INSTITUTE OF AERONAUTICAL ENGINERRING
(AUTONOMOUS)
Dundigal, Hyderabad- 500 043

CONCRETE TECHNOLOGY
(ACE010)
IARE-R16 B.Tech V SEM

Prepared by
Mr. N. Venkat Rao, Associate Professor
Ms.B.Bhavani, Assistant Professor

COURSE GOAL

- To introduce properties of concrete and it constituent materials and the role of various admixtures in modifying these properties to suit specific requirements, such as ready mix concrete, reinforcement detailing, disaster-resistant construction, and concrete machinery have been treated exhaustively the and also special concrete in addition to the durability maintenance and quality control of concrete structure.

COURSE OUTLINE

UNIT	TITILE	CONTENT
I	CEMENT ADMIXTURE & AGGREGATE	Portland cement, chemical composition, Hydration, Setting of cement, Structure of hydrate cement, Test on physical properties, Different grades of cement. Mineral and chemical admixtures, properties, dosage, effects, usage. Classification of aggregate, Particle shape & texture, Bond, strength & other mechanical properties of aggregate, Specific gravity, Bulk density, porosity, adsorption & moisture content of aggregate, Bulking of sand, Deleterious substance in aggregate, Soundness of aggregate, Alkali aggregate reaction, Thermal properties, Sieve analysis, Fineness modulus, Grading curves, Grading of fine & coarse Aggregates, Gap graded aggregate, Maximum aggregate size.

COURSE OUTLINE

UNIT	TITILE	CONTENT
II	FRESH CONCRETE	Workability, Factors affecting workability, Measurement of workability by different tests, Setting times of concrete, Effect of time and temperature on workability, Segregation & bleeding, Mixing and vibration of concrete, Steps in manufacture of concrete, Quality of mixing water.

COURSE OUTLINE

UNIT	TITILE	CONTENT
III	HARDENED CONCRETE TESTING OF HARDENED CONCRETE ELASTICITY, CREEP & SHRINKAGE	Water / Cement ratio, Abram's Law, Gel space ratio, Nature of strength of concrete, Maturity concept, Strength in tension & compression, Factors affecting strength, Relation between compression & tensile strength, Curing. Compression tests, Tension tests, Factors affecting strength, Flexure tests, Splitting tests, Non-destructive testing methods, codal provisions for NDT. Modulus of elasticity, Dynamic modulus of elasticity, Poisson's ratio, Creep of concrete, Factors influencing creep, Relation between creep & time, Nature of creep, Effects of creep, Shrinkage, types of shrinkage.
IV	MIX DESIGN	Factors in the choice of mix proportions, Durability of concrete, Quality Control of concrete, Statistical methods, Acceptance criteria, Proportioning of concrete mixes by various methods, BIS method of mix design.

COURSE OUTLINE

UNIT	TITILE	CONTENT
V	SPECIAL CONCRETES	Light weight aggregates, Light weight aggregate concrete, Cellular concrete, No-fines concrete, High density concrete, Fibre reinforced concrete, Different types of fibres, Factors affecting properties of F.R.C, Applications, Polymer concrete, Types of Polymer concrete, Properties of polymer concrete, Applications, High performance concrete, Self consolidating concrete, SIFCON.

Text books:

1. Concrete Technology by M.S.Shetty. – S.Chand & Co. ; 2004
2. Concrete Technology by M.L. Gambhir. – Tata Mc.Graw Hill Publishers, New Delhi

References:

1. Properties of Concrete by A.M.Neville – Low priced Edition – 4th edition
2. Concrete Technology by A.R. Santha Kumar, Oxford university Press, New Delhi

COURSE OBJECTIVES

At the end of the course, the students will be able to:

I. **Classify** basic principles in concrete science.

II. **Understand** the influence of various materials in concreting.

III. **Analyze** the mechanism of concrete and its properties.

IV. **Identify** the various defects in concrete.

V. **Create** various concrete mix designs.

VI. **Discover** the various types of innovative concretes

VII. **Summarize** research including the fundamentals of scientific writing, literature search, how to give a scientific presentation, how to evaluate a scientific paper, and research ethics.

UNIT-I

CEMENT

CEMENT

Definition: "Cement is the mixture of calcareous (Contains lime), siliceous (Contains silica), argillaceous (Clayey) and other substances. Cement is used as a binding material in mortar, concrete, etc."

History:

- Lime and clay have been used as cementing material on constructions through many centuries.
- Romans are commonly given the credit for the development of hydraulic cement, the most significant incorporation of the Roman's was the use of pozzolan-lime cement by mixing volcanic ash from the Mt. Vesuvius with lime. Best know surviving example is the Pantheon in Rome
- In 1824 "**Joseph Aspdin**" from England invented the Portland cement.

Types of Cement

1. Ordinary Portland Cement
2. Rapid Hardening Cement (or) High Early Strength cement
3. Extra Rapid Hardening Cement
4. Sulphate Resisting Cement
5. Quick Setting Cement
6. Low Heat Cement
7. Portland Pozzolana Cement
8. Portland Slag Cement
9. High Alumina Cement
10. Air Entraining Cement
11. Super sulphated Cement
12. Masonry Cement
13. Expansive Cement
14. Colored Cement
15. White Cement

Types of Cement

(1) ORDINARY PORTLAND CEMENT:

- It is called Portland cement because on hardening (setting) its colour resembles to rocks. It was first of all introduced in 1824 by Joseph Aspdin, England.

➢ Classified into three grades, namely **33 grade, 43 grade and 53 grade.**

1. If the 28 days strength is not less than 33N/mm2, it is called 33 grade cement,
2. If the strength is not less than 43N/mm2, it is called 43 grade cement, and
3. If the strength is not less then 53 N/mm2, it is called 53 grade cement.

Types of Cement

Chemical Composition of O.P. Cement:

O.P.C has the following approximate chemical composition: The major constituents are:

1. Lime (CaO) - 60- 63%
2. Silica (SiO_2) - 17- 25%
3. Alumina (Al_2O_3) - 03- 08%
4. Iron oxide (Fe_2O_3) - 0.5- 06%
5. Magnesia (MgO) - 1.5- 03%
6. Sulphur Tri Oxide (SO_3) - 01- 02%
7. Gypsum - 01- 04%

Types of Cement

(2) RAPID HARDENING CEMENT:

- Also known as early gain in strength of cement. This cement contains more %age of C_3S and less %age of C_2S, high proportion of C_3S will impart quicker hydration.
- The high strength at early stage is due to finer grinding, as fineness of cement will expose greater surface area for the action of water.
- The strength obtained by this cement in 03 days is same as obtained by O.P.C in 7 days.
- Initial and final setting times are same as OPC i.e., 30mins and 10 hrs. And soundness test by Le-Chatelier is 10mm and Autoclave is 0.8%.
- Greater lime content than OPC.

(3) EXTRA RAPID HARDENING CEMENT:

- It is obtained by inter-grinding $Cacl_2$ with rapid hardening cement.
- Addition of $Cacl_2$ should not exceed 2% by weight of the rapid hardening cement.
- Concrete made by using this cement should be transported, placed, compacted & finished within about 20 minutes.
- Strength is higher than 25% than that of rapid hardening cement at 1 or 2 days.

Types of Cement

(4) SULPHATE RESISTING CEMENT:

- It is modified form of O.P.C and is specially manufactured to resist the sulphates.
- This cement contains a low %age of C_3A and high %age of C_3S .
- This cement requires longer period of curing.
- It develops strength slowly, but ultimately it is as strong as O.P.C.

Types of Cement

(5) QUICK SETTING CEMENT:

- This cement is manufactured by adding small %age of aluminum sulphate (Al_2SO_4) which accelerates the setting action.
- Gypsum content is reduced.
- Sets faster than OPC.
- Initial setting time is 5 minutes. Final setting time is 30 minutes.

Types of Cement

(6) LOW HEAT CEMENT:

- Low percentage of tri-calcium aluminates (C_3A) and silicate (C_3S) and high %age of di-calcium silicate (C_2S) to keep heat generation low.
- Very slow rate of developing strength as rate of C_3S Content is low.
- Heat evolved @ 7 days-66 cal/g and 28 days-75 cal/g
- Initial set time-1 hr, final set time-10 hrs
- Better resistance to chemical attack than OPC.

Types of Cement

(7) PORTLAND POZZOLANA CEMENT:

- OPC clinker and Pozzolana (Calcined Clay, Surkhi and Fly ash) ground together. Produces less heat of hydration and offers great resistance to attacks of Sulphates.
- Used in marine works and mass concreting.
- Ultimate strength is more than OPC.
- Low shrinkage on drying
- Water tightness.

Types of Cement

(8) PORTLAND SLAG CEMENT:

- Produced by mixing Portland cement clinker, gypsum and granulated blast furnace slag which shall not exceed 65%.
- Blackish grey in color.
- Lesser heat of hydration.
- Suitable for marine works, mass concreting.
- Offers good resistance to the attack of sulphate.

Types of Cement

(9) HIGH ALUMINA CEMENT:

- Different from OPC.
- Characterised by its dark colour, high heat of hydration and resistance to chemical attack.
- Initial setting time of 4 hrs and final setting time of 5 hrs.
- Raw materials used are limestone and bauxite.

Types of Cement

(10) AIR ENTRAINING CEMENT:

- OPC with small quantity of air entraining materials (oils, fats, fatty acids) ground together.
- Air is entrained in the form of tiny air bubbles which enhances workability and reduces segregation and bleeding.
- It increases sulphate water resistance of concrete.

Types of Cement

(11) SUPER SULPHATED CEMENT:

- Ground blast furnace slag + OPC +Caso4. Heat of hydration which is considerably lower.
- It is also resistant to Sulphate attack.
- Used in a) Marine Structures, b) Mass concrete works

Types of Cement

(12) MASONRY CEMENT:

- Unlike ordinary cement, it is more plastic.
- Made by mixing hydrated lime, crushed stone, granulated slag or highly colloidal clays are mixed with it.
- Addition of above mentioned materials reduces the strength of cement.

(13) EXPANSIVE CEMENT:

- The main difference in this cement is the increase in volume that occurs when it settles.
- Used to neutralize shrinkage of concrete made from ordinary cement so as to eliminate cracks. A small percentage of this cement with concrete will not let it crack. It is specially desirable for hydraulic structures.
- In repair work, it is essential that the new concrete should be tight fitting in the old concrete. This can be done by using this cement.

Types of Cement

(14) COLORED CEMENT:

- Suitable pigments used to impart desired color.
- Pigments used should be durable under light, sun or weather.

Types of Cement

(15) WHITE CEMENT:

- OPC with pure white color produced with white chalk or clay free from iron oxide.
- As iron oxide gives the grey color to cement, it is therefore necessary for white cement to keep the content of iron oxide as low as possible.
- Instead of coal, oil fuel is used for burning.

Chemical Composition of cement

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln at high temperature to form more complex compounds.

➢ **Chemical Composition** of cement is:

- CaO - 60-67%
- SiO_2 - 17-25%
- Al_2O_3 - 3.0-8.0%
- Fe2O3 - 0.5-6.0%
- MgO - 01 to 04%
- Alkalies(K2O, Na2O) - 0.4-1.3%
- SO3 - 1.3-3.0%

Hydration of cement

- The water causes the hardening of **concrete** through a process called **hydration**. **Hydration** is a chemical reaction in which the major compounds in **cement** form chemical bonds with water molecules and become hydrates or **hydration** products.
- Cement consists of the following major compounds
  - Tricalcium silicate, C_3S
  - Dicalcium silicate, C_2S
  - Tricalcium aluminate, C_3A
  - Tetra calcium aluminoferrite, C_4AF
  - Gypsum, CSH_2

Bogue's Compounds:

When water is added to cement it react with the ingredients of the cement chemically & results in the formation of complex chemical compounds terms as **BOGUES** compounds.

Chemical Name	Chemical Formula	Notation	Percent by Weight
Tricalcium Silicate	$3Cao.Sio_2$	C_3S	50
Dicalcium Silicate	$2Cao.Sio_2$	C_2S	25
Tricalcium Aluminate	$3Cao.Al_2O_3$	C_3A	12
Tetracalcium Aluminoferrite	$4Cao.Al_2O_3.\ Fe_2O_3$	C_4AF	8
Gypsum	$CaSO_4.\ H_2O$	CSH_2	3.5

Hydration of cement

Bogue's Compounds:

- ***Tricalcium silicate* (C_3S)** - responsible for early strength and ultimate strength of the cement. First 7 days strength is due to C_3S. C_3S Produces more amount of heat during hydration process. A cement with more C_3S content is suitable for cold weather concreting.
- **Dicalcium silicate (C_2S)** - The hydration of C_2S starts after 7 days. Hence, **it gives strength after a duration of 7 days.** C_2S hydrates and hardens slowly and provides much of the ultimate strength. It produces less heat of hydration. It is responsible for the later strength of concrete.

Hydration of cement

Bogue's Compounds:

- **C_3A** - Sets instantaneously in presence of water. Cement's internal strength is mainly because of this. ***The reaction of C_3A with water is very fast and may lead to an immediate stiffening of paste***, and this process is termed as flash set. To prevent this flash set, 2 to 3 % gypsum is added at the time of grinding the cement clinkers.
- **C_4AF** -Acts as a flux during manufacturing.

  Contributes to the color effects that makes cement gray. Tetra calcium alumino ferrite sets but not fast as Tri-calcium aluminate. It does not contribute to the strength of concrete. The hydrates of C_4AF show a comparatively higher resistance to sulphate attack than the hydrates of C_3A.

Setting of cement

When cement is mixed with water, it hydrates and makes cement paste. This paste can be moulded into any desired shape due to its plasticity. Within this time cement continues with reacting water and slowly cement starts losing its plasticity and set harden. This complete cycle is called Setting time of cement.

- **Initial Setting time of Cement.**
- **Final setting time of Cement.**

As Per **IS: 4031 (Part 5) – 1988.** Initial and final setting time of cement is calculated using **VICAT apparatus** conforming to IS:5513-1976.

VICAT Apparatus with details

Setting time of cement

Initial Setting Time

- ✓ The time to which cement can be moulded in any desired shape without losing it strength is called Initial setting time of cement.
- ✓ The time at which cement starts hardens and completely loses its plasticity is called Initial setting time of cement.
- ✓ The time available for mixing the cement and placing it in position is an Initial setting time of cement. If delayed further, cement loses its strength.
- ✓ **For Ordinary Portland Cement, The initial Setting Time is 30 minutes.**

Final Setting Time

- ✓ The time at which cement completely loses its plasticity and became hard is a final setting time of cement.
- ✓ The time taken by cement to gain its entire strength is a Final setting time of cement.
- ✓ **For Ordinary Portland Cement, The Final Setting Time is 600 minutes (10hrs).**

Structure of hydrate cement

- The presence of water in cement will result in the **hydration process (**Exothermic Reaction - Heat Evolution). This reaction will result in hydration products of silicates and aluminates that will bring a hard mass over a period of time. This hard mass can be called as Hydrated Cement Paste (HCP).

Phases of Concrete:

The concrete is considered to have two phase materials. They are the:

- Paste Phase (Cement Phase)
- Solid Phase (Aggregate Phase)

The properties and quality of the paste phase influence largely on the overall properties of the concrete when compared with the aggregate phase. The strength, permeability, elastic properties, durability and volume change of the concrete are highly influenced by the paste structure.

Test on physical properties

The physical tests which are generally performed to determine the acceptability of cements are –

1. Fineness Test
2. Standard Consistency Test
3. Setting time Test
4. Soundness Test
5. Strength Test
6. Heat of Hydration Test
7. Specific Gravity Test

Test on physical properties

1. Fineness Test:

- Fineness of Cement is measured by sieving cement on standard sieve. The proportion of cement of which the cement particle sizes are greater than the 90 micron is determined. As per **IS: 4031 (Part 1) – 1996.** The cement of good quality should have less than 10% of weight of cement particles larger than 90 µm. (micron)
- Following three methods are applied to test the fineness of cement
- Sieve method
- Air Permeability method
- Sedimentation method

Fineness of Cement Apparatus

Test on physical properties

2. Standard Consistency Test :

- This test is done to estimate the required water quantity to form a normal consistency cement paste. It is defined as the percentage of water required for the cement paste, which permit the vicat plunger to penetrate to a point 5 to 7mm from the bottom of the vicat mould when tested.

Vicat Apparatus

Test on physical properties

3. Setting Time Test :

- Cement has two types of setting time, one is initial setting time and another is final setting.
- Initial setting time is the state of cement mortar or concrete when it starts to become stiffen and unworkable.
- Final setting time is the state when cement mortar or concrete has become fully unworkable.
- Two methods are used to find the initial and final setting time of cement
- Vicat needle method, and
- Gillmore needle method

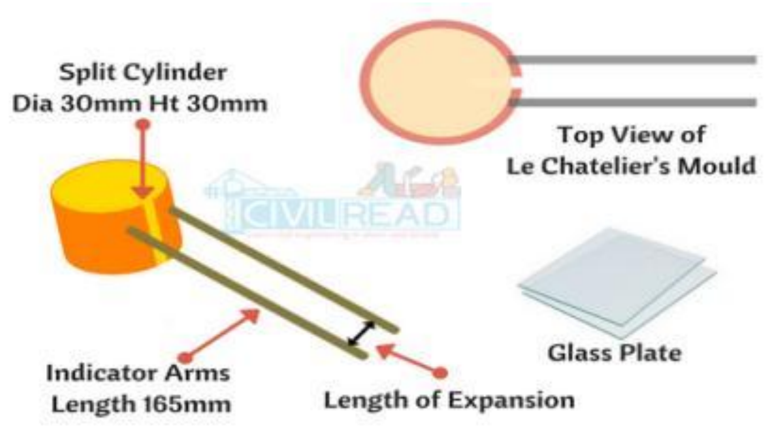
Vicat Apparatus

Test on physical properties

4. Soundness Test :

Soundness test of cement by Le-Chatelier apparatus is very easy but very important test along with many other quality tests on cement. Soundness of cement means it doesn't undergo large volume change after setting. Large changes in volume produce cracks, disintegration and distortion, ultimately leading to failure. So it is very important to test the soundness of cement. **To test the soundness two methods can be applied.**

- Le-chatelier method
- Autoclave method.



-

Fig: Le-chatelier Apparatus

Test on physical properties

5. Strength Test :

Cement has two types of strength – compressive strength and tensile strength.

To know the compressive strength and tensile strength of cement following tests are performed –

- Cement mortar cube test (for compressive strength)
- Briqutte test (for tensile strength)
- Split tensile test (for tensile strength)

Test on physical properties

6. Heat of Hydration Test :

- Cement produce large amount of heat during hydration process. When large amount of concrete volume is poured the inner temperature is greater than outer surface of concrete. Because outer surface is exposed to weather. Thus surface shrinks rapidly than the inner and tends to produce cracks. That is why it is important to test the heat of hydration of cement. Following test is performed to know the heat of hydration of cement
- Calorimeter method

7. Specific Gravity test :

- Specific gravity of cement is a comparison of weight of a cement volume to the weight of same volume of water.
- Le-chatelier flask is used to test the specific gravity of cement.

Fig: Specific gravity bottle

Different grades of cement

There are three Main Grades of Cement :

1. **33 Grade Ordinary Portland Cement**

   33 grade cement refers to cement that has a compressive strength of 33 N/mm2 at the end of 28 days of curing. This type of cement is used for general construction work under normal environmental condition.

2. **43 Grade Ordinary Portland Cement**

   43 grade cement refers to cement that has a comprehensive strength of 43 N/mm2 at the end of 28 days of curing. This type of cement is used for plain concrete work and plastering works.

Different grades of cement

3. 53 Grade Ordinary Portland Cement

53 grade cement refers to cement that has a compressive strength of 53 N/mm2 at the end of 28 days of curing. 53 grade ordinary Portland cement is used for structural purposes as in reinforced cement concrete.

Admixtures: Mineral and chemical admixtures

- Admixtures improve the quality of concrete, accelerate setting time, and decelerate setting time in case of any misshaping. They enhanced the workability of fresh concrete with lesser amount of water than the required one.
- Mineral admixtures and chemical admixtures are the extra ingredients other than water, cement, aggregates and fibers.

➢ **TYPES OF ADMIXTURES**

Chemical composition of admixtures has a very wide range. Depending upon the functions and composition, admixtures are mainly divided in to two main types. These are;

- Mineral admixtures (finely ground solid material)
- Chemical admixtures (water soluble compounds)

Admixtures: Mineral and chemical admixtures

1. Mineral Admixtures :

- Mineral admixtures are the fine ground solid materials I.e. Fly ash, slag and silica fume. It is added to the concrete generally in larger amount than any other type. Because mineral admixtures have an ability to enhance workability as well as finish-ability of freshly laid concrete. Mineral admixtures are also utilized as a replacement of cement. with the use of mineral admixtures reducing concrete cost is very likely possible.

