17BECE302B CONCRETE TECHNOLOGY 3 0 0 3 100

OBJECTIVES:

- To understand the properties of ingredients of concrete
- To study the behavior of concrete at its fresh and hardened state
- To study about the concrete design mix
- To know about the procedures in concreting
- To understand special concrete and their use

UNIT I **9**

CEMENT& ADMIXTURES: Types – chemical composition – Hydration, Setting of cement – Structure of hydrate cement – Test on physical properties – Different grades of cement – Admixtures – Mineral and chemical admixtures.

UNIT – II **9**

AGGREGATES: 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.

UNIT – III **9**

FRESHCONCRETE: 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.

UNIT IV **9**

HARDENED CONCRETE: Water / Cement ratio – Abram's Law – Gelspaoe ratio – Nature of strength of concrete – Maturity concept – Strength in tension & compression – Factors affecting strength – Relation between compression & tensile strength - Curing.

TESTING OF HARDENED CONCRETE: Compression tests – Tension tests – Factors affecting strength – Flexure tests – Splitting tests – Non-destructive testing methods – codal provisions for NDT.

UNIT V **9**

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.

SPECIAL CONCRETES: Light weight concrete – Cellular concrete – No-fines concrete – High Strength concrete-High performance concrete- High density concrete – Fibre reinforced concrete -Polymer concrete – Properties – Applications — Self compacting concrete

TOTAL:45HRS

TEXT BOOKS:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	Concrete Technology	M.S.Shetty	S.Chand& Co, Uttar Pradesh	2004

REFERENCES:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	Concrete Technology	M.L. Gambhir	Tata Mc. Graw Hill Publishers, New Delhi	2004
2	Properties of Concrete	A.M.Neville	Canadian GovtPublishing Centre, Ottawa	2011
3	Concrete Technology	A.R.Santha Kumar	Oxford university Press, New Delhi	2006

WEBSITES:

- http://www.icivilengineer.com
- http://www.engineeringcivil.com/
- http://www.aboutcivil.com/
- http://www.engineersdaily.com
- http://www.asce.org/
- http://www.cif.org/
- http://icevirtuallibrary.com/
- http://www.ice.org.uk/
- http://www.engineering-software.com/ce/

COURSE OUTCOMES

On completion of the course, the students will be able to:

- Test all the concrete materials as per IS code.
- Design the concrete mix using ACI and IS code methods. Determine the properties of fresh and hardened of concrete. Design special concretes and their specific applications.
- Ensure quality control while testing/ sampling and acceptance criteria.

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Established Under Section 3 of UGC Act, 1956)

COIMBATORE-641 021

17BECE302B –CONCRETE TECHNOLOGY

Staff Name : **Dr.N.Balasundaram**
Semester : **4 (2019-20 EVEN)**
Course Type : **Core**
Number of credits : **3**
LTPC : **1 1 0 0**

S.No	Lecture Duration (Hour)	Topics to be covered	Support Materials
UNIT I			
1.	1	Types , chemical composition.	T_1/11
2.	1	Hydration	T_1/12
3.	1	Setting of cement	T_1/14
4.	1	Structure of hydrate cement	T_1/16
5.	1	Test on physical properties	T_1/19
6.	1	Different grades of cement	T_1/21
7.	1	Admixtures	T_1/24
8.	1	Mineral	T_1/27
9.	1	chemical admixtures.	T_1/29
UNIT II			
10.	1	Classification of aggregate – Particle shape & texture	T_1/31
11.	1	Bond, strength & other mechanical properties of aggregate	T_1/32
12.	1	Specific gravity,	T_1/32
13.	1	Bulk density, porosity, adsorption & moisture content of aggregate	T_1/34
14.	1	Bulking of sand	T_1/37
15.	1	Deleterious substance in aggregate – Soundness of aggregate	T_1/41
16.	1	Alkali aggregate reaction – Thermal properties – Sieve analysis	T_1/44
17.	1	Fineness modulus – Grading curves – Grading of fine & coarse	T_1/46
18.	1	Aggregates – Gap graded aggregate – Maximum aggregate size.	T_1/49
UNIT III			
19.	1	Workability	T_1/51
20.	1	Bleeding	T_1/52
21.	1	Factors affecting workability	T_1/55
22.	1	Measurement of workability by different tests	T_1/57
23.	1	Setting times of concrete	T_1/61
24.	1	Effect of time and temperature on workability	T_1/63
25.	1	**Segregation**	T_1/65
26.	1	**Steps in manufacture of concrete**	T_1/68
27.	1	**Quality of mixing water.**	T_1/71

UNIT IV			
28.	1	HARDENED CONCRETE: Water / Cement ratio – Abram's Law	R1/7
29.	1	Gelspaoe ratio	T1/128
30.	1	Nature of strength of concrete – Maturity concept	T1/128
31.	1	Tension tests	T1/107,134, R1/79
32.	1	Strength in tension & compression – Factors affecting strength	R1/80,T1/viii
33.	1	Factors affecting strength	R1/315
34.	1	Flexure tests – Splitting tests	T1/259, R1/313
35.	1	Non-destructive testing methods	T1/152 R1/145
36.	1	codal provisions for NDT.	R1/231,232
UNIT V			
37.	1	Factors in the choice of mix proportions Light weight concrete – Cellular concrete –	R1/97
38.	1	BIS method of mix design	R1/140
39.	1	Acceptance criteria – Proportioning of concrete mixes by various methods	T1/77 R1/76
40.	1	Quality Control of concrete	T1/92
41.	1	Statistical methods	R1/231
42.	1	Durability of concrete	R1/237
43.	1	No-fines concrete – High Strength concrete-	T1/239
44.	1	High performance concrete- High density concrete – Fibre reinforced concrete -	T1/222
45.	1	Polymer concrete – Properties – Applications — Self compacting concrete	T_1/92

UNIT NOTES

1. **Define hydration of cement. (April/May 2019)**
   - Cement in dry state has no bonding property.
   - When mixed with water react chemically and becomes a bonding agent. These reactions are called hydration.
2. **Define setting of cement.**
   - When water is added to cement, hydration takes place immediately as it continuous, cement paste which is plastic becomes stiff and rigid known as setting of cement.
3. **What are pozzolanic?**
   - The siliceous materials which, while having no cementations values within themselves, will chemically react with calcium hydroxide at ordinary temperature and in the presence of moisture to form compounds possessing cementitious properties.
4. **Name any 2 natural pozzolonas.**
   - ✓ Clay and shales
   - ✓ Opalinccherts
   - ✓ Diatomaceous earth
   - ✓ Volcanic tuffs and pumicites.
5. **Name any 2 artificial pozzolonas.**
   - ✓ Surkhi
   - ✓ Fly ash
   - ✓ Blast furnace slag
   - ✓ Silica fume
   - ✓ Rice husk ash
   - ✓ Metakaoline.
6. **What is natural cement?**
   - Natural cement is manufactured by burning and then crushing the natural cement stones.
   - Natural cement stones are such stones which contain 20 to 40% of argillaceous matter i.e. clay, and remaining content mainly calcareous matter which is either calcium carbonate alone or a mixture of calcium carbonate and magnesium carbonate.
7. **What is artificial cement?**
   - Artificial cement is manufactured by burning approximately proportioned mixture of calcareous and argillaceous materials at a very high temperature and then grinding the resulting burnt mixture to a fine powder.
8. **What is the function of gypsum in the manufacture of cement? (April/May 2019)**

- In order to delay the setting action of cement, when mixed with water, a little percentage of gypsum is added in the clinker before grinding them to fine powder.

9. What is known as clinker?

- Artificial cement is manufactured by burning approximately proportioned mixture of calcareous and argillaceous materials at a very high temperature and then grinding the resulting burnt mixture to a fine powder.
- The burnt mixture of calcareous and argillaceous matter is known as clinker.

10. What are the constituents of ordinary cement? (May/June 2016)

- Alumina or clay, silica, lime, iron oxide, magnesia, sulphur trioxide, Alkalies, calcium sulphate (gypsum).

11. What are the harmful constituents of cement?

- Alkalies which are oxides of potassium and sodium, and magnesium oxide are the harmful constituents of cement.

12. What are ball mills?

- Ball mills are used for grinding the clinkers. The ball mills consist of 2 to 2.5m diameter steel cylinder.
- The clinkers to be ground are fed into the cylinder and the cylinder is rotated about its horizontal axis to carry out the grinding action.

13. What are the types of cement? (April/May 2019)

1. Ordinary Portland cement, 8.rapid hardening cement,
2. Low heat cement,9. blast furnace slag cement,
3. Sulphate resistant cement, 10. air entraining cement,
4. white and coloured cement, 11.high alumina cement,
5. Pozzolanic cement, 12. super sulphate cement,
6. expansive cement, 13.quick setting cement,
7. Waterrepellent cement, 14.water proofing cement.

14. What are the 2 methods of manufacture of cement?

- ✓ Dry process
- ✓ Wet process

15. What is meant bymortar?

- The mortar is a paste like substance prepared by adding required amount of water to a dry mixture of sand or fine aggregate with some binding material like clay, lime or cement.

16. What is meant bylime mortar?

- If lime is used as a binding material, the resulting mortar is known as lime mortar.

17. What is meant by mud mortar?

- When clay is used as a binding material, the resulting mortar is known as mud mortar

18. What is known as bulking of sand?

- Bulking of sand means increasing the volume of sand. Fine aggregates or sands, increase in volume when they possess some moisture. Bulking is due to formation of a thin film of water around the fine aggregate or sand particles.
- Thickness of water film goes on increasing with more and more moisture and consequently increase in volume continues.
- But after certain percentage of water, volume of sand starts decreasing with increasing amount of water.
- At certain percentage of water, increase in volume completely vanishes and volume occupied by sand becomes equal to the volume of dry sand.

19. What are the types of mortars?

- ✓ Mud mortar
- ✓ Lime mortar
- ✓ Gauged mortar

20. What is meant by grading of aggregates?(Or)Define particle size distribution of aggregates. Why it is importance? (Nov/Dec 2017, 2019)

The particle size distribution of aggregate is called grading of aggregate. It is well known that the strength of concrete is dependent upon water/cement ratio provided the concrete is workable. One of the most important factors for producing workable concrete is good gradation of aggregates.

21. What are the methods of proportioning of concrete mixes?

- ✓ Arbitrary standard method
- ✓ Minimum voids method
- ✓ Fineness Modulus method
- ✓ Maximum density method

22. Define Abram's water cement law.

- According to Abram's water cement law, the strength of concrete depends on the water cement ratio used.

23. Define bleeding.

- The tendency of water rising above the surface of freshly laid concrete is known as bleeding.

24. Define laitance.

- Water rising above the surface during bleeding carries with it, particles of sand and cement, which on hardening form a scum layer known as laitance.

25. What are the steps adopted to control bleeding?

- ✓ By adding more cement

- ✓ By using more finely ground cement
- ✓ By using little air entraining agent
- ✓ By increasing finer part of fine aggregate
- ✓ By properly designing the mix and using minimum quantity of water.

26. Define Segregation.

- The tendency of separation of coarse aggregate grains from the concrete mass is called segregation.

27. What are the methods adopted to avoid segregations of concrete.

- ✓ Addition of little air entraining agents in the mix.
- ✓ Restricting the amount of water to the smallest possible amount.
- ✓ Concrete should not be allowed to fall from larger heights.

28. Define workability.

- Workability is that property of concrete which determines the amount of internal work necessary to produce full compaction.
- It is a measure with which concrete can be handled from the mixer stage to its final fully compacted stage.

29. What are the factors affecting workability?

- ✓ Quantity of water in the mix
- ✓ Proper grading of the aggregate mix
- ✓ Ratio of fine aggregate and coarse aggregate
- ✓ Maximum size of coarse aggregates
- ✓ Method of compaction of concrete

30. What are the factors affecting proportioning of concrete mixes?

- ✓ Water cement ratio
- ✓ Cement content
- ✓ Temperature
- ✓ Age of concrete
- ✓ Size, shape and grading of aggregate
- ✓ Curing

31. Define mixing of concrete.

- The process of mixing cement, water, fine aggregate and coarse aggregate in suitable proportion is known as mixing of concrete.

32. What are the methods of consolidation or compaction of concrete?

- Hand compaction
- Machine compaction – i) Internal vibrators

ii) Form vibrators

iii) Surface vibrators

33. Define curing of concrete.

- Curing is the operation by which moist conditions are maintained on finished concrete surface, to promote continued hydration of cement.

34. What are admixtures?

- Admixtures are ingredients other than cement, fine aggregate and coarse aggregate to improve the quality of concrete.
- The addition of an admixture may improve the concrete with respect to its strength, hardness, workability, water resisting power etc.

35. Name the types of joints in concrete.

- ✓ Construction joints
- ✓ Expansion joints
- ✓ Contraction joints
- ✓ Working joints

36. What are the types of concrete used?

- Plum concrete, light weight concrete, air-entrained concrete, no-fines concrete, vacuum concrete, water-proof concrete, reinforced cement concrete, pre-stressed concrete, cellular or aerated concrete, foamed concrete, pre-cast concrete.

37. Mention the test adopted to test the quality of water.

a. Determination of acids and alkalis
b. Determination of total solids.

38. Define Aggregate.

- Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids.

- Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete.

39. What are the various tests which are to be done on aggregates? (April/May 2017)

Various test which are done on aggregates are listed below

- ✓ Sieve Analysis
- ✓ Water Absorption
- ✓ Aggregate Impact Value
- ✓ Aggregate Abrasion Value
- ✓ Aggregate Crushing Value

40. What is grade of cement? List any three grades of cement with their strengths.

- Grade of cement represents the specific 28 days compressive strength. The following three grades are given along with their compressive strengths

- ✓ 33 Grade OPC –33 MPa
- ✓ 43 Grade OPC – 43 MPa
- ✓ 53 Grade OPC – 53 MPa

41. What is meant by hydration of cement?

- Cements used for making concrete have the property of reacting chemically with water in an exothermic process called hydration that results in water treatment products.

42. What is false set in cement? Write reasons for it.

- False set in cement occurs when the gypsum dehydrates as a result of contacting hot clinker at high temperatures in a grinding mill.
- This creates plaster to form gypsum and stiffen the concrete**.**

43. What are the types of cement?

- Ordinary Portland cement, rapid hardening cement, low heat cement, blast furnace slag cement, sulphate resistant cement, air entraining cement, white and colored cement, high alumina cement, pozzolanic cement, super sulphate cement, expansive cement, quick setting cement, water repellant cement, water proofing cement.

