types of cement.

2. Portland Pozzolana Cement (PPC)

- To prepared PPC or Portland Pozzolana cement, you need to grind pozzolanic clinker with Portland cement.
- PPC has a high resistance to different chemical assaults on concrete. It is widely used in construction such as:
 1. Marine structures
 2. Sewage works
 3. Bridges
 4. Piers
 5. Dams
 6. Mass concrete works

3. Rapid Hardening Cement

- Cement suppliers in Malaysia also offer rapid Hardening cement. Rapid Hardening Cement is made when finely grounded C3S is displayed in OPC with higher concrete.
- It is commonly used in rapid constructions like the construction pavement.

4. Extra Rapid Hardening Cement

- As the name suggests, Extra rapid hardening cement gains strength quicker and it is obtained by adding calcium chloride to rapid hardening cement.
- Extra rapid hardening cement is widely used in cold weather concreting, to set the cement fast. It is about 25% faster than that of rapid hardening cement by one or two days.

5. Low Heat Cement

- Cement manufacturers in Malaysia offers low heat cement that is prepared by keeping the percentage of tricalcium aluminate below 6% and by increasing the proportion of C₂S.
- This low heat cement is used in mass concrete construction like gravity dams. It is important to know that it is less reactive and the initial setting time is greater than OPC.

6. Sulfates Resisting Cement

- This type of cement is manufactured to resist sulfate attack in concrete. It has a lower percentage of Tricalcium aluminate.
- Sulfates resisting cement is used for constructions in contact with soil or groundwater having more than 0.2% or 0.3% g/l sulfate salts respectively.
- It can also be used in concrete surfaces subjected to alternate wetting and drying like bridge piers.

7. Quick Setting Cement

- Cement suppliers in Malaysia also offer quick setting cement which sets faster than OPC but the strength remains the same. In this formula, the proportion of gypsum is reduced.
- Quick setting cement is used for constructions that need a quick setting, like underwater structures and in cold and rainy weather conditions.

8. Blast Furnace Slag Cement

- This type of cement is manufactured by grinding the clinker with about 60% slag and it is similar to Portland cement. It is used for constructions where economic considerations are important.

9. High Alumina Cement

- High alumina cement is obtained by mixing calcining bauxite and lime with clinker during the manufacturing process of OPC.
- To be considered high alumina cement, the total amount of alumina content should be at least 32%, and the ratio of the weight of alumina to lime should be kept between 0.85 to 1.30.
- The most common uses are in constructions that are subject to high temperatures like a workshop, refractory, and foundries.

10. White Cement

- This type of cement is manufactured by using raw materials that are free from iron and oxide. White cement needs to have lime and clay in a higher proportion. It is similar to OPC but it is more expensive.

*Thank
you*



CONCRETE TECHNOLOGY

Chapter-3

AGGREGATE, WATER & ADMIXTURE

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Fineness Modulus of Coarse Aggregates:-

- Fineness modulus of coarse aggregates represents the average size of the particles in the coarse aggregate by an index number. It is calculated by performing sieve analysis with standard sieves.
- The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate. Higher the aggregate size higher the Fineness modulus hence fineness modulus of coarse aggregate is higher than fine aggregate.
- Coarse aggregate means the aggregate which is retained on 4.75mm sieve when it is sieved through 4.75mm. To find fineness modulus of coarse aggregate we need sieve sizes of 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm.
- Fineness modulus is the number at which the average size of particle is known when we counted from lower-order sieve size to higher-order sieve. So, in the calculation of coarse aggregate we need all sizes of sieves.



HOW TO DETERMINE FINENESS MODULUS



- To find fineness modulus we need to perform sieve analysis and for that above mentioned sieve sizes, mechanical shaker and digital weigh scale are required.

Sample preparation

- Take a sample of coarse aggregate in pan and placed it in dry oven at a temperature of $100 - 110^{\circ}\text{C}$. After drying take the sample weight to nearest gram.

Test Procedure for Fineness Modulus of Coarse Aggregates

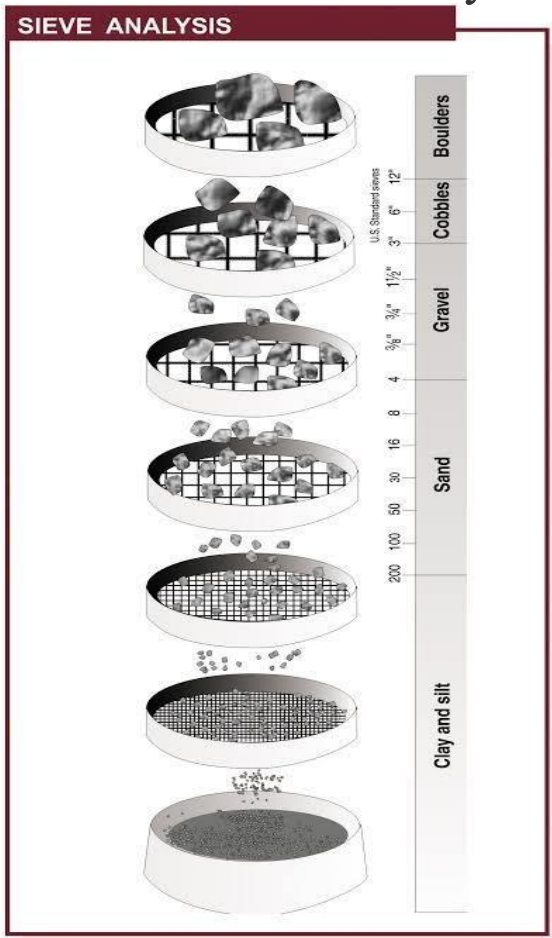
- Arrange the sieves in descending order and put the arrangement on mechanical shaker. It is suggested that, to know the exact value of fineness modulus for coarse aggregate, mechanical shaker will give better value than hand shaking because of more no. of sieves and heavy size particles.
- After proper sieving, record the sample weights retained on each sieve and find out the cumulative weight of retained particles as well as cumulative % retained on each sieve. Finally add all cumulative percentage values and divide the result with 100. Then we get the value of fineness modulus.



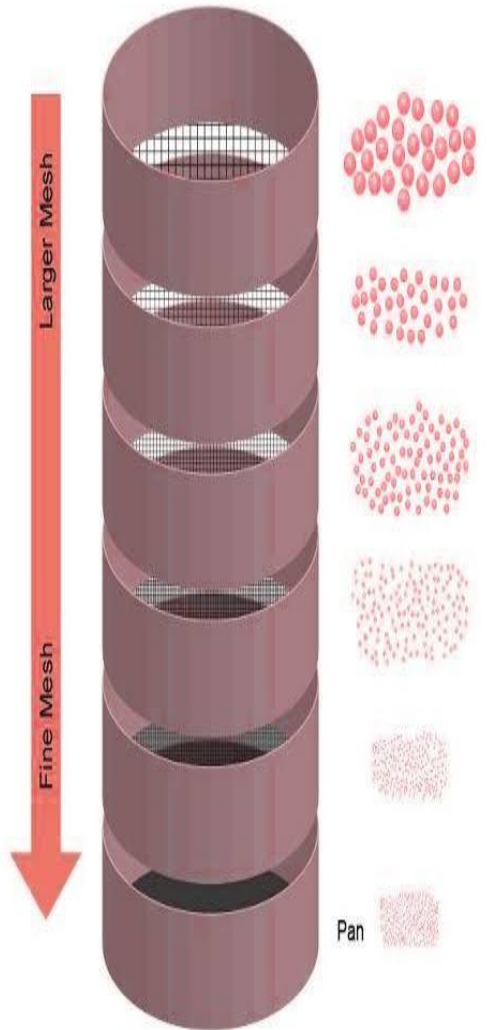
Example for Fineness Modulus Calculation

- Let us say dry weight of coarse aggregate = 5000g

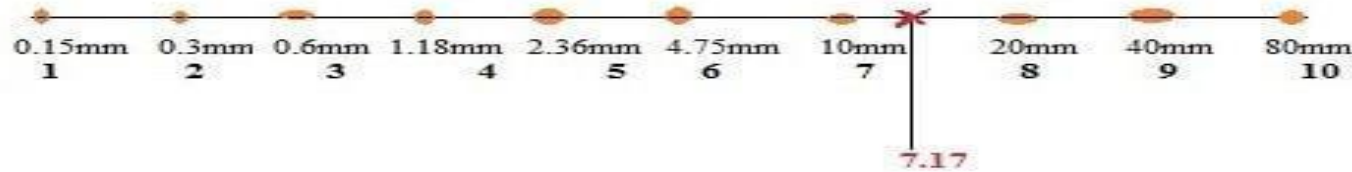
Values after sieve analysis are



Sieve size	Weight retained(g)	Cumulative weight retained (g)	Cumulative % retained (g)
80mm	0	0	0
40mm	250	250	5
20mm	1750	2000	40
10mm	1600	3600	72
4.75mm	1400	5000	100
2.36mm	0	5000	100
1.18mm	0	5000	100
0.6mm	0	5000	100
0.3mm	0	5000	100
0.15mm	0	5000	100
	Sum	=	717



- Therefore, **fineness modulus of coarse aggregates** = $\text{sum (cumulative \% retained)} / 100 = (717/100) = 7.17$
- Fineness modulus of 7.17 means, the average size of particle of given coarse aggregate sample is in between 7th and 8th sieves, that is between 10mm to 20mm.



Limits of Fineness Modulus

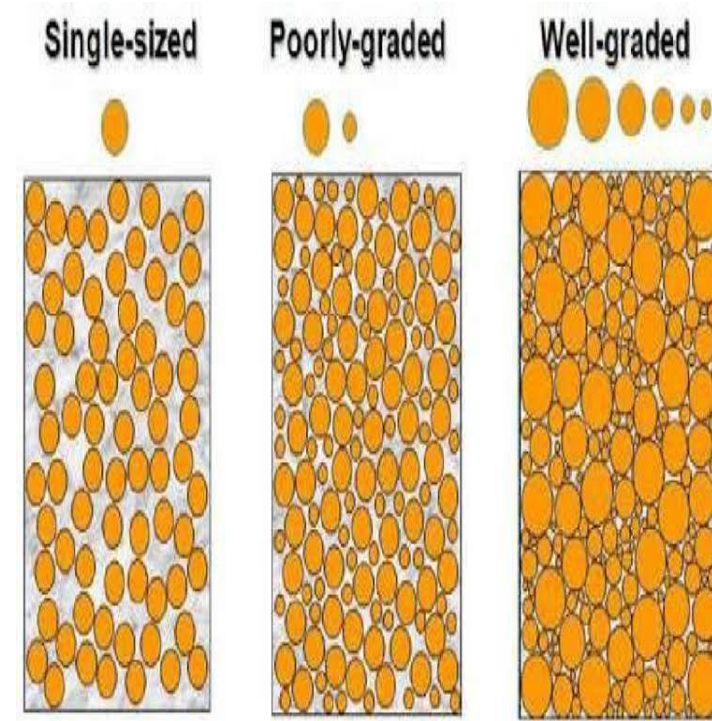
- Fineness modulus of coarse aggregate varies from 5.5 to 8.0. And for all in aggregates or combined aggregates fineness modulus varies from 3.5 to 6.5. Range of fineness modulus for aggregate of different maximum sized aggregates is given below.

Maximum size of coarse aggregate	Fineness modulus range
20mm	6.0 – 6.9
40mm	6.9 – 7.5
75mm	7.5 – 8.0
150mm	8.0 – 8.5



GRADING OF AGGREGATE

- **Grading of Aggregates** is one which is made up of stones of different sizes, ranging from large to small (inclusive of sand) so as to have minimum of air voids (and that will have maximum density) when mixed together.
- In grading of aggregates, the voids in the mixed aggregate would be minimum when the sand is just sufficient to fill the voids in the coarse aggregate. Voids in the coarse aggregate are filled in by sand and voids in the sand are filled in by cement. Mix that occupies the least volume is the densest and will produce the best results.
- In **grading of aggregates**, well graded sand from coarse to fine has less voids than fine sand. The lesser the voids the better is the quality of sand for use in cement concrete, provided there is no silt in sand.
- The combined aggregate when mixed with the required quantity of cement and water, should give a good workable concrete which can be readily placed in position without segregation.
- The proportion of fine to coarse aggregate should be such as will give maximum workability with minimum of water. Mixtures with a deficiency of fine materials will be harsh, hard to work and difficult to finish.
- A little more sand makes the concrete more fluid without extra water. Too much of sand will increase porosity of the concrete and need more cement.



WATER QUALITY FOR CONCRETE

- Quality of water for construction works are same as drinking water. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc.
- The water shall be clean and shall not contain sugar, molasses or gur or their derivatives, or sewage, oils, organic substances.
- For plain and reinforced cement concrete permissible limits for solids shall be as follows:

Type of Solid in water	Permissible Limits for Construction
Organic matter	200 mg/l
Inorganic matter	3000 mg/l
Sulphates (SO ₄)	500 mg/l
Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l



ADMIXTURES

What is Admixture

- Admixtures are the chemical compounds in concrete other than hydraulic cement (O.P.C), water & aggregate and mineral additives which are added to the concrete mix immediately before or during to modify. One or more specific properties of concrete in fresh or hardened state.
- **The properties of concrete commonly modified by the admixtures are-**
 - a) Rate of hydration.
 - b) Setting time.
 - c) Workability.
 - d) Dispersion.
 - e) Air-Entrainment.

Use Of Admixture

Admixtures are used to achieve the following objectives:

- a) To reduce the cost of concrete construction.
- b) To modify the performance of hardened concrete.
- c) To ensure the quality of concrete during mixing, transporting, placing, compacting & curing.
- d) To overcome certain emergencies during concreting operations.