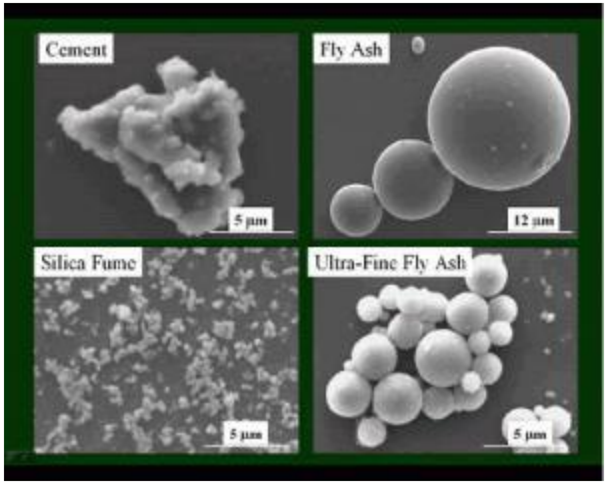


Fig: Mineral admixtures

Admixtures: Mineral and chemical admixtures

Types of Pozzolanic or mineral admixtures:

- **Natural Pozzolans**
- Clay and Shales
- Opalinc Cherts
- Diatomaceous Earth
- Volcanic Tuffs and Pumicites.
- **Artificial Pozzolans**
- Fly ash
- Blast Furnace Slag
- Silica Fume
- Rice Husk ash
- Metakaoline
- Surkhi.

2. Chemical Admixtures :

- Chemical admixtures are the admixtures that are added to concrete in a very small amount for a specific function to concrete. If chemical admixtures are added more than the defined than it has a very wide range of negative effects on the properties of fresh as well as hardened concrete.
- Chemical admixtures are more likely to be added as a water reducing admixtures, as a retarding setting time, accelerating setting time, as a super plasticizer or added as an air-entrainment.

Fig: Chemical admixtures

Admixtures: Mineral and Chemical admixtures

Types of Chemical admixtures:

- Plasticizers
- Super plasticizers
- Retarders and Retarding Plasticizers
- Accelerators and Accelerating Plasticizers
- Air-entraining Admixtures
- Pozzolanic or Mineral Admixtures
- Damp-proofing and Waterproofing Admixtures
- Gas forming Admixtures
- Air-detraining Admixtures

Types of Chemical admixtures:

1. **Super plasticizers** are added to reduce the water requirement by 15 to 20% without affecting the workability leading to a high strength and dense concrete.

- Super plasticizers are liner polymers containing sulfonic acid groups attached to the polymer at regular intervals.
- The main purpose of super plasticizers is to produce a flowing concrete with very high slump 175 to 200 mm which can be used effectively in densely reinforced structures, the increased slump of concrete depends upon dosage, type & time of super–plasticizers (it's better to add it before concrete is placed.), water cement ratio, nature and amount of cement.

Types of Chemical admixtures:

2. **Accelerators** are added to reduce the setting time of concrete thus helping early removal of forms and are also used in cold weather concreting. Calcium chloride is the most commonly used accelerator for concreting. The use of calcium chloride in reinforced concrete can promote corrosion activity of steel reinforcement. As people are getting aware so there is a growing interest in using chloride free accelerator.

Types of Chemical admixtures:

3. **Retarders** are added to increase the setting time by slowing down the hydration of cement. They are preferred in places of high temperature concreting. Retarders consist of organic & inorganic agents. Organic retarders include unrefined calcium, sodium & ammonia salts lignosulfonic acids, hydrocarboxylic acids & carbohydrates. Inorganic retardants include oxides of lead, zinc, phosphate and magnesium salts. Most retarders also act as water reducers. They are called water-reducing retarders. Thus resulting in greater compressive strength due to low water cement ratio.

Admixtures: Mineral and Chemical admixtures

Types of Chemical admixtures:

4. **Water reducing admixtures** are added to concrete to achieve certain workability (slump) at low water cement ratio. A concrete with specified strength at lower cement content thus saving on the cement. Water reducers are mostly used in hot weather concreting and to aid pumping. Water reducer plasticizers are hygroscopic powder, which can entrain air into concrete.
5. **Air entraining admixtures** entrain small air bubbles in concrete. These air bubbles act as rollers thus improving the workability and are also very effective in freeze-thaw cycles as they provide a cushioning effect on the expanding water in the concreting in cold climate. Air entraining admixtures are compatible with most admixtures, care should be taken to prevent them from coming in contact during mixing.

Properties, dosage, effects usage of admixtures

Properties of Admixtures:

- Increase workability without increasing water content or decrease water content at the same workability.
- Retard or accelerate time of initial setting.
- Reduce or prevent settlement.
- Modify the rate or capacity for bleedings.
- Reduce segregation.
- Improve pumpability.
- Reduce the rate of slump loss.

Properties of admixtures

For Fresh properties

- Increase workability without increasing water content or decrease water content at the same workability.
- Retard or accelerate time of initial setting.
- Reduce or prevent settlement.
- Modify the rate or capacity for bleedings.
- Reduce segregation.
- Improve pumpability.
- Reduce the rate of slump loss.

For hardened properties

- Retard or reduce heat evaluation during early hardening.
- Accelerate the rate of strength development at early ages.
- Increase strength (compressive, tensile or flexural).
- Increase durability or resistance to severe condition of exposure.
- Decrease permeability of concrete.
- Inhibit corrosion of embedded metal.

Dosage of admixtures

- Concrete admixtures are liquids or powders which are added to the concrete during mixing in small quantities. Dosage is usually defined based on the cement content.
- Concrete admixtures have significant impact on the fresh and/or hardened concrete properties. Admixtures can act chemically and/or physically.
- **Concrete Admixtures According To European Standard:**
- According to EN 206-1, concrete admixtures are defined and the requirements are described in EN 934-2. The standard differentiates between different product groups, which are described with slight abbreviations in the following tables.

Dosage of admixtures:

Dosage of admixtures according to EN 206-1	**Low dosages**	**Admixture quantities < 0.2% of the cement are only allowed if they are dissolved in part of the mixing water.**
	Permitted dosage	≤ 5% by weight of the cement (The effect of a higher dosage on the performance and durability of the concrete must be verified.)

Effects Usage of Admixtures

Admixtures are used extensively to produce high workable, high strength high performance and highly durable concrete with minimum cost. The effect of usage of admixtures are:

Rapid slum loss : This effect is generally observed in rich mixes with higher cement content and it can be reduced by adding booster dosages at different intervals.

Severe segregation/bleeding : This is generally observed in lean mixes with low cement content and depends on dosage of admixture. This can be minimized either by reducing admixture dosage or by increasing content of fine in the concrete.

Over retardation : This effect a noticed when the admixture is added beyond the specified dosage and it would effect the construction schedule, result in low strength development at early age. However ultimate strength of the concrete remains same.

Effects Usage of Admixtures

Plastic shrinkage : This is general observed in large floor slabs of this sections and due to excess evaporator of water from the surface of the concrete at high temperatures are continuous breezing. However the plastic shrinkage cracks are determental to structures.

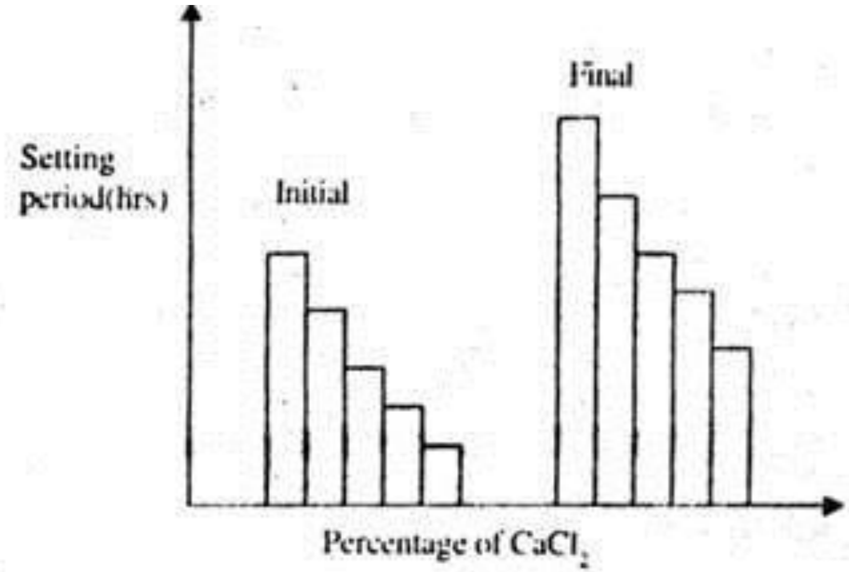


Fig: Effect of $CaCl_2$ on setting time of OPC

Aggregates: Classification of aggregate

Aggregates are inert materials which are mixed with binding material such as cement or lime for manufacturing of mortar or concrete. Aggregates are used as filler in mortar and concrete and also to reduce their cost.

➢ **CLASSIFICATION OF AGGREGATES:**

- Depending upon the **size** of their particles aggregates are classified as:

(1) Fine aggregates

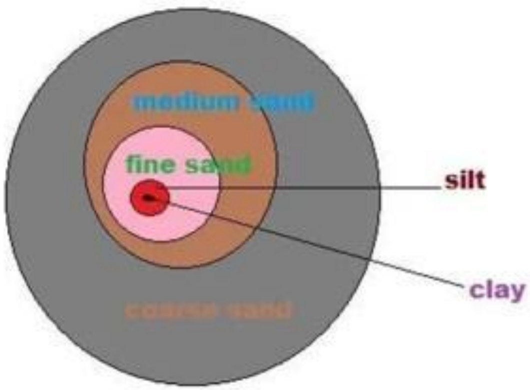
(2) Coarse aggregates

Aggregates: Classification of aggregate

1. Fine Aggregates:

Aggregates whose particles pass through 4.75 mm IS sieve are termed as fine aggregates. Most commonly used fine aggregates are sand (pit or quarry sand, river sand and sea sand) and crushed stone in powdered form, how ever some times sukhi and ash or cinder are also used.

Fine aggregate	Size variation
Coarse Sand	2.0mm – 0.5mm
Medium sand	0.5mm – 0.25mm
Fine sand	0.25mm – 0.06mm
Silt	0.06mm – 0.002mm
Clay	<0.002



2. Coarse Aggregates:

Aggregates whose particles do not pass through 4.75 mm IS are termed as coarse aggregates. Most commonly used coarse aggregates are crushed stone, gravel; broken pieces of burnt bricks, etc. Types of coarse aggregate are:

Coarse aggregate	Size
Fine gravel	4mm – 8mm
Medium gravel	8mm – 16mm
Coarse gravel	16mm – 64mm
Cobbles	64mm – 256mm
Boulders	>256mm

CLASSIFICATION OF AGGREGATES

- According to **Source**:

1. Natural aggregate: Native deposits with no change in their natural state other than washing, crushing & grading. (sand, gravel, crush stone)

2. Artificial aggregates: They are obtained either as a by-product or by a special manufacturing process such as heating. (blast furnace slag, expanded perlite)

CLASSIFICATION OF AGGREGATES

- According to Petrological Characteristics:
  1. Igneous rocks: are formed by solidification of molten lava. (granite)
  2. Sedimentary rocks: are obtained by deposition of weathered & transported pre-existing rocks or solutions. (limestone)
  3. Metamorphic rocks: are formed under high heat & pressure alteration of either igneous & sedimentary rocks (marble).

CLASSIFICATION OF AGGREGATES

- According to Unit Weight:

1. <u>Heavy weight agg.</u>: Hematite, Magnetite Specific Gravity, $G_s > 2.8$
2. <u>Normal weight agg.</u>:Gravel, sand, crushed stone $2.8 < G_s < 2.4$
3. <u>Light weight agg.</u>:Expanded perlite, burned clay $G_s < 2.4$

CLASSIFICATION OF AGGREGATES

Normal-Weight Aggregate
ASTM C 33

- Most common aggregates
  - Sand
  - Gravel
  - Crushed stone

- Produce normal-weight concrete 2200 to 2400 kg/m^3

CLASSIFICATION OF AGGREGATES

Lightweight Aggregate (2)
ASTM C 330

- Pumice
- Scoria
- Perlite
- Vermiculite
- Diatomite

- Produce lightweight insulating concrete— 250 to 1450 kg/m^3

CLASSIFICATION OF AGGREGATES

Heavyweight Aggregate
ASTM C 637, C 638 (Radiation Shielding)

- Barite
- Limonite
- Magnetite
- Ilmenite
- ✓ Hematite
- ✓ Iron
- ✓ Steel punchings or shot

Produce high-density concrete up to 6400 kg/m^3

CLASSIFICATION OF AGGREGATES

- **Aggregates are classified according to shape into the following types**
- Rounded aggregates
- Irregular or partly rounded aggregates
- Angular aggregates
- Flaky aggregates
- Elongated aggregates
- Flaky and elongated aggregates

CLASSIFICATION OF AGGREGATES

1. Rounded Aggregate:

- The rounded aggregates are completely shaped by attrition and available in the form of seashore gravel. Rounded aggregates result the minimum percentage of voids (32 – 33%) hence gives more workability. They require lesser amount of water-cement ratio. They are not considered for high strength concrete because of poor interlocking behavior and weak bond strength.

Fig: Rounded aggregate

2. Irregular Aggregates

- The irregular or partly rounded aggregates are partly shaped by attrition and these are available in the form of pit sands and gravel. Irregular aggregates may result 35- 37% of voids. These will give lesser workability when compared to rounded aggregates. The bond strength is slightly higher than rounded aggregates but not as required for high strength concrete.

Fig: Irregular Aggregates

3. Angular Aggregates:

- The angular aggregates consist well defined edges formed at the intersection of roughly planar surfaces and these are obtained by crushing the rocks. Angular aggregates result maximum percentage of voids (38-45%) hence gives less workability. They give 10-20% more compressive strength due to development of stronger aggregate-mortar bond. So, these are useful in high strength concrete manufacturing.

Fig: Angular Aggregates

4. Flaky Aggregates:

When the aggregate thickness is small when compared with width and length of that aggregate it is said to be flaky aggregate. Or in the other, when the least dimension of aggregate is less than the 60% of its mean dimension then it is said to be flaky aggregate.

Fig: Flaky aggregate

CLASSIFICATION OF AGGREGATES

5. Elongated Aggregates

- When the length of aggregate is larger than the other two dimensions then it is called elongated aggregate or the length of aggregate is greater than 180% of its mean dimension.

Fig: Elongated Aggregates

CLASSIFICATION OF AGGREGATES

6. Flaky and Elongated Aggregates

- When the aggregate length is larger than its width and width is larger than its thickness then it is said to be flaky and elongated aggregates. The above 3 types of aggregates are not suitable for concrete mixing. These are generally obtained from the poorly crushed rocks.

Fig: Flaky and Elongated Aggregates

Particle shape and Surface Texture

- ✓ Aggregate particle shape and surface texture are important for proper compaction, deformation resistance, and workability. However, the ideal shape for Hot Mix Asphalt (HMA) and Plain Cement concrete (PCC) is different because aggregates serve different purposes in each material.
- ✓ In HMA, since aggregates are relied upon to provide stiffness and strength by interlocking with one another, cubic angular-shaped particles with a rough surface texture are best. However, in PCC, where aggregates are used as an inexpensive high-strength material to occupy volume, workability is the major issue regarding particle shape.

Particle shape and Surface Texture

Particle shape:

- Rounded particles create less particle-to-particle interlock than angular particles and thus provide better workability and easier compaction. However, in Hot Mix Asphalt (HMA) less interlock is generally a disadvantage as rounded aggregate will continue to compact, shove and rut after construction.
- Thus angular particles are desirable for HMA (despite their poorer workability), while rounded particles are desirable for (PCC) because of their better workability (although particle smoothness will not appreciably affect strength.

Particle shape and Surface Texture

Flat or Elongated Particles:

- These particles tend to impede compaction or break during compaction and thus, may decrease strength.

Smooth-Surfaced Particles:

- These particles have a lower surface-to-volume ratio than rough-surfaced particles and thus may be easier to coat with binder. However, in HMA asphalt tends to bond more effectively with rough-surfaced particles, and in PCC rough-surfaced particles provide more area to which the cement paste can bond. Thus, rough-surface particles are desirable for both HMA and PCC.

Particle shape and Surface Texture

Test Methods:

There are several common tests used to identify and quantify aggregate particle shape and surface texture. Among the most popular are:

1. Particle index
2. Percent fractured face (or coarse aggregate angularity)
3. Fine aggregate angularity
4. Flat and Elongated Particles

Murdock suggested a different method for expressing the shape of aggregate by a parameter called Angularity Index ‘fA’

$$\text{Angularity Index} \quad fA = \frac{3\,fH}{20} + 1.0$$

where fH is the Angularity number.

- Other tests, using automated machines equipped with video cameras and lasers are under development.

Particle shape and Surface Texture

Surface Texture:

- Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it.
- As surface smoothness increases, contact area decreases, hence a highly polished particle will have less bonding area with the matrix than a rough particle of the same volume.

Particle shape and Surface Texture

Table: Surface characteristics of aggregate:

Group	Surface Texture	Examples
1	Glassy	Black Flint
2	Smooth	Marble, slate
3	Granular	Sandstone
4	Crystalline	Limestone, granite,basalt
5	Honeycombed and porous	Scoria, pumice

Strength of Aggregate

- Concrete is an assemblage of individual pieces of aggregate bound together by cementing material, its properties are based primarily on the quality of the cement paste.
- This strength is dependent also on the bond between the cement paste and the aggregate. If either the strength of the paste or the bond between the paste and aggregate is low, a concrete of poor quality will be obtained irrespective of the strength of the rock or aggregate.
- But when cement paste of good quality is provided and its bond with the aggregate is satisfactory, The test for strength of aggregate is required to be made in the following situations:

(i) For production of high strength and ultra high strength concrete.

(ii) When contemplating to use aggregates manufactured from weathered rocks.

(iii) Aggregate manufactured by industrial process.

Strength of Aggregate

Strength of aggregate can be determined by:

- Aggregate Crushing Value
- Aggregate Impact Value
- Aggregate Abrasion Value
- Deval Attrition Test
- Dorry Abrasion Test
- Los Angeles Test
- Modulus of Elasticity

Strength of Aggregate

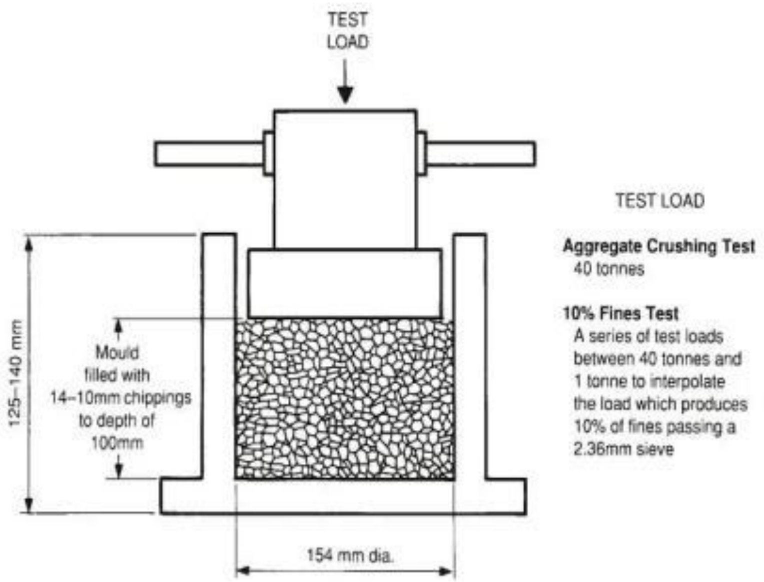
Aggregate Crushing Value:

- Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. ggregate crushing value is a numerical index of the strength of the aggregate and it is used in construction of roads and pavements.
- Crushing value of aggregates indicates its strength. Lower crushing value is recommended for roads and pavements as it indicates a lower crushed fraction under load and would give a longer service life and a more economical performance.
- The aggregates used in roads and pavement construction must be strong enough to withstand crushing under roller and traffic. If the aggregate crushing value is 30 or higher' the result may be anomalous and in such cases the ten percent fines value should be determined instead.

Strength of Aggregate

Aggregate crushing value = (W2 x 100) / (W1-W)

- W2 =Weight of fraction passing through the appropriate sieve
- W1-W =Weight of surface dry sample.