44. What is the function of gypsum in the manufacture of cement? (April/May 2019)

- In order to delay the setting action of cement, when mixed with water, a little percentage of gypsum is added in the clinker before grinding them to fine powder.

45. What are bogue's compounds? (April/May 2018) (Nov/Dec 2019)

- ✓ Tricalcium silicate $CaO.SiO_2$ C_3S
- ✓ Dicalcium silicate $CaO.SiO_2$ C_2S
- ✓ Tricalcium aluminate $Cao.Al_2O_3$ C_3A
- ✓ Tetracalciumaluminoferrite $CaO.Al_2O_3.Fe_2O_3$ C_4AF

46. What is the Chemical Composition of cement? (Nov/Dec 2019)

- Oxide Per cent content CaO 60–67
- SiO_2 17–25
- Al_2O_3 3.0–8.0
- Fe_2O_3 0.5–6.0
- MgO 0.1–4.0
- Alkalies(K_2O,Na_2O) 0.4–1.3
- SO_3 1.3–3.0

47. Mention the test adopted to test the properties of cement in laboratories? (Nov/Dec 2016)

- ✓ Fineness
- ✓ Consistency test
- ✓ Setting time
- ✓ Soundness

- ✓ Compressive strength

48. Mention the test adopted to test the properties of cement in field? (May/June 2016)

- Open the bag and take a good look at the cement, there should not be any visible lumps.
- Thrust your hand into the cement bag should feel cool feeling.
- Take a pinch of cement and feel between the fingers. It should give a smooth feeling not a gritty feeling
- Take a hand full of cement and throw it on a bucket full of water, the particle should float for some time before they sink.

49. What are the qualities of water in concrete making? (May/June 2016)

- If water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all conditions.
- Some waters containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking.
- Some specification also accept water for making concrete if the pH value of water lies between 6 and 8 and the water is free from organic matter.

50. What are the advantages of Portland pozzolanic cement? (Nov/Dec 2016)

The following are the advantages of this cement:

- ➢ It attains compressive strength with age.
- ➢ It is cheap.
- ➢ It offers great resistance to the expansion.
- ➢ It evolves less heat during setting.
- ➢ It can resist action of sulphates.
- ➢ It imparts higher degree of water tightness.
- ➢ It possesses higher tensile strength.

51. What are the Properties of cement?

The properties of good cement primarily depend upon its chemical composition, thoroughness of burning and fineness of grinding:

- It gives strength to the masonry.
- It is easily workable.
- It is an excellent binding material.
- It stiffens or hardness early.
- It offers good resistance to the moisture.
- It possesses-a good plasticity.

52. What are the advantages of high alumina cement?

(i) The initial setting time of this cement is more than 3.5 hours. The final setting time is about 5 hours. It therefore allows more time for mixing and placing operations.

(ii) It can stand high temperatures.

(iii) It involves great heat during setting. It is therefore not affected by frost.

(iv) It resists the action of acids in a better way.

(v) It sets quickly and attains higher ultimate strength in a short period. Its strength after 1 day isabout 40 N/mm^2 and that after 3 days is about 50 N/mm^2.

53. Write any two Advantages of Portland slag cement.

(a) Reduced heat of hydration
(b) Refinement of pore structure
(c) Increased resistance to chemical attack.

54. Name the major compounds of OPC and mention the approximate percentage of each. (May/June 2016)

Oxide	Chemical formula	% content range
Lime	Cao	60-67
Silica	Sio_2	17-25
Alumina	Al_2O_3	3-8
Iron oxide	Fe_2O3	0.5-6
Magnesium oxide	MgO	0.1-4
Sulphur trioxide	SO_3	1.3-3
Alkalies	K_2O, Na_2O	0.4-3
Calcium Sulphate (Gypsum)	$CaSO_4$	3-4

55. How do you classify aggregates based on different categories? (April/May 2018) (Nov/Dec 2019)

Aggregates can be divided into several categories according to different criteria.

a) In accordance with size:
(i)Coarse aggregate (ii) Fine aggregate
b) In accordance with sources:
(i)Natural aggregates (ii) Manufactured (synthetic) aggregates
c) In accordance with unit weight:
(i)Light weight aggregate (ii) Normal weight aggregate (iii) Heavy weight aggregate
d) In accordance with origin:
(i)Igneous rock Aggregate (ii) Sedimentary rock Aggregates (iii) Metamorphicrock Aggregate
e) Particle shape:
(i)Rounded Aggregate (ii)AngularAggregate(iii)FlakyAggregate(iv) Elongated Aggregate
(v) Irregular Aggregate
f) Texture:
(i)Glassy textured aggregate (ii) Granular textured aggregate (iii) crystalline textured aggregate
(iv) Porous textured aggregate (v) Smooth textured aggregate

56. What are the different types of tests conducted on coarse aggregates?(April/May 2017)

- ✓ Test for determination of flakiness index
- ✓ Test for determination of elongation index
- ✓ Test for determination of clay and fine silt
- ✓ Test for determination of organic impurities
- ✓ Test for determination of specific gravity

- ✓ Test for determination of bulk density and voids

57. Write any two advantages of sulphate resisting cement. (April/May 2017)

- ✓ The use of sulphate resisting cement provides excellent protection against the formation of sulpho-aluminates and consequent resistance to concrete against sulphate attack.
- ✓ Very high compressive strength by economic concrete mix design.
- ✓ Very low heat of hydration helps to avoid shrinkage cracks.
- ✓ Improve life and durability of structures under aggressive conditions.
- ✓ Improve corrosion resistance of steel by preventing sulphate attack.

58. What is meant by 53 grade cement? (Nov/Dec 2017)

The grade indicates the compression strength (N/mm^2) of a concrete that will attain after 28 days of setting. 53 grade cement means compression strength of the cement concrete after 28 days of setting; it gives a strength of 53 mpa. (or 53 N/mm^2)

59. Define fineness modulus? Give the practical range of fineness modulus for fine aggregate. (April/May 2019)

- ➢ It is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing by sum by 100.
- ➢ Ranges from 2.00 to 4.00 for fine aggregate

PART- B& C

1. Explain in detail about the various types of cement.

- ❖ Ordinary Portland Cement
    - Ordinary Portland Cement 33 Grade
    - Ordinary Portland Cement 43 Grade
    - Ordinary Portland Cement 53 Grade
- ❖ Rapid Hardening Cement
- ❖ Extra Rapid Hardening Cement
- ❖ Sulphate Resisting Cement
- ❖ Portland Slag Cement
- ❖ Quick Setting Cement
- ❖ Super Sulphated Cement
- ❖ Low Heat Cement
- ❖ Portland Pozzolana Cement
- ❖ Air Entraining Cement
- ❖ Coloured Cement: White Cement

- ❖ Hydrophobic Cement
- ❖ Masonry Cement
- ❖ Expansive Cement
- ❖ High Alumina Cement

Ordinary Portland cement(May/June 2016)

- The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988.
- If the 28 days strength is not less than 33N/mm^2, it is called 33 grade cement,if the strength is not less than 43N/mm^2, it is called 43 grade cement, and if the strength is not less than 53 N/mm^2, it is called 53 grade cement. But the actual strength obtained is much higher than the BIS specifications.
- To upgrade the qualities of cement by using high quality limestone, modern equipments, and closer on line control of constituents, maintaining better particle size distribution, finer grinding and better packing.
- Generally use of high grade cements offer many advantages for making stronger concrete. Although they are little costlier than low grade cement, they offer 10-20% savings in cement consumption and also they offer many other hidden benefits.
- One of the most important benefits is the faster rate of development of strength.

Rapid Hardening Cement

- This cement is similar to ordinary Portland cement. Rapid hardening cement which develops higher rate of development of strength should not be confused with quick-setting cement which only sets quickly.
- Rapid hardening cement develops at the age of three days, the same strength as that is expected of ordinary Portland cement at seven days.
- The rapid rate of development of strength is attributed to the higher fineness of grinding (specific surface not less than 3250 sq. cm per gram) and higher C3S and lower C2S content.
- A higher fineness of cement particles expose greater surface area for action of water and also higher proportion of C3S results in quicker hydration.
- Consequently, Rapid hardening cement gives out much greater heat of hydration during the early period. Therefore, rapid hardening cement should not be used in mass concrete construction.

Uses:

- ➢ In pre-fabricated concrete construction.
- ➢ Where formwork is required to be removed early for re-use elsewhere,
- ➢ Road repair works,

- In cold weather concrete where the rapid rate of development of strength reduces the vulnerability of concrete to the frost damage.

Sulphate Resisting Cement (April/May 2019)

- Sulphate Resisting Portland Cement is a type of Portland cement in which the amount of Tricalcium aluminate (C3A) is restricted to lower than 5 % and (2 C3A + C4AF) is lower than 25%.
- SRC can be used for structural concrete wherever OPC or PPC or Slag Cement is usable under normal conditions.
- The use of SRC is particularly beneficial in such conditions where the concrete is exposed to the risk of deterioration due to sulphate attack.

Uses:

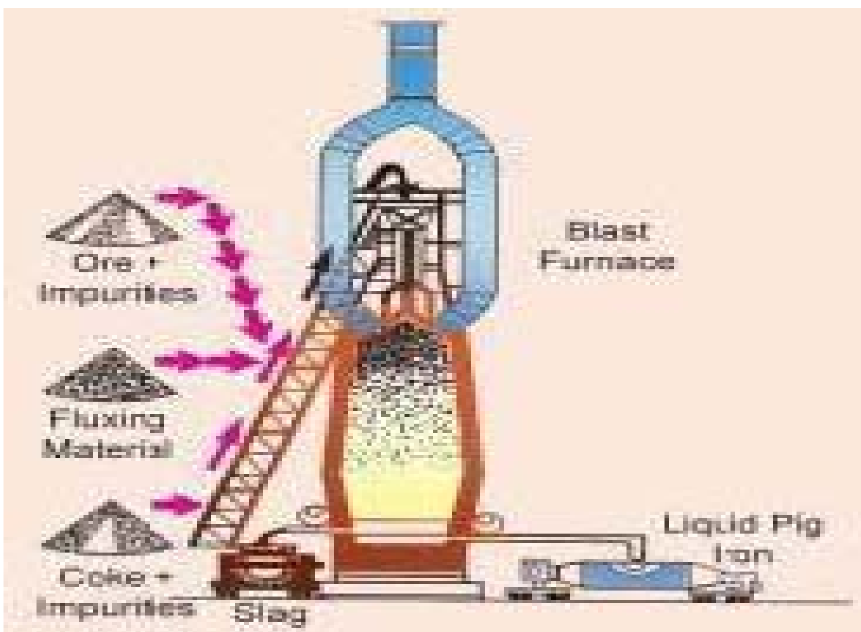
- Foundations, piles.
- Basements and underground structures.
- Sewage and Water treatment plants.
- Chemical, Fertilizers and Sugar factories.
- Food processing industries and Petrochemical projects.
- Coastal works.
- Also for normal construction works where OPC is used.
- Construction of building along the coastal area within 50 km from sea

Portland Slag Cement

- Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportions and grinding the mixture to get a thorough and mixture between the constituents.
- It may also be manufactured by separately grinding Portland cement clinker, gypsum and ground granulated blast furnace slag and later mixing them intimately.
- The resultant product is cement which has physical properties similar to those of ordinary Portland cement.
- In addition, it has low heat of hydration and is relatively better resistant to chlorides, soils and water containing excessive amount of sulphates or alkali metals, alumina and iron, as well as, to acidic waters, and therefore, this can be used for marine works with advantage.
- The manufacture of blast furnace slag cement has been developed primarilyto utilize blast furnace slag, a waste product from blast furnaces.
- The developmentof this type of cement has considerably increased the total output of cement production in India.
- The quantity of granulated slag mixed with Portland clinker will range from 25-65 percent. Early

strength is mainly due to the cement clinker fraction and later strength is that due to the slag fraction.

- Separate grinding is used as an easy means of varying the slag clinker proportion in the finished cement Portland blast furnace cement is similar to ordinary Portland cement with respect to fineness, setting time, soundness and strength.
- It is generally recognized that the rate of hardening of Portland blast furnace slag cement in mortar or concrete is somewhat slower than that of ordinary Portland cement during the first 28 days, but thereafter increases, so that at 12 months the strength becomes close to or even exceeds those of Portland cement.
- The heat of hydration of Portland blast furnace cement is lower than that of ordinary Portland cement. So this cement can be used in mass concrete structures with advantage. However, in cold weather the low heat of hydration of Portland blast furnace cement coupled with moderately low rate of strength development, can lead to frost damage.
- Extensive research shows that the presence of GGBS leads to the enhancement of the intrinsic properties of the concrete both in fresh and hardened states.



Advantages:

(a) Reduced heat of hydration

(b) Refinement of pore structure

(c) Increased resistance to chemical attack.

- The slag which is used in the manufacture of various slag cement is chilled very rapidly either by pouring it into a large body of water or by subjecting the slag stream to jets of water, or of air and water.
- The purpose is to cool the slag quickly so that crystallization is prevented and it solidifies as glass.

- The product is called granulated slag. Portland slag cement exhibits very low diffusivity to chloride ions and such slag cement gives better resistance to corrosion of steel reinforcement.

Application of GGBS Concrete

- In recent years the use of GGBS concrete is also recommended for use in water retaining structures.
- Aggressive water can affect concrete foundations. In such conditions GGBS concrete can perform better.

Quick Setting Cement

- This cement as the name indicates sets very early. The early setting property is brought out by reducing the gypsum content at the time of clinker grinding.
- This cement is required to be mixed, placed and compacted very early. It is used mostly in under water construction where pumping is involved.
- Use of quick setting cement in such conditions reduces the pumping time and makes it economical.
- Quick setting cement may also find its use in some typical grouting operations.

Low Heat Cement (April/May 2019)

- It is well known that hydration of cement is an exothermic action which produces large quantity of heat during hydration.
- Formation of cracks in large body of concrete due to heat of hydration has focussed the attention of the concrete technologists to produce a kind of cement which produces less heat or the same amount of heat, at a low rate during the hydration process.
- Cement having this property was developed in U.S.A. during 1930 for use in mass concrete construction, such as dams, where temperature rise by the heat of hydration can become excessively large.
- A low-heat evolution is achieved by reducing the contents of C3S and C3A which are the compounds evolving the maximum heat of hydration and increasing C2S.
- A reduction of temperature will retard the chemical action of hardening and so further restrict the rate of evolution of heat.
- The rate of evolution of heat will, therefore, be less and evolution of heat will extend over a longer period.
- Therefore, the feature of low-heat cement is a slow rate of gain of strength. But the ultimate strength of low-heat cement is the same as that of ordinary Portland cement.
- As per the Indian Standard Specification the heat of hydration of low-heat Portland cement shall be as follows:

7 days — not more than 65 calories per gm.