■ The commonly used admixtures of this category are:

- 1) **Accelerating admixtures**: Example — Calcium Chloride (CaCl_2).
- 2) **Retarding admixtures**: Example — Sugar, Soluble Starch.
- 3) **Air-entraining admixtures**: Example — Natural wood resin, Olive oil.
- 4) **Water reducing admixtures**: Example — Plasticizers

Functions of Admixtures

- a) To accelerate or retard the initial set of concrete.
- b) To enhance the workability.
- c) To improve the flow-ability & pump-ability of concrete.
- d) To reduce the segregation in concrete.
- e) To increase the strength of concrete by reducing the water content.
- f) To increase the durability of concrete.



- g) To increase the impermeability of concrete.
- h) To control alkali-aggregate reaction
- i) To reduce the corrosion of reinforcement in concrete.
- j) To increase the resistance to chemical attack.
- k) To reduce the heat of hydration.
- l) To increase the bond between concrete & steel.
- m) To increase the bond between old and new concrete surfaces.
- n) To produce cellular concrete, colored concrete.
- o) To produce non-skid wearing surface.
- p) To decrease the unit weight of concrete.
- q) To produce concrete of fungicidal, germicidal and insecticidal properties



Thank
you



CONCRETE TECHNOLOGY

CHAPTER-04

PROPERTIES OF FRESH CONCRETE

BY:- Er. Abhijit Sahoo



4 PROPERTIES OF FRESH CONCRETE:

4.1 Concept of fresh concrete, workability, slump test, compacting factor test, V-bee consistency test and flow test, requirement of workability, I.S. 1199.

- Concept of fresh concrete :-

Fresh Concrete:-

- Fresh concrete is that stage of concrete in which concrete can be moulded and it is in plastic state. This is also called “Green Concrete”. Another term used to describe the state of fresh concrete is **consistence**, which is the ease with which concrete will flow.

- **Properties of Fresh Concrete**

1. Setting of Concrete

- The hardening of concrete before its hydration is known as setting of concrete. OR The hardening of concrete before it gains strength. OR The transition process of changing of concrete from plastic state to hardened state. Setting of concrete is based or related to the setting of cement paste. Thus cement properties greatly affect the setting time.

Factors affecting setting:

Following are the factors that affect the setting of concrete.

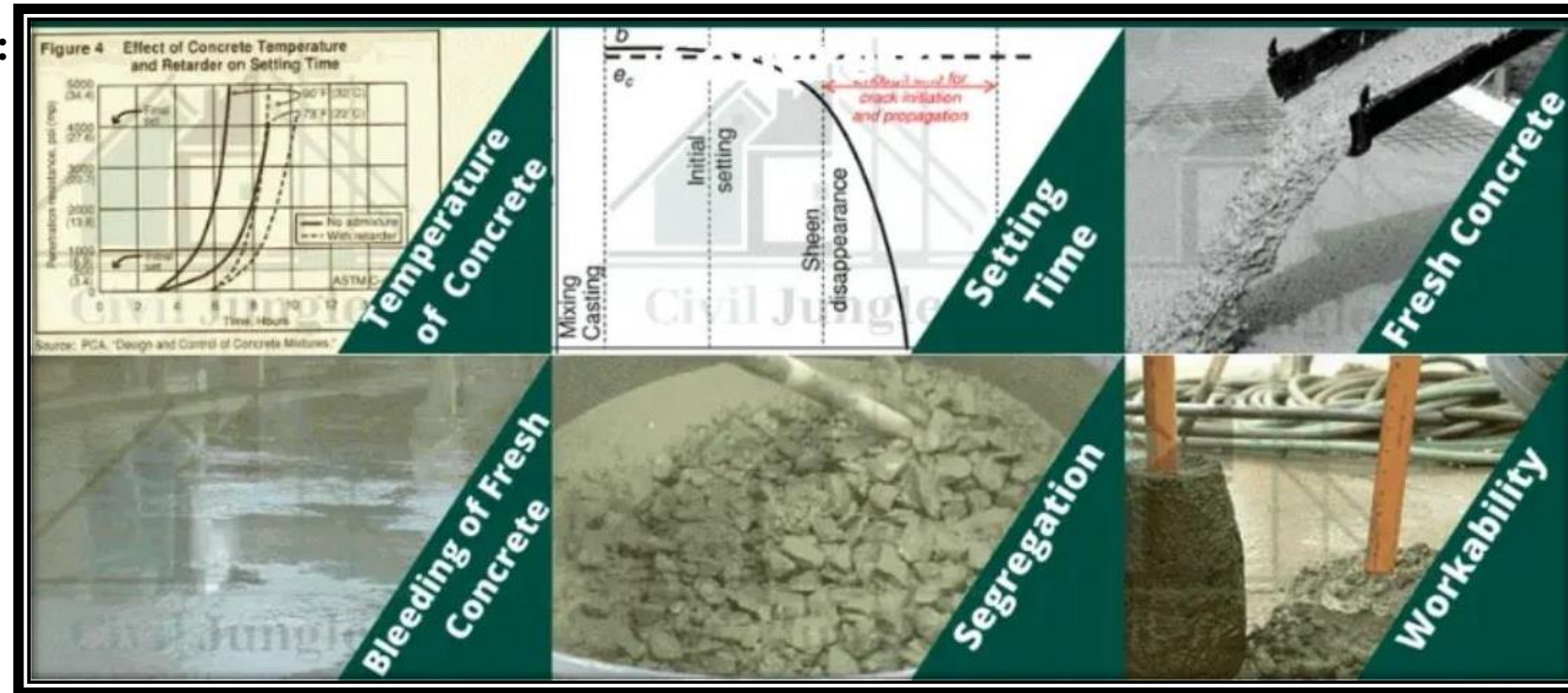
- 1. Water Cement ratio
- 2. Suitable Temperature
- 3. Cement content
- 4. Type of Cement
- 5. Fineness of Cement
- 6. Relative Humidity
- 7. Admixtures
- 8. Type and amount of Aggregate

2. Workability of Concrete

- Workability is often referred to as the ease with which a concrete can be transported, placed and consolidated without excessive bleeding or segregation.
- In the case of concrete, consistence is sometimes taken to mean the degree of wetness; within limits, wet concretes are more workable than dry concrete, but concrete of same consistence may vary in workability.
- Because the strength of concrete is adversely and significantly affected by the presence of voids in the compacted mass, it is vital to achieve a maximum possible density. This requires sufficient workability for virtually full compaction to be possible using a reasonable amount of work under the given conditions. Presence of voids in concrete reduces the density and greatly reduces the strength: 5% of voids can lower the strength by as much as 30%.

Factors affecting concrete workability:

- Water-Cement ratio
- Amount and type of Aggregate
- Amount and type of Cement
- Weather conditions
 - Temperature
 - Wind
- Chemical Admixtures
- Sand to Aggregate ratio



3. Concrete Bleeding

- Bleeding in concrete is sometimes referred as water gain. It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete. Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete.
- In thin members like roof slab or road slabs and when concrete is placed in sunny weather show excessive bleeding.

4. Segregation in concrete

- Segregation can be defined as the separation of the constituent materials of concrete. A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture. There are considerable differences in the sizes and specific gravities of the constituent ingredients of concrete. Therefore, it is natural that the materials show a tendency to fall apart.

5. Hydration in concrete

- 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. In the field and in actual work, even a higher water/cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates and the water available in the concrete will not be sufficient for effective hydration to take place particularly in the top layer.
- If the hydration is to continue, extra water must be added to refill the loss of water on account of absorption and evaporation. Therefore, the curing can be considered as creation of a favorable environment during the early period for uninterrupted hydration. The desirable conditions are, a suitable temperature and ample moisture.
- Concrete, while hydrating, releases high heat of hydration. This heat is harmful from the point of view of volume stability. Heat of hydration of concrete may also shrinkage in concrete, thus producing cracks. If the heat generated is removed by some means, the adverse effect due to the generation of heat can be reduced. This can be done by a thorough water curing.

6. Air Entrainment

- Air entrainment reduces the density of concrete and consequently reduces the strength. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. *These include:*
- Resistance to freeze–thaw action in the hardened concrete.
- Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.
- Compaction of low workability mixes including semi-dry concrete.
- Stability of extruded concrete.
- Cohesion and handling properties in bedding mortars.

7. Temperature

- Concrete is not recommended to be placed at a temperature above 40°C without proper precautions, as laid down in IS:7861(part -1).
- Special problems are encountered in the preparation, placement, and curing of concrete in hot weather. The First 24 to 72 hours after placing fresh concrete are of extreme importance.
- If the temperature of concrete is not controlled and it goes beyond maximum range during hydration, then stresses are produced, and cracks are formed in concrete.
- Also if the temperature falls below the minimum temperature, then concrete takes a large time to set, and the hydration process slows down.

Workability :-

Types of Workability of Concrete:- Workability of concrete can be classified into following three types:

- **Unworkable Concrete:** An unworkable concrete also known as harsh concrete, is a concrete with a very little amount of water. The hand mixing of such concrete is difficult. Such type of concrete has high segregation of aggregates. and it is very difficult to maintain the homogeneity of concrete mix. Water cement ratio of such concrete is below 0.4.
- **Medium Workable concrete:** Medium workable concrete is used in most of the construction works. This concrete is relatively easy to mix, transport, place, and compact without much segregation and loss of homogeneity. Water cement ratio for medium workable concrete is 0.4 to 0.55.
- **Highly Workable Concrete:** This type of concrete is very easy to mix, transport, place and compact. It is used where effective compaction of concrete is not possible. The problem is that there are high chances of segregation and loss of homogeneity in highly workable concrete. Water cement ratio of such concrete is more than 0.55.

Desirable Workability for Construction

Desirable workability depends on two factors which are:

1. **Section size, amount and spacing of reinforcement:** When a section is narrow, complicated, several narrow corners, inaccessible parts; a highly workable concrete is desirable to obtain full compaction through a reasonable amount of effort. When the section is crowded with steel reinforcement and spacing of bars is relatively small, compaction can be difficult and hence highly workable concrete is recommended in such cases. If there are no limitations of the critical section or heavy reinforcement, we can get a wide range of workability for concrete casting.
2. **Method of compaction:** If concrete is compacted manually, more workability is recommended because hand compaction is not very much uniform and effective. If there is a scope of the vibrator or machine compaction, we can choose workability from a wide range.

Strength of Concrete & Workability Relationship

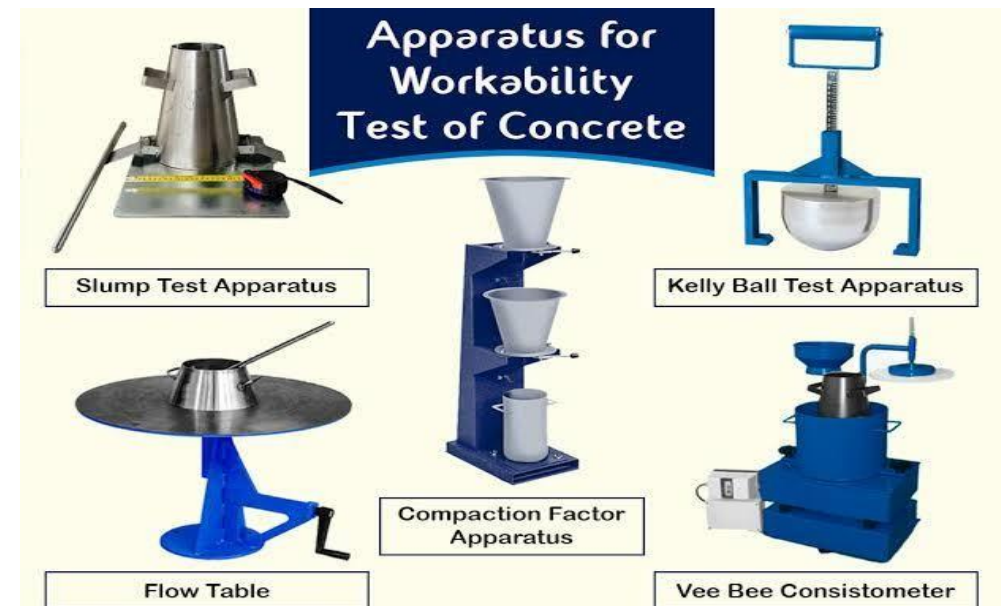
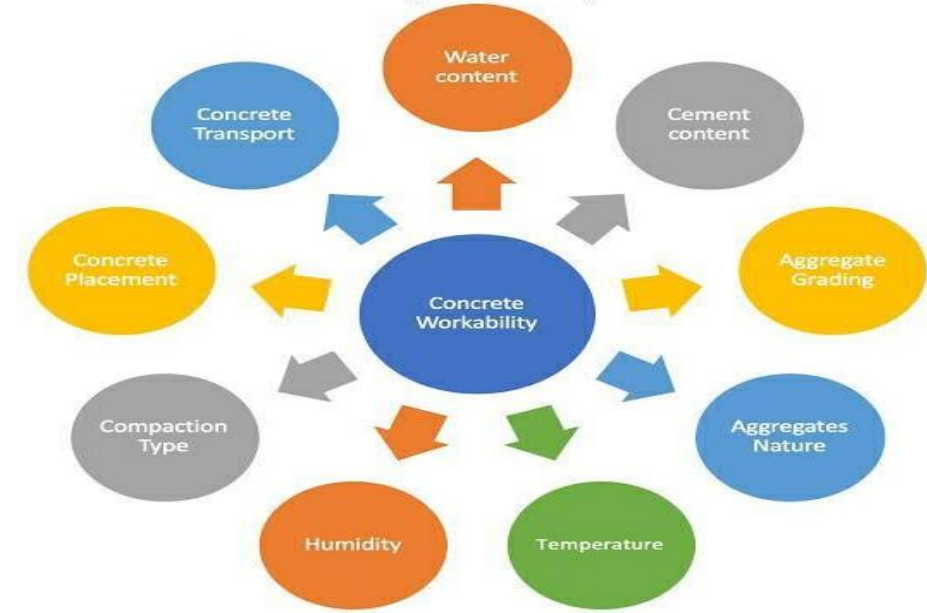
- The strength of concrete is the most important property for us. It depends on density ratio or compaction and compaction depend on sufficient workability. Fresh concrete must have a workability as compaction to maximum density is possible with a reasonable amount of work.
- But excessive workability can lessen compressive strength. From the above graph, we see that compressive strength of concrete decreases with increase in w/c ratio. An increase of w/c ratio indicates an increase of workability. Hence, the strength of concrete inversely proportional to the workability and too much workability should be avoided.