Types of Roads / Pavements	Aggregate Crushing Value Limit
Flexible Pavements	
Soling	50
Water bound macadam	40
Bituminous macadam	40
Bituminous surface dressing or thin premix carpet	30
Dense mix carpet	30
Rigid Pavements	
Other than wearing course	45
Surface or Wearing course	30

Strength of Aggregate

Aggregate Impact Value:

- The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces.
- The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test.
- The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

Strength of Aggregate

- Calculations:

Observations	Sample 1	Sample 2
Total weight of dry sample (W_1 gm)		
Weight of portion passing 2.36 mm sieve (W_2 gm)		
Aggregate Impact Value (percent) = W_2 / W_1 X 100		

Mean =

Strength of Aggregate

Classification of aggregates using Aggregate Impact Value is as given:

Aggregate Impact Value	Classification
<20%	Exceptionally Strong
10 – 20%	Strong
20-30%	Satisfactory for road surfacing
>35%	Weak for road surfacing

Strength of Aggregate

Specified limits of percent aggregate impact value for different types of road construction by Indian Roads Congress is given below:

Sl No	Type of pavement	Aggregate impact value not more than
1.	Wearing Course	30
a)	Bituminous surface dressing	
b)	Penetration macadam	
c)	Bituminous carpet concrete	
d)	Cement concrete	
2.	Bitumen bound macadam base course	35
3.	WBM base course with bitumen surfacing	40

Strength of Aggregate

- **Aggregate Abrasion Value:**
- When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface cause abrasion of road aggregates. The steel rimmed wheels of animal driven vehicles also cause considerable abrasion of the road surface.
- Therefore, the road aggregates should be hard enough to resist abrasion. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine.
- The principle of Los Angeles abrasion test is to produce abrasive action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates.

Strength of Aggregate

Testing the aggregate with respect to its resistance to wear is an important test for aggregate to be used for road constructions, ware house floors and pavement construction. Three tests are in common use to test aggregate for its abrasion resistance.

(i) Deval attrition test

(ii) Dorry abrasion test

(iii) Los Angels test.

Los Angeles Test:

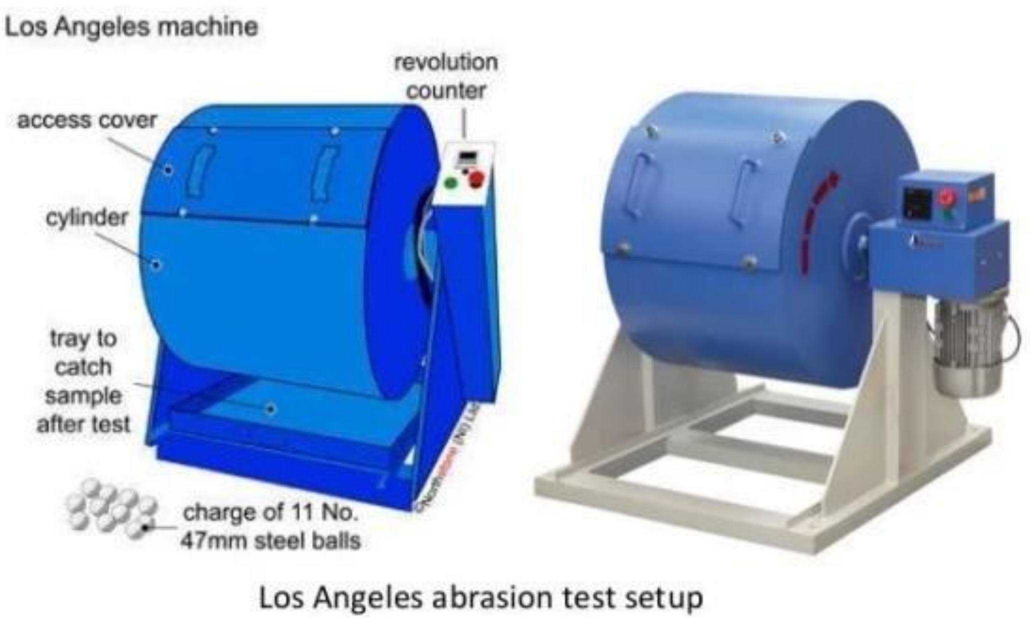


Fig: Los Angeles Abrasion Value

Strength of Aggregate

Selection of Abrasive Charge

Grading	No of Steel balls	Weight of charge in gm.
A	12	5000 ± 25
B	11	4584 ±25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

Strength of Aggregate

Original weight of aggregate sample = W1 g

Weight of aggregate sample retained = W2 g

Weight passing 1.7mm IS sieve = W1 – W2 g

Abrasion Value = (W1 – W2) / W1 X 100

Depending upon the value, the suitability of aggregates for different road constructions can be judged as per IRC specifications as given:

Sl. No.	Type of Pavement	Max. permissible abrasion value in %
1	Water bound macadam sub base course	60
2	WBM base course with bituminous surfacing	50
3	Bituminous bound macadam	50
4	WBM surfacing course	40
5	Bituminous penetration macadam	40
6	Bituminous surface dressing, cement concrete surface course	35
7	Bituminous concrete surface course	30

Mechanical properties of aggregate,

1. Toughness

- It is defined as the resistance of aggregate to failure by impact. The impact value of bulk aggregate can be determined as per I.S. 2386, 1963.

2. Hardness:

- It is defined as the resistance to wear by abrasion, and the aggregate abrasion value is defined as the percentage loss in weight on abrasion.

For testing hardness of aggregate following three methods can be used:

(a) Deval Attrition test.

(b) Dorry abrasion test.

(c) Los Angeles test.

Mechanical properties of aggregate,

3. Specific gravity

Specific gravity of a substance is the ratio of the weight of unit volume of the substance to the unit volume of water at the stated temp. In concrete making, aggregates generally contain pores both permeable and impermeable hence the term specific gravity has to be defined carefully.

Table: Specific gravity of cement and aggregate

Material	Specific gravity
Cement	3.15
Average sand	2.00
Gravel	2.66
Sand	2.65

Mechanical properties of aggregate,

4. Porosity and Absorption of Water by Aggregate:

The porosity, permeability, and absorption of aggregates in-fluence the resistance of concrete to freezing and thawing, bond strength between aggregate and cement paste, resistance to abrasion of concrete etc.

Table: Water absorption by aggregate

Aggregate	Moisture absorbed by weight of aggregate
Average sand	1.0%
Pebbles and crushed lime stone	1.0%
Granite	0.5%
Porous sand stone	7.0%
Very light and porous aggregate	25.0%

5. Bulking of Sand:

The moisture present in fine aggregate causes increase in its volume, known as bulking of sand. The moisture in the fine aggregate develops a film of moisture around the particles of sand and due to surface tension pushes apart the sand particles, occupying greater volume.

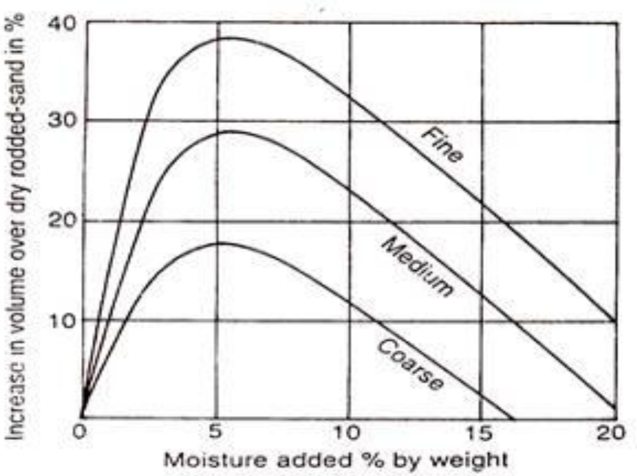


Fig: Bulking of sand

Mechanical properties of aggregate

6. Modulus of Elasticity:

Modulus of elasticity of aggregate depends on its composition, texture and structure. The modulus of elasticity of aggregate will influence the properties of concrete with respect to shrinkage and elastic behaviour and to very small extent creep of concrete.

Moisture content of aggregate

Moisture content of aggregate:

The absorption depends on pore size parameter as discussed in previous post. Here we will learn about state of aggregate depends on moisture content. These are

a. Oven dry
b. Air dry
c. Saturated and surface dry
d. Moist

Moisture content of aggregate

a. OVEN DRY

This is an artificial condition where prolonged drying of aggregates in oven reduces all moisture from them. This condition is sometimes called bone-dry. Thus the aggregate is completely dry on the other hand means fully-absorbent.

b. AIR DRY

The aggregate have some moisture but dry at surface. The moisture content is less than saturation. That means there have some degree of absorption affinity.

c. SATURATED AND SURFACE DRY

Usually known as SSD. This state of moisture defines all pores of aggregate are filled but have a dry surface. Thus the aggregates are saturation-surface dry.

Moisture content of aggregate

d. **MOIST:**

These have moisture in surface looks darker and which leave water to concrete mix.

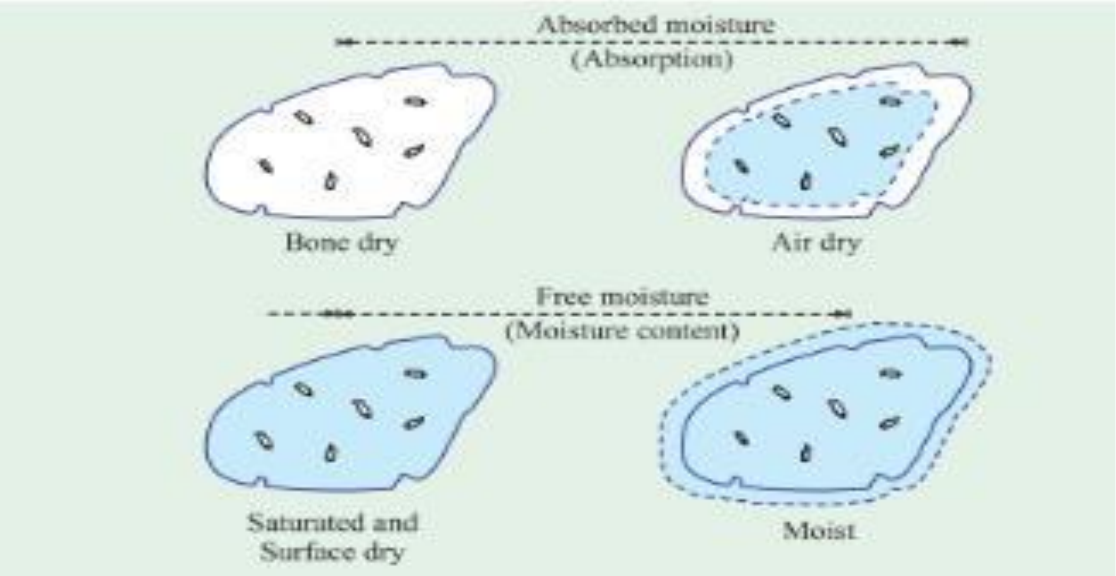


Fig: Representation of Moisture in Aggregate

BULK DENSITY OF AGGREGATE

Bulk Density:

- ✓ The bulk density or unit weight of an aggregate gives valuable information's regarding the shape and grading of the aggregate. For a given specific gravity the angular aggregates show a lower bulk density.
- ✓ The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it.
- ✓ Bulk density shows how densely the aggregate is packed when filled in a standard manner. The bulk density depends on the particle size distribution and shape of the particles.

Percentage voids = $[(G_s - g)/G_s] \times 100$

where G_s = specific gravity of aggregate and

g is bulk density in kg/litre.

BULK DENSITY OF AGGREGATE

Its value for different materials as per concrete hand book CIA Bombay is shown in Table below:

Table: Bulk Density kg/lit

Material	Specific gravity
Cement	1.44
Medium	1.52
Coarse	1.60
Broken Stone	1.60
Stone screaning	1.44
Broken Granite	1.68

Deleterious substance in aggregate

Deleterious and cleanliness of aggregate:

The concrete aggregates should be free from impurities and deleterious substances which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix. The impurities sometimes reduce the durability of the aggregate.

Deleterious Material:

Clay lumps, shale, soft or laminated particles, vegetable matter, or other objectionable material or The harmful material in any construction is called Deleterious material.

Deleterious substance in aggregate

➢ The substances that are harmful to concrete performance are:

a. Clay lumps and other friable particles
b. Materials that are finer than 75µm (No. 200 sieve)
c. Coal
d. Soft particles
e. Lightweight chert

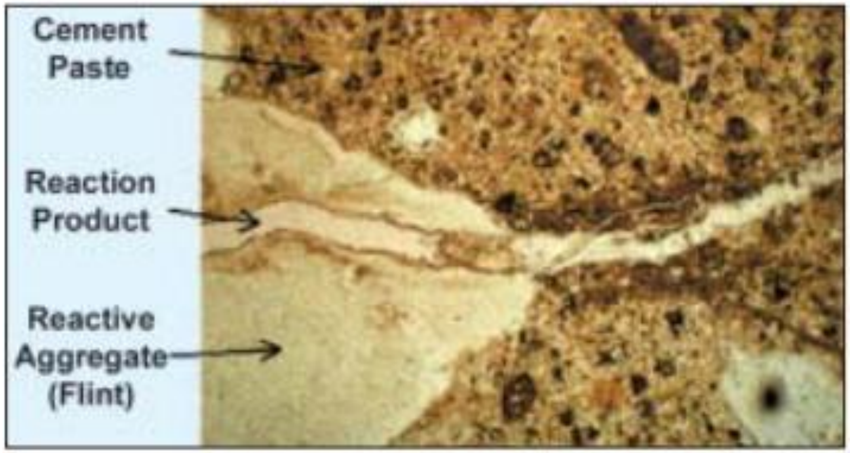
➢ Main reaction of deleterious material:

1. Alkali aggregates reaction
2. Alkali silica reaction
3. Alkali carbonates reaction

Deleterious substance in aggregate

1. Alkali aggregate reactions (AAR):

Alkali–aggregate reaction is a term mainly referring to a reaction which occurs over time in concrete between the highly alkaline cement paste and non-crystalline silicon dioxide, which is found in many common aggregates.



Typical Alkali - Aggregate reaction. Alkali silicate gels of unlimited swelling type are formed under favourable conditions.

Fig: Alkali–aggregate reaction

Deleterious substance in aggregate

- Factors Promoting the Alkali-Aggregate Reaction

(i) Reactive type of aggregate;

(ii) High alkali content in cement;

(iii) Availability of moisture;

(iv) Optimum temperature conditions.

2. Alkali silica reaction:

The alkali–silica reaction (ASR), more commonly known as "concrete cancer", is a reaction which occurs over time in concrete between the highly alkaline cement paste and the reactive non-crystalline (amorphous) silica found in many common aggregates, given sufficient moisture.

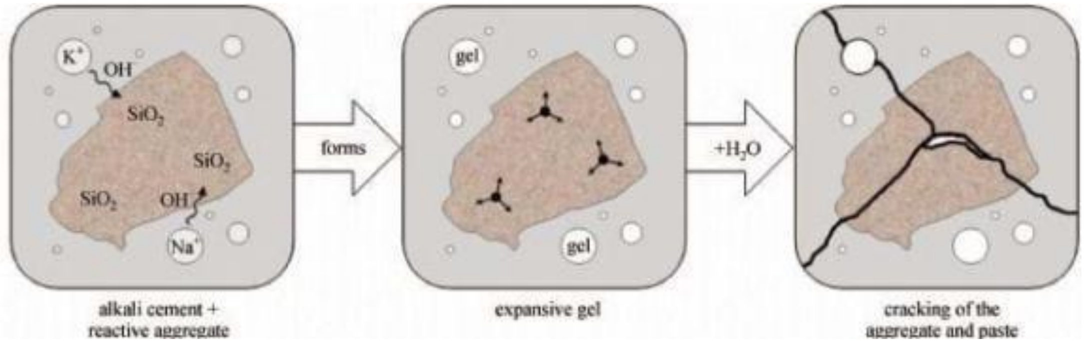


Fig: Alkali-Silica Reaction

Mechanism of concrete deterioration:

- The alkaline solution attacks the siliceous aggregate, converting it to viscous alkali silicate gel.
- Consumption of alkali by the reaction induces the dissolution of Ca2+ ions into the cement pore water.
- The accumulated pressure cracks the aggregate and the surrounding cement paste when the pressure exceeds the tolerance of the aggregate.

Deleterious substance in aggregate

Alkali carbonate reaction:

- The alkali–carbonate reaction is a process suspected for the degradation of concrete containing dolomite aggregate. Alkali from the cement might react with the dolomite crystals present in the aggregate inducing the production of brucite, $(MgOH)_2$, and calcite ($CaCO_3$).
- This mechanism was tentatively proposed by Swenson and Gillott (1950) and may be written as follows:

$$CaMg(CO_3)_2 + 2\,NaOH \rightarrow CaCO_3 + Na_2CO_3 + Mg(OH)_2$$

Deleterious substance in aggregate

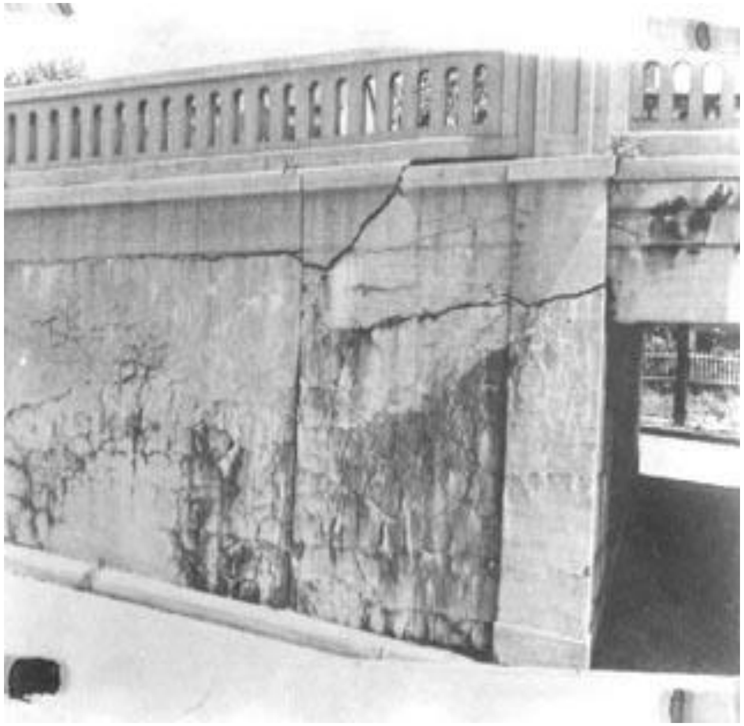


Fig: Alkali–carbonate reaction

Soundness of aggregate

- Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions.
- The physical conditions that affect the soundness of aggregate are the freezing the thawing, variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water.
- Aggregates which undergo more than the specified amount of volume change is said to be unsound aggregates.
- To determine the durability of those weak aggregates, soundness test is specified in **IS: 2386 Part-V**.

Thermal properties

- Rock and aggregate possesses three **thermal properties** which are significant in establishing the quality of aggregate for concrete constructions. They are:

  (i)Coefficient of expansion;

  (ii)Specific heat;

  (iii)Thermal conductivity.

- Out of these, specific heat and conductivity are found to be important only in mass concrete construction where rigorous control of temperature is necessary.
- Also these properties are of consequence in case of light weight concrete used for insulation purpose.
- The range of coefficient of thermal expansion for hydrated cement paste may vary from 10.8 x 10–6 Per °C to 16.2 x 10–6 per °C.

Grading of aggregate

Grading is the particle-size distribution of an aggregate as determined by a sieve analysis using wire mesh sieves with square openings.

As per IS:2386(Part-1)

- ✓ **Fine aggregate** : 6 standard sieves with openings from 150 µm to 4.75 mm. (150 µm, 300 µm, 600 µm, 1.18mm, 2.36mm, 4.75mm)
- ✓ **Coarse aggregate**: 5 sieves with openings from 4.75mm to 80 mm. (4.75mm, 10mm, 12.5mm, 20mm, 40mm).
- Grain size distribution for concrete mixes that will provide a dense strong mixture. Ensure that the voids between the larger particles are filled with medium particles. The remaining voids are filled with still smaller particles until the smallest voids are filled with a small amount of fines.

Grading of aggregate

For determining the Grading of aggregate, sieve Analysis test can be carried out:

- The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron.
- The aggregate fraction from 80 mm to 4.75 mm are termed as coarse aggregate and those fraction from 4.75 mm to 150 micron are termed as fine aggregate. The size 4.75 mm is a common fraction appearing both in coarse aggregate and fine aggregate (C.A. and F.A.).
- Grading pattern of a sample of C.A. or F.A. is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top.

Grading of aggregate

Fig: Sieve Analysis for grading of aggregate

Fineness Modulus of aggregate

The results of aggregate sieve analysis is expressed by a number called Fineness Modulus. Obtained by adding the sum of the cumulative percentages by mass of a sample aggregate retained on each of a specified series of sieves and dividing the sum by 100.