28 days — not more than 75 calories per gm.

- The specific surface of low heat cement as found out by air-permeability method is not less than 3200 sq. cm/gm.
- The 7 days strength of low heat cement is not less than 16 MPa in contrast to 22 MPa in the case of ordinary Portland cement. Other properties, such as setting time and soundness are same as that of ordinary Portland cement.

Uses:

- ➢ Water retaining type of structures.
- ➢ Where it is needed for Bridge abutments.
- ➢ Massive retention of walls.
- ➢ Slabs for multi-use etc.

2. Explain the various grades of cement. (Nov/Dec 2016)

- In the U.S.A and UK Cement is covered by one specification, whereas in Germany, it is available in 5 grades. The German practice has also been accepted in India and it came about as follows:
- Till around 1973, only Grade-33 cement was available in India. However, in between of 1973-75, the Indian Railways adopted the use of prestressed concrete sleepers in a big way for running high speed trains.
- It was soon apparent that the common Grade-33 cement available in the market was inadequate to develop the needed minimum characteristics concrete strength of about 50 N/mm^2 required for the purpose.
- Hence, the railways developed their own specifications for "sleeper cements" with minimum cement strength of 52.5 N/mm^2 in 28 days.
- Some of the factories in India came forward to make these types of cements for the railways, which made them available only to the sleeper manufactures.
- Very soon, with the advancement of cement technology, more and more factories found it is easy to manufacture higher grade cements with their modernized cement plants.

Thus, we have the following typesofCement in India:

1. Grade - 33 as per IS 269 (1989) - C 33
2. Grade - 43 as per IS 8112 (1989) - C 43
3. Grade - 53 as per IS 12269 (1987) - C 53
4. Sleeper cements as per IRS - T40-85 (this will be between C43 and C53) supplied only therailways.

- The easily available cement today is of Grade - 43. It should be noted that the testing procedures used in India are different from those in U.S.A., where cylinders are used so that the 53-grade cement produced in India would give approximately 25 to 30% less strength as per ASTM standards.

  Thecompressive strength developed by the cements with time is shown in the table:

Compressive strength of mortar cubes of different grades of cement in N/mm^2					
Age grade sleeper cement (in days)	**Grade**			**Sleeper cement**	
	Grade 33	**Grade 43**	**Grade 53**	**Code**	**actual**
3	16	23	27		40.3
7	22	33	37	37.5	55.3
28	33	43	53		70.3

3. Explain in detail the tests for cement. (April/May 2019)

Testing of cement can be brought under two categories:

(a) Field testing

(b) Laboratory testing.

Field Testing

It is sufficient to subject the cement to field tests when it is used for minor works.

The following are the field tests:

(a) Open the bag and take a good look at the cement. There should not be any visible lumps. The colour of the cement should normally be greenish grey.

(b) Thrust your hand into the cement bag. It must give you a cool feeling. There should not be lump inside.

(c) Take a pinch of cement and feel-between the fingers. It should give a smooth and not a gritty feel

(d) Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

(e) Take about 100 grams of cement and a small quantity of water and make a stiff paste. From the stiff paste, pat a cake with sharp edges.

Put it on a glass plate and slowly take it under water in a bucket. See that the shape of the cake is not disturbed while taking it down to the bottom of the bucket.

After 24 hours the cake should retain its original shape and at the same time it should also set and attain some strength.

Laboratory testing:

The following tests are usually conducted in the laboratory.

(a) Fineness test. (b) Setting time test.
(c) Strength test.(d) Soundness test.
(e) Heat of hydration test.(f) Chemical composition test.

Fineness Test

- ✓ Fineness of cement is a relative measure of particle size.
- ✓ The fineness of cement has an important bearing on the rate of hydration arid hence on the rate of gain of strength and also on the rate of evolution of heat.
- ✓ Finer cement offers a greater surface area for hydration and hence the faster and greater the development of strength.
- ✓ Maximum number of particles in a sample of cement should have a size less than 90 micron.
- ✓ The smallest particle may have a size of 1.5 micron. An average size of the cement particles may be taken as 10 micron.

Fineness of cement is tested in two ways:

- ✓ By sieving.
- ✓ By determination of specific surface (total surface area of all the particles in one gram of cement) by air permeability apparatus. Expressed as cmvgm or mvkg.

Sieve Test

- ✓ Weigh correctly 100 grams of cement and take it on a standard IS sieve No.9 (90 microns) as shown in Figure 1.2. Break down the air-set lumps in the sample with fingers.
- ✓ Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes.
- ✓ Mechanical sieving device may also be used. Weigh the residue left on the sieve. The weight shall not exceed 10 % for OPC. However, sieve test is rarely used.

Where,

S = Specific surface area

K = Apparatus constant and is given as:

$$K = 1.414\, S_0 \rho_0 \frac{\sqrt{0.1\eta_0}}{\sqrt{t_0}}$$

So= Specific surface of reference cement

Po= Density of reference cement

t_o= Mean of three' measured times

η_0=Air viscosity at the mean of the three temperatures

P = Density of cement

t = Time

Note: Generally the fineness value for OPC should not be less than 225 m//kg.

Air Permeability Method

- This method of test covers the procedure for determining the fineness of cement as represented by specific surface expressed as total surface area in sq. cm/gm. of cement.
- It is also expressed in m^2/kg. Lea and Nurse Air Permeability Apparatus is shown in Fig. 2.6. This apparatus can be used for measuring the specific surface of cement.
- The principle is based on the relation between the flow of air through the cement bed and the surface area of the particles comprising the cement bed.
- From this the surface area per unit weight of the body material can be related to the permeability of a bed of a given porosity.
- The cement bed in the permeability cell is 1 cm. high and 2.5 cm. in diameter. Knowing the density of cement the weight required to make a cement bed of porosity of 0.475 can be calculated.
- Slowly pass on air through the cement bed at a constant velocity. Adjust the rate of air flow until the flowmeter shows a difference in level of 30-50 cm. Read the difference in level (h1) of the manometer and the difference in level (h2) of the flowmeter.
- Repeat these observations to ensure that steady conditions have been obtained as shown by a constant value of h1/h2. Specific surface.
- Fineness can also be measured by Blain Air Permeability apparatus. This method is more commonly employed in India.

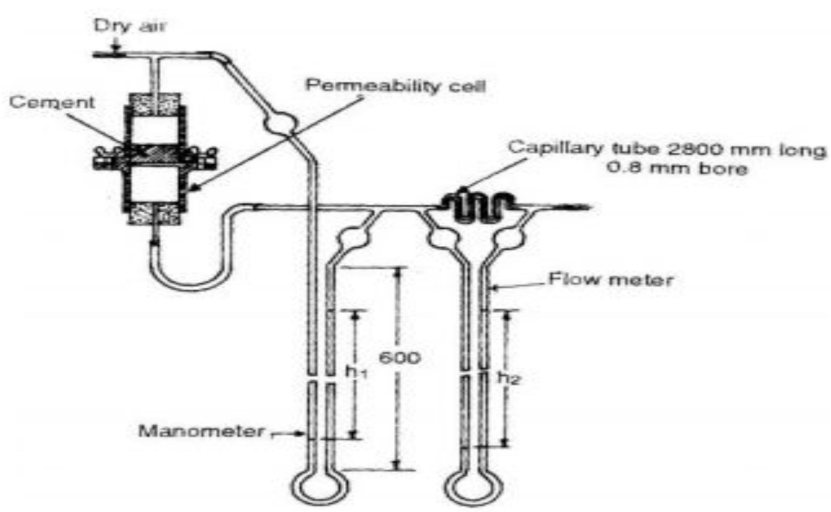
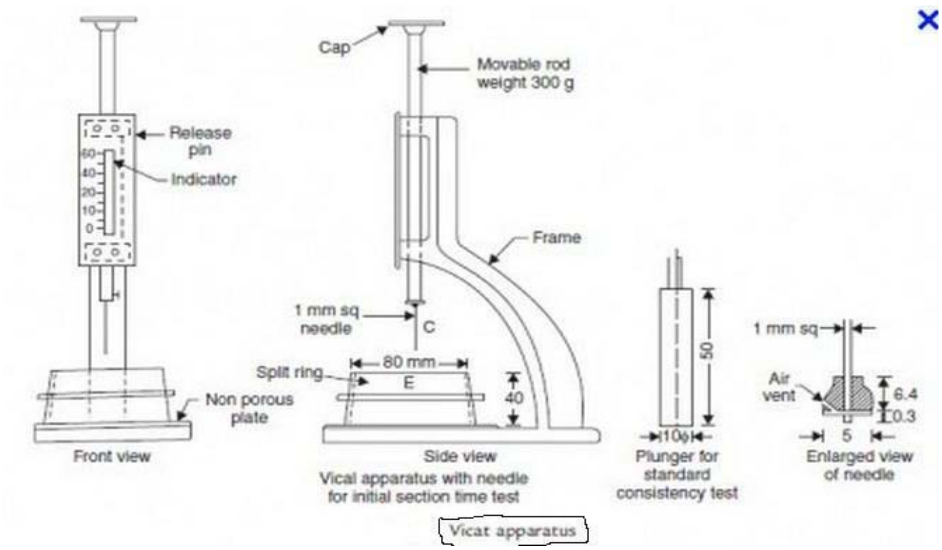


Fig. 28 Permeability Apparatus

Standard Consistency Test

- For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used.
- The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould .The apparatus is called VicatApparatus.
- This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency or normal consistency.



Procedure:

- Take about 500 gms of cement and prepare a paste with a weighed quantity of water (say 24 per cent by weight of cement) for the first trial.
- The paste must be filled into the Vicatmould within 3-5 minutes. After completely filling the mould, shake the mould to expel air.
- A standard plunger, 10 mm diameter, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight.
- Take the reading by noting the depth of penetration of the plunger. Conduct a 2nd trial (say with 25 per cent of water) and find out the depth of penetration of plunger.
- Similarly, conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 33-35 mm from the top.
- That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as P.
- The test is required to be conducted in a constant temperature (27° + 2°C) and constant humidity (90%).

Setting Time Test (Nov/Dec 2017)

- Initial Setting Time is the time elapsed between the moments that the water is added to the cement, to the time that the paste starts losing its plasticity.
- The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.
- In actual construction dealing with cement paste, mortar or concrete certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar, or concrete should be in plastic condition.
- The time interval for which the cement products remain in plastic condition is known as the initial setting time. Normally a minimum of 30 minutes is given for mixing and handling operations.
- Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies.
- This time should not be more than 10 hours which is often referred to as final setting time.

Preparationofspecimen

- Take 500 gm. of cement sample and guage it with 0.85 times the water required to produce cement paste of standard consistency (0.85 P).
- The paste shall be gauged and filled into the Vicatmould in specified manner within 3-5 minutes. Start the stop watch the moment water is added to the cement.
- The temperature of water at the time of gauging shall be within 27°C ± 2°C.

Procedure

INITIAL SETTING TIME.

- Lower the needle (C) gently and bring it in contact with the surface of the test block and quickly release.
- Allow it to penetrate into the test block and the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35 mm from the top.
- The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

FINAL SETTING TIME

- Replace the needle (C) of the Vicatapparatus by a circular attachment (F) The cement shall be considered as finally set when, upon, lowering the attachment gently over the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so.
- In other words the paste has attained the hardness and the centre needle does not pierce through the

paste more than 0.5 mm.

Strength Test (Compressive strength test)(Nov/Dec 2017)

- The compressive strength of hardened cement is the most important of all the properties. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement.
- Strength of cement is indirectly found on cement sand mortar in specific proportions.
- The standard sand is used for finding the strength of cement. It shall conform to IS 650-1991. Take 555 gms of standard sand (Ennore sand), 185 gms of cement (i.e., ratio of cement to sand is 1:3) in a non-porous enamel tray and mix them with a trowel for one minute, then add water of quantity + 3.0 per cent of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour.
- The time of mixing should not be less than 3 minutes nor more than 4 minutes. Immediately after mixing, the mortar is filled into a cube mould of size 7.06 cm. The area of the face of the cube will be equal to 50 sq cm.
- Compact the mortar either by hand compaction in a standard specified manner on the vibrating equipment (12000 RPM) for 2 minutes.
- Keep the compacted cube in the mould at a temperature of 27°C ± 2°C and at least 90 per cent relative humidity for 24 hours. Where the facility of standard temperature and humidity room is not available, the cube may be kept under wet gunny bag to simulate 90 per cent relative humidity.
- After 24 hours the cubes are removed from the mould and immersed in clean fresh water until taken out for testing.
- The periods being reckoned from the completion of vibration. The compressive strength shall be the average of the strengths of the three cubes for each period respectively.

Soundness Test

- It is very important that the cement after setting shall not undergo any appreciable change of volume.
- Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass.
- This will cause serious difficulties for the durability of structures when such cement is used. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance.
- The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln.
- This is also due to inadequate burning or insufficiency in fineness of grinding or thorough mixing of raw materials.
- It is also likely that too high aproportion of magnesium content or calcium sulphate content may cause

unsoundness in cement. For this reason the magnesia content allowed in cement is limited to 6 per cent. It can be recalled that, to prevent flash set, calcium sulphate is added to the clinker while grinding.

- The quantity of gypsum added will vary from 3 to 5 per cent depending upon C3A content. If the addition of gypsum is more than that could be combined with C3A, excess of gypsum will remain in the cement in Free State.
- This excess of gypsum leads to an expansion and consequent disruption of the set cement paste.
- Unsoundness in cement is due to excess of lime, excess of magnesia or excessive proportion of sulphates.
- Unsoundness in cement does not come to surface for a considerable period of time. Therefore, accelerated tests are required to detect it.
- There are number of such tests in common use. It consists of a small split cylinder of spring brass or other suitable metal. It is 30 mm in diameter and 30 mm high.
- On either side of the split are attached two indicator arms 165 mm long with pointed ends.
- Cement is gauged with 0.78 times the water required for standard consistency (0.78 P), in a standard manner and filled into the mould kept on a glass plate.
- The mould is covered on the top with another glass plate. The whole assembly is immersed in water at a temperature of 27°C – 32°C and kept there for 24 hours.
- Measure the distance between the indicator points. Submerge the mould again in water. Heat the water and bring to boiling point in about 25-30 minutes and keep it boiling for 3 hours.
- Remove the mould from the water, allow it to cool and measure the distance between the indicator points.
- The difference between these two measurements represents the expansion of cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements.
- If in case the expansion is more than 10 mm as tested above, the cement is said to be unsound. The Le Chatelier test detects unsoundness due to free lime only.
- This method of testing does not indicate the presence and after effect of the excess of magnesia.
- Indian Standard Specification stipulates that cement having a magnesia content of more than 3 per cent shall be tested for soundness by Autoclave test which is sensitive to both free magnesia and free lime.
- In this test a neat cement specimen 25 × 25 mm is placed in a standard autoclave and the steam pressure inside the autoclave is raised in such a rate as to bring the gauge pressure of the steam to 21 kg/ sq cm in 1 – 1 1/4 hours from the time the heat is turned on. This pressure is maintained for 3 hours.
- The autoclave is cooled and the length measured again. The high steam pressure accelerates the hydration of both magnesia and lime. No satisfactory test is available for deduction of unsoundness due to an excess of calcium sulphate. But its content can be easily determined by chemical analysis.