Methods of Improving Workability of Concrete

To increase workability there are some ways like:

- Increasing water/cement ratio
- Using larger aggregate
- Using well-rounded and smooth aggregate instead of irregular shape
- Increasing the mixing time and mixing temperature
- Using non-porous and saturated aggregate
- With addition of air-entraining mixtures
- Adding appropriate admixtures

Factors Affecting Workability of Concrete

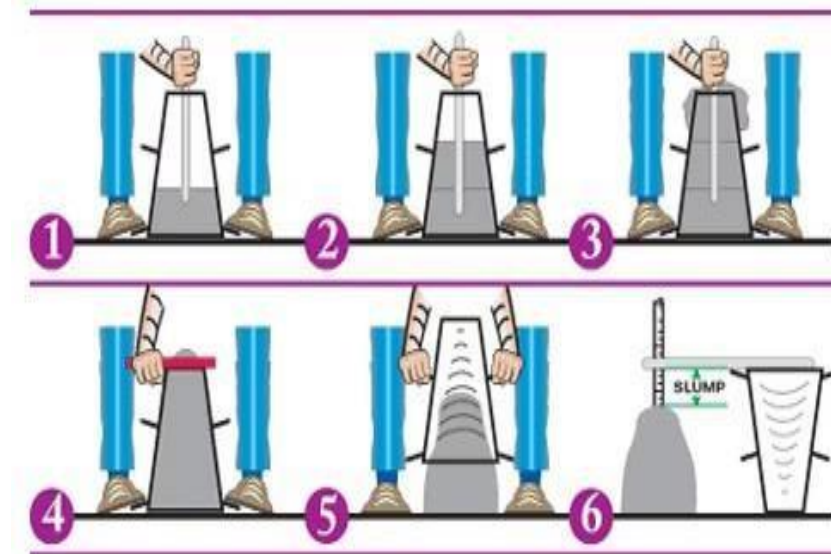
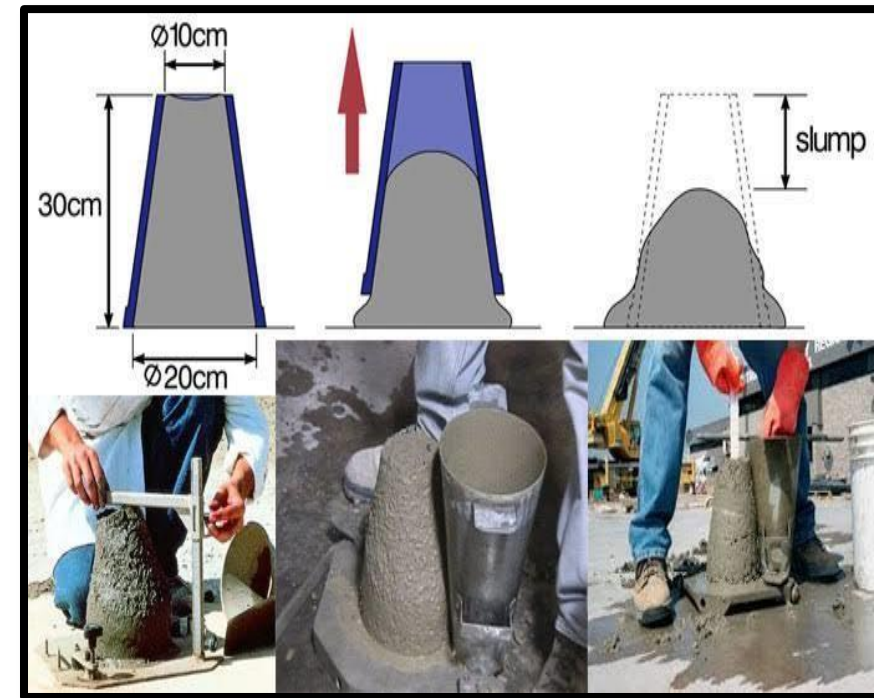


1. Slump test for Workability of Concrete-

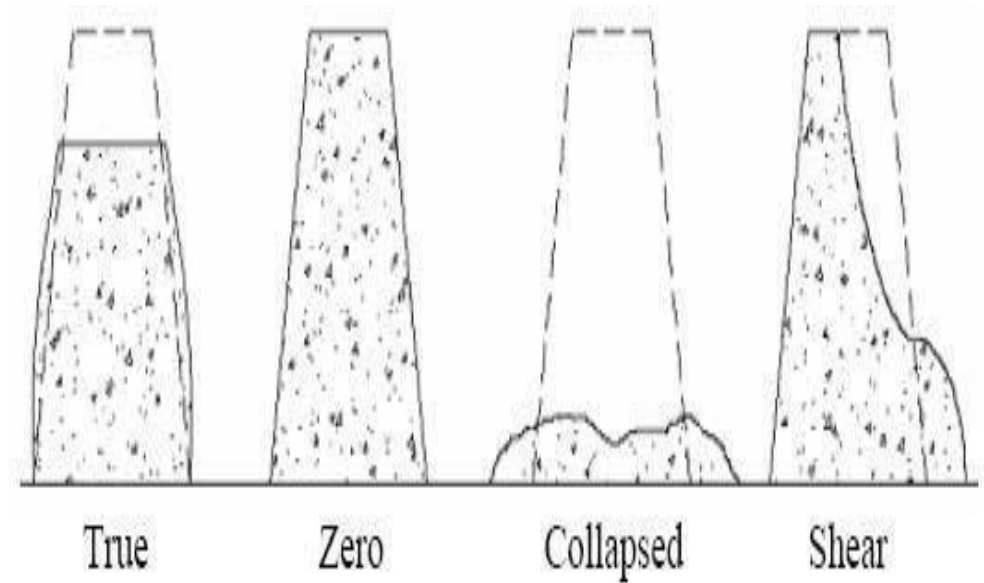
- The slump test is perhaps the most frequently used, primarily due to the ease of the apparatus required as well as the test procedure. The slump test suggests the behavior of a compacted concrete cone below the action of gravitational forces.
- The test is carried out with a mold known as the slump cone. The slump cone is placed on a horizontal and also non-absorbent surface and full of three equal layers of fresh concrete, and each layer being tamped 25 occasions with a typical tamping rod. mold is raised vertically without disturbing the concrete cone.
- The subsidence of concrete in millimeters is known as the slump as shown in as per below figure — the concrete after the test when slumps evenly all around are called true slump.

Slump Test of Concrete

- In the case of very lean concrete, one-half of the cone may slide down the other, which is known as a shear slump; also, it can collapse in case of very moist concretes..The slump test is fundamentally a ***measure of consistency*** or the wetness of this mix.
- The test is suitable Just for concretes of medium to high workabilities (i.e., having slump values of 25 mm to 125mm). For very stiff mixes having zero slump, the slump test does not indicate any difference in concretes of different workabilities.
- It must be appreciated that the different concrete of the same slump may, indeed, have different workabilities under the site conditions. But, the slump test was found to be useful in ensuring that the uniformity among different batches of allegedly similar concrete under field conditions.
- The slump test is limited to concretes with a maximum size of aggregate less than 38 mm.



- **Collapse slump** : In this case, fresh concrete collapses completely. Mix is too wet or high workability mix , slump test isn't appropriate for such mix.
- **Shear Slump**: If one-half of the cone slides down in an inclined plane, it is called a shear slump. It is an indication of lack of cohesion of the mix. Again perform the experiment to avoid shear slump .
- **True Slump**: Mix has high stiff consistency. In a true slump concrete just subsides shortly and more or less maintain the mould shape. This type of slump is most desirable.
- **Zero Slump**: If concrete maintains the actual shape of the mould, it is called zero slump which represents stiff, consistent and almost no workability.



7 WORKABILITY OF CONCRETE

7.1 The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below:

Placing Conditions (1)	Degree of Workability (2)	Slump (mm) (3)
Blinding concrete; Shallow sections; Pavements using pavers	Very low	See 7.1.1
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns; Slipform work; Pumped concrete	Medium	50-100 75-100
Trench fill; In-situ piling	High	100-150
Tremie concrete	Very high	See 7.1.2

NOTE—For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used (see also 13.3).

(4) Recommended value of slump for various types of construction as per ACI 211.1-91

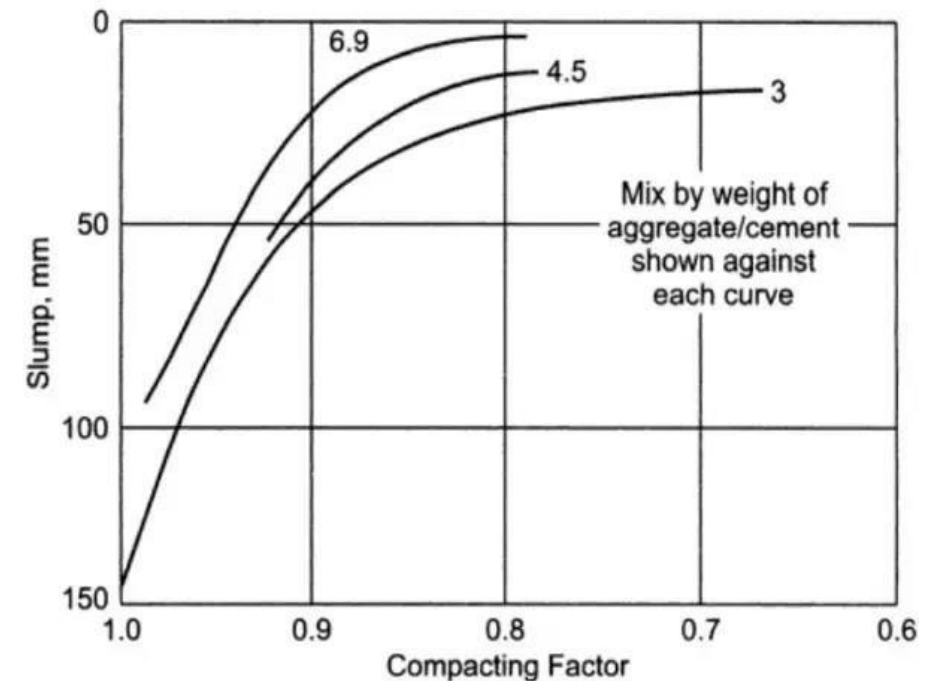
Type of construction	Range of slump (mm)
Reinforced foundation walls & footings	20-80
Plain footings, substructure wall	20-80
Beams & reinforced walls	20-100
Building columns	20-100
Pavements & slabs	20-80
Mass concrete	20-80

2. Competing Factor Test for Workability of Concrete-

- The compacting factor test gives the behavior of fresh concrete under the action of external forces.
- It measures the compatibility of concrete that is an important aspect of workability, by measuring the total amount of compaction attained for a given amount of work.
- The compacting factor test has been held to be more accurate than slump test, especially for concrete mixes of medium and low workabilities, i.e., compacting factor of 0.9 to 0.8, because the test is more sensitive and gives more consistent results.
- The test has been more popular in laboratory conditions.
- For concrete of very low workabilities of the order of 0.70 or below, the test is not suitable, because this concrete cannot be fully compacted for comparison in the manner described in the test. The relationship between a slump and compacting factor is given in as per figure.

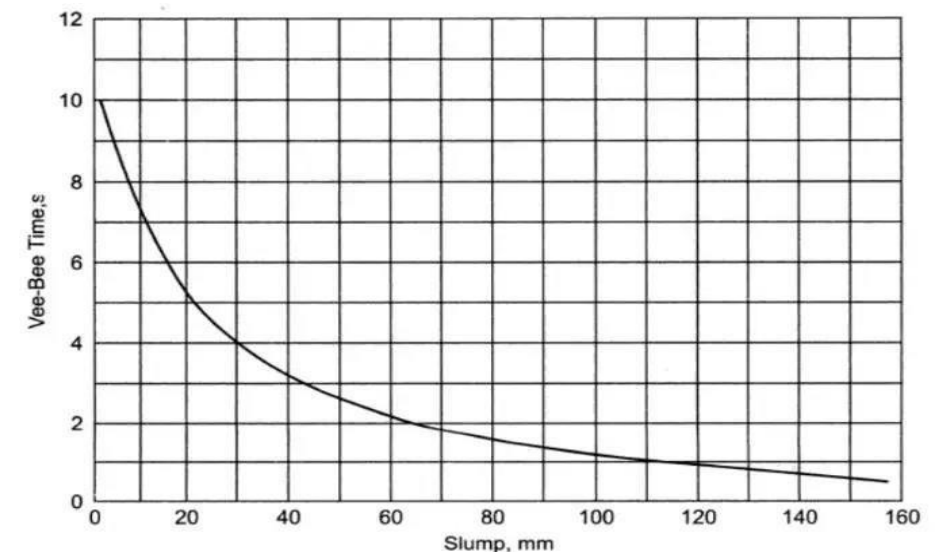
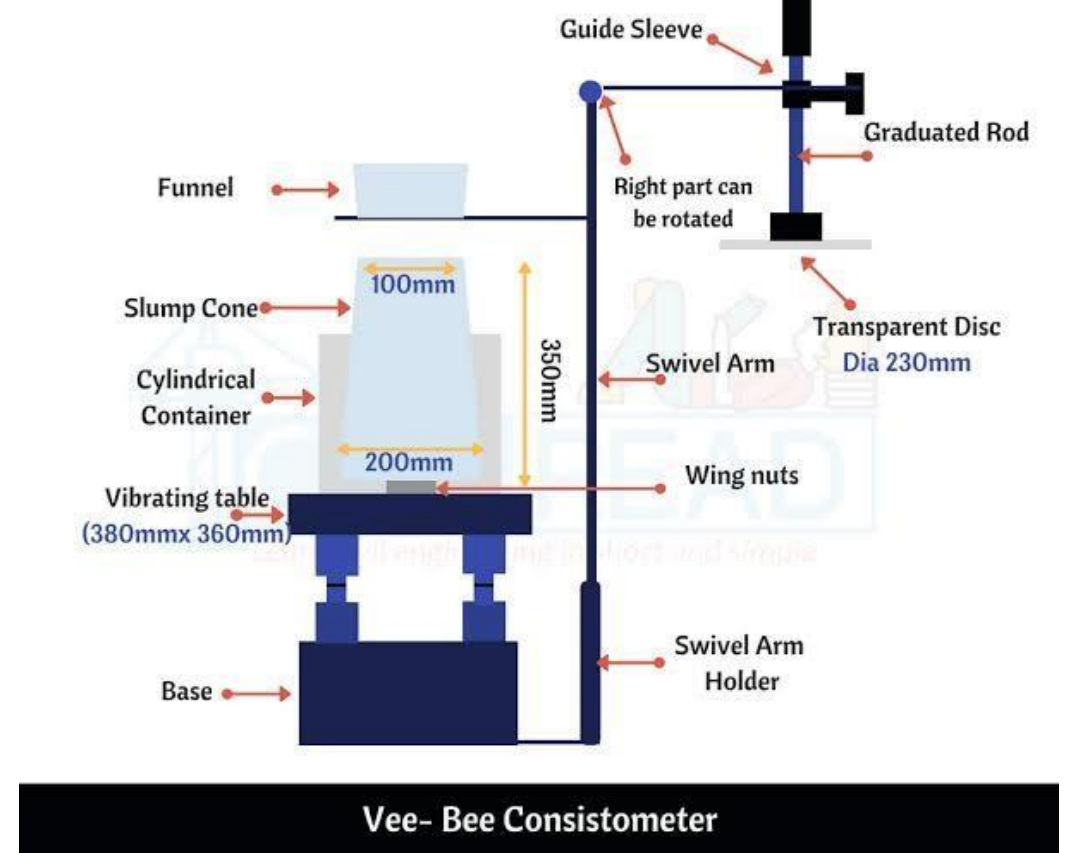
3. Vee-Bee Consistency Test for Workability of Concrete-