The following limits may be taken as guidance:

Fine sand : Fineness Modulus : 2.2 - 2.6

Medium sand : F.M. : 2.6 - 2.9

Coarse sand : F.M. : 2.9 - 3.2

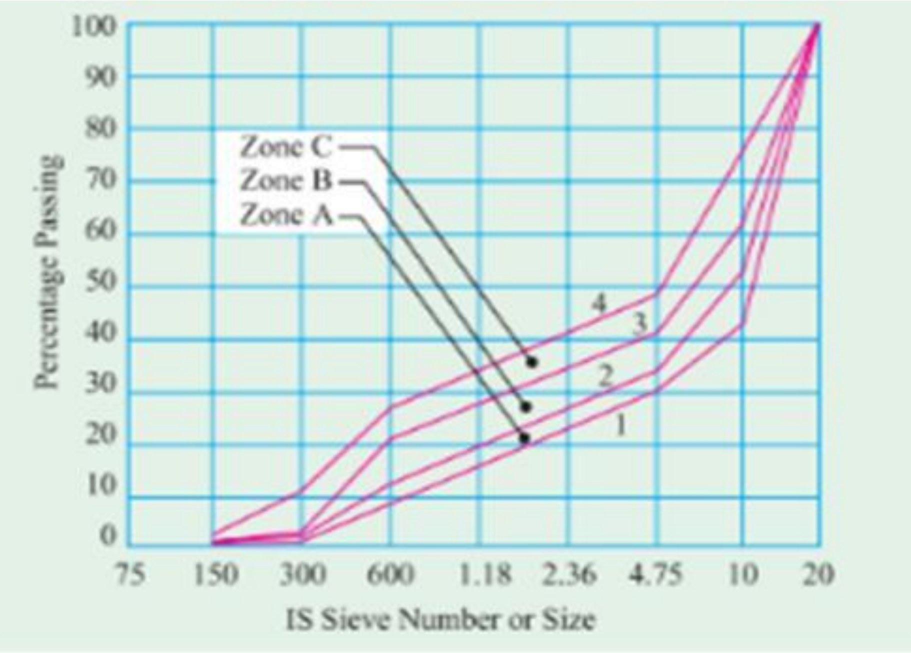
A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

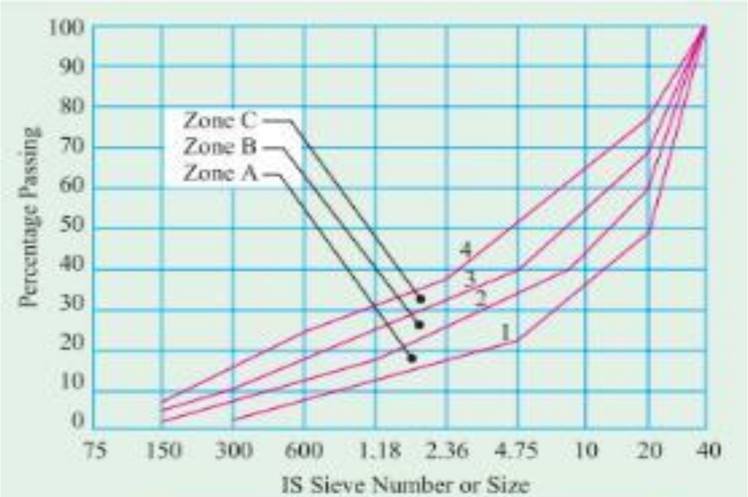
$$\text{Finess Modulus, } FM = \left(\frac{\text{Total of Cumulative Percentage of Passing (\%)}}{100} \right)$$

Grading Curves of aggregate

- Expressing grading limits by means of a chart gives a good pictorial view.
- The comparison of grading pattern of a number of samples can be made at one glance. For this reason, often grading of aggregates is shown by means of grading curves.
- One of the most commonly referred practical grading curves are those produced by Road Research Laboratory(U.K).
- **Four** curves are shown for each maximum size of aggregate except 80 mm size. From values of percentage passing it can be seen that the lowest curve i.e., curve No. 1 is the coarsest grading and curve No. 4 at the top represents the finest grading. Between the curves No. 1 to 4 there are three zones: A, B, C.

Grading Curves of aggregate





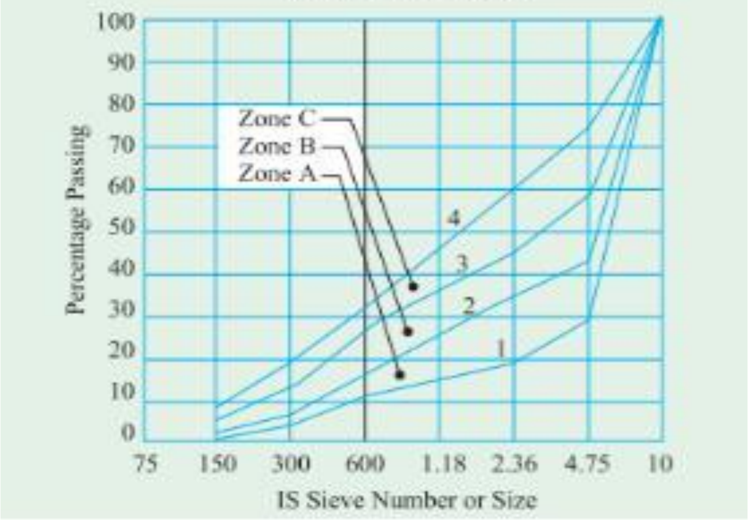


Fig: Grading curve with different sieve sizes

Grading Curves of aggregate

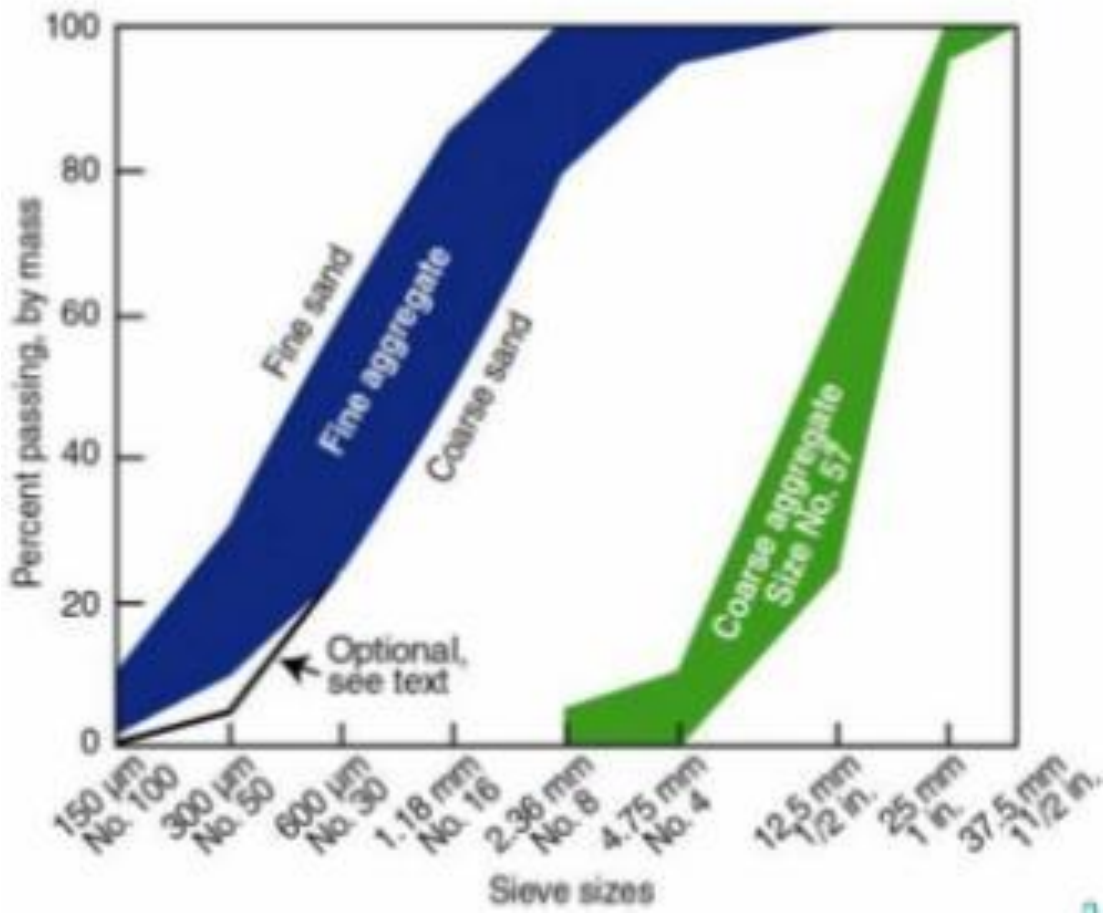


Fig: Grading curve with different sieve sizes

Gap graded aggregate

- Assumption made in well gradation is that voids created by the higher size of aggregate will be filled-up by immediate next lower size of aggregate and again some smaller voids will be left out which will again be filled-up by next lower size aggregates.
- Practically it has been found that voids created by a particular size may be too small to accommodate the very next lower size. Therefore the next lower size may not be accommodated in the available gap without lifting the upper layer of the existing size. Therefore, **Particle Size Interference** is created which disturbs the very process of achieving the maximum density.
- In fact the size of voids created by a particular size of aggregate can accommodate the second or third lower size aggregates only i.e. voids created by 40 mm will be able to accommodate size equal to 10 mm or 4.75 mm but not 20 mm. This concept is called **Gap Grading**.

Gap graded aggregate

- **ADVANTAGES OF GAP GRADING**
- Requirements of sand is reduced by 26 to 40%. Specific area of area of total aggregates will be reduced due to less use of sand..
- Point contact between various size fractions is maintained, thus reducing the dying shrinkage.
- It requires less cement as the net volume of voids to a greater extent.

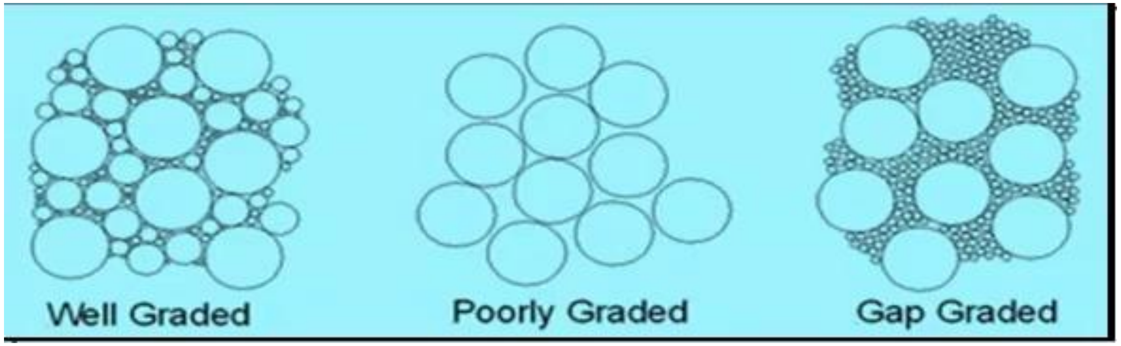


Fig: Grading of aggregate

Tests on aggregate

Shape tests on coarse aggregates such as flakiness index and elongation Index, its importance in concrete construction as per IS 2386 part I are:

1.Flakiness Index

2. Elongation Index

1.Flakiness Index(thickness):

The Flakiness index of aggregates is the percentage by weight of particles whose least dimension (thickness) is less than three- fifths (0.6times) of their mean dimension. This test is not applicable to sizes smaller than 6.3mm.

Flakiness Index = $(X_1 + X_2 + \ldots..) / (W_1 + W_2 + \ldots.) \times 100$

2. Elongation Index (length):

The Elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than nine-fifths (1.8times) their mean dimension. This test is not applicable for sizes smaller than 6.3mm.

Elongation Index = $(Y_1 + Y_2 + \ldots) / (W_1 + W_2 + \ldots.) \times 100$

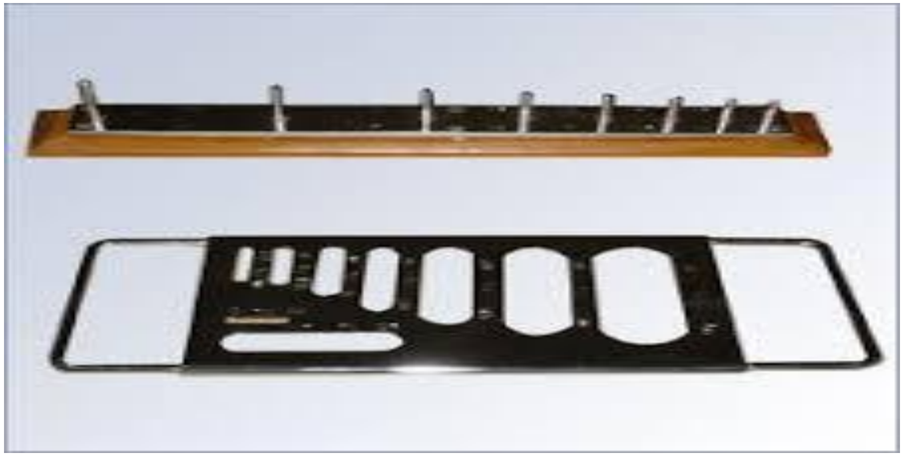


Fig: Flakiness and Elongation Index

Tests on aggregate

Table : Flakiness and Elongation Index

Size of aggregates		Weight of fraction consisting of at least 200 pieces,g	Thickness gauge size, mm	Weight of aggregates in each fraction passing thickness gauge,mm	Length gauge size, mm	Weight of aggregates in each fraction retained on length gauge,mm
Passing through IS Sieve, mm	Retained on IS Sieve, mm					
1	2	3	4	5	6	7
63	50	W_1	23.90	X_1	–	–
50	40	W_2	27.00	X_2	81.00	Y_1
40	31.5	W_3	19.50	X_3	58.00	Y_2
31.5	25	W_4	16.95	X_4	–	–
25	20	W_5	13.50	X_5	40.5	Y_3
20	16	W_6	10.80	X_6	32.4	Y_4
16	12.5	W_7	8.55	X_7	25.5	Y_5
12.5	10	W_8	6.75	X_8	20.2	Y_6
10	6.3	W_9	4.89	X_9	14.7	Y_7
Total	W =		X =		Y =	

Maximum size of aggregate

- The smallest sieve through which 100% of aggregate pass is called maximum aggregate size. While nominal aggregate size is sieve size higher than largest size on which 15% or more of aggregate is retained.
- A maximum size up to **40 mm** is used for coarse aggregate in most structural applications, while for mass concreting purposes such as dams, sizes up to **150 mm** may be used. Fine aggregates, on the other hand, have particles up to a minimum size of 0.075 mm.
- For **PCC** work the usual range employed is between 9.5mm and 37.5mm in diameter. – Fine aggregates are usually sand or crushed stone that are less than 9.55mm in diameter. Typically the most common size of aggregate used in construction is 20mm for **RCC** works. A larger size, 40mm, is more common in mass concrete.

Maximum size of aggregate(Contd...)

- When the size of aggregate is greater than 4.75 mm (say 5 mm) it is called coarse aggregate. Graded aggregates are used for better particle packing. The larger the size of aggregate lesser the cement required for same strength up to certain grade of concrete. The constraints for Nominal Maximum Size of Aggregate (NMSA) are follows

  1.Cover to Concrete

  2.Clear distance between reinforcements- 5 mm

  3.One third of least lateral dimension

- In general 20 mm is used as NMSA but use of 40 mm provides economy for substructures. For too congested structures 12.5 mm or 10 mm is also used.
- For mass concrete dams up to 150 mm is used. For shotcretes 8 mm is used.

UNIT -II
FRESH CONCRETE

Properties OF Fresh Concrete

- **Fresh concrete**

It is that stage of concrete in which concrete can be moulded and it is in plastic state.

Fig: Fresh concrete

Properties OF Fresh Concrete

Elasticity and Strength Of Concrete:

- The elastic properties of materials are a measure of their resistance to deformation under an applied load (but the elastic strain is recovered when the load is removed).
- Strength usually refers to the maximum stress that a given kind of sample can carry.

Properties OF Fresh Concrete

- Main Properties of Fresh Concrete are:

Consistency

- Slump Test
- Flow Test
- Penetration Test

Segregation

- ---
- ---

Workability

- Compacting Factor Test
- Vee-Bee Time Test

Bleeding

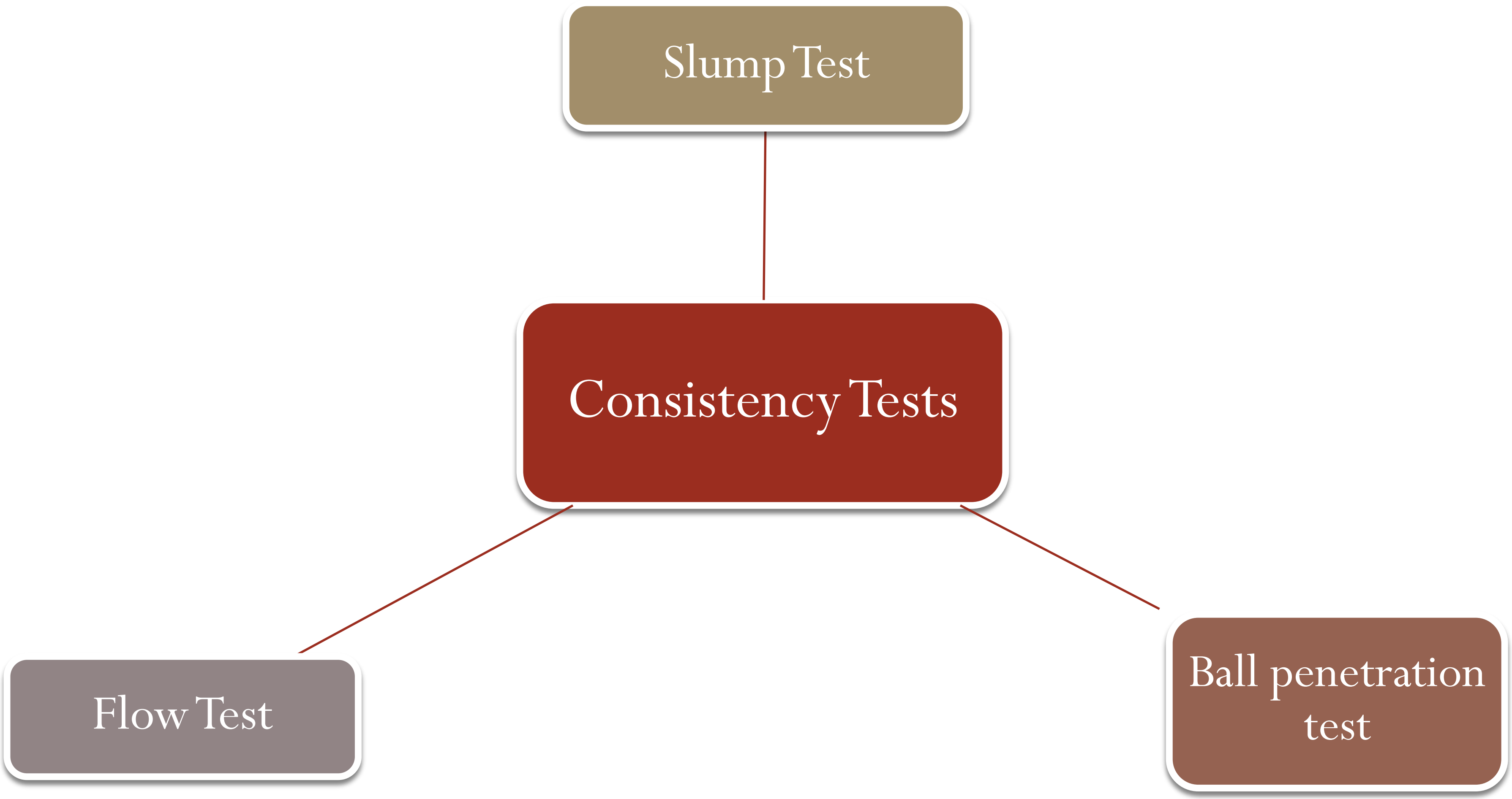
- Bleeding Water Test

Consistency of Concrete

- Consistency or fluidity of concrete is an important component of workability and refers in a way to the wetness of the concrete.
- If a mix is too wet, segregation may occur with resulting honeycomb, excessive bleeding, and sand streaking on the formed surfaces if a mix is too dry it may be difficult to place and compact, and segregation may occur because of lack of cohesiveness and plasticity of the paste.

Fig: Consistency of concrete

3 Ways to determine Consistency of Fresh Concrete



Slump Test

Definition

A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product quality

- Slump is a measurement of concrete's workability, or fluidity.
- It's an indirect measurement of concrete consistency or stiffness.