4. Explain in detail about mechanical properties of aggregate. Or Explain in detail of any three tests for coarse aggregates. (May/June 2016) (Nov/Dec 2017, 2019)

The mechanical properties of aggregate can be determined by using following test

- ✓ Test for determination of aggregate crushing value
- ✓ Test for determination of ten per cent fines value‘
- ✓ Test for determination of aggregate impact value
- ✓ Test for determination of aggregate abrasion value

A. Test for Determination of Aggregate Crushing Value:(Nov/Dec 2017)(April/May 2019)

- Strength of rock is found out by making a test specimen of cylindrical shape of size 25 mm diameter and 25 mm height.
- This cylinder is subjected to compressive stress. Different rock samples are found to give different compressive strength varying from a minimum of about 45 MPa to a maximum of 545 MPa.
- As said earlier, the compressive strength of parent rock does not exactly indicate the strength of aggregate in concrete. For this reason assessment of strength of the aggregate is made by using a sample of bulk aggregate in a standardized manner.
- This test is known as aggregate crushing value test. Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load.
- Generally, this test is made on single sized aggregate passing 12.5 mm and retained on 10 mm sieve.
- The aggregate is placed in a cylindrical mould and a load of 40 ton is applied through a plunger. The material crushed to finer than 2.36 mm is separated and expressed as a percentage of the original weight taken in the mould.
- This percentage is referred as aggregate crushing value. The crushing value of aggregate is restricted to 30 per cent for concrete used for roads and pavements and 45 per cent may be permitted for other structures.
- The crushing value of aggregate is rather insensitive to the variation in strength of weaker aggregate. This is so because having been crushed before the application of the full load of 40 tons, the weaker materials become compacted, so that the amount of crushing during later stages of the test is reduced. For this reason a simple test known as —10 per cent fines valueis introduced.
- When the aggregate crushing value become 30 or higher, the result is likely to be inaccurate, in which case the aggregate should be subjected to —10 per cent fines valuetest which gives a better picture about the strength of such aggregates.

- This test is also done on a single sized aggregate as mentioned above. Load required to produce 10 per cent fines (particles finer than 2.36 mm) is found out by observing the penetration of plunger.
- The 10 per cent fines value test shows a good correlation with the standard crushing value test for strong aggregates while for weaker aggregates this test is more sensitive and gives a truer picture of the differences between more or less weak samples.
- It should be noted that in the 10 per cent fines value test unlike the crushing value test, a higher numerical result denotes a higher strength of the aggregate. The detail of this test is given at the end of this chapter under testing of aggregate.

B. Test for determination of 'ten percent fines value':

- The sample of aggregate for this test is the same as that of the sample used for aggregate crushing value test.
- The test sample is prepared in the same way as described earlier. The cylinder of the test apparatus is placed in position on the base plate and the test sample added in thirds, each third being subjected to 25 strokes by tamping rod.
- The surface of the aggregate is carefully leveled and the plunger inserted so that it rests horizontally on this surface.
- The apparatus, with the test sample and plunger in position is placed in the compression testing machine.
- The load is applied at a uniform rate so as to cause a total penetration of the plunger in 10 minutes of about: 15.00 mm for rounded or partially rounded aggregates (for example uncrushed gravels) 20.0 mm for normal crushed aggregates, and 24.0 mm for honeycombed aggregates (for example, expanded shales and slags).
- After reaching the required maximum penetration, the load is released and the whole of the material removed from the cylinder and sieved on a 2.36 mm I.S. Sieve.
- The fines passing the sieve are weighed and the weight is expressed as a percentage of the weight of the test sample.
- This percentage would fall within the range 7.5 to 12.6, but if it does not, a further test shall be made at a load adjusted as seems appropriate to bring the percentage fines with the range of 7.5 to 12.5 per cent.
- Repeat test is made and the load is found out which gives a percentage of fines within the range of 7.5 to 12.5.

Load required for 10 per cent fines = $\frac{14 \times X}{Y + 4}$

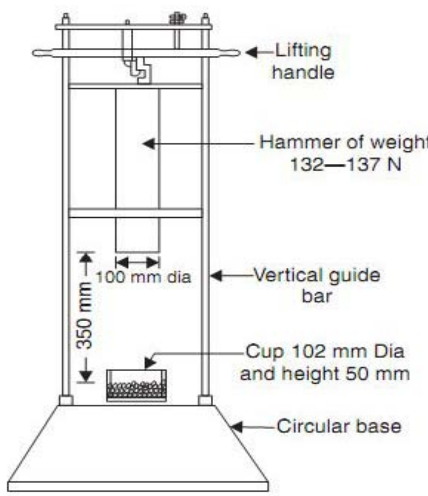
Where, X = load in tons, causing 7.5 to 12.5 percent fines.

Y = mean percentage fines from two tests at X tons load.

C. Test for determination of Aggregate Impact Value or toughness value(Nov/Dec 2017) (April/May

2019)

- With respect to concrete aggregates, toughness is usually considered the resistance of the material to failure by impact. Several attempts to develop a method of test for aggregates impact value have been made.
- The most successful is the one in which a sample of standard aggregate kept in a mould is subjected to fifteen blows of a metal hammer of weight 14 Kgs. falling from a height of 38 cms.
- The quantity of finer material (passing through 2.36 mm) resulting from pounding will indicate the toughness of the sample of aggregate.
- The ratio of the weight of the fines (finer than 2.36 mm size) formed, to the weight of the total sample taken is expressed as a percentage.
- This is known as aggregate impact value IS 283-1970 specifies that aggregate impact value shall not exceed 45 per cent by weight for aggregate used for concrete other than wearing surface and 30 per cent by weight, for concrete for wearing surfaces, such as run ways, roads and pavements.



5. Explain any two methods of finding the abrasion value of coarse aggregates. (May/June 2016)

Test for determination of Aggregate Abrasion Value

- Apart from testing aggregate with respect to its crushing value, impact resistance, 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 Angles test.

Deval Attrition Test

- In the Deval attrition test, particles of known weight are subjected to wear in an iron cylinder rotated

10000 times at certain speed.

- The proportion of material crushed finer than 1.7 mm size is expressed as a percentage of the original material taken.
- This percentage is taken as the attrition value of the aggregate. This test has been covered by IS 2386 (Part IV) – 1963. But it is pointed out that wherever possible Los Angeles test should be used.

Dorry Abrasion Test

- This test is not covered by Indian Standard Specification. The test involves in subjecting a cylindrical specimen of 25 cm height and 25 cm diameter to the abrasion against rotating metal disk sprinkled with quartz sand.
- The loss in weight of the cylinder after 1000 revolutions of the table is determined

Los Angeles Test

- Los Angeles test was developed to overcome some of the defects found in Deval test.
- Los Angeles test is characterized by the quickness with which a sample of aggregate may be tested.
- The applicability of the method to all types of commonly used aggregate makes this method popular.
- The test involves taking specified quantity of standard size material along with specified number of abrasive charge in a standard cylinder and revolving if for certain specified revolutions.
- The particles smaller than 1.7 mm size is separated out.
- The loss in weight expressed as percentage of the original weight taken gives the abrasion value of the aggregate.
- The abrasion value should not be more than 30 per cent for wearing surfaces and not more than 50 per cent for concrete other than wearing surface.

6. Explain in detail about the test carried in aggregate. (April/May 2018) (Nov/Dec 2019)

The various test carried out in aggregate are

- ✓ Sieve analysis test
- ✓ Test for determination of flakiness index
- ✓ Test for determination of elongation index
- ✓ Test for determination of clay, fine silt and fine dust
- ✓ Test for determination of organic impurities

A) Sieve Analysis Test:

- The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. A convenient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled, such as 10 mm, 20 mm, 40 mm etc.
- Under such a system, employing a logarithmic scale, lines can be spaced at equal intervals to represent

the successive sizes.

- 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 is termed as coarse aggregate and those fractions 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 the entire sieves mounted one over the other in order of size, with larger sieve on the top.
- The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above.
- Sieving can be done either manually or mechanically. In the manual operation the sieve is shaken giving movements in all possible direction to give chance to all particles for passing through the sieve.
- Operation should be continued till such time that almost no particle is passing through. Mechanical devices are actually designed to give motion in all possible direction, and as such, it is more systematic and efficient than hand sieving.
- Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by an arbitrary number 100. The larger the figure, the coarser is the material.
- 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
- Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

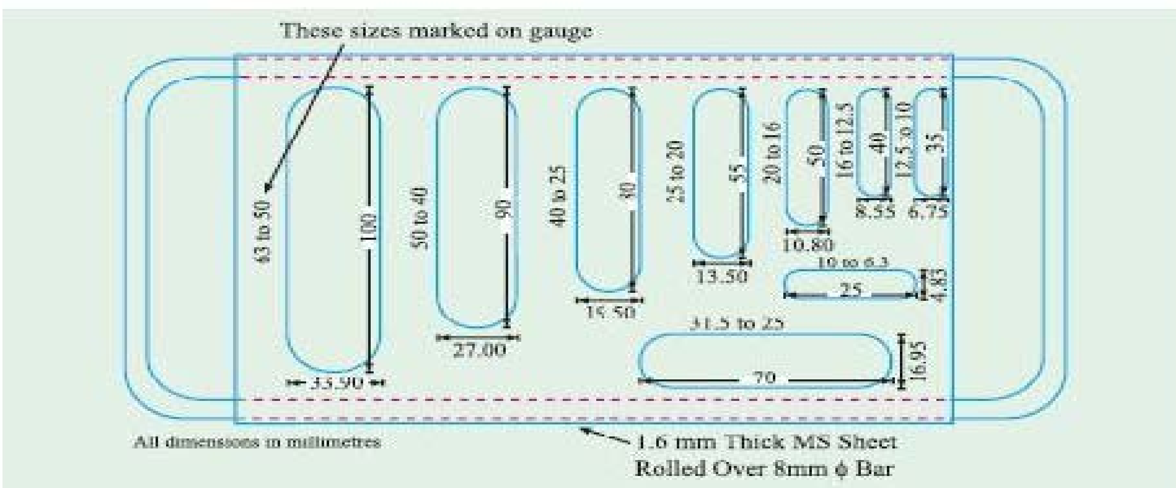
B) Test for Determination of Flakiness Index:

- The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.
- This test is conducted by using a metal thickness gauge, sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested. Each fraction is gauged in turn for thickness on the metal gauge.
- The total amount passing in the gauge is weighed to an accuracy of percent of the weight of the samples taken.

- The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken. Table shows the standarddimensions of thickness and length gauges.

Size of Aggregate Thickness		Length of Gauge* mm	Gauge† mm
Passing through IS Sieve	Retained on IS Sieve		
63 mm	50 mm	33.90	–
50 mm	40 mm	27.00	81.0
40 mm	25 mm	19.50	58.5
31.5 mm	25 mm	16.95	–
25 mm	20 mm	13.50	40.5
20 mm	16 mm	10.80	32.4
16 mm	12.5 mm	8.55	25.6
12.5 mm	10.0 mm	6.75	20.2
10.0 mm	6.3 mm	4.89	14.7

* This dimension is equal to 0.6 times the mean Sieve size.
† This dimension is equal to 1.8 times the mean Sieve size.

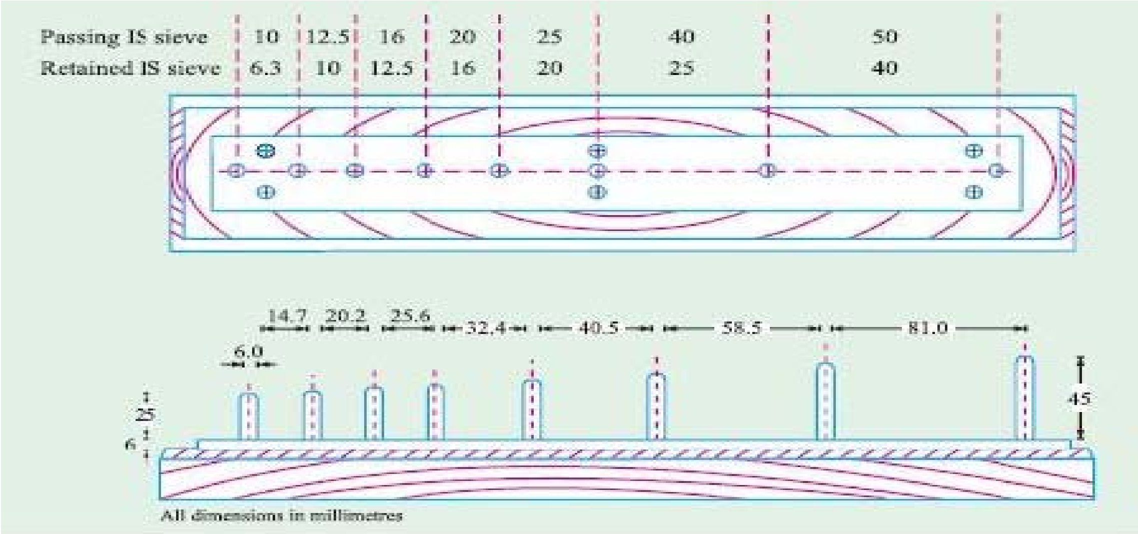


Dimensions of Thickness and Length Gauges (IS: 2386 (Part I) – 1963

C) Test for Determination of Elongation Index:

- The elongation index on an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times their mean dimension. The elongation index is not applicable to sizes smaller than 6.3 mm.
- This test is conducted by using metal length gauge of the description shown in Fig. A sufficient quantity of aggregate is taken to provide a minimum number of 200 pieces of any fraction to be tested.
- Each fraction shall be gauged individually for length on the metal gauge.
- The gauge length used shall be that specified in column of 4 of Table for the appropriate size of material.
- The total amount retained by the gauge length shall be weighed to an accuracy of at least 0.1 per cent of the weight of the test samples taken.