- The Vee-Bee test is suitable for stiff concrete mixes having low and very low workability Compared to the slump test and compacting factor test, the Vee-Bee test has the advantage that the concrete in the test receives similar treatment as it would in actual practice.
- The test consists in molding a fresh concrete cone in a cylindrical container mounted on a vibrating table as shown in as per the figure.



Vee-Bee Consistency Test

- The concrete cone, Even when Exposed to vibration by starting the vibrator, Begins to Devour the cylindrical container by way of Being remolded.
- The remolding is deemed complete when the cement surface becomes horizontal.
- The time necessary for the whole remolding in seconds is considered as a measure of workability and can be expressed as the number of Vee-Bee seconds.
- Since the endpoint of the test—when the concrete surface be-comes horizontal—is To be discovered visually, it introduces a source of error that is more pronounced for concrete mixes of high workability and hence records low Vee-Bee time
- For concrete of slump in excess of 125 mm, the remolding is so quick that time cannot be measured. The test is, therefore, not suitable for concrete of higher workability, i.e., a slump of 75 mm or above. An approximate relationship between a slump and Vee-Bee time is given in as per below figure.



4. Flow Test for Workability of Concrete-

- Flow test gives the satisfactory performance for concretes of the consistencies for which the slump test can be used.
- The test consists of molding a fresh concrete cone on the top of the platform of the flow table, and in giving 15 jolts of 12.5 mm magnitudes.
- The spread of this concrete, measured as the increase in diameter of the cone, is accepted as a measure of the movement or flow of the concrete.
- The test suffers from the drawback that the concrete may scatter on the flow table with a tendency towards segregation.

■ The workability requirements for a concrete construction depends on:

- Water cement ratio
- Type of construction work
- Method of mixing concrete
- Thickness of concrete section
- Extent of reinforcement
- Method of compaction
- Distance of transporting
- Method of placement
- Environmental condition



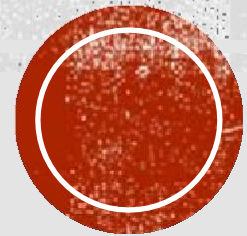
CONCRETE TECHNOLOGY

CHAPTER-05

PROPERTIES OF HARDENED CONCRETE



BY:- Er. Abhijit Sahoo



5 PROPERTIES OF HARDENED CONCRETE:

5.1 Cube and cylinder compressive strengths, flexural strength of concrete, stress-strain and elasticity, phenomena of creep and shrinkage, permeability, durability of concrete, sulphate, chloride and acid attack on concrete, efflorescence.



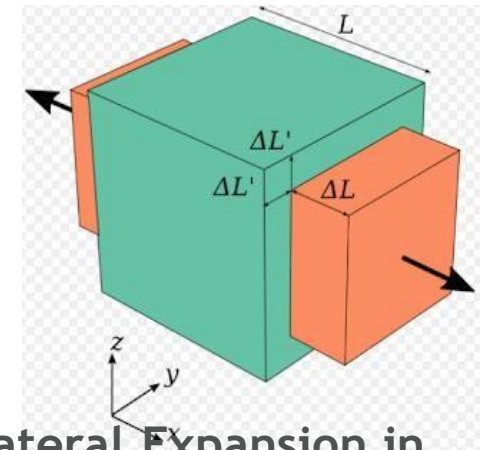
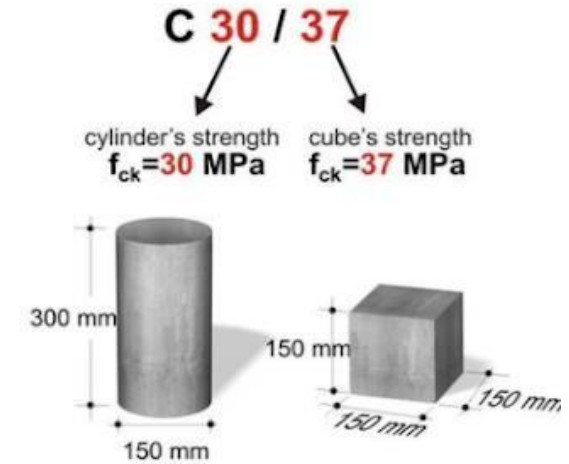


The principal properties of hardened concrete which are of practical importance can be listed as:

- Strength
 - Permeability & durability
 - Shrinkage & creep deformations
 - Response to temperature variations
- Of these compressive strength is the most important property of concrete.

5.1.1 Cube and cylinder compressive strengths

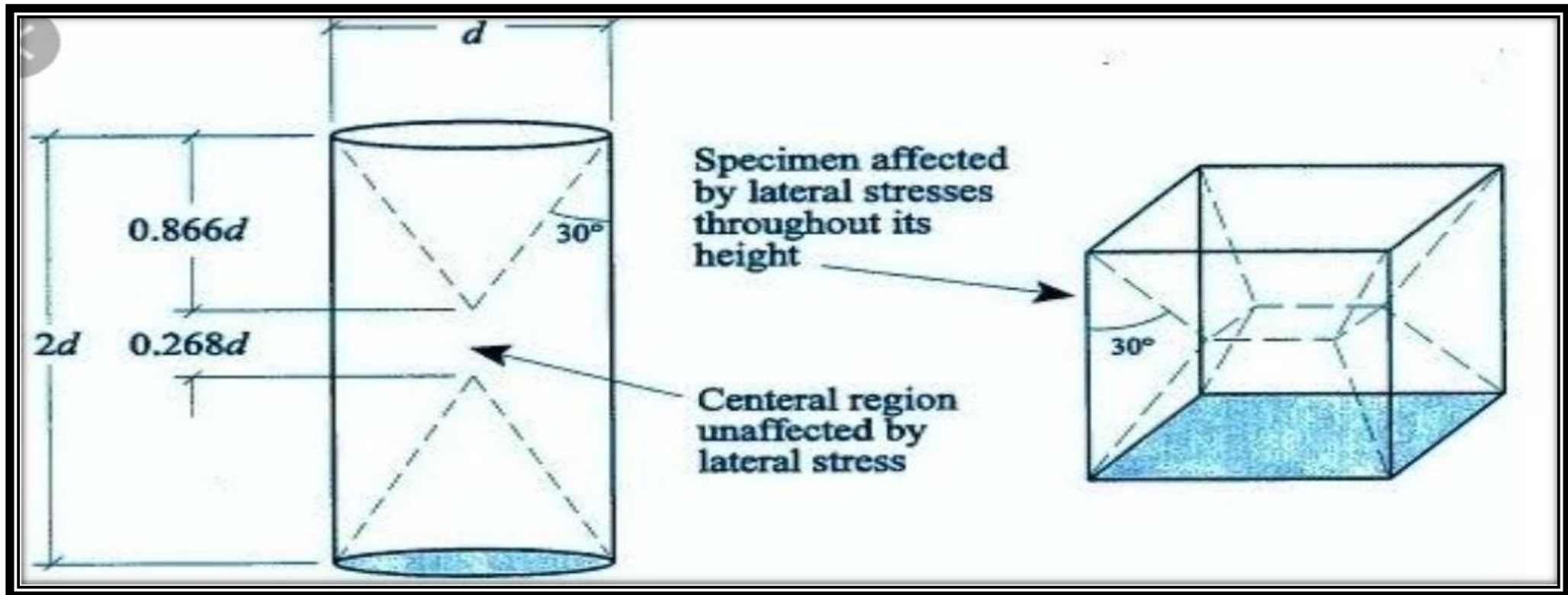
- The Compressive strength test will result in a compressive load on the cube and the cylinder during the test procedure. This process will result in the Lateral Expansion of the sample which will result in the Poisson's ratio effect. The figure shows the compressive testing arrangement of a cube.
- The steel platens are placed above and below the specimen (cube/ cylinder) before the specimen is loaded. There no kind of lateral expansion carried out in the steel plates when compared to the concrete specimen. This means that the steel will restrain the tendency of concrete to expand in the lateral direction.
- This restrains for lateral expansion by the platen is shown in the concrete which is near to the end of the plate. The degree of restraining is depended on the friction that is actually developed.
- Hence under normal conditions, an element within the specimen will undergo a combination of “shear stress”. This is because of the
 - Friction between the platens and the specimen – Stress 1
 - Compressive Load due to the loading action - Stress 2
- It is observed that the combination of Stress 1 and Stress 2 will result in the axial load failure. This will result in providing a compressive strength value which is higher.