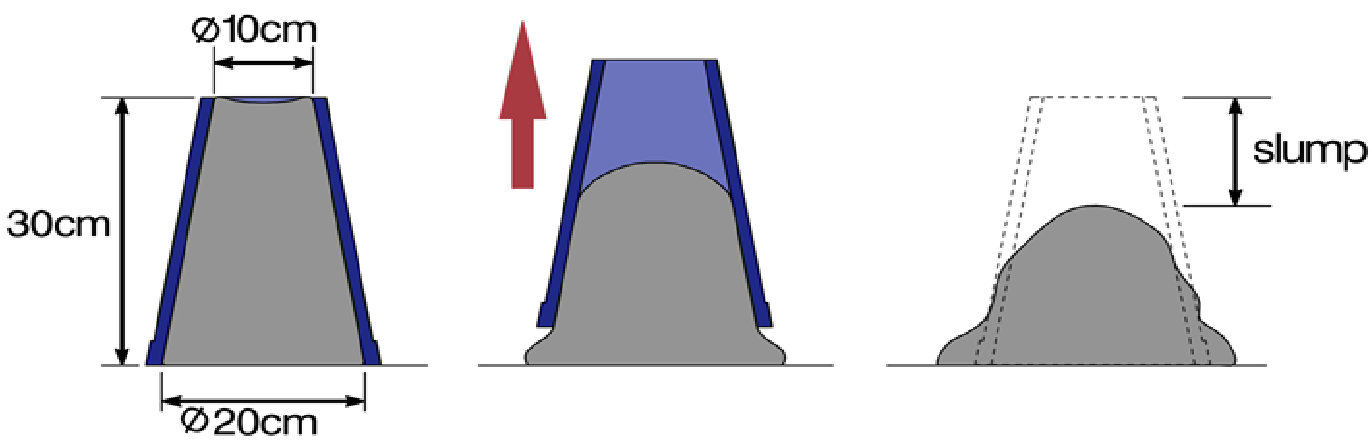
Principle

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.

Slump Test

Apparatus

- Slump cone : frustum of a cone, 300 mm (12 in) of height. The base is 200 mm (8in) in diameter and it has a smaller opening at the top of 100 mm
- Scale for measurement,
- Temping rod(steel) 15mm diameter, 60cm length.

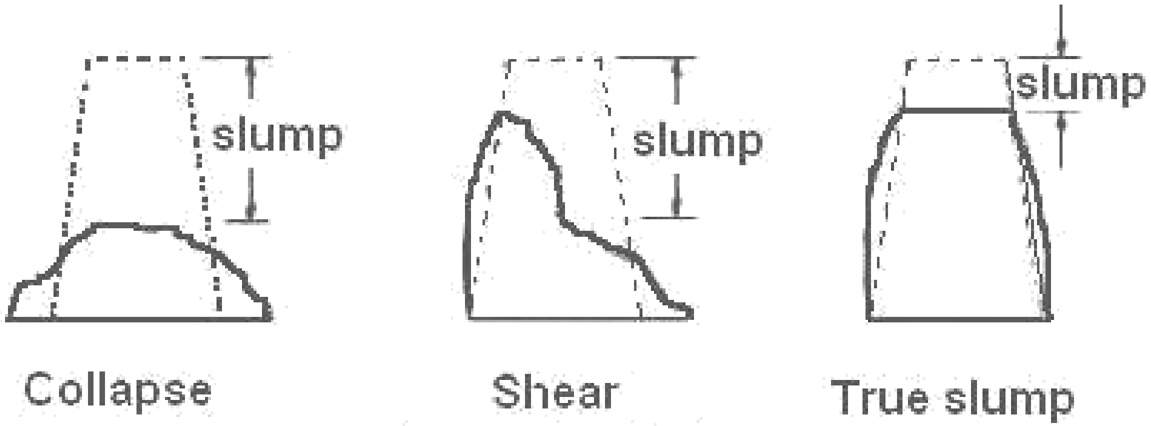


Slump Test

- **Types Of Slump**

  The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as;

  - Collapse Slump
  - Shear Slump
  - True Slump



Types of slump

Slump test

Degree of workability	Slump (mm)	Compacting Factor	Use for which concrete is suitable
Very low	0 - 25	0.78	Very dry mixes; used in road making. Roads vibrated by power operated machines
Low	25 - 50	0.85	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines
Medium	50 - 100	0.92	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations
High	100 - 175	0.95	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

Flow Table Test

- **Definition**

  The flow table test is a method to determine the consistence of fresh concrete

- **Equipment**
  - Flow table with a grip and a hinge, 70 cm x 70 cm.
  - Abrams cone, open at the top and at the bottom - 30 cm high, 17 cm top diameter, 25 cm base diameter
  - Water bucket and broom for wetting the flow table.
  - Tamping rod, 60 cm height
  - Scale for measurement

Fig: Flow table apparatus

Flow Table Test

Fig: Testing of Flow table test

Ball Penetration Test (Kelly Ball)

- **Definition**

  Another method used in the field and laboratory to measure the consistency of concrete is the ball penetration test (ASTM C360) which is also known as the **Kelly ball test***.

- **Procedure**

  - It is performed by measuring the penetration, in inches, of a 6-in. diameter steel cylinder with a hemi spherically shaped bottom , weighing 30 lbs.

Fig: Ball penetration test

WORKABILITY

- **Definition**

  The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product.

  Concrete is said to be workable when it is easily placed and compacted homogeneously i.e., without bleeding or Segregation . Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete.

  An on site simple test for determining workability is the SLUMP TEST.

- **Factors affecting workability**

  1. Water content in the concrete mix
  2. Amount of cement & its Properties
  3. Aggregate Grading (Size Distribution)

WORKABILITY

4. Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.)
5. Temperature of the concrete mix
6. Humidity of the environment
7. Mode of compaction
8. Method of placement of concrete
9. Method of transmission of concrete

How To improve the workability of concrete :

- increase water/cement ratio
- increase size of aggregate
- use well-rounded and smooth aggregate instead of irregular shape
- increase the mixing time
- increase the mixing temperature
- use non-porous and saturated aggregate
- with addition of air-entraining mixtures

TEST METHODS FOR WORKABILITY

- Depending upon the water cement ratio in the concrete mix, the workability may be determined by the following three methods.

1. Slump Test
2. Compaction Factor Test
3. Vee-bee Consistometer Test

1. Slump Test:

- This method is suitable only for the concrete of high workability.
- This test is carried out with a mould called slump cone whose top diameter is 10 cm, bottom diameter is 20 cm and height is 30 cm.
- **LIMITATIONS OF SLUMP TEST**
- Not suitable for concrete containing aggregates larger than 40 mm.
- Not suitable for concrete of dry mix.
- Not suitable for very wet concrete.

Compacting Factor Test

- **Introduction**
  - These tests were developed in the UK by Glanville (1947) and it is measure the degree of compaction .The test require measurement of the weight of the partially and fully compacted concrete and the ratio the partially compacted weight to the fully compacted weight, which is always less than one, is known as compacted factor .
  - For the normal range of concrete the compacting factor lies between 0.8 - 0.92
- **Apparatus**
  - Trowels
  - Hand Scoop (15.2 cm long)
  - Rod of steel or other suitable material (1.6 cm diameter, 61 cm long rounded at one end).
  - Balance

Fig: Compaction factor apparatus

Compacting Factor Test

$$\text{The Compacting Factor } (CF) = \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}}$$

Workability	Slump (mm)	C.F	Uses
Very Low	0 - 25	0.78	Roads - Pavements
Low	25 - 50	0.85	Foundations Concrete
Medium	25 - 100	0.92	Reinforced Concrete
High	100 - 175	0.95	Reinforced Concrete (High Reinforcement)

Vee -Bee Time Test

- **Definition**
  - It is based on measuring the time (Called VEBE time) needed to transfer the shape of a concrete mix from a frustum cone to a cylinder (these shapes are standardized by the apparatus of this test), by vibrating and compacting the mix. The more VEBE time needed the less workable the mix is. This method is very useful for stiff mixes.
- **Apparatus**
  - Cylindrical container with diameter = 240 mm, and height = 200 mm
  - Mold: the same mold used in the slump test.
  - Disc : A transparent horizontal disc attached to a rod which slides vertically
  - Vibrating Table : 380*260 mm, supported by four rubber shock absorbers
  - Tamping Rod
  - Stop watch

SETTING TIMES OF CONCRETE

- **Setting time** of concrete differs widely from setting time of cement. Setting time of concrete does not coincide with the setting time of cement with which the concrete is made.
- The setting time of concrete depends upon the w/c ratio, temperature conditions, type of cement, use of mineral admixture, use of plasticizers–in particular retarding plasticizer.
- The setting parameter of concrete is more of practical significance for site engineers than setting time of cement. When retarding plasticizers are used, the increase in setting time, the duration upto which concrete remains in plastic condition is of special interest.
- The setting time of concrete is found by pentrometer test. This method of test is covered by IS 8142 of 1976 and ASTM C – 403. The procedure given below may also be applied to prepared mortar and grouts.

PENTROMETER TEST:

Apparatus:

1. Non absorptive metal container having minimum lateral dimension of 150 mm and minimum depth of 150 mm
2. Penetration resistance apparatus having a pressure gauge of capacity 700 to 900 N. Removable needles of 645, 323, 161, 65, 32 & 16 mm2.
3. Pipette
4. Tamping rod of 16 mm dia.

Fig: Penetration Resistance Apparatus

SETTING TIMES OF CONCRETE

- **SAMPLE PREPARATION & STORING**
- Select a representative sample of concrete of sufficient volume to provide enough mortar to fill the test container to a depth of at least 140 mm.
- Sieve the concrete through 4.75 mm IS sieve in order to remove all the mortar from concrete. Mix the mortar thoroughly and place it in the container in layers.
- Compact each layer of mortar using tamping rod. The final height of mortar after tamping should be less than 13 mm from the height of the container.
- This space is required for the collection and removal of bleeding Water. Cover the specimen in the container, with a suitable tight fitting, water impermeable blanket for the duration of the test.

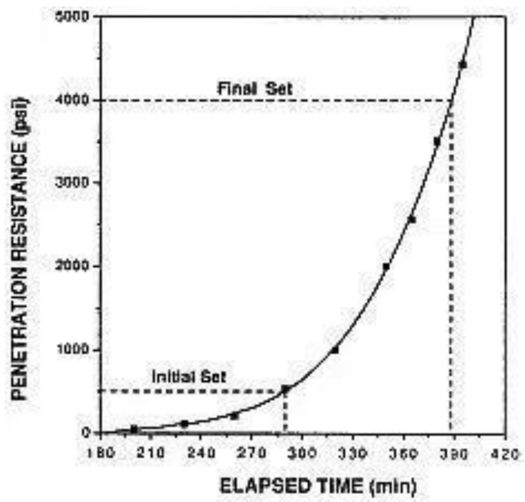


Fig: Setting time plot

Effect Of Time And Temperature On Workability

- When temperature increases, then in the same proportion workability of fresh concrete decreases.
- The reason that stands behind is " when temperature increases then evaporation rate also increases due to that hydration rate decreases and hence, concrete will gain strength earlier ".
- Due to fast hydration of concrete, a hardening comes in concrete and that decreases the workability of fresh concrete. Therefore, In return manipulation of concrete become very difficult.

Segregation of Concrete

- **Definition**
  - Segregation is when the coarse and fine aggregate, and cement paste, **become separated**. Segregation may happen when the concrete is mixed, transported, placed or compacted

  - Segregation makes the concrete
    - WEAKER,
    - LESS DURABLE,
    - A POOR SURFACE FINISH

Fig: Segregation in concrete

Segregation of Concrete

- **Basic types of segregation**
  - *<u>Coarse segregation</u>* : Occurs when gradation is shifted to include too much coarse aggregate and not enough fine aggregate. Coarse segregation is characterized by low asphalt content, low density, high air voids, rough surface texture, and accelerated rutting and fatigue failure (Williams et. al., 1996b). Typically, coarse segregation is considered the most prevalent and damaging type of segregation; thus segregation research has typically focused on coarse segregation. The term "segregation" by itself is usually taken to mean "coarse segregation."
  - *<u>Fine segregation</u>* : Occurs when gradation is shifted to include too much fine aggregate and not enough course aggregate. High asphalt content, low density, smooth surface texture, accelerated rutting, and better fatigue performance characterize fine segregation (Williams, Duncan and White, 1996).

Segregation of Concrete

- **To Avoid Segregation**
  - Check the concrete is not 'too wet' or 'too dry'.
  - Make sure the concrete is properly mixed. It is important that the concrete is mixed at the correct speed in a transit mixer for at least two minutes immediately prior to discharge.
  - Always pour new concrete into the face of concrete already in place. When compacting with a poker vibrator be sure to use it carefully.

Fig: Segregation

Bleeding of Concrete

- This refers to the appearance of water along with cement particles on the surface of the freshly laid concrete. This happens when there is excessive quantity of water in the mix or due to excessive compaction.
- Bleeding causes the formation of pores and renders the concrete weak. Bleeding can be avoided by suitably controlling the quantity of water in the concrete and using finer grading of aggregates.
- A thorough knowledge of why concrete bleeds and how mix proportions affect it, is required to preventing the harmful effects of bleeding. Adoption of right finishing methods also helps to ensure that the bleeding problems won't ruin a slab surface.

Bleeding of Concrete

How to control bleeding

- Use a more finely ground cement. Concretes made with high early strength (Type III) cement bleed less because the cement is ground finer than normal (Type I) cement.
- Use more cement. At the same water content, rich mixes bleed less than lean mixes. Use fly ash or other pozzolons in the concrete.
- If concrete sands don't have much material passing the No. 50 and 100 sieves, blend in a fine blow sand at the batch plant.

Fig: Bleeding

Mixing And Vibration Of Concrete

- **Mixing** is the uniform incorporation of the ingredients within the concrete mix and vibration usually means the mechanical process to assist in the removal of any entrapped air. The air entrapment causes a honeycomb effect which weakens the concrete,
- There are calculations and processes for concrete to allow for movement, which often translates to vibration due to friction or the dis-similarity of materials , a serious concern as it would be the cause for structural fatigue and failure.
- Vibration of concrete is carried out for the sake of consolidation. The main objective of vibration is to compact the concrete and to achieve the maximum possible density of concrete. Almost 5 to 8% by volume of freshly placed concrete in the form is occupied by air bubbles. Air bubbles occupy this space in a high workable concrete mix.

Mixing And Vibration Of Concrete

- Air bubbles can be removed by decreasing in the amount of required water, but it affects workability of concrete. Therefore, vibration of concrete is the only suitable method that helps without affecting much the properties of fresh concrete.

Steps In Manufacture Of Concrete

- The various stages of manufacture of concrete are:
  (a) Batching
  (b) Mixing
  (c) Transporting
  (d) Placing
  (e) Compacting
  (f) Curing
  (g) Finishing.

Steps In Manufacture Of Concrete

(a) Batching :

- The process of measuring different concrete materials such as cement, coarse aggregate, sand, water for the making of concrete is known as batching. Batching can be done in two different ways.

  1.Volume Batching

  2.Weight Batching.

- In volume batching the measurements of concrete materials are taken by volume & On the other hand the measurements are taken by weight in weight batching.

1. **Volume Batching:**

- In volume batching the measurements of concrete materials are taken by volume & On the other hand the measurements are taken by weight in weight batching.
- For unimportant concrete or for any small job, concrete may be batched by volume.

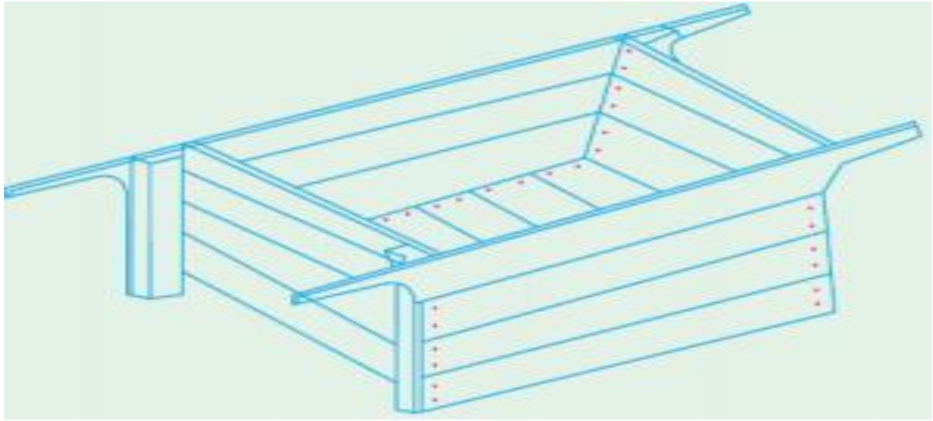


Fig: Volume Batching

Steps In Manufacture Of Concrete

2. Weight Batching:

- Weigh batching is the correct method of measuring the materials. Use of weight system in batching, facilitates accuracy, flexibility and simplicity.
- Large weigh batching plants have automatic weighing equipment. On large work sites, the weigh bucket type of weighing equipment's are used.


Fig: Weight Batching

Steps In Manufacture Of Concrete

(b) Mixing :

- In this process, all the materials are thoroughly mixed in required proportions until the paste shows uniform color and consistency.
- The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency.
- There are two methods adopted for mixing concrete:

  (i) Hand mixing

  (ii)Machine mixing

Steps In Manufacture Of Concrete

(i) Hand mixing:

- Hand mixing is practiced for small scale unimportant concrete works. As the mixing cannot be thorough and efficient, it is desirable to add 10 per cent more cement to cater for the inferior concrete produced by this method.
- Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement.
- Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers.


Fig: Hand mixing

Steps In Manufacture Of Concrete

(ii) Machine Mixing:

- In normal concrete work, it is the batch mixers that are used.
- Batch mixer may be of **pan type or drum type**.
- The drum type may be further classified as tilting, non-tilting,
- reversing or forced action type. As per I.S. 1791–1985, concrete mixers are designated by a number representing its nominal mixed batch capacity in liters.
- The following are the standardized sizes of three types:

 a. Tilting: 85 T, 100 T, 140 T, 200 T

 b. Non-Tilting: 200 NT, 280 NT, 375 NT, 500 NT, 1000 NT

 c. Reversing: 200 R, 280 R, 375 R, 500 R and 1000 R

Steps In Manufacture Of Concrete

Fig: Machine mixing

Steps In Manufacture Of Concrete

(c) Transporting:

When the mixing is done properly the freshly made concrete is then transported to the construction site. After that, the concrete is correctly placed on the formworks.

Fig: Buggies

Fig: Belt conveyors

Fig: Transit Mixer

Fig: Pumps

Fig: Cranes and Buckets

Steps In Manufacture Of Concrete

d. Placing:

- The concrete should be placed and compacted before its setting starts. The method of placing concrete should be such as to prevent segregation.
- It should not be dropped from a height more than one meter. In case, placing of concrete is likely to take some time it should be kept in an agitated condition.

Following precautions should be taken while placing concrete.

- Concrete should be laid continuously to avoid irregular and unsightly lines.
- To avoid sticking of concrete, formwork should be oiled before concreting.
- To avoid segregation, concrete should not be dropped from a height more than 1 meter.

Steps In Manufacture Of Concrete

- Concrete should not be placed during rain.
- The thickness of the concrete layer should not be more than 15 – 30 cm in case of RCC and 30 – 40 cm in case of mass concrete.
- Walking on freshly laid concrete should be avoided.
- While placing concrete, the position of formwork and reinforcement should not get disturbed.
- It should be placed as near to its final position as practicable.

Fig: Placing at construction at site

Steps In Manufacture Of Concrete

(e) Compaction:

- Compaction is the process in which the air bubbles are eliminated from the freshly placed concrete. It is required to increase the ultimate strength of concrete by enhancing the bond with reinforcement.

Steps In Manufacture Of Concrete

(a) Hand Compaction

(i) Rodding

(ii) Ramming

(iii) Tamping

(b) Compaction by Vibration

(i) Internal vibrator (Needle vibrator)

(ii) Formwork vibrator (External vibrator)

(iii) Table vibrator

(iv) Platform vibrator

(v) Surface vibrator (Screed vibrator)

(vi) Vibratory Roller.

(c) Compaction by Pressure and Jolting

(d) Compaction by Spinning.

Steps In Manufacture Of Concrete

f . Curing:

- Curing is the process in which the concrete keeps its moisture for a certain time period to complete the hydration process. Curing should be done properly to increase the strength of concrete.

  Required Curing days:

- Ordinary Sulphate Resistant Cement – 8 Days.
- Low Heat Cement – 14 Days.
- Curing methods may be divided broadly into four categories:

  (a) Water curing

  (b) Membrane curing

  (c) Application of heat

  (d) Miscellaneous

Steps In Manufacture Of Concrete

Fig: Water curing

Fig: Membrane curing

Steps In Manufacture Of Concrete

Fig: Application of heat

Steps In Manufacture Of Concrete

g. Finishing:

- Finishing operation is the last operation in making concrete. For a beam concreting, finishing may not be applicable, whereas for the concrete road pavement, airfield pavement or for the flooring of a domestic building, careful finishing is of great importance.
- Surface finishes may be grouped as under:

  (a) Formwork Finishes

  (b) Surface Treatment

  (c) Applied Finishes.