- The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged.
- The presence of elongated particles in excess of 10 to 15 per cent is generally considered undesirable, but no recognized limits are laid down.



D) Test for Determination of clay, fine silt and fine dust:

- This is a gravimetric method for determining the clay, fine silt and fine dust which includes particles upto 20 microns.

- The sample for test is prepared from the main sample, taking particular care that the test sample contains a correct proportion of the finer material.

- The amount of sample taken for the test is in accordance with Table

Weight of Sample for Determination of Clay, Fine Silt and Fine Dust

Maximum size present in substantial proportions mm	*Approximate weight of sample for Test kg*
63 to 25	6
20 to 12.5	1
10 to 6.3	0.5
4.75 or smaller	0.3

- Sedimentation pipette of the description shown in Fig. 3.11 is used for determination of clay and silt content.
- In the case of fine aggregate, approximately 300 gm. of samples in the air-dry condition, passing the 4.75 mm IS Sieve, is weighed and placed in the screw topped glass jar, together with 300 ml of diluted sodium oxalate solution.

- The rubber washer and cap are fixed. Care is taken to ensure water tightness.
- The jar is then rotated about its long axis with this axis horizontal, at a speed of 80 ± 20 revolutions per minute for a period of 15 minutes.
- At the end of 15 minutes the suspension is poured into 1000 ml measuring cylinder and the residue washed by gentle swirling and decantation of successive 150 ml portions of sodium oxalate solution, the washings being added to the cylinder until the volume is made upto 1000 ml.
- In the case of coarse aggregate the weighed sample is placed in a suitable container, covered with a measured volume of sodium oxalate solution (0.8 gm per liter), agitated vigorously to remove all fine material adhered and the liquid suspension transferred to the 1000 ml measuring cylinder.
- This process is repeated till all clay material has been transferred to the cylinder. The volume is made upto 1000 ml with sodium oxalate solution.
- The suspension in the measuring cylinder is thoroughly mixed. The pipette A is then gently lowered until the pipette touches the surface of the liquid, and then lowered a further 10 cm into the liquid.
- Three minutes after placing the tube in position, the pipette A and the bore of tap B is filled by opening B and applying gentle suction at
- C.A small surplus may be drawn up into the bulb between tap B and tube C, but this is allowed to run away and any solid matter is washed out with distilled water from E.
- The pipette is then removed from the measuring cylinder and its contents run into a weighed container. The contents of the container is dried at 100°C to 110°C to constant weight, cooled and weighed.

The percentage of the fine slit and clay or fine dust is calculated from the formula.

$$\frac{100}{W_1}\left(\frac{1000\,W_2}{V}-0.8\right)$$

Where W1 = weight in gm of the original sample.

W2 = weight in gm of the dried residue

V = volume in ml of the pipette and

0.8 = weight in gm of sodium oxalate in one liter of diluted solution

E) Test for Determination of Organic Impurities:

- This test is an approximate method for estimating whether organic compounds are present in the natural sand in an objectionable quantity or within the permissible limit.
- The sand from the natural source is tested as delivered and without drying. A 350 ml graduated clear glass bottle is filled to the 75 ml mark with 3 per cent solution of sodium hydroxide in water
- The sand is added gradually until the volume measured by the sand layer is 125 ml.

- The volume is then made up to 200 ml by adding more solution. The bottle is then Stoppard and shaken vigorously.
- Roding also may be permitted to dislodge any organic matter adhering to the natural sand by using glass rod. The liquid is then allowed to stand for 24 hours.
- The colour of this liquid after 24 hours is compared with a standard solution freshly prepared, as follows: Add 2.5 ml of 2 per cent solution of tannic acid in 10 percent alcohol, to 97.5 ml of a 3 per cent sodium hydroxide solution.
- Place in a 350 ml. bottle, stopper, shake vigorously and allow standing for 24 hours before comparison with the solution above and described in the preceding paragraph. Alternatively, an instrument or colored acetate sheets for making the comparison can be obtained, but it is desirable that these should be verified on receipt by comparison with the stand

F) Test for Determination of Specific Gravity:(Nov/Dec 2017)

- Indian Standard Specification IS: 2386 (Part III) of 1963 gives various proceduresto find out the specific gravity of different sizes of aggregates. The following procedureis applicable to aggregate size larger than 10 mm.

- A sample of aggregate not less than 2 kg is taken. It is thoroughly washed to remove the finer particles and dust adhering to the aggregate.
- It is then placed in a wire basket and immersed in distilled water at a temperature between 22° to 32°C.
- Immediately after immersion, the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per sec.

- During the operation, care is taken that the basket and aggregate remain completely immersed in water. They are kept in water for a period of 24 ± 1/2 hours afterwards.
- The basket and aggregate are then jolted and weighed (weight A1) in water at a temperature 22° to 32° C.
- The basket and the aggregate are then removed from water and allowed to drain for a few minutes and then the aggregate is taken out from the basket and placed on dry cloth and the surface is gently dried with the cloth.
- The aggregate is transferred to the second dry cloth and further dried. The empty basket is again immersed in water, jolted 25 times and weighed in water (weight A2).
- The aggregate is exposed to atmosphere away from direct sunlight for not less than 10 minutes until it appears completely surface dry. Then the aggregate is weighed in air (weight B).

$$\text{Specific Gravity} = \frac{C}{B-A}; \quad \text{Apparent Sp. Gravity} = \frac{C}{C-A}$$

$$\text{Water absorption} = \frac{100\,(B-C)}{C}$$

- Then the aggregate is kept in the oven at a temperature of 100 to 110°C and maintained at this temperature for 24 ± 1/2 hours. It is then cooled in the air-tight container, and weighed (weight C).

$$\text{Bulk dinsity} = \frac{\text{net weight of the aggregate in kg}}{\text{capacity of the container in litre}}; \quad \text{Percentage of voids} = \frac{G_s - \gamma}{G_s} \times 100$$

where, G_s = specific gravity of aggregate and γ = bulk dinsity in kg/litre.

Where, A= the weight in gm of the saturated aggregate in water (A1 – A2),

B = the weight in gm of the saturated surface-dry aggregate in air, and

C = the weight in gm of oven-dried aggregate in air.

Test for Determination of Bulk Density and Voids

- Bulk density is the weight of material in a given volume. It is normally expressed in kg per liter. A cylindrical measure preferably machined to accurate internal dimensions is used for measuring bulk density. The size of the container for measuring bulk density is shown in Table

Size of Container for Bulk Density Test

Size of Largest Particles	Nominal Capacity	Inside Diameter	Inside Height	Thickness of Metal
	litre	cm	cm	mm
4.75 mm and under	3	15	17	3.15
Over 4.75 mm to 40 mm	15	25	30	4.00
Over 40 mm	30	35	31	5.00

- The cylindrical measure is filled about 1/3 each time with thoroughly mixed aggregate and tamped with 25 strokes by a bullet ended tamping rod, 16 mm diameter and 60 cm long.
- The measure is carefully struck off level using tamping rod as a straight edge. The net weight of the aggregate in the measure is determined and the bulk density is calculated in kg/liter.

7. Describe in detail about the importance of the quality of water used for concreting. (April/May 2019) (Nov/Dec 2019)

- Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement.

<u>Qualities of Water:</u>

- A popular yard-stick to the suitability of water for mixing concrete is that, if water is fit for drinking it is fit for making concrete.
- This does not appear to be a true statement for all conditions. Some waters containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking.
- Some specifications require that if the water is not obtained from source that has proved satisfactory, the strength of concrete or mortar made with questionable water should be compared with similar concrete or mortar made with pure water.
- Some specification also accept water for making concrete if the pH value of water lies between 6 and 8 and the water is free from organic matter.
- Instead of depending upon pH value and other chemical composition, the best course to find out whether a particular source of water is suitable for concrete making or not, is to make concrete with this water and compare its 7 days 'and 28 days 'strength with companion cubes made with distilled water.
- If the compressive strength is upto 90 per cent, the source of water may be accepted. These criteria may be safely adopted in places like coastal area of marshy area or in other places where the available water is brackish in nature and of doubtful quality.
- However, it is logical to know what harm the impurities in water do to the concrete and what degree of impurity is permissible is mixing concrete and curing concrete.
- Carbonates and bi-carbonates of sodium and potassium effect the setting time of cement. While sodium carbonate may cause quick setting, the bi-carbonates may either accelerate or retard the setting.
- The other higher concentrations of these salts will materially reduce the concrete strength. If some of these salts exceed 1,000 ppm, tests for setting time and 28 days strength should be carried out. In lower concentrations they may be accepted.
- Brackish water contains chlorides and sulphates. When chloride does not exceed 10,000 ppm and

sulphate does not exceed 3,000 ppm the water is harmless, but water with even higher salt content has been used satisfactorily.

- Salts of Manganese, Tin, Zinc, Copper and Lead cause a marked reduction in strength of concrete. Sodium iodate, sodium phosphate, and sodium borate reduce the initial strength of concrete to an extra-ordinarily high degree.
- Another salt that is detrimental to concrete is sodium sulphide and even a sulphide content of 100 ppm warrants testing.
- Silts and suspended particles are undesirable as they interfere with setting, hardening and bond characteristics. A turbidity limit of 2,000 ppm has been suggested.
- The initial setting time of the test block made with cement and the water proposed to be used shall not differ by ±30 minutes from the initial setting time of the test block made with same cement and distilled water.

Impurity		Tolerable Concentration
Sodium and potassium carbonates and bi-carbonates	:	1,000 ppm (total). If this is exceeded, it is advisable to make tests both for setting time and 28 days strength
Chlorides	:	10,000 ppm.
Sulphuric anhydride	:	3,000 ppm
Calcium chloride	:	2 per cent by weight of cement in non-pre-stressed concrete
Sodium iodate, sodium sulphate, sodium arsenate, sodium borate	:	very low
Sodium sulphide	:	Even 100 ppm warrants testing
Sodium hydroxide	:	0.5 per cent by weight of cement, provided quick set is not induced.
Salt and suspended particles	:	2,000 ppm. Mixing water with a high content of suspended solids should be allowed to stand in a s ettling basin before use.
Total dissolved salts	:	15,000 ppm.
Organic material	:	3,000 ppm. Water containing humic acid or such organic acids may adversely affect the hardening of concrete; 780 ppm. of humic acid are reported to have seriously impaired the strength of concrete. In the case of such waters there- fore, further testing is necessary.
pH	:	shall not be less than 6

<u>Tolerable Concentrations of Some Impurities in Mixing Water</u>

The following guidelines should also be taken into consideration regarding the quality of water.

- ✓ To neutralize 100 ml sample of water using phenopthaline as an indicator, it should not require more than 5 ml of 0.02 normal NaOH.
- ✓ To neutralize 100 ml of sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H2SO4.

Permissible limit for solids as per IS 456 of 2000

Material	Tested as per	Permissible limit Max.
Organic	IS 3025 (pt 18)	200 mg/l
Inorganic	IS 3025 (pt 18)	3000 mg/l
Sulphates (as SO_3)	IS 3025 (pt 24)	400 mg/l
Chlorides (as Cl)	IS 3025 (pt 32)	2000 mg/l for concrete work not containing embedded steel and 500 mg/l for reinforced concrete work
Suspended	IS 3025 (pt 17)	2000 mg/l

- Algae in mixing water may cause a marked reduction in strength of concrete either bycombining with cement to reduce the bond or by causing large amount of airentrainment in concrete.
- Algae which are present on the surface of the aggregate havethe same effect as in that of mixing water.

8. Discuss the role of various major components of cement and its hydrated products in the properties of cement. (May/June 2016) (April/May 2018)

- Portland cement gets its strength from chemical reactions between the cement and water. The process is known as hydration.
- This is a complex process that is best understood by first understanding the chemical composition of cement.

Manufacture of cement

Portland cement is manufactured by crushing, milling and proportioning the following materials:

- ✓ Lime or calcium oxide, CaO: from limestone, chalk, shells, shale or calcareous rock
- ✓ Silica, SiO2: from sand, old bottles, clay or argillaceous rock
- ✓ Alumina, Al2O3: from bauxite, recycled aluminum, clay
- ✓ Iron, Fe2O3: from clay, iron ore, scrap iron and fly ash
- ✓ Gypsum, CaSO4.2H20: found together with limestone

- The materials, without the gypsum, are proportioned to produce a mixture with the desired chemical composition and then ground and blended by one of two processes -dry process or wet process.
- The materials are then fed through a kiln at 2,600º F to produce grayish-black pellets known as clinker. The alumina and iron act as fluxing agents which lower the melting point of silica from 3,000 to 2600º F.
- After this stage, the clinker is cooled, pulverized and gypsum added to regulate setting time. It is then ground extremely fine to produce cement.

Chemical shorthand

- Because of the complex chemical nature of cement, a shorthand form is used to denote the chemical compounds. The shorthand for the basic compounds is:

Compound	Formula
Calcium oxide (lime)	Ca0
Silicon dioxide (silica)	$SiO2$
Aluminum oxide (alumina)	$Al2O3$
Iron oxide	$Fe2O3$
Water	$H2O$
Sulfate	$SO3$

Chemical composition of clinker

The cement clinker formed has the following typical composition:

Compound	Formula
Tricalcium aluminate	$Ca3Al2O6$
Tetracalciumaluminoferrite	$Ca4Al2Fe2O10$
Belite or Dicalcium silicate	$Ca2SiO5$
Alite or tricalcium silicate	$Ca3SiO4$
Sodium oxide	$Na2O$
Potassium oxide	$K2O$
Gypsum	$CaSO4.2H2O$

Properties of cement compounds

These compounds contribute to the properties of cement in different ways

Tricalcium aluminate, C3A:-

- ✓ It liberates a lot of heat during the early stages of hydration, but has little strength contribution. Gypsum slows down the hydration rate of C3A. Cement low in C3A is sulfate resistant.

Tricalcium silicate, C3S:-

- ✓ This compound hydrates and hardens rapidly. It is largely responsible for portland cement's initial set and early strength gain.

Dicalcium silicate, C_2S:

- ✓ C_2S hydrates and hardens slowly. It is largely responsible for strength gain after one week.

Ferrite, C_4AF:

- ✓ This is a fluxing agent which reduces the melting temperature of the raw materials in the kiln (from 3,000 ^{o}F to 2,600 ^{o}F).
- ✓ It hydrates rapidly, but does not contribute much to strength of the cement paste. By mixing these compounds appropriately, manufacturers can produce different types of cement to suit several

construction environments.