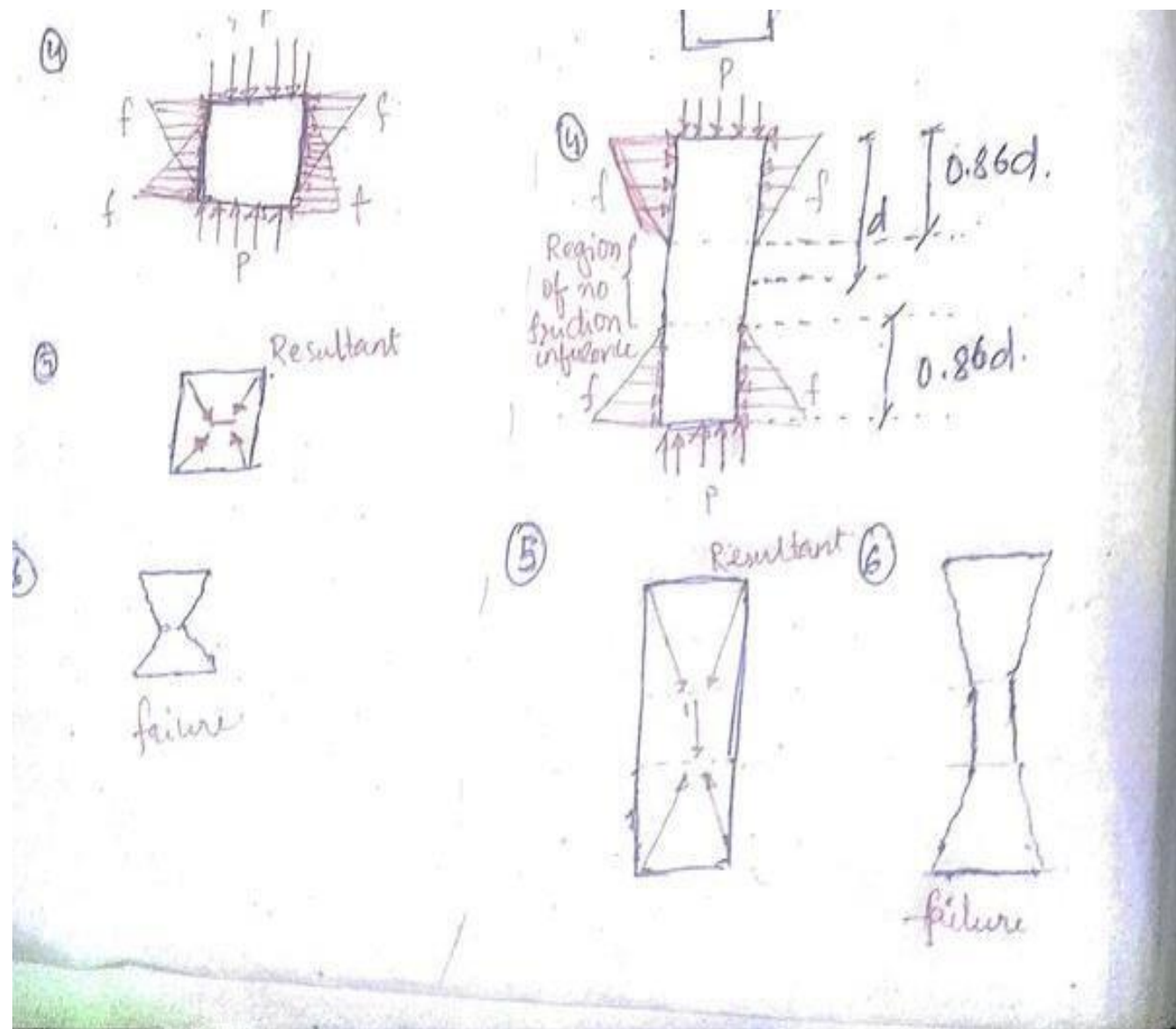
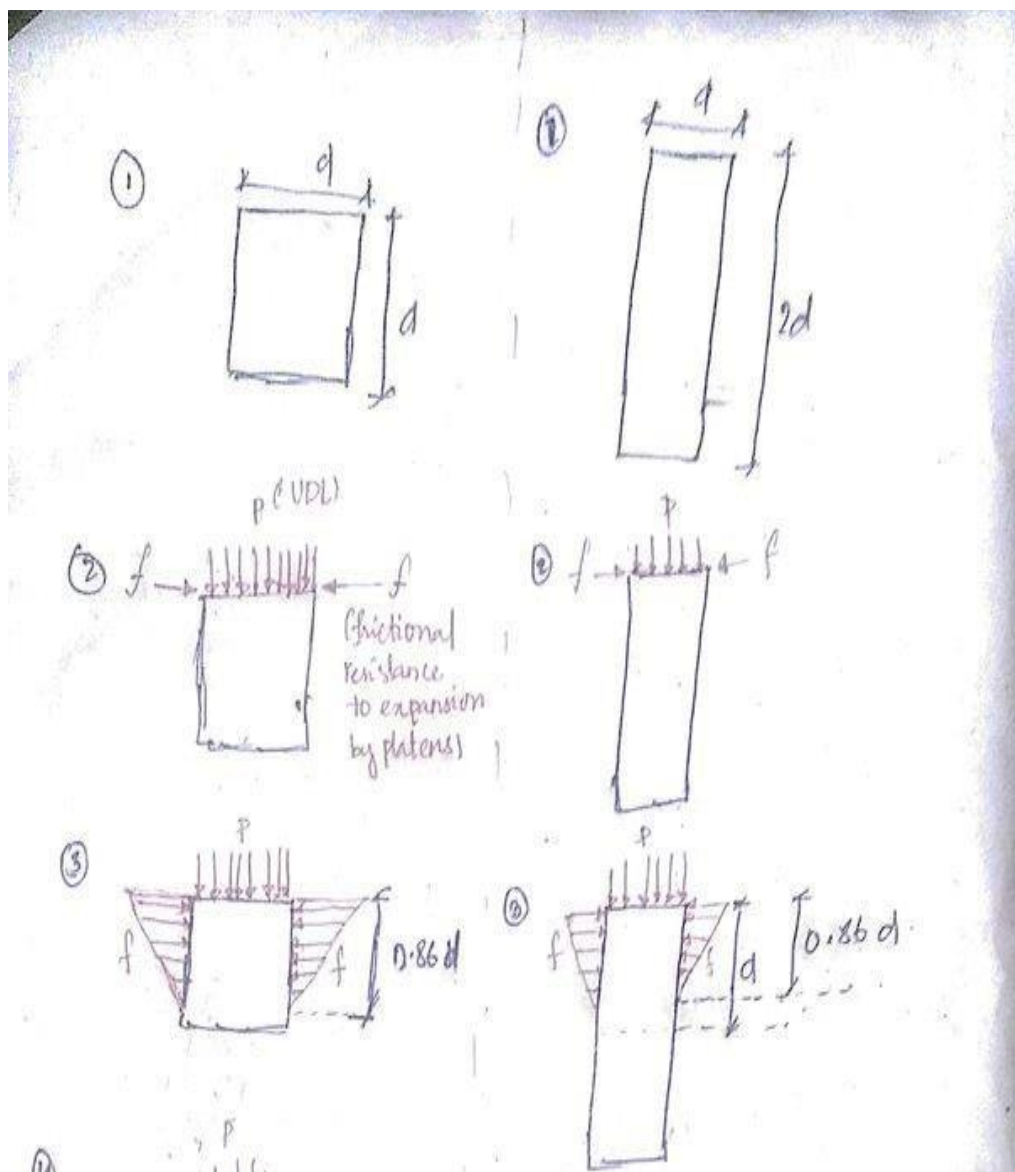


**Lateral Expansion in
Cube during Compression
Test**



- It has been observed that the restraining effect due to friction between the specimen and the platens extends over the entire height of the cube. But in the case of the cylinder, it remains unaffected. The activity is explained in the figure-1 and figure-2.
- Hence, it is clear that the total stress that will be created in the cube will be higher compared with the cylinder specimen. This will result in a higher value of the compressive strength in cubes than the cylinder even by employing the same concrete mix.
- Hence their relation can be given as: **Compressive Strength of cylinder = 0.8 x (Compressive Strength of Cube)**





5.1.2 flexural strength of concrete:-

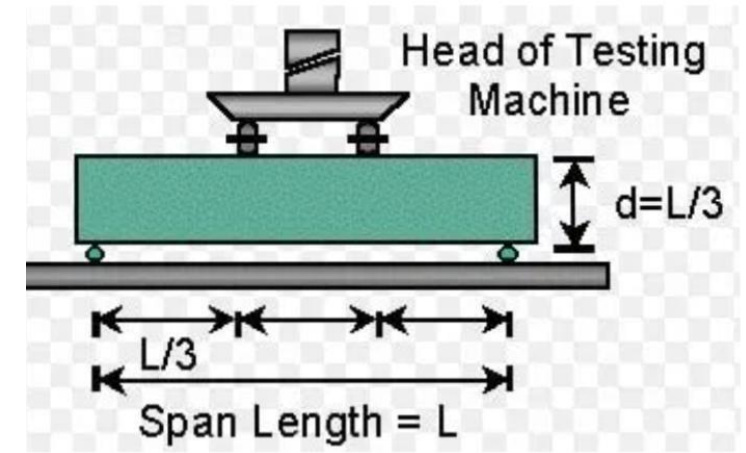
- Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending.
- The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi.
- The flexural test on concrete can be conducted using either three point load test (ASTM C78) or center point load test (ASTM C293)
- It should be noticed that, the modulus of rupture value obtained by center point load test arrangement is smaller than three-point load test configuration by around 15 percent.
- Moreover, it is observed that low modulus of rupture is achieved when larger size concrete specimen is considered.
- Furthermore, modulus of rupture is about 10 to 15 percent of compressive strength of concrete. It is influenced by mixture proportions, size and coarse aggregate volume used for specimen construction.
- Finally, the following equation can be used to compute modulus of rupture, but it must be determined through laboratory test if it is significant for the design:

Where:

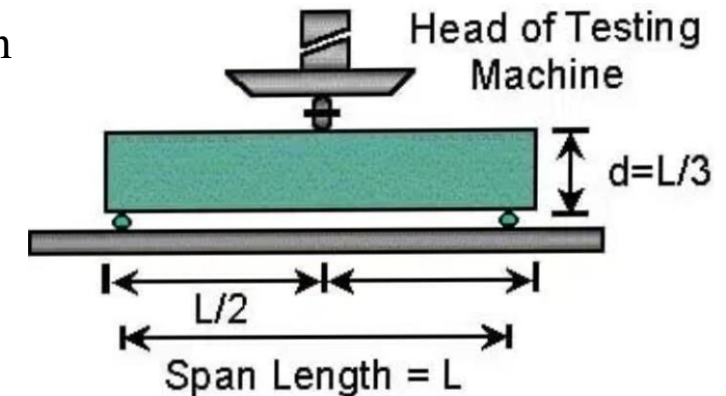
f_r : Modulus of rupture

f'_c : concrete compressive strength

$$f_r = 7.5\sqrt{f'_c} \rightarrow \text{Equation-1}$$



Three-Point Load Test (ASTM C78)



Center Point Load Test (ASTM C293)



Applications of Flexural Test on Concrete

Following are the applications of flexural test:

- Specifying compliance with standards
- It is an essential requirement for concrete mix design
- It is employed in testing concrete for slab and pavement construction

Factors Cause Variability in Flexural Test Results

- Concrete specimen preparation
- Specimen size
- Moisture condition of the concrete specimen
- Curing of the concrete specimen
- And whether the specimen is molded or sawed to the required size

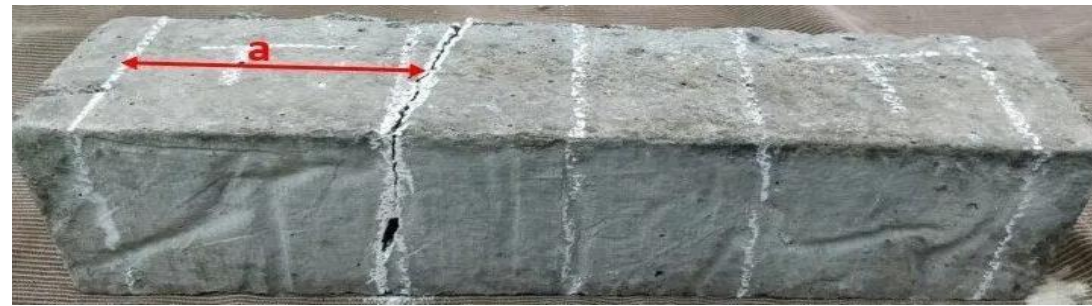
Size of Concrete Specimen for Flexural Test

- According to ASTM the size of the specimen is 150mm width, 150mm depth and the length should not be at least three times the depth of the specimen.
- Indian standard determined the size of the concrete specimen as 150mm width, 150mm depth, and span of 700mm.
- It also states that a size of 100mm width, 100mm depth, and span of 500mm can be used if the maximum aggregate size used is not greater than 19mm.
- British standard specifies square specimen cross section with 100mm or 150mm dimension and the span ranges from four to five times specimen depth.
- However, it preferred 150mm width, 150mm depth, and span of 750mm for the specimen.



Sample Preparation of Concrete

- Determine proportions of materials including cement, sand, aggregate and water.
- Mix the materials using either by hand or using suitable mixing machine in batches with size of 10 percent greater than molding test specimen.
- Measure the slump of each concrete batch after blending.
- Place molds on horizontal surface and lubricate inside surface with proper lubricant material and excessive lubrication should be prevented.
- Pour fresh concrete into the molds in three layers.
- Compact each layer with 16mm rod and apply 25 strokes for each layer or fill the mold completely and compact concrete using vibration table.
- Remove excess concrete from the top of the mold and smoothen it without imposing pressure on it.
- Cover top of specimens in the molds and store them in a temperature room for 24 hours.
- Remove the molds and moist cure specimens at $23 \pm 2^\circ \text{C}$ till the time of testing.
- The age of the test is 14 days and 28 days and three specimens for each test should be prepared (according to Indian Code, the specimen is stored in water at $24\text{-}30^\circ \text{C}$ for 48 hours and then tested)



Procedure of Flexural Test on Concrete

- The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength.
- Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points.
- Center the loading system in relation to the applied force.
- Bring the block applying force in contact with the specimen surface at the loading points.
- Applying loads between 2 to 6 percent of the computed ultimate load.
- Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more.
- Eliminate any gap greater than 0.10mm using leather shims (6.4mm thick and 25 to 50mm long) and it should extend the full width of the specimen.
- Capping or grinding should be considered to remove gaps in excess of 0.38mm.
- Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 Kg/min for 150mm specimen and 180kg/min for 100mm specimen, stress increase rate $0.06 \pm 0.04 \text{ N/mm}^2 \text{ s}$ according to British standard).
- The loading rate as per ASTM standard can be computed based on the following equation:

$$r = \frac{Sbd^2}{L} \rightarrow \text{Equation-2}$$

Where:

- r : loading rate, S : rate of increase of extreme fiber, b : average specimen width, d : average specimen depth, L : span length
- Finally, measure the cross section of the tested specimen at each end and at center to calculate average depth and height.



Computation of Modulus of Rupture

The following expression is used for estimation of modulus of rupture:

$$MR = \frac{3PL}{2bd^2} \rightarrow \text{Equation-3}$$

Where:

MR : modulus of rupture

P : ultimate applied load indicated by testing machine, L : span length

b : average width of the specimen at the fracture, d : average depth of the specimen at the fracture



5.1.3 Stress-strain and elasticity:-

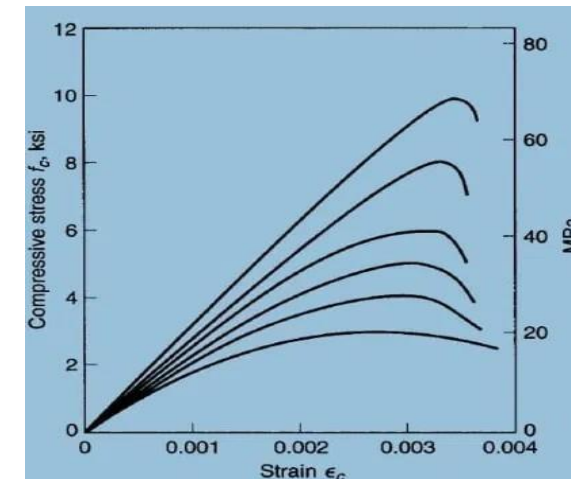
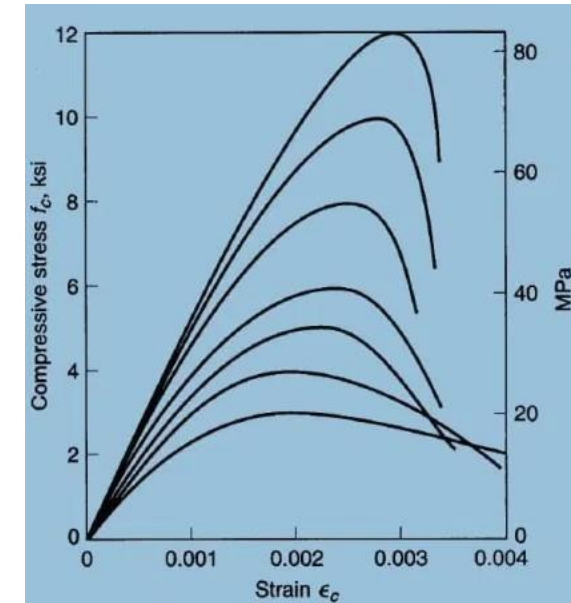
- Stress strain curve of concrete is a graphical representation of concrete behavior under load. It is produced by plotting concrete compress strain at various interval of concrete compressive loading (stress). Concrete is mostly used in compression that is why its compressive stress strain curve is of major interest.
- The stress and strain of concrete is obtained by testing concrete cylinder specimen at age of 28days, using compressive test machine. The stress strain curve of concrete allows designers and engineers to anticipate the behavior of concrete used in building constructions. Finally, the performance of concrete structure is controlled by the stress strain curve relationship and the type of stress to which the concrete is subjected in the structure.