Steps In Manufacture Of Concrete

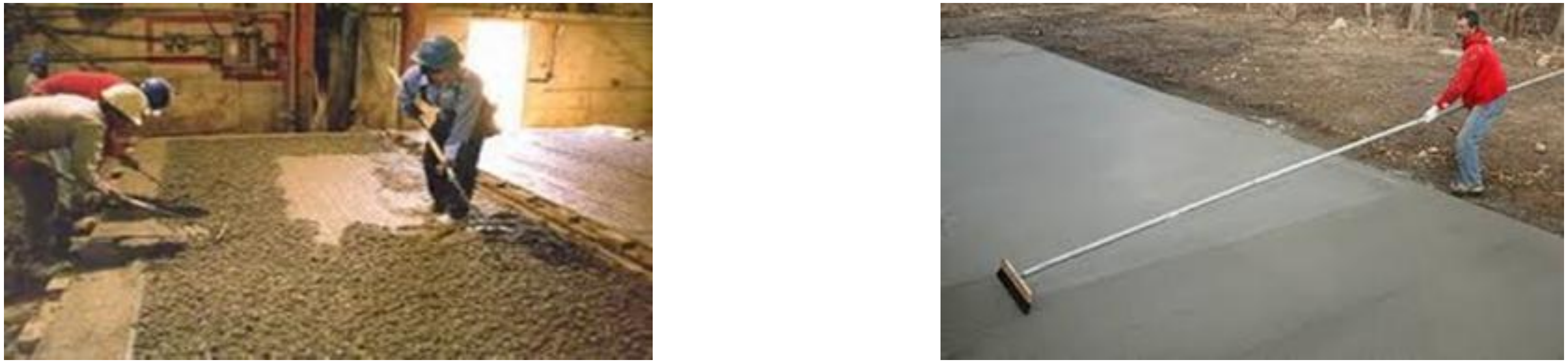


Fig: Surface finish

Fig: Floor finish

Fig: Applied finish

Quality of mixing water

- The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have inorganic solid less than 1000 ppm.
- This 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 color 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.

Quality of mixing water

- In coastal areas where local water is saline and have no alternate sources, the chloride concentration up to 1000 ppm is even allowed for drinking, this excessive amount of alkali carbonates and bicarbonates, in some natural mineral water, may cause alkali-silica reaction.
- Besides potable water, various new and existing sources are available for mixing water which can be used for complete and partial replacement of valuable potable water. This includes

  1.Groundwater

  2.Reclaimed water

  3.Treated water from municipal sewer

  4.Waste water of ready-mix concrete plant etc.

UNIT-III

HARDENED CONCRETE AND ITS TESTING

Introduction

- Hardened concrete is a 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.
- It will be the strongest and durable building material.
- The principal properties of hardened concrete which are of practical importance can be listed as:

1. Strength
2. Permeability & durability
3. Shrinkage & creep deformations
4. Response to temperature variations

Of these compressive strength is the most important property of concrete.

WATER CEMENT RATIO & ABRAM'S LAW

- **Water/cement ratio and degree of compaction :**

  Strength of concrete primarily depends upon the strength of cement paste. The strength of cement paste depends upon the dilution of paste or in other words, the strength of paste increases with cement content and decreases with air and water content.

  In 1918**; Abrams' law** states that "assuming full compaction, and at a given age and normal temperature, strength of concrete can be taken to be inversely proportional to the water/cement ratio"

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

  where x =water/cement ratio by volume and for 28 days results the constants A and B are 96N/mm2 and 7 respectively

GEL-SPACE RATIO

GEL-SPACE RATIO:

- 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 water/cement ratio of concrete
- A higher water/cement ratio decreases the gel/space ratio increasing the porosity thereby decreasing the strength of concrete.

GEL-SPACE RATIO

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

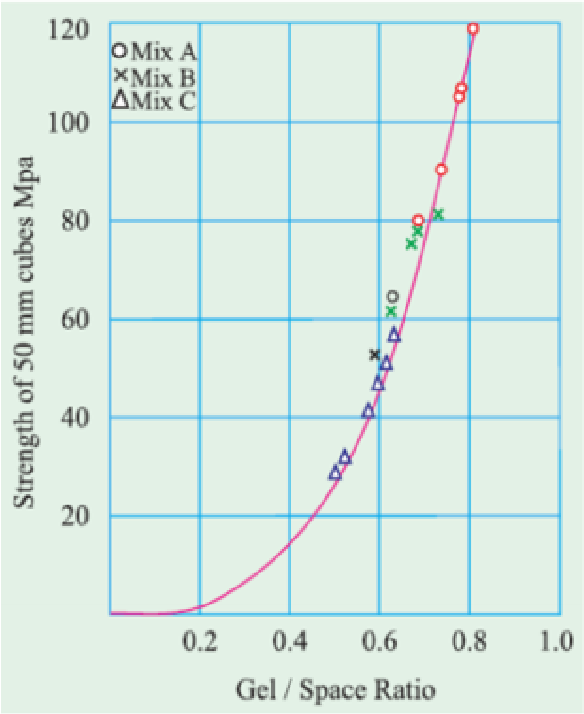
He found the relationship to be 240 x^3, where x is the gel/space ratio and 240 represents the intrinsic strength of the gel in MPa for the type of cement and specimen used.

Calculation of gel/space ratio for complete hydration

$$Gel\ /Space\ Ratio = \frac{Volume\ of\ gel}{Space Available} = \frac{0.657C}{0.319C + W_o}$$

Calculation of gel/space ratio for partial hydration

$$Gel\ /Space\ Ratio = \frac{Volume\ of\ gel}{Space Available} = \frac{0.657C\alpha}{0.319C\alpha + W_o}$$



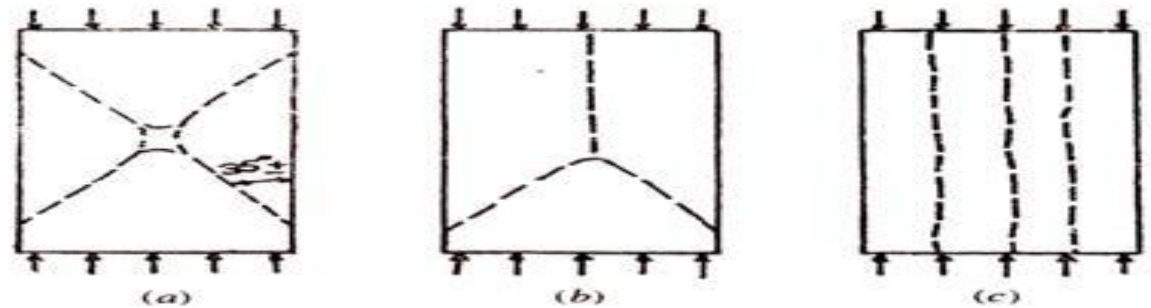
Nature of strength of concrete

The strength can be defined as the ability to resist force. The strength of a concrete specimen prepared, cured and tested under specified conditions at a given age depends on:

- w/c ratio
- Degree of compaction.
- Stress Distribution in Specimens.
- Effect of L/d ratio.
- Specimen Geometry.
- Rate of Loading.
- Moisture Content.
- Temperature at Testing.

Nature of strength of concrete

- Rupture of concrete may be caused by applied tensile stress, shearing stress or by compressive stress or a combination of two of the above stresses.
- 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 plane.



- **Fig**: Mode of rupture
- It is called as shear or cone failure. As the resistance to failure is due to both cohesion and internal friction, the angle of rupture is not 45° (plane of maximum shear stress), but is a function of the angle of internal friction.

Nature of strength of concrete

Strength may be classified as follows:

1. Compressive strength
2. Tensile strength
3. Shear strength, and
4. Bond strength.

1. Compressive strength:

To determine the compressive strength of concrete following three types of specimens can be used:

i. Cubes

ii. Cylinders

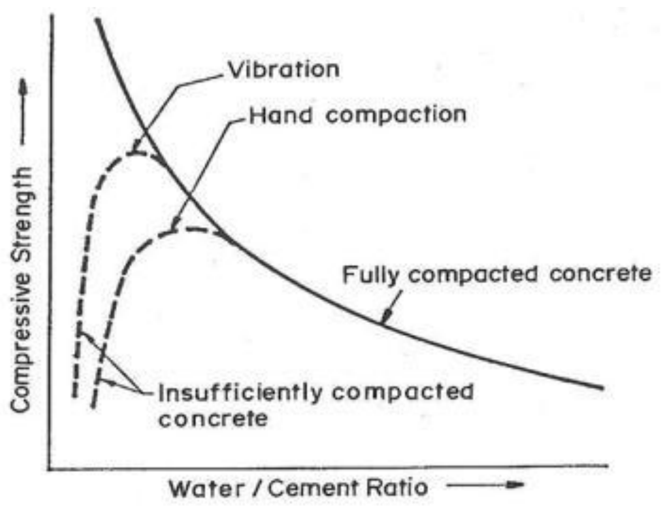


Fig: W/C ratio Vs Compressive strength

Nature of strength of concrete

2. Tensile strength:

- Concrete being a brittle material is not expected to resist direct tensile forces. However 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 tensile strength of concrete varies from 7% to 11% of the compressive strength but on average it is taken as 10% of compressive strength. The maximum tensile strength of concrete has been found of the order of 42.0 kg/cm.
- Generally for concrete quality control, tensile test is never made. However to have an idea of tensile strength an indirect method known as splitting test is applied.

Nature of strength of concrete

3. Shear Strength:

- 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.
- Pure shear can be applied only through torsion of a cylindrical specimen in which case the stresses are equal in primary shear.
- Secondary tension (maximum at 45° to shear) and secondary compression (maximum at 45° to shear, per-pendicular to tension). As the concrete is weaker in tension than in shear, failure in tension invariably occurs in diagonal tension. Direct determination of shear is very difficult.

Nature of strength of concrete

4. Bond Strength:

- 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 and adhesion between the concrete and steel friction between concrete and the lugs of deformed bars.
- It is also affected by the shrinkage of concrete relative to the steel. Bond involves not only the properties of concrete, but also mechanical properties of steel and its position in the concrete member.
- In general bond strength is approximately proportional to the compressive strength of concrete upto about 200 kg/cm^2. Bond strength is also a function of specific surface of gel.

Maturity concept of concrete

- While dealing with curing and strength development, we have so far considered only the time aspect. It has been pointed out earlier that it is not only the time but also the temperature during the early period of hydration that influences the rate of gain of strength of concrete.
- Since the strength development of concrete depends on both time and temperature it can be said that strength is a function of summation of product of time and temperature. This summation is called maturity of concrete.

Maturity = Σ (time x temperature)

The temperature is reckoned from an origin lying between -12 and -10°C. Strength at any maturity as a percentage of strength at maturity of

$$19{,}800^{0}\text{Ch} = A + B \log 10\ (\text{maturity}) / 10^{3}$$

Maturity concept of concrete

It was experimentally found that the hydration of concrete continues to take place upto about -11°C. Therefore, -11°C is taken as a datum line for computing maturity. Maturity is measured in degree centigrade hours (°C hrs) or degree centigrade days (°C days)..

The values of coefficients, A and B depend on the strength level of concrete. The value are given in Table :

Plowman's coefficients for Maturity Equation

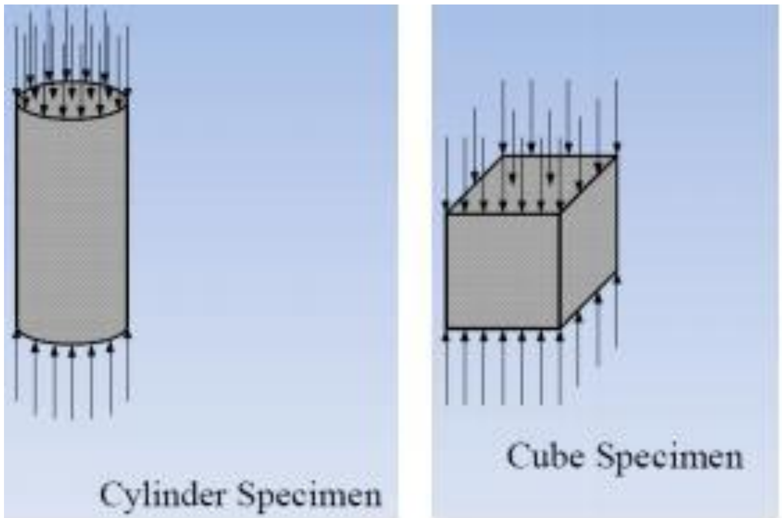
Strength after 28 days at 18°C (Maturity of 19,800°Ch): MPa	Coefficient	
	A	B
Less than 17.5	10	68
17.5 – 35.0	21	61
35.0 – 52.5	32	54
52.5 – 70.0	42	46.5

Strength in tension & compression

Compression:

- Concrete has enormous compressive strength, the ability to withstand heavy weights or forces on it. It also gains strength as it ages. Concrete will solidify in a few hours and harden or set in a few days, but continues to gain strength for at least 28 days. The compressive strength of concrete is defined as the strength of 28 days old specimens tested under monotonic uniaxial compressive load.
- Testing of cylindrical samples with 15 cm diameter and 30 cm height is standard.
- Cube specimens of 15 cm × 15 cm × 15 cm are also being used.
- Normally, the compressive strength of concrete is determined by testing, and the tensile strength and modulus of elasticity are expressed in terms of the compressive strength.

Strength in tension & compression



$$(f_c)_{cylinder} = (0.85-0.80)(f_c)_{cube}$$

Fig: Compressive strength

Strength in tension & compression

Tension:

- Concrete has almost no tensile strength, the ability to withstand pressing or stretching. Put a board between two supports and press down on the center. It will bend. The top of the board is under compression, the bottom which bends is under tension.
- Concrete can resist the compression, but will break under the tension. Concrete cracks in roads and slabs are largely due to tension; different weights in different areas produce tensile forces.
- The tensile strength of concrete is much lower than the compressive strength, largely because of the ease with which cracks can propagate under tensile loads .
- The tensile strength of concrete is measured in three ways: direct tension, splitting tension, and flexural tension.

1. Direct-Tension Test:

- The most direct way of measuring the tensile strength.
- Not a practical test.

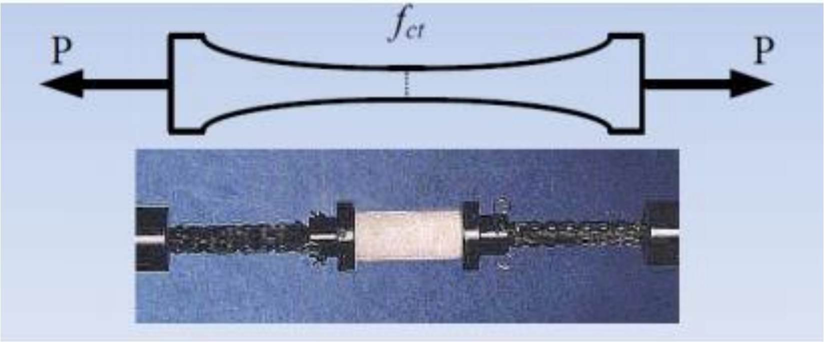


Fig: Direct-Tension Test

2. Split-Cylinder Test:

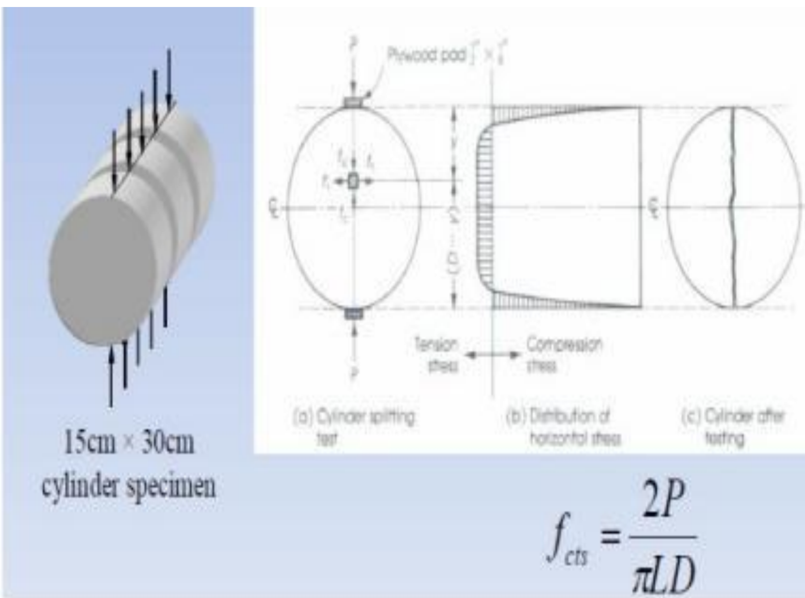


Fig: Split tensile test

Modulus of Rupture Test:

1. Four-point bending (two-point loading)
2. Three-point bending (third point loading)

$$f_{ctf} = \frac{6M}{b \cdot h^2}$$

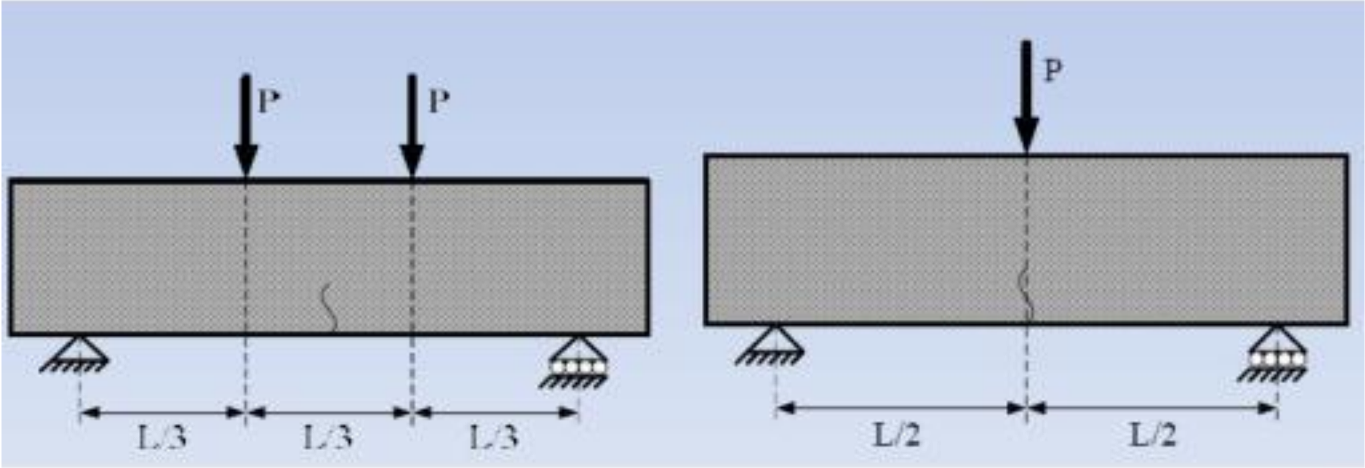


Fig: Modulus of rupture test

Factors Affecting the Strength of Concrete

Factors Affecting the Strength of Concrete:

Generally following factors affect the strength of concrete.

1. Type of cement
2. Type of aggregate(Shape, size, texture, Grading)
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, and
9. Effect of loading condition.

Relation between compression & 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 relations can be used as a rule of thumb:

$$\text{Direct tensile strength}: f_{ct} = 0.35\sqrt{f_c} \quad (f_c \text{ in MPa})$$

$$\text{Split tensile strength}: f_{cts} = 0.50\sqrt{f_c} \quad (f_c \text{ in MPa})$$

$$\text{Flexural tensile strength}: f_{ct} = 0.64\sqrt{f_c} \quad (f_c \text{ in MPa})$$

Testing of hardened concrete: Compression tests, Tension tests

Compressive Strength is determined by loading properly prepared and cured cubic, cylindrical or prismatic specimens under compression.

Testing of hardened concrete: Compression tests, Tension tests

- Cubic: 15x15x15 cm

  Cubic specimens are crushed after rotating them 90° to decrease the amount of friction caused by the rough finishing.
- Cylinder: h/D=2 with h=15

  To decrease the amount of friction, capping of the rough casting surface is performed.