HYDRATION OF CEMENT (April/May 2019) (Nov/Dec 2019)

- It is the reaction (series of chemical reactions) of cement with water to form the binding material. In other words, in the presence of water, the silicates (C3S and C2S) and aluminates (C3A and C4AF) form products of hydration which in time produce a firm and hard mass - the hydrated cement paste.
- There are two ways in which compounds of the type present in cement can react with water:
- In the first, a direct addition of some molecules of water takes place, this being a true reaction of hydration.
- The second type of reaction with water is hydrolysis, in which its nature can be illustrated using the C3S hydration equation:

$$3CaO.SiO_2 + H_2O \rightarrow Ca(OH)_2 + xCaO.ySiO_2.aq. \text{ (calcium silicate hydrate)}$$

- The reaction of C3S with water continue even when the solution is saturated with lime and the resulted amounts of lime precipitate in crystals form $Ca(OH)_2$.
- **Calcium silicate hydrate** → remains stable when it is in contact with the solution saturated with lime.
- **Calcium silicate hydrate** → hydrolyzed when being in water - some of lime form, and the process continues until the water saturate with lime.
- If the calcium silicate hydrate remains in contact with water → it will leave the hardened compound only as hydrated silica due to the hydrolysis of all of the lime.

9. What are the raw materials for the manufacture of cement? Mention the functions in the properties of cement. (May/June 2016)

- Lime
- Silica
- Alumina
- Iron oxide
- Magnesium oxide
- Sulphur trioxide
- Alkalies
- Calciumsulphe

Lime

- Lime in excess makes the cement unsound and causes the cement to expand and disintegrate.
- If it is in deficiency, the strength of cement is decreased and cement sets quickly.
- Therefore it should be in right proportion to produce the cement sound and strong.

Silica

- Silica imports strength to cement.
- In excess provides greater strength to the cement but at the same time prolongs cement setting time.

Alumina

- It imports quick setting quality to the cement, lowers the clinkering temperature.
- In excess reduces the strength of cement.

Iron oxide

- Provides color, hardness and strength to cement.

Magnesium oxide

- Imparts hardness and color to cement.
- In excess makes the cement unsound.

Sulphur trioxide

- It makes the cement sound.
- In excess it causes the cement unsound.

Alkalies

- In excess will cause efflorescence.

Calcium sulphate

- Control the initial setting time of cement

10. Explain the physical properties of OPC. (Nov/Dec 2016)

Physical Properties

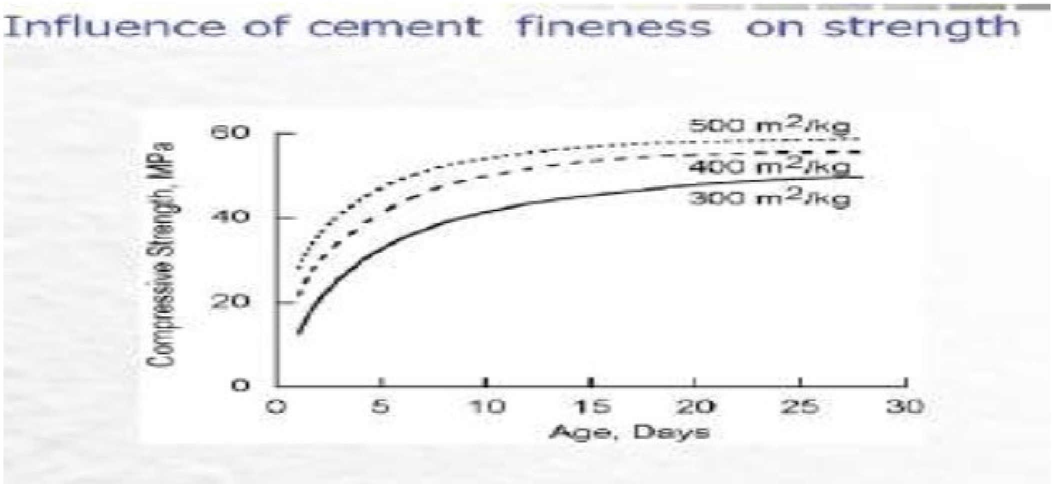
Portland cements are commonly characterized by their physical properties for quality control purposes. Their physical properties can be used to classify and compare Portland cements. The challenge in physical property characterization is to develop physical tests that can satisfactorily characterize key parameters.

The physical properties of cement

- Fineness
- Soundness
- Setting Time
- Strength

Fineness

- Fineness or particle size of Portland cement affects Hydration rate and thus therate of strength gain. The smaller the particle size, the greater the surface areatovolumeratio, and thus, the more area available for water-cement interactionper unit volume. The effects of greater fineness on strength are generally seenduring the first seven days.
- When the cement particles are coarser, hydration starts on the surface of theparticles. So the coarser particles may not be completely hydrated. This causeslow strength and low durability.
- For a rapid development of strength a high fineness is necessary.



Soundness

When referring to Portland cement, "soundness" refers to the ability of a hardened cement paste to retain its volume after setting without delayed expansion. This expansion is caused by excessive amounts of free lime (CaO) or magnesia (MgO). Most Portland cement specifications limit magnesia content and expansion.

Setting Time

- Cement paste setting time is affected by a number of items including: cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. Setting tests are used to characterize how a particular cement paste sets. For construction purposes, the initial set must not be too soon and the final set must not be too late. Normally, two setting times are defined:
- Initial set. Occurs when the paste begins to stiffen considerably.
- Final set. Occurs when the cement has hardened to the point at which it can sustain some load.
- Setting is mainly caused by C3A and C3S and results in temperature rise in the cement paste.
- False set: No heat is evolved in a false set and the concrete can be remixed without adding water.

Strength

Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water-cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading conditions and age.

11) How the strength of cement is important? Explain its testing procedure.

Strength test

- ✓ Compressive strength test is the most important test ensures the quality of cement.
- ✓ Strength test cannot perform on pure cement paste because of difficulties excessive shrinkage and subsequent development of crack of neat cement.
- ✓ Strength of cement is indirectly found cement sand mortar in specific proportions.

- ✓ Hence standard sand conforming to IS 650-1991 is used in specific proportion with the cement to make mortar specimen is in the form I cubes 70.6 x 70.6 x 70.6 mm cubes (50 sq.cm face compacted by means of a standard vibration machine; shown in Figure' 1.7. Minimum three mortar cubes a prepared and tested for compression.

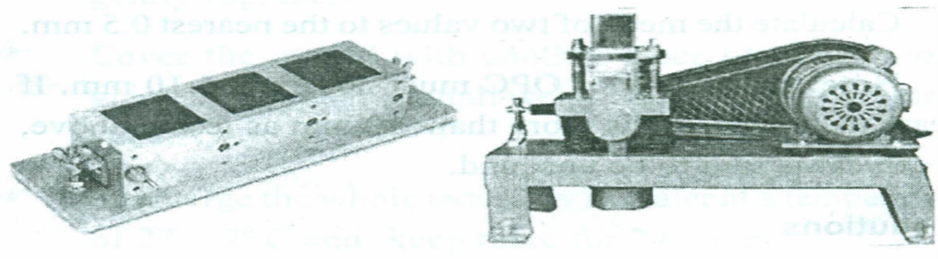


Figure 1.7 Moulds of 70.6 mm and mortar cube vibratir machine

The following procedure IS adopted to find soundness of cement:

- ✓ Take 200 gm of cement and 600 gm of standard in a non-porous enamel tray and mix them with a throw in dry thoroughly for one minute.
- ✓ Add water (4" + 3) % of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour (where P is % of water required for preparing paste of standard consistency)
- ✓ The time of mixing is minimum of 3 minutes and maximum of 4 minutes to obtain a mix of uniform colour.
- ✓ Place the thoroughly cleaned and oil (on interior face) mould on the vibrating machine and hold it in position by clamps provided on the machine for the purpose.
- ✓ Fill the mould with entire quantity of mortar using a suitable hopper attached to the top of the mould for facility Of filling and vibrate it for 2 minutes at a specified speed of 12000 ± 400 per minute to achieve full compaction.
- ✓ Remove the mould from the machine and keep it in a place with temp of 27±2°C and relative humidity of 90% for 24 hours.
- ✓ At the end of 24 hours remove the cube from the mould and immediately submerge in fresh clean water until taken out for testing.
- ✓ Prepare 6 cubes (at least 3 cubes) in the manner explained above.
- ✓ Place the test cube on the platform of a compressive testing machine without any packing between the cube and the plates of the testing machine.
- ✓ Apply the load steadily and uniformly, starting from zero at a rate of 35 N/mm^2

Calculate the compressive strength of cement as

Compressive strength = P/A

Where,

P = Maximum load applied to the cube. (N)

A = Cross-sectional area (Calculated from the mean dimensions) (mm^2).

- ✓ Compressive strength his reported to the nearest0.5N/mm2
- ✓ Specimens that are manifestly faulty, or that give strengths differing by more than 10% from the average value of the entire test specimen should not be considered.
- ✓ Test three cubes for compressive strength for each period of curing.

Precautions

- ✓ The mould should be oiled before use
- ✓ The weighing should be done accurately
- ✓ The temperature and humidity must be accurately controlled
- ✓ Increase the load gradually during testing.
- ✓ The cubes should be tested immediately after taking out of water and not allowed to dry until they fail under testing.
- ✓ The gauging time should be-strictly observed.
- ✓ The cubes should be tested on their sides and not on their faces.

12. Define: Specific gravity of cement. Explain the testing procedure.

Specific gravity test:

Specific gravity is defined as the ratio between the weight of a given volume of cement and weight of an equal volume of water. Le-chatelier flask which is shown in

Figure 1.8 can be used for this test.

The following procedure IS adopted to find out soundness of cement:

- ✓ Dry the Le-chatelier flask and fill with kerosene oil or Naptha to a point on the stem between 0 and 1 ml.
- ✓ Dry the inside of the flask above the level of the liquid.
- ✓ Immerse the flask in a constant temp water bath maintained at room temp for sufficient time.
- ✓ Record the level of the kerosene oil in the flask as initial reading.
- ✓ Introduce about 60 gm of cement into the flask so that the level of kerosene rises to about say 22 ml mark. Splashing should be avoided and cement should not be allowed to adhere to the sides of the flask above the liquid.
- ✓ Insert the glass nipple into the flask and roll it gently in an inclined position to free the cement from air until no further air bubble rises to the surface of the liquid.
- ✓ Keep the flask again in constant temp water bath and note down the new liquid level as final reading.

The difference between the first and final readings represents the volume of liquid displaced by the mass of cement used in test. The density is calculated as per the below mentioned formula to the second place of decimal.

$$\text{Density} = \frac{\text{mass of cement, g}}{\text{displaced volume, cm}^3}$$

Once the density of cement is found, then the specific gravity of cement can be found by dividing tile density of cement by the density of water. Specific gravity of OPC
normally varies between 3.10 - 3.15.

Precautions

- ✓ While pouring cement in the Lechatelier flask, care should be taken to avoid splashing and cement should not adhere to the inside of the flask above the liquid.
- ✓ The kerosene or Naptha should be completely free from water.

13) Explain the testing procedure of initial setting time test of cement and final setting time of cement? (Nov/Dec 2017)

<u>Setting time test</u>

- ✓ As soon as water is added to cement, hydration of cement starts which results in changing the water cement mix from fluid to solid state.
- ✓ Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.
- ✓ Otherwise, initial setting time is regarded as the time elapsed between the moments that the water is added to the cement, to the time that the paste losing its plasticity.
- ✓ Final setting time is that time period between the time 'water is added to cement and the time a which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression Otherwise, final setting time is the time elapsed between that moment the water is added to the cement, and the time where the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.
- ✓ The test also should be conducted at temperature 27°±2° C am the maximum humidity 90 %.

The following procedure is adopted to find out setting time of cement:

- ✓ Before commencing setting time test, do the consistency test to obtain the water required to give the paste normal consistency (P).
- ✓ Take 400 gm of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
- ✓ Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time(t1) \
- ✓ Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.
- ✓ Place the test block confined in the mould and resting or the non-porous plate, under the rod bearing the needle. Lower the needle gently until it comes in contact with the t surface of test block and quick release, allowing it to penetrate into the test block.
- ✓ In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (t.), Calculate, initial setting time =(t2-tl)
- ✓ For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment.
- ✓ The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. Record this time (t1)
- ✓ Calculate, final setting time = (t3-t1)

Where,

t1= Time at which water is first added to cement 1

t2= Time when needle fails to penetrate 5 mm to 7mm from bottom of the mould

t3= Time when the needle makes an impression but

the attachment fails to do so.

Precautions

- ❖ Release the initial and final setting time needles gently.
- ❖ The experiment should be performed away from vibration and other disturbances.
- ❖ Needle should be cleaned every time it is used.
- ❖ Position of the mould should be shifted slightly after each penetration to avoid penetration at the same place.
- ❖ Test should be performed at the specified environmental conditions.

14. Summarize the test procedure for water absorption and moisture content of aggregates. (Nov/Dec 2019)

Water absorption test Procedure:

1. Objective

Water absorption gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests.

2. Apparatus Required

Fig. 1: Wire Mesh Bucket

Wire basket of not more than 6.3mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.

Fig. 2: Setup of Water Absorption Test

The setup consists of container for filling water and suspending the wire basket in it and an airtight container of capacity similar to that of basket, a shallow tray and two dry absorbent clothes.

3. Reference

IS 2386(Part 3):1963 Methods of Test for Aggregates. Reaffirmed- Dec 2016

4. Procedure

Procedure For Aggregate Coarser Than 6.3mm:

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0C to 32^0C.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 25 mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.
3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.
4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 22^0C to 32^0C.
5. The basket and aggregates are removed from water and dried with dry absorbent cloth.
6. The surface dried aggregates are also weighed.
7. The aggregate is placed in a shallow tray and heated to 100 to 110^0C in the oven for 24 ± 0.5 hours. Later, it is cooled in an airtight container and weighed.

5. Calculation

1. Weight of saturated aggregates in air: W1 g =
2. Weight of oven dry aggregates in air: W2 g =

Water Absorption (%)= [(W1-W2)*100]/W2 =

Moisture content test procedure:

This procedure is an alternate to using a pycnometer and is also intended for determining the moisture content of aggregates for Portland Cement Concrete.

A. Apparatus

1. Balance having a capacity of at least 5,000 grams and accurate to 0.5 gram

B. Preparation of Sample

1. Prepare the test sample identical to that described in Procedure A.

C. Test Procedure

1. Bring the weighed wet sample to a saturated-surface-dry condition in the manner described in Materials IM 307 and weigh to the nearest 0.5 gram.