1. Straight or Elastic Portion

- Initially, all stress strain curves (Fig.1 and Fig. 2) are fairly straight; stress and strain are proportional. With this stage, the material should be able to retain its original shape if the load is removed. The elastic range of concrete stress strain curve continues up to $0.45f_{ck}$ (maximum concrete compressive strength). The slope of elastic part of stress strain curve is concrete modulus of elasticity. The modulus of elasticity of concrete increases as its strength is increased. ACI Code provides equations for computing concrete modulus of elasticity.

2. Peak Point or Maximum Compress Stress Point

- The elastic range is exceeded and concrete begin to show plastic behavior (Nonlinear), when a load is further increased. After elastic range, the curve starts to horizontal; reaching maximum compress stress (maximum compressive strength). For normal weight concrete, the maximum stress is realized at compressive strain ranges from 0.002 to 0.003. however, for lightweight concrete, the maximum stress reached at strain ranges from 0.003 to 0.0035. The higher results of strain in both curves represent larger strength. For normal weight concrete, the ACI Code specified that, a strain of 0.003 is maximum strain that concrete can reach and this value used for design of concrete structural element. However, the European Code assumes concrete can reach a strain of 0.0035, and hence this value is used for the design of concrete structural element.



3. Descending Portion

- After reaching maximum stress, all the curves show descending trend. The characteristics of the stress strain curve in descending part is based on the method of testing. Long stable descending part is achieved if special testing procedure is employed to guarantee a constant strain rate while cylinder resistance is decreasing. However, if special testing procedure is not followed, then unloading after peak point would be quick and the descending portion of the curve would not be the same.

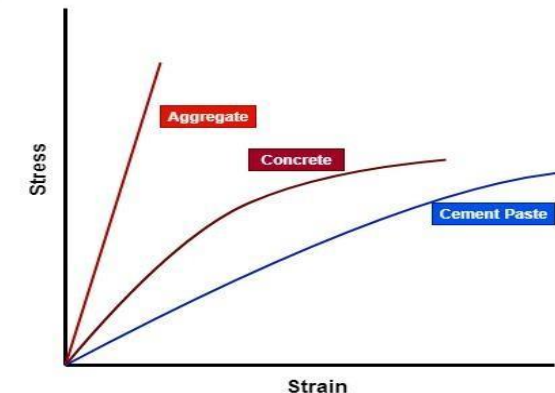
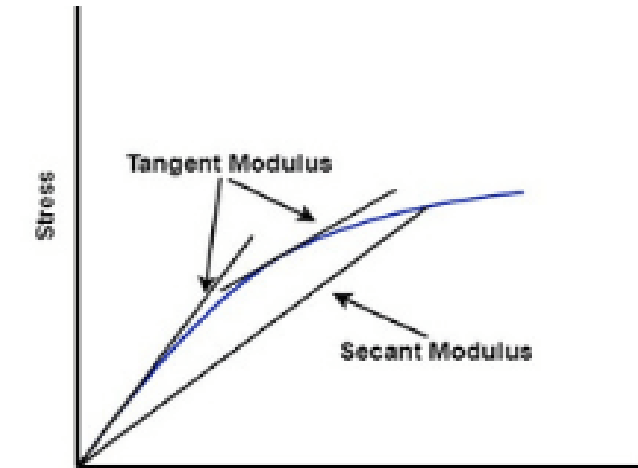
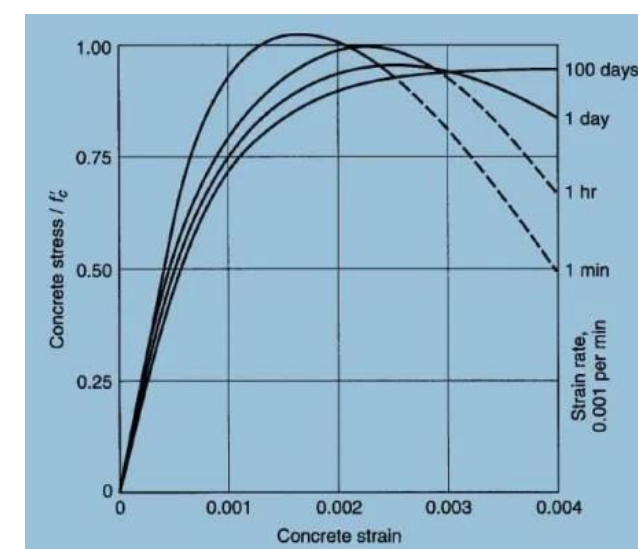
5.1.4 Modulus of Elasticity of Concrete:-

- Modulus of elasticity of concrete is the measurement of the stiffness of the concrete which is a good indicator of strength.
- At a higher value of modulus of elasticity, the concrete can withstand higher stress and become brittle. In general, Concrete has an elastic modulus in a range of 30 to 50 GPa.
- In recent years, design codes have specified a required minimum modulus of elasticity of concrete to be met. The objective is to limit the excessive deformation and sway in tall buildings.
- The expression for the modulus of elasticity of concrete, recommended by IS 456:2000 is

$$E_c = 5000f_{ck}$$

where f_{ck} is the characteristic strength of concrete.

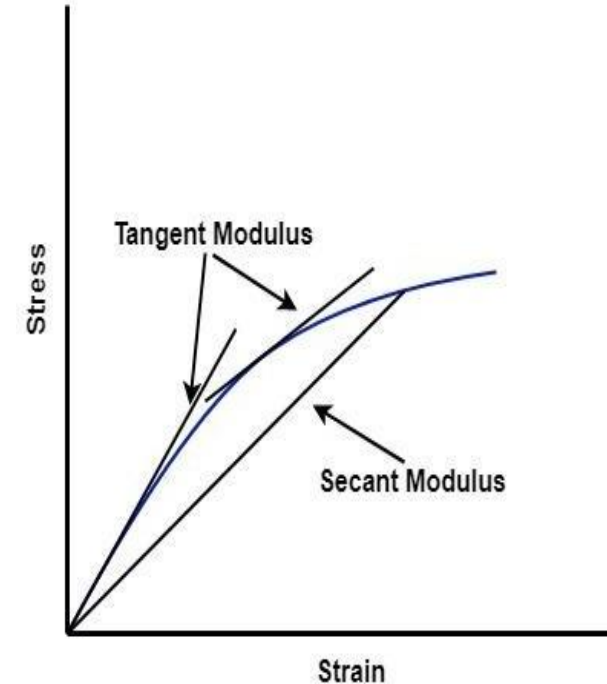
- Concrete is a heterogeneous, multi-phase material, whose behaviour is influenced by the elastic properties and morphology of its component materials. So, the stress-strain curve does not exactly follow Hooke's law.
- The components of concrete i.e. cement paste and aggregates, when individually subjected to loading, they show almost linear stress-strain relation.



■ Types of Modulus of Elasticity of Concrete

Static Modulus of elasticity

- Static modulus of elasticity of concrete is defined as the slope of the stress-strain curve under uniaxial tension or compression loading.
- When we test a concrete specimen in tension or compression, the following stress-strain relation is observed.
 - Young's modulus of elasticity can be applied only to the linear portion of the stress-strain curve. When the curve for concrete is not straight any point, the modulus of elasticity is found out reference to a tangent drawn the curve at the origin. This is called the **initial tangent modulus**.
 - But it gives a satisfactory result at a low-stress value only. It is of no practical importance because it applies only to very small changes in load at which the tangent modulus is considered.
 - The strain in the specimen depends on the speed of loading. So it is difficult to differentiate between elastic and creep strains. For ease in understanding, any strain occurring during loading is called elastic and any subsequent increase in strain is called creep.
 - The modulus of elasticity of concrete which includes both strains is called **Secant modulus** or chord modulus. It is the common elastic modulus of concrete. It is given by the slope of the line drawn connecting a specified point on the curve to the origin of the curve.
 - **The secant modulus is a static modulus because it is determined on a test specimen.**
 - The secant modulus decreases with an increase in stress. So the stress at which secant modulus is determined must be mentioned.



Dynamic modulus of concrete

- Dynamic modulus of elasticity of concrete represents the progressive changes in the state of a concrete specimen. The change can be observed by determining the fundamental resonant frequency of the specimen at appropriate stages of the investigation.



5.1.5 Phenomena of creep and shrinkage:-

Throughout the course of time, structural concrete may undergo wear and tear, which may cause cracking, stresses or deflections that will affect the in-service behavior of the reinforced concrete structures. This time-dependent phenomenon in concrete that we observed is called the creep and shrinkage.

Creep

- Creep is the gradual increase in a strain of a structural member which is subjected to certain loading over a period of time. When the concrete is loaded in compression. If this load remains on the member, creep strain developed with time.
- The main factors affecting creep strain are the concrete strength and mixture, the type of aggregate, curing, the relative humidity and the duration of the sustained loading.

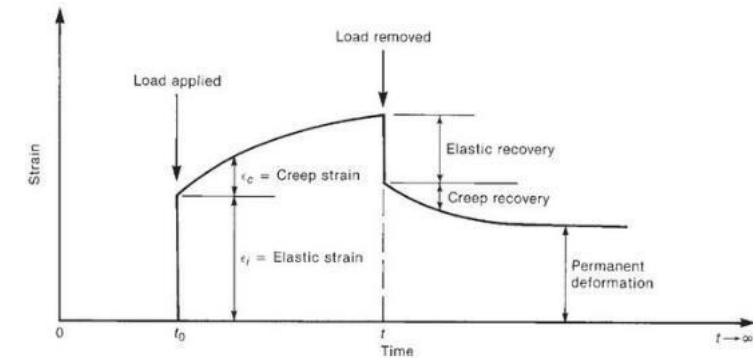
$$\epsilon_{cc} = (\text{Stress} / E_t) * \phi$$

where:

creep strain in concrete, ϵ_{cc}

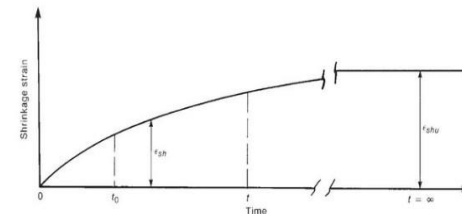
E_t : is the modulus of elasticity of concrete at the age of loading t

Φ is the creep coefficient which can be taken from figure 7.1 of BS8110: Part 2



Shrinkage

- Shrinkage is the contraction that occurs in concrete when it dries and hardens due to moisture content evaporation. The amount of shrinkage increases with time. The aggregate contents present in concrete are the most important factors influencing shrinkage. This is because the larger the aggregate, the lower is the shrinkage and the higher is the aggregate content, the lower the water-cement ratio and workability are. A decrease in ambient humidity also increases shrinkage.



- On the other hand, Shrinkage has been discussed in BS8110: Part 2, section 7.4. The values obtained from the shrinkage strain are used in the deflection calculation. An estimate of the shrinkage of the symmetrically reinforced concrete section may be obtained from: $(\epsilon_{sh}/(1+K\rho))$

where: ϵ_{sh} is the shrinkage of the plain concrete

ρ (rho) is the area of steel relative to that of concrete

K is a coefficient, taken as 25 for internal exposure and as 15 for external exposure.

- Hardened Concrete undergoes in three types of shrinkage that are important with respect to its dimensional stability:
 1. Plastic shrinkage.
 2. Drying shrinkage.
 3. Thermal shrinkage.

1. Plastic Shrinkage.

- This is the shrinkage that the freshly placed concrete undergoes till it sets completely. It may also be called initial shrinkage. Such a volumetric change is due to loss of water from the fresh concrete due to evaporation, bleeding, seepage and soaking by formwork.
- Excessive shrinkage at initial stages may develop extensive cracking in the concrete on the setting. Therefore, all precautions should be taken to avoid excessive loss of water due to evaporation.

2. Drying Shrinkage :

- As the concrete has completely set and hardens, some further shrinkage may result because of contraction of gel-structure due to further loss of moisture, or drying.
- This kind of shrinkage is practically an essential and irreversible property of concrete. It has to be met with by careful design of reinforcement to avoid its ill effects.

3. Thermal Shrinkage:- This may be due to fall in temperature of concrete from the time it is laid till it sets completely. Thus, when concrete laid at 30°C cools down to 15°-18°C, some shrinkage may be expected. It may be negligible on its own account. But when added to drying shrinkage, it becomes necessary.



5.1.6 Durability

- Environmental forces such as weathering, chemical attack, heat, freezing and thawing try to destroy concrete. The period of existence of concrete without getting adversely affected by these forces is known as durability. Generally dense and strong concretes have better durability. The cube crushing strength alone is not a reliable guide to the durability. Concrete should have an adequate cement content and should have low water cement ratio.

5.1.7 Impermeability

- This is the resistance of concrete to the flow of water through its pores. Excess water during concreting leaves a large number of continuous pores leading to the permeability. Since the permeability reduces the durability of concrete, it should be kept very low by using low water cement ratio, dense and well graded aggregates, good compaction and continuous curing at low temperature conditions. The cement content used should be sufficient to provide adequate workability with low water cement ratio and the available compaction method.