Testing of hardened concrete: Compression tests, Tension tests

- **SPLIT TENSILE STRENGTH**

  1. Direct Tensile:

     No standard Test

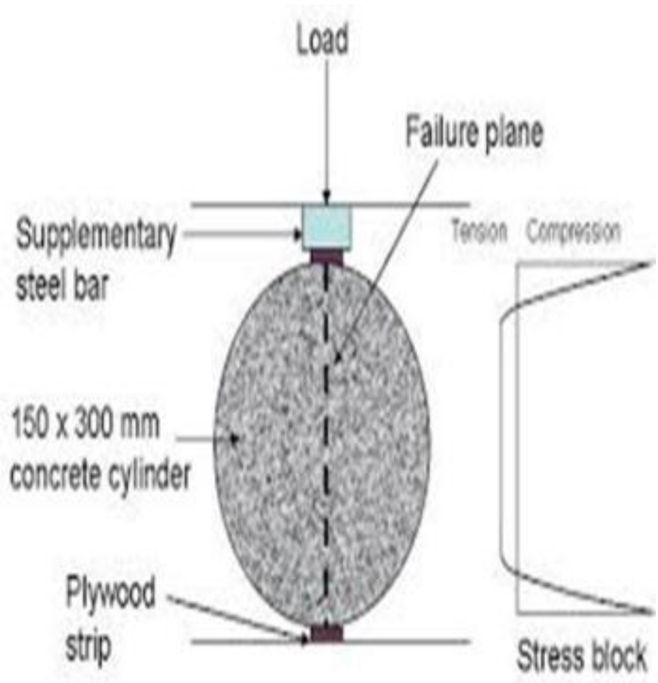
  2. Indirect Tensile:

     A. Splitting Tension Test.

$$\sigma_{sp} = \frac{2P}{\pi L D}$$

- The tensile strength of concrete is approximately equal to 10% of its compressive strength.

Testing of hardened concrete: Compression tests, Tension tests



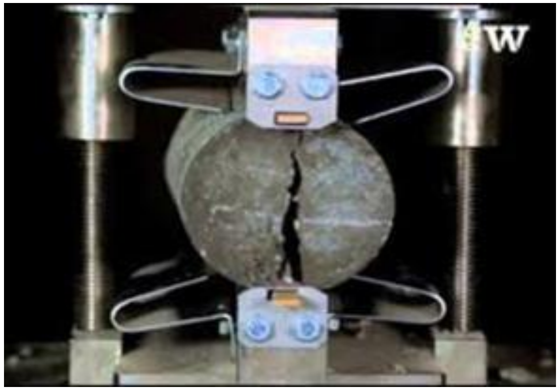


Fig: Tensile strength

3. Flexural strength:

- The test is useful since most concrete members is loaded in bending rather than in axial tension.
- This test is mostly used for quality control of highways and airport runways. It gives more useful information than do compression tests.
- Flexural strength:

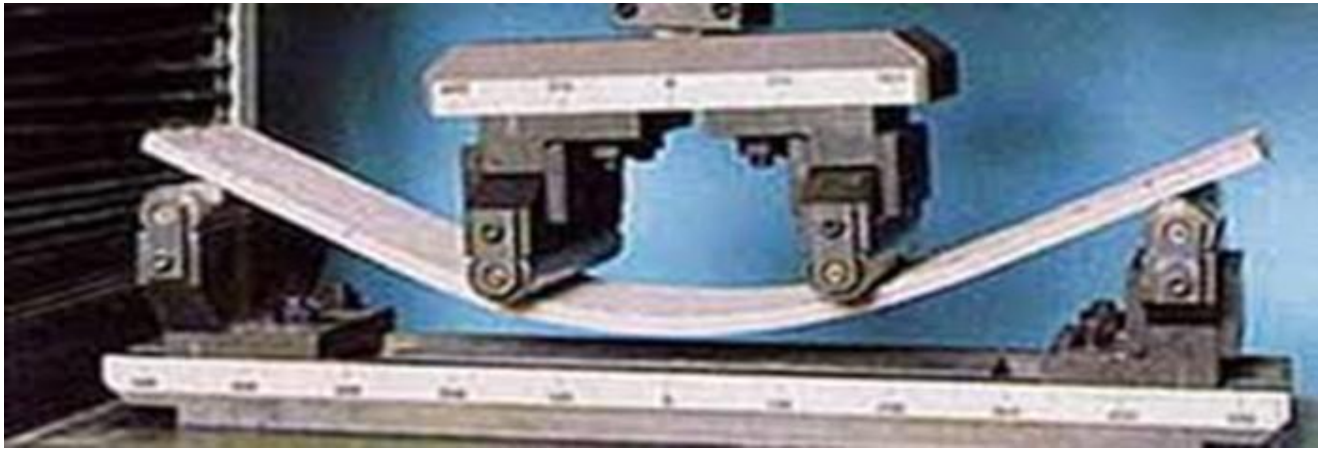
  Affected by:

  - Specimen Size ↑ → strength ↓

  - Temperature: Same as in compression.

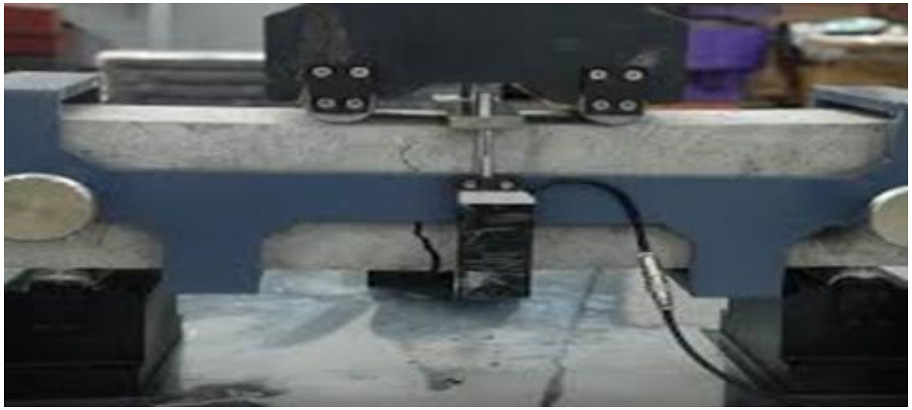
  The tensile strength of concrete is approximately equal to 10% of its compressive strength.

Flexural Strength (Three Point Flexural Test):



Testing of hardened concrete: Compression tests, Tension tests

Flexural Strength (Centre Point Flexural Test):



Testing of hardened concrete: Compression tests, Tension tests

Other Compressive Tests:

Fig: RING TENSION TEST

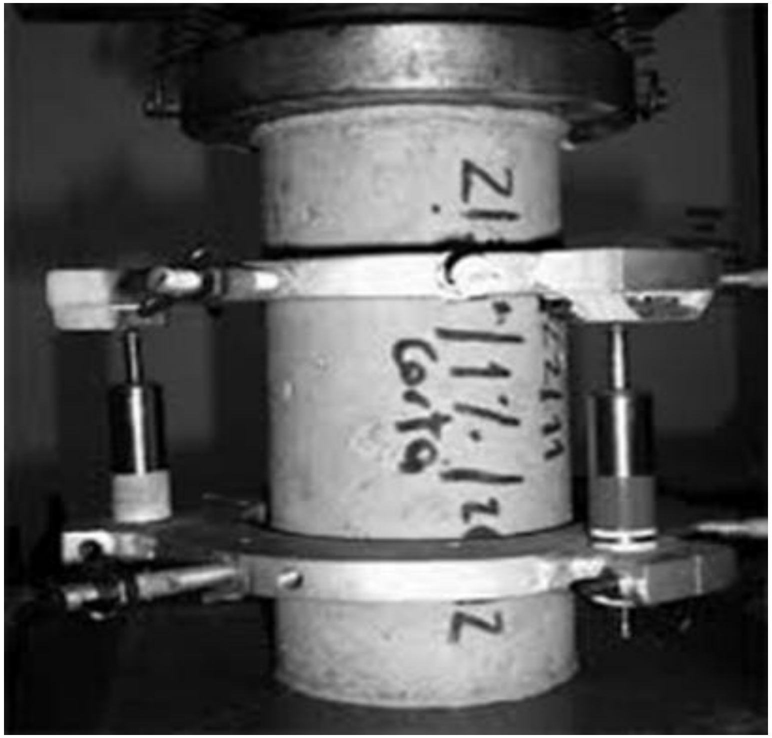


Fig: DOUBLE PUNCH TEST

Non-destructive testing methods

Non-destructive testing (**NDT**) is widely used for quality control in the fabrication of process plant and equipment. It is a set of **techniques** used to evaluate the structural integrity of materials and detect any flaws that can compromise their safety or functionality.

1. **Surface hardness tests**: These are of indentation type, include the Williams testing pistol and impact hammers, and are used only for estimation of concrete strength.
2. **Rebound test**: The rebound hammer test measures the elastic rebound of concrete and is primarily used for estimation of concrete strength and for comparative investigations.
3. **Penetration and Pull out techniques**: These measure the penetration and pullout resistance of concrete and are used for strength estimations, but they can also be used for comparative studies.

Non-destructive testing methods

4. **Dynamic or vibration tests:** These include resonant frequency and mechanical sonic and ultrasonic pulse velocity methods. These are used to evaluate durability and uniformity of concrete and to estimate its strength and elastic properties.

5. **Combined methods**: The combined methods involving ultrasonic pulse velocity and rebound hammer have been used to estimate strength of concrete.

6. **Radioactive and nuclear methods**: These include the X-ray and Gamma-ray penetration tests for measurement of density and thickness of concrete. Also, the neutron scattering and neutron activation methods are used for moisture and cement content determination.

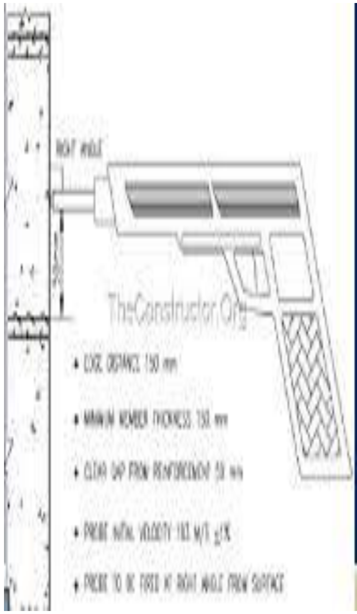
Non-destructive testing methods

Fig: Rebound Hammer Test

Non-destructive testing methods

Fig: Surface Hardness

Fig: William Pistol



Non-destructive testing methods

Fig: Pull Out test

Fig: Penetration Test

Non-destructive testing methods

Fig : Ultrasonic Pulse Velocity

Non-destructive testing methods

Fig : Surface Transmission

Fig : Direct Transmission

Fig: Semidirect Transmission

Non-destructive testing methods

Fig: Mechanical Sonic Velocity Tests

Elasticity, Creep & Shrinkage

- Creep is time dependent deformations of concrete under permanent loads (self weight), PT forces and permanent displacement.

- When concrete is subjected to compressive loading it deforms instantaneously. This immediate deformation is called instantaneous strain. Now, if the load is maintained for a considerable period of time, concrete undergoes additional deformations even without any increase in the load. This time-dependent strain is termed as creep.

Elasticity, Creep & Shrinkage

Fig: Creep Of concrete

Elasticity, Creep & Shrinkage

Factors affecting creep:

- Concrete mix proportion
- Aggregate properties
- Age at loading
- Curing conditions
- Cement properties
- Temperature
- Stress level

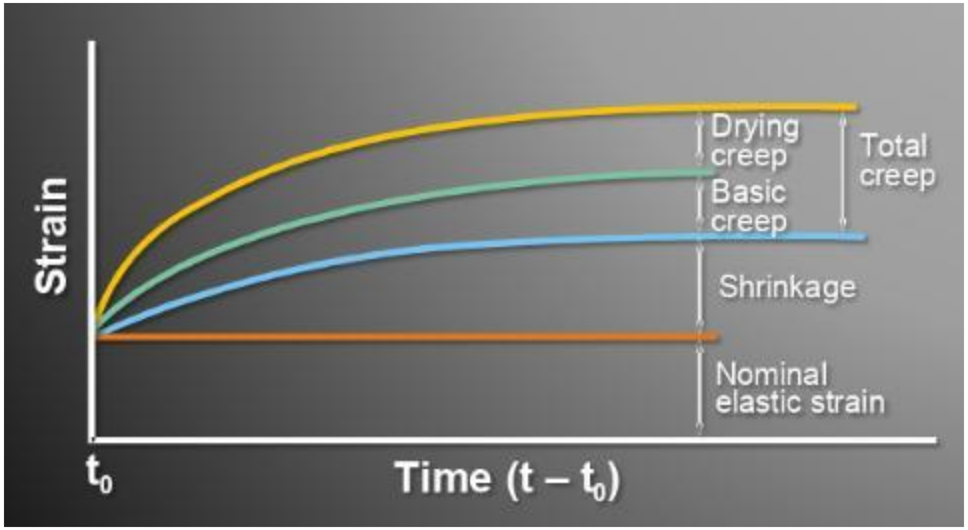


Fig: Creep analysis

Relation between creep & time

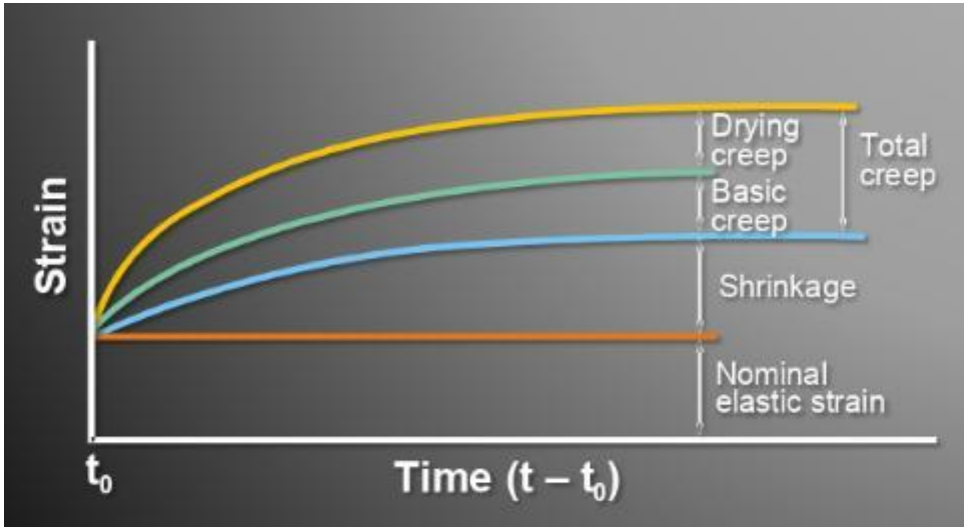


Fig: Creep analysis

Elasticity, Creep & Shrinkage

Effects of creep on concrete structures:

In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.

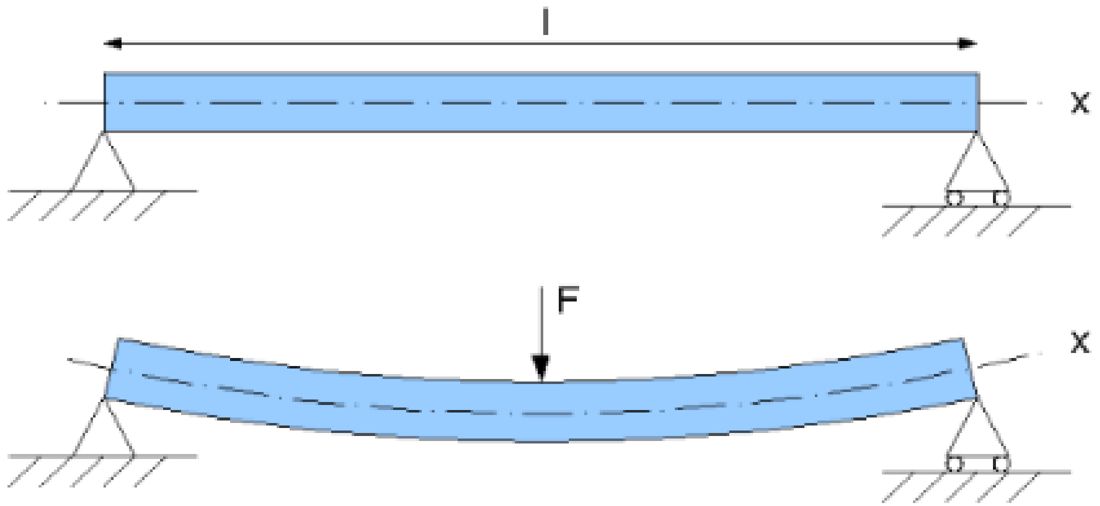


Fig: Effect of creep

Effects of creep on concrete structures:

- Loss of pre stress due to creep of concrete in pre stressed concrete structure.

- Creep property of concrete will be useful in all concrete structures to reduce the internal stresses due to non-uniform load or restrained shrinkage.

Elasticity, Creep & Shrinkage

- Shrinkage is shortening of concrete due to drying and is independent of applied loads.
- Shrinkage of concrete is the time-dependent strain measured in an unloaded and unrestrained specimen at constant temperature.

Factors Affecting Shrinkage:

- Drying conditions
- Time
- Water cement ratio

Elasticity, Creep & Shrinkage

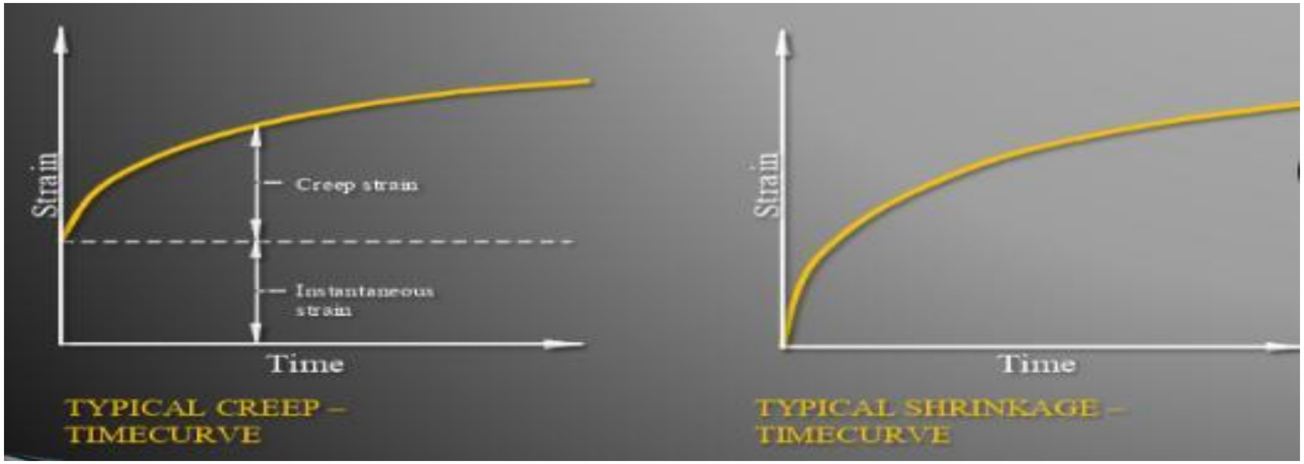
Fig: Shrinkage

Elasticity, Creep & Shrinkage

Types of shrinkage:

- Plastic Shrinkage
- Drying Shrinkage
- Autogeneous Shrinkage
- Carbonation Shrinkage

Creep and Shrinkage Typical Time Curve:



Prevention of Shrinkage:

Provide shun shades in case of slab construction to control the surface temperature.

Dampen the subgrade of concrete before placement it is liable to water absorption but should not over damp.

UNIT-IV

MIX DESIGN

INTRODUCTION

Cement 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.

Introduction

- Concrete is obtained by mixing cement, fine aggregate, coarse aggregate, water and admixtures in required proportions. The mixture when placed in forms and allowed to cure becomes hard like stone.
- The hardening is caused by chemical action between water and the cement due to which concrete grows stronger with age.
- It is the most widely-used man-made construction material in the world.

Introduction

CONCRETE MAKING MATERIALS:

- Cement
- Aggregates
- Water
- Admixtures

DEFINITION

" **Mix Design** is the science of determining the relative proportions of the ingredients of concrete to achieve the desired properties in the most economical way."

Introduction

Table 3 Environmental Exposure Conditions

(*Clauses* 8.2.2.1 *and* 35.3.2)

Sl No. (1)	Environment (2)	Exposure Conditions (3)
i)	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.
ii)	Moderate	Concrete surfaces sheltered from severe rain or freezing whilst wet
		Concrete exposed to condensation and rain
		Concrete continuously under water
		Concrete in contact or buried under non-aggressive soil/ground water
		Concrete surfaces sheltered from saturated salt air in coastal area
iii)	Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation.
		Concrete completely immersed in sea water
		Concrete exposed to coastal environment
iv)	Very severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet
		Concrete in contact with or buried under aggressive sub-soil/ground water
v)	Extreme	Surface of members in tidal zone
		Members in direct contact with liquid/ solid aggressive chemicals

Table 2 Grades of Concrete

(*Clause* 6.1, 9.2.2, 15.1.1 *and* 36.1 *)*

Group (1)	Grade Designation (2)	Specified Characteristic Compressive Strength of 150 mm Cube at 28 Days in N/mm² (3)
Ordinary Concrete	M 10	10
	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

NOTES

1 In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm².

2 For concrete of compressive strength greater than M 55, design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

Introduction

Table 8 Assumed Standard Deviation
(*Clause* 9.2.4.2 and *Table* 11)

Grade of Concrete	Assumed Standard Deviation N/mm^2
M 10 M 15	3.5
M 20 M 25	4.0
M 30 M 35 M 40 M 45 M 50	5.0

NOTE—The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate gradings and moisture content; and periodical checking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by $1N/mm^2$.