D. Calculation

1. Calculate the moisture content, based on wet mass (weight), to the nearest 0.1 percent as follows:

$$\text{Percent Moisture} = \frac{\text{Wt. as received - Wt. SSD}}{\text{Wt. as received}} \times 100$$

A negative result is due to absorption of the aggregate rather than free moisture.

2. The percent of moisture, based on saturated-surface-dry mass (weight), is calculated to the nearest 0.1 percent as follows:

$$\text{Percent Moisture SSD} = \frac{\text{\% Moisture as received}}{\text{100 - \% Moisture by wet mass (weight) as received}} \times 100$$

or

$$\text{Percent Moisture (SSD)} = \frac{\text{wet mass (weight) - saturated - surface - dry mass (weight)}}{\text{saturated - surface - dry mass (weight)}} \times 100$$

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15. Detail about the properties of aggregate. (April/May 2019)

- Aggregates are used in concrete to provide economy in the cost of concrete. Aggregates act as filler only. These do not react with cement and water.
- But there are properties or characteristics of aggregate which influence the properties of resulting concrete mix. These are as follow.
  - Composition
  - Size & Shape
  - Surface Texture
  - Specific Gravity
  - Bulk Density
  - Voids
  - Porosity & Absorption
  - Bulking of Sand
  - Fineness Modulus of Aggregate
  - Surface Index of Aggregate
  - Deleterious Material
  - Crushing Value of Aggregate
  - Impact Value of Aggregate
  - Abrasion Value of Aggregate

16. Explain about any two types of blended cements available in Indian market along with its properties and behaviour. (April/May 2019)

- Blended cement can be defined as uniform mix of ordinary Portland cement (OPC) and blending materials such as silica fumes, fly ash, limestone and slag to enhance its properties for different uses. Blended cement can improve workability, strength, durability and chemical resistance of concrete.

Characteristics of Blended Cement:

The enhanced properties that are obtained due to blending of cement with different materials are,

- Improved workability and pumpability.
- Reduced water demand
- Enhanced bleed control
- Lower drying shrinkage and creep
- Improved resistance to sulphate attack and chloride penetration
- Reduced potential for Alkali Aggregate Reaction

Types of Blended Cement:

The classification of blended cement is based in the type of blending material used in the cement. As per American Society for Testing and Materials (ASTM) specification, blended cement are classified in to 4 types,

- **Type IS (X), Portland-Slag Cement**
- **Type IP (X), Portland-Pozzolan Cement**
- **Type IL (X), Portland-Limestone Cement**
- **Type IT, Ternary Blended Cement**

Type IS (X), Portland-Slag Cement

Blends containing up to 70% slag cement are used for general construction.

Type IP (X), Portland-Pozzolan Cement

Used for general construction, this blend can contain up to 50% pozzolan. Fly ash is the most common pozzolan used in blended cement.

Type IL (X), Portland-Limestone Cement

Relatively new to the U.S. market, portland-limestone cement contains between 5% and 15% percent interground limestone.

Type IT, Ternary Blended Cement

Ternary cements are blends two complementary supplementary materials such as fly ash, slag cement or silica fume.

Advantages of Blended Cement

- It provides a finer texture than OPC when mixed and placed. So it can be used for finishing and elevation works.
- Water consumption is less which makes it easy to work with and shape.
- The strength gained after 28 days is significantly stronger than OPC, in both compressive and flexural stress.
- The permeability of blended concrete is low, due to which the life of concrete is extended by reducing penetration of aggressive water run-off compounds such as sulfates and chlorides when compared to ordinary cement.
- Cracks occurred due to thermal stress by variation of temperature is reduced by the use of blended cement.

- Reduced problems related to Alkali-Silica Reaction by using a mix of blended cement as either silica fume and slag, or silica fume and fly ash.
- Blending material used are industrial by products, the used of these industrial by product reduces the use of natural resources such as limestone, silica and clay.

Uses of Blended Cement

Blended cement makes it an ideal choice for a wide range of applications such as,

- Domestic construction
- Major engineering project.
- Pre-cast concrete where high durability and off-form finish are required
- Stabilisation including pavement recycling for road construction
- Mining applications
- Specialist formulations such as adhesives, renders, mortars and grouts.

PART-A

1. Define accelerators.

- Accelerators reduce the setting time and produce early removal of forms and speed up hardening.
- The common accelerators are $cacl_2$, Al_2cl, Nacl, and Na_2SO4.

2. What is meant byRetarders?

- A Retarder is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder.
- Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting.
- Retarders increases the setting time of concrete mix and reduce the water cement ratio. Up to 10% water reduction is achieved.

3. What is the purpose of retarders? (Nov/Dec 2019)

- Retarders increases the setting time of concrete mix and reduce the water cement ratio. Up to 10% water reduction is achieved.

4. Define plasticizers.

- Plasticizers are defined as chemical admixtures added to wet concrete mix to impart adequate workability properties.

5. Mention the types of plasticizers.

a. Finely divided minerals
b. Air entraining agents
c. Synthetic derivatives

6. Define superplasticizers.

- Super plasticizers produce extreme workability and achieve reduction of water content without loss of water cement ratio i.e. workability.

7. What is the use of super plasticizers? (NOV/DEC 2016, MAY/JUNE 2016)

- It extent up to 30% without reducing workability in contrast to the possible reduction up to 15% in case of plasticizers.
- It is practiced for production of flowing, self-leveling, and self-compacting and for the production of high strength and high performance concrete.
- It is possible to use water/cement ratio as low as 0.25 or even lower and yet to make concrete to obtain strength of the order120 N/mm^2 or more.
- It is possible to use fly ash, slag and particularly silica fume to make high performance concrete.

8. Define Super plasticizers & List out its advantages. (May/June 2016)

- Super plasticizers produce extreme workability and achieve reduction of water content without loss of water cement ratio i.e. workability.

Super plasticizers can produce:

- ✓ At the same w/c ratio much more workable concrete than the plain ones,
- ✓ For the same workability, it permits the use of lower w/c ratio,
- ✓ As a consequence of

9. What is meant by waterproofing admixtures?

- Waterproofing admixtures may be obtained in powder, paste or liquid form and may consist of pore filling or water repellent materials.
- The chief materials in the pore filling class are silicate of soda, aluminium and zinc sulphates and aluminium and calcium chloride. These are chemically active pore fillers.

10. Write the classification of fly ash.

Fly is classified into two classes.

Class F:

- Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.

Class C:

- Fly ash normally produced by burning lignite or sub-bituminous coal. Some class C fly ash may have CaO content in excess of 10%.
- In addition to pozzolanic properties, class C fly ash also possesses cementitious properties.

11. Write the advantages of GGBS in concrete.

- The major advantages recognized are
- Reduced heat of hydration
- Refinement of pore structures
- Reduced permeability's to the external agencies
- Increased resistance to chemical attack.

12. Define chemical admixtures.

- Chemicals mixed with concrete ingredients and spread throughout the body of concrete to favorably modify the molding and setting properties of concrete mix known as chemical admixtures.

13. Define Mineral admixtures.

- It is a siliceous materials used to strengthen the durability properties that is classified as pozzolanic or cementitious materials.
- It acts as by-product agent. E.g.: fly ash

14. Define plasticizers and mention its types.

- Plasticizers are defined as chemical admixtures added to wet concrete mix to impart adequate workability properties.
  - Finely divided minerals
  - Air entraining agents
  - Synthetic derivatives

15. Mention the few mineral admixtures.

- Fly ash
- Silica fume
- Rice husk ash
- Metakaoline
- GGBFS

16. What are the various admixtures used other than chemical and mineral admixtures.

- Gas forming and expansive chemicals
- Pigments
- Antifungal admixtures
- Curing compounds
- Sealants
- Flooring
- Guniting aids.

17. Name the admixtures available in India. Or List any four commercially available admixtures. (Nov/ Dec 2019)

a. Plasticizers

- Conplast P211-Water reducing plasticizers
- Conplast P509-Water reducing plasticizers/High performance plasticizers

b. Super Plasticizers

- Conplast SP337-High workability aid
- Conplast SP430-High range water reducer

18. What is meant by Pozzolanic action? (May/June 2016)

- The pozzolanic reaction is the chemical reaction that occurs in Portland cement upon the addition of pozzolans.
- The pozzolanic reaction converts a silica-rich precursor with no cementing properties, to a calcium silicate, with good cementing properties.

19. List Air-entraining admixtures and their properties. (April/May 2018)

Air-entraining admixtures

- Salts of wood resins (Vinsol resin), some synthetic detergents, salts of sulfonated lignin, salts of petroleum acids, salts of proteinaceous material, fatty and resinous acids and their salts, alkyl benzenesulfonates, salts of sulfonated hydrocarbon.

Properties of Air-entraining admixtures

- Improve durability in freeze-thaw, deicer, sulfate, and alkali- reactive environmentsimprove workability

20. What are admixtures? (NOV/DEC 2017)

- Admixtures are ingredients other than cement, fine aggregate and coarse aggregate to improve the quality of concrete.
- The addition of an admixture may improve the concrete with respect to its strength, hardness, workability, water resisting power etc.

21. What is the importance of super plasticizers added in cement concrete? (Nov/Dec 2016)

- It increases workability at same water cement ratio (w/c) and decreases w/c ratio at the same workability level.
- The fluidizing property remains longer due to the retarding property on cement hydration.
- In other words, use of super-plasticizers reduces much more segregations and bleedings than any normal plasticizers.
- Super-plasticizers are most effective mix ingredient for concrete.

22. What are the Factors Affecting Air Entraining Admixtures?(Nov/Dec 2016)

- Amount of fine aggregates
- Temperature also affects the amount of air entrained in concrete.
- Slump value also has a positive effect on amount of air entrained.
- Time

23. Define Metakaolin. (April/May 2017)

- Metakaolin is an unpurified natural pozzolans material made on thermally activated ordinary clay and kaolinitic clay.

24. Mention the advantages of Metakaolin.

- Increased compressive and flexural strengths
- Reduced permeability (including chloride permeability)
- Increased resistance to chemical attack
- Increased durability
- Reduced effects of alkali-silica reactivity (ASR)
- Enhanced workability and finishing of concrete
- Reduced shrinkage, due to "particle packing" making concrete denser

25. State the uses of Metakaolin.

- High performance, high strength, and lightweight concrete
- Precast and poured-mold concrete
- Fiber cement and Ferrocement products
- Glass fiber reinforced concrete
- Countertops, art sculptures

26. What is the importance of Acceleratorsadded in cement concrete? (April/ay 2019)

Accelerating admixtures are added to concrete to increase the rate of early strength development in concrete to

- ✓ Permit earlier removal of formwork;
- ✓ Reduce the required period of curing;
- ✓ Advance the time that a structure can be placed in service;
- ✓ Partially compensate for the retarding effect of low temperature during cold weather concreting.

27. List the Advantages of Fly Ash.

- It is highly economical.
- Use of Fly Ash is environmentally friendly as the waste materials from industries are effectively being used to create quality building materials.
- Fly Ash has very small particles which makes the concrete highly dense and reduces the permeability of concrete. It can add greater strength to the building.
- The concrete mixture generates a very low heat of hydration which prevents thermal cracking.
- Fly Ash concrete is resistant to acid and sulphate attacks.
- The shrinkage of fly ash concrete is very less.
- The use of fly ash gives concrete good work ability, durability and finish.

28. Mention the Disadvantages of Fly Ash.

- The quality of fly ash can affect the quality and strength of Cement concrete.
- Poor quality fly ash can increase the permeability of the concrete and cause damage to the building.

29. What is Silica Fume?

- It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy.

30. What are the Advantages of Using Silica Fume in concrete?

- High early compressive strength
- High tensile flexural strength and modulus of elasticity
- Very low permeability to chloride and water intrusion
- Enhanced durability
- Increased toughness

- Increased abrasion resistance on decks, floors, overlays and marine structures
- Superior resistance to chemical attack from chlorides, acids, nitrates and sulfates and life-cycle cost efficiencies
- Higher bond strength
- High electrical resistivity and low permeability

31. Where GGBS can be used?

GGBS significant attribute of providing ultimate strength when added to Portland cement makes it the preferred material in the construction of;

- High-rise buildings.
- Marine applications such as dams, shore protection construction.
- Effluent and sewage treatment plants.
- Cement products such as tiles, pipes, blocks, etc.

32. Write the Properties of Hardened Concrete with Blast Furnace Slag.

- Setting Time of GGBFS concrete
- Compressive strength of concrete containing slag
- Curing of blast furnace slag concrete
- Color of concrete incorporating slag
- Flexural strength of Blast furnace slag concrete
- Permeability of concrete incorporating slag
- Young's modulus of elasticity of concrete incorporating slag
- Drying shrinkage of concrete containing slag
- The change in properties of concrete microstructure with the replacement of cement by GGBFS.

33. What are the importances of water proofers added in the concrete? (April/May 2017)

- ➢ Concrete Is Stronger
- ➢ Concrete Looks Better
- ➢ Prevent Water Damage
- ➢ Reduced Concrete Maintenance Costs

34. List out the disadvantage of superplasticizer in concrete. (May/June 2016)

- Loss of workability as a result of rapid slump loss.
- Incompatibility of cement.

35. What are the methods of making blast furnace slag?

There are two methods for making blast furnace slag cement:

- ❖ In the first method blast furnace slag is inter ground with cement clinker along with gypsum.
- ❖ In the second method blast furnace slag is separately ground and then mixed with the cement.

36. What is an additive?

Additive is a material which is added at the time ofgrinding cement clinker at the cement factory.

37. Mention some of the situations where high degreeof workability is required.

A high degree of workability is required in situationslike:

- ❖ Deep beams
- ❖ Thin walls structures

- ❖ Structural elements having high percentage of steelreinforcement
- ❖ Beam and column junctions.
- ❖ Pumping of concrete
- ❖ Hot weather concreting
- ❖ Concrete to be conveyed for considerable distance
- ❖ Ready mixed concrete industries, etc.

38. What are the conventional methods followed for obtaining high workability?

The conventional method followed for obtaining highworkability is by

- ❖ Improving the gradation
- ❖ Use of relatively higher percentage of fine aggregate
- ❖ Increasing the cement content
- ❖ Use of extra water.

39. Name any two chemical admixtures used in concrete. (Nov/Dec 2017)

Some of chemical admixtures used in concrete are:

(i)Plasticizers (ii) Super plasticizers (iii) Accelerators (iv) Retarders (v) Water proofers

40. What are the desirable properties of silica fume? (April/May 2018)

- ✓ They are spherical shaped.
- ✓ Mean particle size between 0.1 and 0.2 micron.
- ✓ Specific surface area is about 15,000 m^2/kg.
- ✓ It has about 90% SiO_2 content.