5.1.8 Chloride attack on concrete

Chloride attack on concrete is one of the important aspects of durability of concrete. It primarily affects the reinforcement of concrete and cause corrosion. Chlorides can be introduced into the concrete either during or after construction as follows.

Before construction Chlorides can be admitted in admixtures containing calcium chloride, through using mixing water contaminated with salt water or improperly washed marine aggregates.

After construction Chlorides in salt or sea water, in airborne sea spray and from de-icing salts can attack permeable concrete causing corrosion of reinforcement.

The chloride in the presence of water and oxygen reacts with alkaline protected layer around the reinforcement and removes it.



▪ Sulphate attack on concrete

- Most of the soil types contains sulphates in the form of calcium, magnesium, sodium, ammonium and potassium. They occur in soil or ground water. When a concrete structure is built on these types of soils, they may attack the concrete.
- Generally sulphates in solid form do not attack the concrete severely but when they are in liquid form they pass into the voids of concrete and react with hydrated cement products. Calcium sulphate causes minimum damage because of its low solubility while magnesium sulphate causes maximum damage.
- Most of the sulphates attacks calcium hydroxide and hydrated calcium aluminates present in the concrete and results in changing the volume of cement paste in concrete. Hence deterioration of concrete structure takes place. Along with calcium hydroxide, Magnesium sulphate also reacts with hydrated calcium silicate and makes concrete into powdered mass.

Precautions

- Concrete with low water cement ratio is less affected by magnesium sulphate while high water cement ratio concrete is highly affected
- Use Super sulphate Cement and Sulfate Resisting cement in place of OPC.

Acid attack on concrete

- Acids can attack concrete easily since concrete is not fully resistant against acids. Some acids like oxalic acid, phosphoric acids are not harmful to the concrete. Calcareous aggregates are more affected by acids while siliceous aggregates are good resistant.
- The damage level is purely depends upon the pH of the acid solution. Damage is very severe if the pH value is very low. If they reach reinforcement through crack or pores, they will cause corrosion of bars and cracking of concrete will occur.

Prevention of acid attack

- To prevent acid attack good dense concrete with adequate cover is required and sulphate-resistant cements should be used.



Efflorescence:-

- Efflorescence in concrete is a whitish coloured powdered deposition of salts on the concrete surface that is formed due to evaporation of water from the concrete. It is caused when water soluble salts are present in the concrete material, which comes on to the surface while evaporation of water from the concrete.

Causes for Formation of Efflorescence in Concrete

The formation of efflorescence in concrete is factored by many external factors.

- Presence of salts in one of the materials of concrete. Commonly salts are found in the fine aggregate or sand taken from the river beds.
- If the concrete is not cured properly, the hydration process is incomplete on which the un-hydrated products near the surface form the efflorescence on the surface of concrete.
- Slow rate of evaporation of water allowing time for salts to permeate to the surface (this is why efflorescence tends to be more of a problem during the winter months; in summer, high temperatures may cause evaporation and hence depositing of salts within the concrete rather than on the surface)
- If the water content in the concrete mix is more, it makes the concrete porous. Thus allowing the path for water and salts to come to the surface and for efflorescence.
- In wet conditions such as rainy season, the surplus water acts as a medium for the salts to transport to the surface of concrete and form crystalline white powder.
- Variability of concrete (compaction or curing) can result in localised problems where water can permeate more easily through the concrete.



▪ **Type of Salts in Efflorescence**

- **Calcium Sulphate** A common efflorescence salt source in brick • **Sodium Sulphate** Often seen in cement-brick reactions
- **Potassium Sulphate** Noticeable in many cement-brick reactions
- **Calcium Carbonate** May be discovered in mortar or concrete backing • **Sodium Carbonate** Frequently seen in mortar
- **Potassium Carbonate** Like sodium carbonate, commonly found in mortar
- **Vanadyl Sulphate** Usually found in brick b • **Manganese Oxide** Often present in brick.

Prevention of Efflorescence in Concrete

1. The preventive methods that can be used to avoid efflorescence in concrete are,
2. Inclusion of Class-F fly ash or metakaolin can lock up significant amounts of calcium hydroxide in the concrete.
3. Installing vapour barrier to prevent the movement of moisture from the sub grade to the surface of a slab.
4. Application of sealers and coatings can prevent surface water from penetrating slabs.
5. Waterproofing agents to be used to reduce permeability of concrete.
6. Making the concrete denser will reduce the permeability of concrete to a greater extent.
7. Preventing the hardened concrete from exposure to moisture by maintaining surface sealers and site drainage, and from rising groundwater by placing a plastic membrane under slabs.
8. Avoiding the concrete from premature drying.
9. Use of concrete ingredient such as aggregate, cement and sand which contains very less amount of salts in it.



- Removal of efflorescence can be done in 3 methods,

1. Pressurised Water

- Efflorescence in the concrete can be removed using the pressurised water jet. Applying pressurised water may dissolve efflorescence quickly. But care must be taken that the water after removing of efflorescence is completely dried off. If not dried, the same water can cause efflorescence to reappear.



2. Brushing

- Some type of efflorescence that are easily removable can be easily removed using a stiff bristle broom or brush. If the result is not satisfactory by dry brushing, scrub with clean water then lightly rinse the surface.

3. Dilute Acid Solution

- Concentrated acid is not recommended to be applied on concrete, diluted proportion of 1:20 is used. the surface in which the acid is applied must be moist but without any free water. The applied solution should be allowed to react on the concrete surface for 10 to 15 minutes. The surface should then be thoroughly rinsed and scrubbed with lots of clean water. Repeat rinsing at least twice or until all traces of the acid solution have been removed.
- Washing with acid may cause colour variations and alter the surface texture. For coloured finishes a more dilute acid solution (2% or 1 part acid to 50 parts water) may be required. A small trial area should be done first to assess the results.
- Proper safety to be followed while doing this procedure. Ensure good ventilation and avoid contact between the acid and the reinforcement.



■ **Acids used in Removal of Efflorescence in Concrete**

1. Hydrochloric acid.
2. Phosphoric acid.
3. Phosphoric acid.
4. Prepackaged efflorescence removers.

Applying of Coating to Prevent Efflorescence in Concrete

- Clear water repellents, silicone and acrylic coatings also may help you remove efflorescence as well. The coating will absorb water across a masonry surface and prevent efflorescence from recurring. Plus, the combination of warm water and white wine vinegar has been shown to eliminate efflorescence.
- Application of sealant coat is done in 3 steps,

1. Rinsing of Concrete

- Rinse the building surface with water. If the surface is outdoors, you can use a hose to spray down the surface. Or, if the surface is indoors, you can use a spray bottle filled with water to rinse the surface thoroughly.

2. Applying the Solution

- Spray the cleaning solution onto the building surface and allow it to sit for several minutes. If necessary, you may need to apply multiple coats of the cleaning solution to the surface for optimal results.

3. Rinsing of Concrete Again

- Rinse the building surface with water one last time. Then, use a fresh, dry cloth to clean the surface. Ensure the surface is dry to minimize the risk of ongoing efflorescence.
- Apply coatings roughly 1/8 in. to 1/4 in. below the surface of the building material. This will prevent water from evaporating and passing through the treated area as vapour and soluble salts.



Properties Of Hardened concrete

Following are the properties of hardened concrete:

1. Strength of concrete
2. Concrete Creep
3. Shrinkage
4. Modulus Of Elasticity
5. Water tightness (impermeability)
6. Rate of Strength gain of Concrete

1. Strength:

- The strength of concrete is basically referred to compressive strength and it depends upon three factors.
 - 1- Paste Strength
 - 2- Interfacial Bonding
 - 3- Aggregate Strength

1. Paste strength:

- It is mainly due to the binding properties of cement that the ingredients are compacted together. If the paste has higher binding strength, higher will be strength of concrete.

2. Interfacial bonding:

- Interfacial bonding is very necessary regarding the strength. Clay hampers the bonding between paste and aggregate. The aggregate should be washed for a better bonding between paste and aggregate.



3. Aggregate strength:

- It is mainly the aggregate that provide strength to concrete especially coarse aggregates which act just like bones in the body. Rough and angular aggregate provides better bonding and high strength.
- **Factors affecting Strength of concrete:**
- Following are the factors that affect the strength of concrete:
 1. Water-Cement ratio
 2. Type of cementing material
 3. Amount of cementing material
 4. Type of aggregate
 5. Air content
 6. Admixtures

1. Water-Cement ratio:

It is water cement ratio that basically governs the property of strength. Lesser the water cement ratio, greater will be strength.

2. Type of cement:

Type of cement affect the hydration process and therefore strength of concrete. Amount of cementing material: it is the paste that holds or binds all the ingredients. Thus greater amount of cementing material greater will be strength.

3. Type of Aggregate:- Rough and angular aggregates is preferable as they provide greater bonding.

4. Admixtures:

Chemical admixtures like plasticizers reduce the water cement ratio and increase the strength of concrete at same water cement ratio. Mineral admixtures affect the strength at later stage and increase the strength by increasing the amount of cementing material.



2. Creep in Concrete:- Concrete creep is defined as: deformation of structure under sustained load. Basically, long term pressure or stress on concrete can make it change shape. This deformation usually occurs in the direction the force is being applied. Like a concrete column getting more compressed, or a beam bending. Creep does not necessarily cause concrete to fail or break apart. Creep is factored in when concrete structures are designed.

3. Shrinkage:- Concrete is subjected to changes in volume either autogenous or induced. Volume change is one of the most detrimental properties of concrete, which affects the long-term strength and durability. To the practical engineer, the aspect of volume change in concrete is important from the point of view that it causes unsightly cracks in concrete.

4. Modulus of Elasticity

- Young's modulus (E) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain. It is often referred to simply as the elastic modulus.
- 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. The modulus of elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops.
- The elastic modulus of the hardened paste may be in the order of 10-30 GPa and aggregates about 45 to 85 GPa. The concrete composite is then in the range of 30 to 50 GPa.

5. Water Tightness

- Watertightness is the ability of concrete to keep water out or in. **Watertight** is a versatile range of specialized ready mix concretes designed to protect a structure from water ingress or to retain water within a structure.
- Water-tight concrete, or concrete made water-tight by some kind of waterproof coating, is frequently required, either for inclosing a space which must be kept dry, or for storing water or other liquids. Concrete, even when most carefully prepared from materials of the highest grade, is never of itself completely waterproof.

6. Rate of Strength Gain of Concrete:- Strength can be defined as ability to resist change. One of the most valuable properties of the concrete is its strength. Strength is most important parameter that gives the picture of overall quality of concrete. Strength of concrete usually directly related to cement paste.



CONCRETE TECHNOLOGY

CHApTUR-02

CONCRETE MIX DESIGN

BY:- Er. Abhijit Sahoo



6 Concrete mix Design

- 6.1 a) Introduction b) Data or input required for mix design.
- 6.2 Nominal mix concrete & design mix concrete.
- 6.3 Basic consideration for concrete mix design, Methods of proportioning concrete mix – I.S Code method of mix design(I.S.10262)



6.1 A) Introduction

- Concrete mix design is process of preparation of concrete with suitable proportion of ingredients to meet the required strength and durability of concrete structure.
- Every ingredient of concrete consists different properties so, it is not an easy task to get economical and good concrete mix.
- Concrete Mix Design means, determination of the proportion of the concrete ingredients i.e. Cement, Water, Fine Aggregate, Coarse Aggregate which would produce concrete possessing specified properties such as workability, strength and durability with maximum overall economy.

B) DATA REQUIRED for Mix Design(IS 10262 - 2009) :-

- a) Grade designation
- b) Type of cement;
- c) Maximum nominal size of aggregate
- d) Minimum cement content
- e) Maximum water-cement ratio
- f) Workability
- g) Exposure conditions as per Table 4 and Table 5 of IS 456
- h) Maximum temperature of concrete at the time of placing
- i) Method of transporting and placing
- j) Early age strength requirements, if required
- k) Type of aggregate
- l) Maximum cement content; and
- m) Whether an admixture shall or shall not be used and the type of admixture and the condition of use.



6.2 Nominal mix concrete & design mix concrete:-

1. Nominal Concrete Mix

- Nominal concrete mix are low grade concrete mixes which are used for small and unimportant works. In this method, fine aggregate quantity is fixed irrespective of cement and coarse aggregate proportions. Hence, the quality of concrete mix will be varied and required strength may not be obtained.
- In Nominal mix design water-cement ratio also not specified. Grades of concrete M20 and below are prepared by the Nominal mix design. For higher grade designed concrete mix is preferred.

2. Designed Concrete Mix

- The designed concrete mix does not contain any specified ranges in proportions. The design is done according to the requirements of concrete strength. So, we can achieve the desirable properties of concrete either it is in fresh stage or in hardened stage.
- The fresh concrete properties like workability, setting time and hardened concrete properties like compressive strength, durability etc. are attained surely by this method. Use of additives like admixtures, retarders etc. other than basic ingredients are used to improve the properties of mix.
- Using design concrete mix, one can design various grades of concrete from as low as M10 grade to higher grades such as M80, M100 can also be prepared. The workability requirements of each mix can also meet using this method from zero slump to the 150 mm slump. Each mix prepared is tested in laboratory after hardening to verify whether it meet the requirement or not.



Advantages of Using Design Mix Concrete

- High-strength concrete and high-performance concrete design are possible
- Concrete can be designed for a variety of environmental conditions and requirements.
- Different varieties of concrete can be prepared such as flyash concrete, pumpable concrete etc.
- Different properties of the materials such as moisture content, fineness, grading are considered in calculation.
- Very accurate & Cost-effective.

Advantages of using Nominal Mix Concrete over Design Mix concrete

- They are easy to design and manufacture
- Batching of materials is easier using pans and batching boxes.
- This method can be easily understood by the workers and followed on the site.