Factors Defining The Choice Of Mix Proportions

1. Compressive Strength
2. Workability
3. Durability
4. Type, size and grading of aggregates
5. Aggregate-cement ratio

COMPRESSIVE STRENGTH:

Abram's Law:

$$\log F = \log A_1 - x \log B_1$$

where F is the compressive strength

A1, B1 are constants and

x is the w/c ratio by weight

Factors Defining The Choice Of Mix Proportions

WORKABILITY

"that property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished."

DURABILITY

"the resistance to weathering action due to environmental conditions such as changes in temperature and humidity, chemical attack, abrasion, frost and fire."

METHODS OF CONCRETE MIX DESIGN

1. American Concrete Institute Committee 211 method
2. **Bureau of Indian Standards Recommended method IS 10262-82**
3. Road note No. 4 (Grading Curve) method
4. Department Of Environment (DOE - British) method
5. Trial and Adjustment Method
6. Fineness modulus method
7. Maximum density method
8. Indian Road Congress, IRC 44 method

METHODS OF CONCRETE MIX DESIGN

- Bureau of Indian Standards Recommended method IS 10262-82:

  The BIS recommended mix design procedure is covered in IS 10262-82.

  In line with IS 456-2000, the first revision IS 10262-2009 was published, to accommodate some of the following changes:

- Increase in strength of cement
- Express workability in terms of slump, rather than the compacting factor
- Extend the W/C ratio v/s compressive strength graph

- **Modifications in IS 10262-2009**

S.N.	Old Edition	Revised 2009 Edition
1	Title - " Recommanded guidelines for Concrete mix Design"	Title - "Concrete mix Proportioning - Guidelines"
2	Applicability was not specified for any specific Concrete Grades	Specified for Ordinary (M 10 - M 20) and Standard (M25 - M 55) Concrete Grades only.
3	Based on IS 456 : 1982	Modification in line with IS 456 : 2000
4	W / C ratio was based on Concrete grade and 28 days compressive strength of Concrete and the durability criteria	W/C ratio is based on Durability criteria and the Experience and Practical trials
5	Water Content could be modified taking into account the compaction factor value (Laboratory based test for Workability) and the shape of aggregates.	Water content can be modified Based on Slump vale (Field test of Workability) and Shape of Aggreagtes, and use of Admixtures.
6	Entrapped Air cotent considered according to Nominal Maximum size of Aggregates	No Entrapped Air content taken into account
7	Not much Consideration for Trial Mixes	Trial Mixes concept is mentioned
8	Concrete Mix Design with Fly ash is not mentioned	An illustrative example of Concrete Mix Prportioning using Fly ash has been added

METHODS OF CONCRETE MIX DESIGN

- As per IS 10262:2009 method of concrete mix proportioning

Step 1 : Target mean strength :

$$fm = fck + 1.65\sigma$$

Where fm - Target average mean compressive strength.

fck- characteristic compressive strength.

σ - standard deviation for each grade of concrete.

The standard deviations for different grades of concrete are :

- **M10-M15 : 3.5 Mpa**
- **M20-M25 : 4.0 Mpa**
- **M30-M50 : 5.0 MPa**

METHODS OF CONCRETE MIX DESIGN

- **Step 3:** Estimate water content & sand contents for concrete grades up to M35 grade

Maximum size of aggregate (mm)	Water content (kg/m3)	p=Fagg .Vol (%ofTotal)
10	208	40
20	186	35
40	165	30

Maximum size of aggregate (mm)	Water content (kg/m3)	p=Fagg .Vol (%of Total)
10	200	28
20	180	25

METHODS OF CONCRETE MIX DESIGN

Step 3: Estimate water content & sand contents for concrete grades up to M35/ above M35 IS METHOD :

The Tables are for:

- Crushed Coarse Aggregate
- Fine aggregate Zone II
- w/c=0.6(up to M35) & 0.35 (>M35)
- Compaction factor =0.8

Condition	Adjustments	
	Water content ΔW	% sand in total aggregate Δp (%)
Sand Zone I,III,IV of IS 383	0	+1.5% for zone I -1.5% for zone III -3.0% for zone IV
Compaction Factor(±) 0.1	(±) 3%	0
Water cement ratio(±) 0.05	0	±1%
Rounded aggregate	-15 kg/m3	-7%

Step 4: Calculate cement content, Aggregate contents :

- **w/c*= Min (W/Ccurve, W/Cdurability)**
- **C=Max(W/ w/c*, Cdurability).**
- V=[W+C/Sc+1/p*Fagg/Sfagg]*1/1000
- V=[W+C/Sc+1/1-p*Cagg/Scagg]*1/1000

Where V = Absolute volume of concrete, W = Mass of water in kg per m3 of concrete, C = Mass of cement in kg per m3 of concrete, Sc= specific gravity of cement, P =Ratio of fine aggregate to total aggregate by absolute volume, Fagg = Total mass of fine aggregate in kg per m3 of concrete, Cagg = Total mass of coarse aggregate in kg per m3 of concrete, Sfagg = specific gravity of fine aggregate in kg per m3 , Scagg = specific gravity of coarse aggregate in kg per m3

METHODS OF CONCRETE MIX DESIGN

- V =1-air content

Maximum size of aggregate (mm)	Air content (%)
10	3.0
20	2.0
40	1.0

IS METHOD (Example)

STEP 1 : TARGET MEAN STRENGTH :

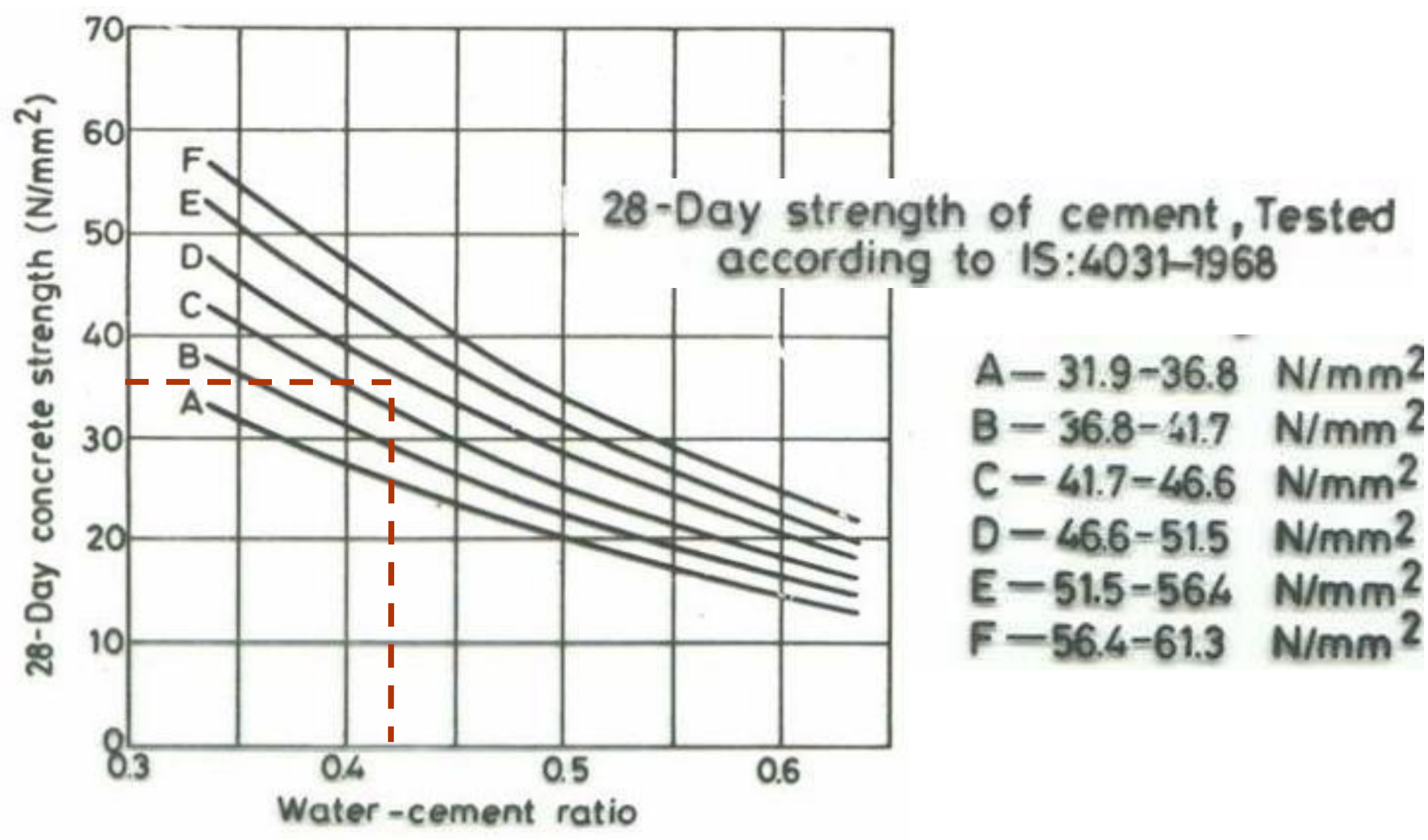
$fm = fck + 1.65\sigma$

$\sigma = 4$

$f\,m = 32$ *Mpa*

Grade	Standard Deviation	Target mean strength (fm)
25	4	31.6

- **Step 2 : selection of w/c from curves w/c=0.43 is**



STEP:2 W/C:0.43

Exposure	Minimum cement content	Maximum water content	Minimum grade
Mild	300	0.55	M 20
Moderate	300	0.50	M 25
Severe	320	0.45	M 30
Very severe	340	0.45	M 35
Extreme	360	0.40	M 40

Step 3: Estimate water content & sand contents for concrete grades up to M35 grade:

Maximum size of aggregate (mm)	Water content (kg/m3)	p=Fagg .Vol (%ofTotal)
10	200	40
20	186	35
40	165	30

Step 3: Adjustments

- **$\Delta W=(0.9-0.8)/0.1\times 0.03*186-15 = -9.2$ kg/m3**
- **Δp (%)= $-1.5+(0.43-0.6)\times 0.01/0.05-7 = -11.9\%$**

Condition	Adjustments	
	Water content ΔW	% sand in total aggregate Δp (%)
Sand Zone I,III,IV of IS 383	0	+1.5% for zone I -1.5% for zone III -3.0% for zone IV
Compaction Factor(±) 0.1	(±) 3%	0
Water cement ratio(±) 0.05	0	±1%
Rounded aggregate	-15 kg/m3	-7%

METHODS OF CONCRETE MIX DESIGN

Step 4:

w/c*= Min (0.43, 0.50)=0.43

W=186-9.2≈177kg/m3

C=Max(177/ 0.43, 300) =411.6 ≈ 412 kg/m3

p= 35-11.9=23.1

(1-0.002) = [177+412/3.15+1/0.231*Fagg/2.7]*1/1000

=> Fagg = 419.25 kg/m3

(1-0.002)=[177+412/3.15+1/1-0.231*Cagg/2.7]*1/1000

=> Cagg = 1344.0 kg/m3

METHODS OF CONCRETE MIX DESIGN

IS METHOD

- W=186-9.2≈177kg/m3
- C=Max(177/ 0.43, 300).=411.6≈412 kg/m3
- Fagg=419.25 kg/m3
- Cagg= 1344.0kg/m3
- Total= 2352 kg/m3

METHODS OF CONCRETE MIX DESIGN

- Actual water to be added =177-water (present –absorption) in aggregate in kg/m3
- Actual quantity of aggregate in the mix shall be Aggregate content + extra due to (moisture content-absorption)
- Trial mix and final adjustment can be made.

UNIT-V

SPECIAL CONCRETES

Introduction

- Special types of concrete are those with out-of-the- ordinary properties or those produced by unusual techniques. Concrete is by definition a composite material consisting essentially of a binding medium and aggregate particles, and it can take many forms.
- These concretes do have advantages as well as disadvantages.

Types of special concrete

1. High Volume Fly Ash Concrete.
2. Silica fume concrete.
3. GGBS, Slag based concrete.
4. Ternary blend concrete.
5. Light weight concrete.
6. Polymer concrete.
7. Self Compacting Concrete.
8. Coloured Concrete.
9. Fibre-reinforced Concrete.
10. Pervious Concrete.
11. Water-proof Concrete.
12. Temperature Controlled Concrete.

High Volume Fly Ash Concrete.

- HVFC is used to replace a portion of the portland cement used in the mix.
- According to IS: 456 – 2000 replacement of OPC by Fly-ash up to 35% as binding material is permitted.
- HVFAC is a concrete where excess of 35%of fly-ash is used as replacement.
- Use of fly ash is because of many factors such as
  a) Abundance of fly ash i.e. 110million tons of fly ash is produced in India every year.
  b) Fly ashes from major TPP are of very high quality i.e. quality of fly ash.
  c) Economic factor i.e. Cost of fly ash with in 200 km from a TPP is as low as 10% to 20% of the cost of cement.
  d) Environmental factors i.e. reduction in CO_2 emission.

Silica fume concrete

- Very fine non-crystalline silica produced in electric arc furnaces as a by product.
- Highly reactive pozzolana used to improve mortar and concrete.
- Silica fume in concrete produces two types of effect viz.
  - Physical effect
  - Chemical effect
- The transition zone is a thin layer between the bulk hydrated cement paste and the aggregate particles in concrete. This zone is the weakest component in concrete, and it is also the most permeable area. Silica fume plays a significant role in the transition zone through both its physical and chemical effects.

GGBS, Slag based concrete

- By-product of the iron manufacturing industry, replacement of Portland cement with GGBS will lead to significant reduction of carbon dioxide gas emission.
- GGBS powder is almost white in colour in the dry state Fresh GGBS concrete may show mottled green or bluish-green areas on the surface mainly due to the presence of a small amount of sulphide.
- GGBS concrete requires longer setting times than Portland cement concrete, probably due to the smooth and glassy particle forms of GGBS. If the temperature is 23oC or replacement level of portland cement by GGBS is less than 30% , the setting times will not significantly be affected. When GGBS replacement level is less than 40%, bleeding is generally unaffected.
- At higher replacement levels, bleeding rates may be higher.

Ternary blend concrete

- Ternary concrete mixtures include three different cementitious materials i.e. combinations of portland cement, slag cement, and a third cementitious material. The third component is often fly ash, but silica fume is also common.
- Other material in combination with portland and slag cement, such as rice husk ash are not currently in common usage.
- Slag cement has been used in ternary mixtures for decades.

Light weight concrete

- Structural lightweight concrete is similar to normal weight concrete except that it has a lower density.
- Made with lightweight aggregates.
- Air-dry density in the range of 1350 to 1850 kg/m3
- 28-day compressive strength in excess of 17 Mpa.
- Structural lightweight concrete is used primarily to reduce the dead-load weight in concrete members, such as floors in high-rise buildings.
- **Structural Lightweight Aggregates:**
  - Rotary kiln expanded clays, shales, and slates
  - Sintering grate expanded shales and slates
  - Pelletized or extruded fly ash
  - Expanded slags.

Light weight concrete

Compressive strength: Compressive strength of structural lightweight concrete is usually related to the cement content at a given slump and air content, rather than to a water-to- cement ratio. This is due to the difficulty in determining how much of the total mix water is absorbed into the aggregate and thus not available for reaction with the cement.

- Slump:

1. Due to lower aggregate density, structural lightweight concrete does not slump as much as normal-weight concrete with the same workability.
2. A lightweight air-entrained mixture with a slump of 50 to 75 mm (2 to 3 in.) can be placed under conditions that would require a slump of 75 to 125 mm (3 to 5 in.)
3. With higher slumps, the large aggregate particles tend to float to the surface, making finishing difficult.

Light weight concrete

Placing, Finishing, and Curing :

1. Structural lightweight concrete is generally easier to handle and place than normal-weight concrete.
2. A slump of 50 to 100 mm (2 to 4 in.) produces the best results for finishing.
3. If pumped concrete is being considered, the specified suppliers and contractor should all be consulted about performing a field trial using the pump and mixture planned for the project.
4. Adjustments to the mixture maybe necessary.
5. pumping pressure causes the aggregate to absorb more water, thus reducing the slump and increasing the density of the concrete.

Advantages

- Rapid curing at ambient temperatures
- Good adhesion to most surfaces
- High tensile, flexural, and compressive strengths.
- Good long-term durability w.r.t freeze and thaw cycles.
- Low permeability to water and aggressive solutions.
- Good chemical resistance.
- Good resistance against corrosion.
- Lighter weight(only somewhat less dense than traditional concrete, depending on the resin content of the mix).
- May be vibrated to fill voids in forms.
- Allows use of regular form-release agents (in some applications).
- Dielectric.

Disadvantages

- Product hard to manipulate with conventional tools such as drills and presses due to its strength and density. Recommend getting pre-modified product from the manufacturer.
- Small boxes are more costly when compared to its precast counterpart however pre cast concretes induction of stacking or steel covers quickly bridge the gap.

Polymer concrete

Polymer concrete tends to be more expensive than the traditional version and is measured more specifically in terms of density and shrinkage.

Definition:

Polymer concrete is an aggregate mixture that uses some type of epoxy binder to cure and harden into place. A polyester, vinyl ester, or normal epoxy mixture is often used, but polymer concrete can be made with many kinds of polymer resins that allow the concrete to be poured or troweled and then hardened. It cures through a chemical reaction with the polymer material. Like traditional concrete, it also has water, sand and gravel or crushed stone as primary ingredients.

Polymer concrete

Advantages:

- Polymer concrete offers different benefits depending on the resin used to make it.
- Acrylic binders set very quickly and offer resistance to weathering, while epoxies create a very strong material that shrinks very little as it cures.

Uses:

- Polymer concrete is used for many kinds of specialized construction projects. Like other types of concrete, it can be used to join two different components or to provide a structure or base. The material is used in electrical or industrial construction where the concrete needs to last a long time and be resistant to many types of corrosion.

Self compacting concrete

- Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.
- The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Self compacting concrete

- Very close to the Kolhapur there is project of steel industry, sand used for the formation of mould when the moulds are opened the waste sand is dumped for the filling the low lying areas while doing this the agriculture areas is converted into barren area.
- Because there is no space for the waste other than the land filling. similar case is in case of aluminium industry where red mud is concluded to be waste, which contains lot amount of bauxite and that is why red mud is also dump in the nearby areas here it is causing big threat for the society and it is disturbing the eco system of the environment. So it is the need to use this particular otherwise waste material for the constructive in such fashion in the case of concrete so that concrete which became cost effective as well as eco-friendly.

Coloured concrete

- Coloured concrete can be produced by using coloured aggregates or by adding colour pigments (ASTM C 979) or both. If surfaces are to be washed with acid, a delay of approximately two weeks after casting is necessary.
- Coloured aggregates may be natural rock such as quartz, marble, and granite, or they may be ceramic materials.
- synthetic pigments generally give more uniform results. The amount of colour pigments added to a concrete mixture should not be more than 10% of the mass of the cement.
- For example, a dose of pigment equal to 1.5% by mass of cement may produce a pleasing pastel colour, but 7% may be needed to produce a deep colour. Use of white portland cement with a pigment will produce cleaner, brighter colours and is recommended in preference to gray cement, except for black or dark gray colours.

Fibre reinforced concrete

- Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres.
- The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post- cracking “ductility”.
- The real contribution of the fibres is to increase the toughness of the concrete under any type of loading.
- The fibre reinforcement may be used in the form of three – dimensionally randomly distributed fibres throughout the structural member when the added advantages of the fibre to shear resistance and crack control can be further utilised.

Pervious concrete

- Pervious (porous or no-fines) concrete contains a narrowly graded coarse aggregate, little to no fine aggregate, and insufficient cement paste to fill voids in the coarse aggregate.
- Low water-cement ratio, low-slump concrete resembling popcorn held together by cement paste.
- Produces a concrete with a high volume of voids (20% to 35%) and a high permeability that allows water to flow through it easily.
- Pervious concrete is used in hydraulic structures as drainage media, and in parking lots, pavements, and airport local groundwater supply by allowing water to penetrate the concrete to the ground below.
- Pervious concretes have also been used in tennis courts and green houses.
- The compressive strength of different mixes can range from 3.5 to 27.5 Mpa.
- Drainage rates commonly range from 100 to 900 lit.per minute per square meter.


Thank you