Disadvantages

- Materials calculated from the Nominal mix method are not as accurate as the Design mix method
- Grades more than M20 cannot be designed.
- Concrete cannot be adjusted to suit environmental or construction requirements
- They are not as cheap as the Design mix concrete method when prepared in large quantities.
- High performance or High strength concrete cannot be produced.
- It is dangerous to add compounds such as fly ash or super plasticizers because the calculation does not take these things into account.
- Not Suitable for producing Ready Mix Concrete



6.3 Basic consideration for concrete mix design, Methods of proportioning concrete mix – I.S Code method of mix design(I.S.10262)

- To produce concrete of required strength and properties, selection of ingredients and their quantity is to be found which is called concrete mix design. Proper mix design will solve every problem arises in concrete while placing or curing etc.
- The mix design also helps to produce economical concrete. Generally, cement is more costly than other ingredients of concrete. So, quantity and quality of cement is designed by proper mix design concept.
- **Concrete mix design concept is majorly depending upon the following**
 - Strength and durability
 - Workability
 - Economy
 - specifications

Concrete Mix Design Procedure as per is 10262 – 2009

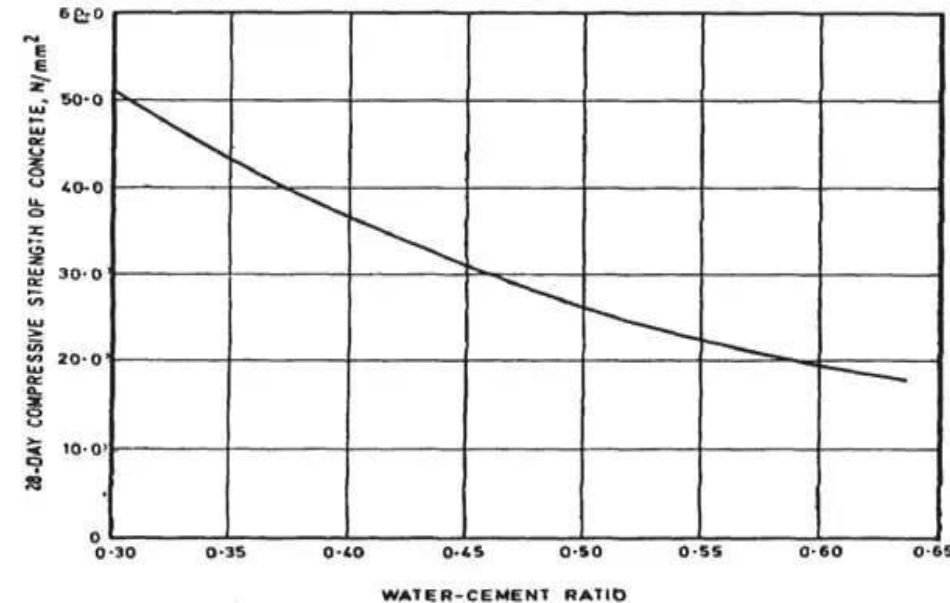
- **Procedure for concrete mix design requires following step by step process:**
 1. Calculation of *target strength* of concrete
 2. Selection of *water-cement ratio*
 3. Determination of *aggregate air content*
 4. Selection of *water content for concrete*
 5. Selection of *cement content for concrete*
 6. Calculation of *aggregate ratio*
 7. Calculation of *aggregate content for concrete*
 8. Trial mixes for *testing concrete mix design strength*



1: Calculation of Target Strength of Concrete

- Target strength is denoted by f_t which is obtained by characteristic compressive strength of concrete at 28 days (f_{ck}) and value of standard deviation (s) $f_t = f_{ck} + 1.65 s$

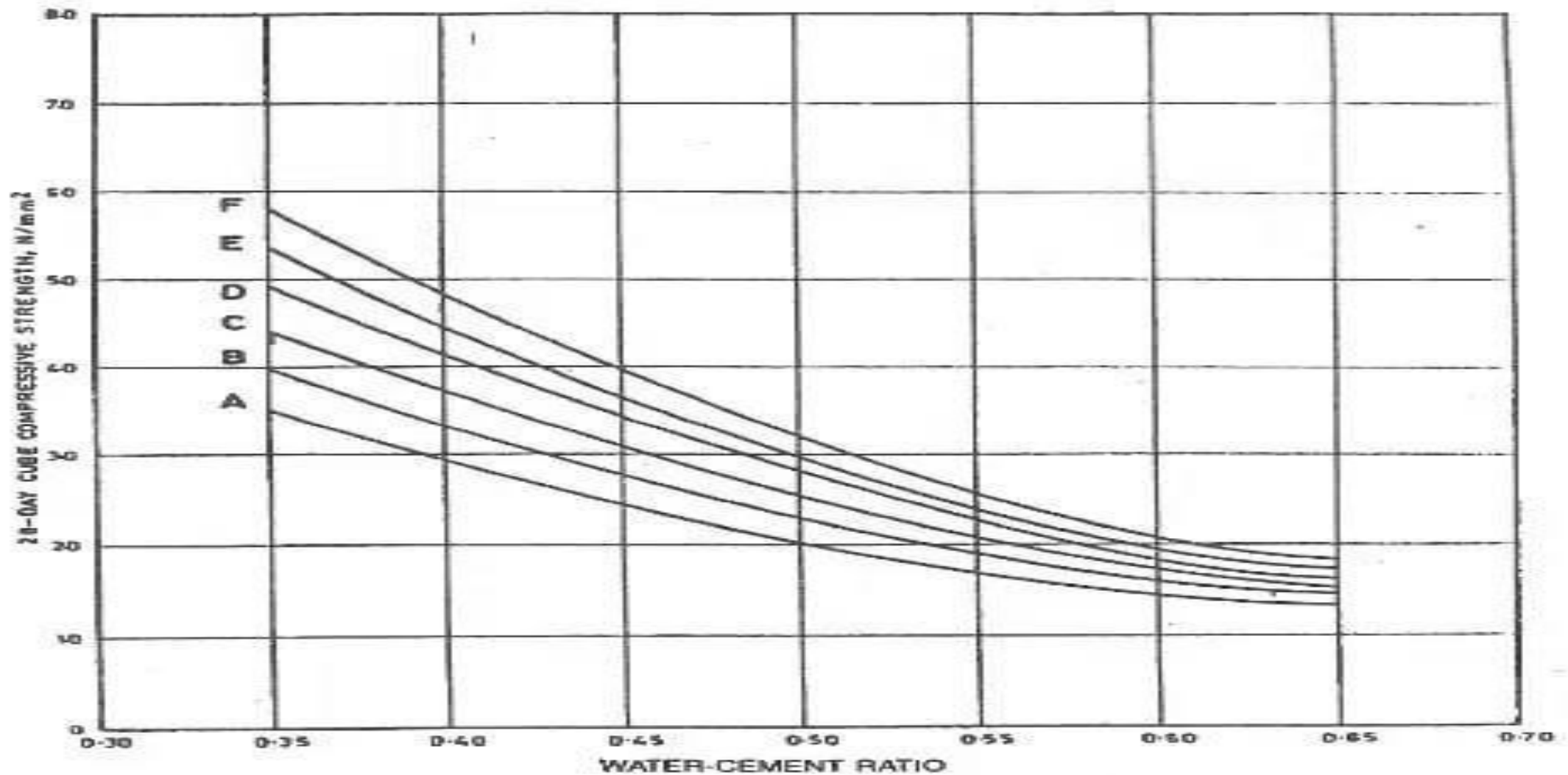
<u>Grade of Concrete</u>	<u>Standard deviation (N/mm²)</u>
M10 & M15	3.5
M20 & M25	4.0
M30,M35,M40,M45 & M50	5.0



2: Selection of Water-Cement Ratio

- Ratio of the weight of water to weight of cement in the concrete mix is water-cement ratio. It is the important consideration in concrete mix design to make the concrete workable. Water cement ratio is selected from the below curve for 28 days characteristic compressive strength of concrete.
- we can determine the water-cement ration from the 7-day concrete strength, the curves are divided on the basis of strength from water cement ratio is decided. Which is observed from the below graph.





7 - Day Strength of Cement, Tested According to IS : 4031-1968

A = 21.6 - 25.0 N/mm²

B = 25.0 - 29.8 N/mm²

C = 29.8 - 35.0 N/mm²

D = 35.0 - 41.5 N/mm²

E = 41.5 - 48.0 N/mm²

F = 48.0 - 53.4 N/mm²



3: Determination of Aggregate Air content

- Air content in the concrete mix is determined by the nominal maximum size of aggregate used. Below table will give the entrapped air content in percentage of volume of concrete.

Nominal maximum size of aggregate	Air content (% of volume of concrete)
10mm	5%
20mm	2%
40mm	1%

4: Selection of Water Content for Concrete

- Select the water content which is useful to get required workability with the help of nominal maximum size of aggregate as given in below table. The table given below is used when only angular shaped aggregates are used in concrete as well as the slump should be 25 to 50mm.

Nominal maximum size of aggregate	Maximum water content
10mm	208
20mm	186
40mm	165



- If the shape of aggregate or slump value is differing from above, then some adjustments are required as follows

Condition	Adjustment
Sub angular aggregate	Reduce the selected value by 10%
Gravel with crushed stone	Reduce the selected value by 20kg
Rounded gravel	Reduce the selected value by 25kg
Using plasticizer	Decrease the selected value by 5-10%
Using superplasticizer	Decrease the selected value by 20-30%
For every increment of 25mm slump	Increase the selected value by 3%

5: Selection of Cement Content for Concrete

- Water – cement ratio is determined in step2 and quantity of water is determined in step -4. So, we can easily calculate the quantity of cement from these two conditions. But, the value obtained should satisfy the minimum conditions as given in the below table. The greater of the two values is decided as quantity of cement content.



Cement Content for Plain Cement Concrete

Exposure	Plain Cement Concrete (P.C.C)		
	Minimum Cement Content Kg/m ³	Max Free Water – Cement Ratio	Minimum Grade of Concrete
Mild	220	0.6	-
Moderate	240	0.6	M15
Severe	250	0.5	M20
Very severe	260	0.45	M20
Extreme	280	0.4	M25

Cement Content for Reinforced Concrete

Exposure	Reinforced Cement Concrete (RCC)		
	Minimum Cement Content Kg/m ³	Max Free Water – Cement Ratio	Minimum Grade of Concrete
Mild	300	0.55	M20
Moderate	300	0.5	M25
Severe	320	0.45	M30
Very severe	340	0.45	M35
Extreme	360	0.4	M40

7: Calculation of Aggregate Content for Concrete

- We already determine the coarse aggregate volume ratio in the total aggregate volume. So, it is very easy that, 1 – volume of coarse aggregate will give the volume of fine aggregate. Alternatively, there are some formulae to find the volume of fine and coarse aggregates as follows.

- Mass of fine aggregate is calculated from below formula

$$V = \left[W + \frac{C}{G_c} + \left(\frac{1}{1-P} \right) \times \frac{F.A}{G_f} \right] \times \frac{1}{1000}$$

- Similarly, mass of coarse aggregate is calculated from below formula

$$V = \left[W + \frac{C}{G_c} + \left(\frac{1}{P} \right) \times \frac{C.A}{G_{ca}} \right] \times \frac{1}{1000}$$

- .Where, V = volume of concrete W = water content C = cement content G_c = sp. Gravity of cement P = aggregate ration obtained in step6 F.A & C.A = masses of fine and coarse aggregates G_f & G_{ca} = sp. Gravities of fine and coarse aggregates.



8: Trial Mixes for Testing Concrete Mix Design Strength

- Based on the values obtained above, conduct a trial test by making at least 3 cubes of 150mm size as per above standards. Test that cubes and verify whether the required strength is gained or not. If not, redesign the mix with proper adjustments until required strength of cube occurs.

Difference between Design mix and Nominal Mix concrete



Nominal Mix	Design Mix
1. The nominal mix is site-level mixing small concrete mixer can be used to mix the ingredients. 2. Mix Design:- There are many grades of nominal mix concrete like M-5, M-7.5, M-10, M-15, and M-20. 3. Tests:- For a nominal mix, no laboratory tests are conducted. 4. Time: The nominal mix is easy to make at the construction site. It does not take more time to decide the proportion because proportions are already given in IS456:2000. 5. Skilled Persons: For a nominal mix, there is no need of skilled persons. 6. Basis Nominal Mix: The nominal mix is based on past experience and has no scientific approach. 7. Strength of Nominal Mix: The nominal mix may or may not give exactly design strength unless all other factors like compaction, water-cement ratio curing of concrete are strictly followed. 8. Accuracy of Nominal Mix: In the case of nominal mix water-cement ratio is considered by the assumption so if we do not take care of it sometimes it leads to bleeding segregation and may make concrete of poor strength and durability. 9. Use:- The nominal mix is preferred for simpler relatively unimportant and small concrete works, in other words, the nominal mixes adopted for ordinary concrete work nominal mix may be used for concrete of M 20 grade or lower grade.	1. The design mix is designed from a ready mix concrete plant that is RMC plant. 2. Mix design:- Design mix is a process to prepare the concrete by testing all necessary properties (like properties of cement, fine aggregate and coarse aggregate) of concrete ingredients. 3. Tests: The design mix is based on laboratory trial-and-error experiment method. 4. Time: Whereas the design mix is very difficult and its process takes more than 30 days, time to find out the most suitable mix for the project for design mix IS-20262 shall be followed. 5. Skilled persons:- Whereas for design mix skilled person shall be required to prepare the mix design. 6. Basis Design Mix: Whereas the design mix is more scientific than the nominal mix. 7. Strength of Design Mix: Whereas design mix not only makes concrete of design strength but also makes it economical too. 8. Accuracy:- Whereas in the case of design mix, there is no such problem slump and strength can be related that is for the strength. We can use different slump by changing the water-cement ratio with or without admixtures. 9. Use : Whereas design mixed is used for more extensive and important concrete works design mix can be used for all the grades but it is generally used for M 25 and above grades. 