41. Which property of concrete can be modified by the addition of accelerators? (April/May 2019)

The addition of an accelerator speeds the setting time and thus cure time starts earlier. This allows concrete to be placed in winter with reduced risk of frost damage.

42. Write any two brand name of water proofing chemicals. (April/May 2019)

- ➢ Dubond Rain Shield water proofing
- ➢ BSK Hydrocrete-909
- ➢ Samplast Liquid water proofing

43.Difference between Plasticizers and Super Plasticizers.(April/May 2019)

Plasticizers	Super Plasticizers
A plasticizer is an additive used to improve the plasticity of a certain substance.	Super plasticizer is a water-reducing admixture capable of producing large water reduction or great flowability without causing undue set retardation or entrainment of air in mortar or concrete.
Plasticizers are used to increase the plasticity of polymer materials such as PVC and as a water reducer in concrete mixtures.	Super plasticizers are used to further increase the water requirement for concrete mixtures, increasing the strength and durability of concrete.

44. Write the function of accelerators. (April/May 2019)

Accelerating admixtures are added to concrete to increase the rate of early strength development in concrete to

- ➢ Permit earlier removal of formwork;

- Reduce the required period of curing;
- Advance the time that a structure can be placed in service;
- Partially compensate for the retarding effect of low temperature during cold weather concreting;
- In the emergency repair work.

45. Differentiate mineral admixtures and chemical admixtures. (Nov/Dec 2019)

Mineral admixtures	Chemical admixtures
Mineral admixtures are usually added to concrete in large quantity	These admixtures have formulated chemical composition and these are used for certain proportions of concrete.
They can improve the resistance of concrete to thermal cracking alkali-akorgate expansion, and sulfate attack	They are mainly used to reduce the cost of concrete construction.
Natural pozzolanic material and industrial byproducts, such. fly ash and slag are commonly used mineral admixtures.	Chemical compounds are added to concrete in very small amounts for purposes such as entertainment of air, plasticization of fresh concrete mixtures, or comic.' of setting time
These are added in a large amount to improve the performance of the concrete and reduce the cost of construction.	Chemical admixtures are used in the construction industry for building durable. strong and water-proof structure.

PART –B& C

1) Explain in detail about the retarders (Chemical admixture). (Or) what kind of chemical admixture that can be added while concreting is under hot weather condition? (Nov/Dec 2016, 2019) (April/May 2017)

- A retarder is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder.
- Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting.
- The retarders are used in casting and consolidating large number of pours without the formation of cold joints.
- They are also used in grouting oil wells. Oil wells are sometimes taken upto a depth of about 6000 meter deep where the temperature may be about 200°C.
- The annular spacing between the steel tube and the wall of the well will have to be sealed with cement grout.
- Retarding admixtures are sometimes used to obtain exposed aggregate look in concrete.
- The retarder sprayed to the surface of the formwork, prevents the hardening of matrix at the interface of concrete and formwork, whereas the rest of the concrete gets hardened.
- The appropriate amount of gypsum to be used must be determined carefully for the given job.
- Use of gypsum for the purpose of retarding setting time is only recommended when adequate inspection and control is available, otherwise, addition of excess amount may cause undesirable expansion and indefinite delay in the setting of concrete.
- In addition to gypsum there are number of other materials found to be suitable for this purpose.
- They are: starches, cellulose products, sugars, acids or salts of acids. These chemicals may have variable action on different types of cement when used in different quantities.
- Unless experience has been had with a retarder, its use as an admixture should not be attempted without technical advice. Any mistake made in this respect may have disastrous consequences.
- Common sugar is one of the most effective retarding agents used as an admixture for delaying the setting time of concrete without detrimental effect on the ultimate strength.
- Addition of excessive amounts will cause indefinite delay in setting.
- At normal temperatures addition of sugar 0.05 to 0.10 per cent have little effect on the rate of hydration, but if the quantity is increased to 0.2 per cent, hydration can be retarded to such an extent that final set may not take place for 72 hours or more.

- Skimmed milk powder (casein) has a retarding effect mainly due to sugar content.
- Other admixtures which have been successfully used as retarding agents are Lignosulphonic acids and their salts, hydroxylated carboxylic acids and their salts which in addition to the retarding effect also reduce the quantity of water requirement for a given workability. This also increases 28 days compressive strength by 10 to 20 per cent.

Effect of retarding/water-reducing admixtures on setting time and strength build up

Admixture addition litres/50 kgs.	Setting time hrs.		W : C ratio	Compressive Strength MPa		
	Initial	Final		3 days	7 days	28 days
0	4.5	9	0.68	20	28	37
0.14	8.0	13	0.61	28	36	47
0.21	11.5	16	0.58	30	40	50
0.28	16.0	21	0.58	30	42	54

2) Explain in detail about the Accelerators(Chemical admixture). (Or) what kind of chemical admixture that can be added while concreting is under cold weather condition?(Nov/Dec 2016, 2019) (April/May 2017)

- Accelerating admixtures are added to concrete to increase the rate of early strength development in concrete to
  - Permit earlier removal of formwork;
  - Reduce the required period of curing;
  - Advance the time that a structure can be placed in service;
  - Partially compensate for the retarding effect of low temperature duringcold weather concreting;
  - In the emergency repair work.
- In the past one of the commonly used materials as an acceleratorwas calcium chloride. But, now days it is not used. Instead, some of the solublecarbonates, silicates fluosilicates
- Accelerators such as fluosilicates and triethenolamine are comparatively expensive.
- The recent studies have shown that calcium chloride is harmful for reinforced concrete and prestressed concrete.
- It may be used for plain cement concrete in comparatively high dose.
- Some of the accelerators produced these days are so powerful that it is possible to make the cement set into stone hard in a matter of five minutes are less.
- With the availability of such powerful accelerator, the underwater concreting has become easy. Similarly, the repair work that would be carried out to the waterfront structures in the region of tidal

variations has become easy.

- The use of such powerful accelerators have facilitated, the basement waterproofing operations. In the field of prefabrication also it has become an invaluable material.
- As these materials could be used up to 10°C, they find an unquestionable use in cold weather concreting.
- Some of the modern commercial accelerating materials are Mc-Schnell OC, Mc-Schnell SDS, Mc-Torkrethilfe BE, manufactured by Mc-Bauchemic (Ind) Pvt. Ltd. MC-Torkrethilfe BE is a material specially formulated to meet the demand for efficient and multifold properties desired for sprayed concrete and shotcreting operations.
- A field trial is essential to determine the dose for a given job and temperature conditions when the above materials are used.

Accelerating Plasticizers:

- Certain ingredients are added to accelerate the strength development of concrete to plasticizers or superplasticizers.
- Such accelerating superplasticizers, when added to concrete result in faster development of strength.
- The accelerating materials added to plasticizers or superplasticizers are triethenolamine chlorides, calcium nutrite, nitrates and flousilicates etc.
- The accelerating plasticizers or accelerating super plasticizers manufactured by well known companies are chloride free.

3. Explain in detail about the plasticizers and super plasticizers (Chemical admixture). (May/June 2016) (April/May 2018) (Nov/Dec 2019)

- These plasticizers can help the difficult conditions for obtaining higher workability without using excess of water.
- One must remember that addition of excess water, will only improve the fluidity or the consistency but not the workability of concrete.
- The excess water will not improve the inherent good qualities such as homogeneity and cohesiveness of the mix which reduces the tendency for segregation and bleeding.
- The use of superplasticizer has become almost an universal practice to reduce water/cement ratio for the given workability, which naturally increases the strength.
- The organic substances or combinations of organic and inorganic substances, which allow a reduction in water content for the given workability, or give a higher workability at the same water content, are termed as plasticizing admixtures.
- The advantages are considerable in both cases: in the former, concretes are stronger, and in the latter

they are more workable.

The basic products constituting plasticizers are as follows:

- Anionic surfactants such as lingo sulphonates and their modifications and derivatives, salts of sulphonates hydrocarbons.
- Nonionic surfactants, such as polyglycol esters, acid of hydroxylated carboxylic acids and their modifications and derivatives.
- Other products, such as carbohydrates etc. Among these, calcium, sodium and ammonium lingo sulphonates are the most used.

- Plasticizers are used in the amount of 0.1% to 0.4% by weight of cement. At these doses, at constant workability the reduction in mixing water is expected to be of the order of 5% to 15%. This naturally increases the strength.
- The increase in workability that can be expected, at the same w/c ratio, may be anything from 30 mm to 150 mm slump, depending on the dosage, initial slump of concrete, cement content and type.
- A good plasticizer fluidizes the mortar or concrete in a different manner than that of the air-entraining agents. Some of the plasticizers, while improving the workability, entrain air also.
- As the entrainment of air reduces the mechanical strength, a good plasticizer is one which does not cause air-entrainment in concrete more than 1 or 2%.
- Such a product would allow adsorption into cement particles without any significant interference with the hydration process or hydrated products.
- Normal water reducing admixtures may also be formulated from wholly synthetic raw materials.

Action of Plasticizers

- The action of plasticizers is mainly to fluidity the mix and improves the workability of concrete, mortar or grout.
- The mechanisms that are involved could be explained in the following way:
- Dispersion. Portland cement, being in fine state of division, will have a tendency to flocculate in wet concrete.
- These flocculation entraps certain amount of water used in the mix and thereby all the water is not freely available to fluidity the mix.
- When plasticizers are used, they get adsorbed on the cement particles. The adsorption of charged polymer on the particles of cement creates particle-to-particle repulsive forces which overcome the attractive forces.
- This repulsive force is called Zeta Potential, which depends on the base, solid content, quantity of plasticizer used.
- The overall result is that the cement particles are deflocculated and dispersed.

- When cement particles are deflocculated, the water trapped inside the flocks gets released and now available to fluidity the mix.
- When cement particles get flocculated there will be interring particles friction between particle to particle and floc to floc.
- But in the dispersed condition there is water in between the cement particle and hence the inter particle friction is reduced.

Retarding Effect

- It is mentioned earlier that plasticizer gets adsorbed on the surface of cement particles and form a thin sheath.
- This thin sheath inhibits the surface hydration reaction between water and cement as long as sufficient plasticizer molecules are available at the particle/solution interface.
- The quantity of available plasticizers will progressively decrease as the polymers become entrapped in hydration products.
- Many research workers explained that one or more of the following mechanisms may take place simultaneously:
  - Reduction in the surface tension of water.
  - Induced electrostatic repulsion between particles of cement.
  - Lubricating film between cement particles.
  - Dispersion of cement grains, releasing water trapped within cement flocs.
  - Inhibition of the surface hydration reaction of the cement particles, leaving more water to fluidity the mix.
  - Change in the morphology of the hydration products.
  - Induced steric hindrance preventing particle-to-particle contact.

Super plasticizers (High Range Water Reducers)

- They are chemically different from normal plasticizers. Use of super plasticizers permit the reduction of water to the extent upto 30 per cent without reducing workability in contrast to the possible reduction up to 15 per cent in case of plasticizers
- The use of superplasticizer is practiced for production of flowing, self leveling, and self compacting and for the production of high strength and high performance concrete.
- The mechanism of action of super plasticizers is more or less same as explained earlier in case of ordinary plasticizer.
- Only thing is that the super plasticizers are more powerful as dispersing agents and they are high range water reducers.
- They are called High Range Water Reducers in American literature. It is the use of super plasticizer

which has made it possible to use w/c as low as 0.25 or even lower and yet to make flowing concrete to obtain strength of the order 120 MPa or more.

- It is the use of super plasticizer which has made it possible to use fly ash, slag and particularly silica fume to make high performance concrete. Superplasticizers can produce:

➢ At the same w/c ratio much more workable concrete than the plain ones,

➢ For the same workability, it permits the use of lower w/c ratio,

➢ As a consequence of increased strength with lower w/c ratio, it also permits a reduction of cement content.

- The superplasticizers also produce a homogeneous, cohesive concrete generally without any tendency for segregation and bleeding.

Classification of Superplasticizer:

Following are a few polymers which are commonly used as base for superplasticizers.

➢ Sulphonatedmalanie-formaldehyde condensates (SMF)

➢ Sulphonated naphthalene-formaldehydecondensates (SNF)

➢ Modified lingo sulphonates (MLS)

In addition to the above, in other countries the following new generation superplasticizers are also used.

➢ Acrylic polymer based (AP)

➢ Copolymer of carboxylic acrylic acid with acrylic ester (CAE)

➢ Cross linked acrylic polymer (CLAP)

➢ Polycarboxylate ester (PC)

➢ Multicarboxylatethers (MCE)

➢ Combinations of above.

- The first four categories of products differs Plasticizers and superplasticizers are water based.
- The solid contents can vary to any extent in the products manufactured by different companies. Cost should be based on efficiencies and solid content, but not on volume or weight basis. Generally in projects cost

Effects of Superplasticizers on Fresh Concrete:

- It is to be noted that dramatic improvement in workability is not showing up when plasticizers or superplasticizers are added to very stiff or what is called zero slump concrete at nominal dosages.
- A mix with an initial slump of about 2 to 3 cm can only be fluidized by plasticizers or superplasticizers at nominal dosages. A high dosage is required to fluidity no slump concrete.
- An improvement in slump value can be obtained to the extent of 25 cm or more depending upon the initial slump of the mix, the dosage and cement content

4. Describe in detail about the water proofers(Chemical admixture). Or Brief about the functions and

requirements of water proofing admixtures. (April/May 2019)

- Waterproofing admixtures may be obtained in powder, paste or liquid form and may consist of pore filling or water repellent materials.
- The chief materials in the pore filling class are silicate of soda, aluminium and zinc sulphates and aluminium and calcium chloride. These are chemically active pore fillers.
- In addition they also accelerate the setting time of concrete and thus render the concrete more impervious at early age.
- The chemically inactive pore filling materials are chalk, fuller's earth and talc and these are usually very finely ground.
- Their chief action is to improve the workability and to facilitate the reduction of water for given workability and to make dense concrete which is basically impervious.
- Some materials like soda, potash soaps, calcium soaps, resin, vegetable oils, fats, waxes and coal tar residues are added as water repelling materials in this group of admixtures.
- In some kind of waterproofing admixtures inorganic salts of fatty acids, usually calcium or ammonium stearate or oleate is added along with lime and calcium chloride.
- Calcium or ammonium stearate or oleate will mainly act as water repelling material, lime as pour filling material and calcium chloride accelerates the early strength development and helps in efficient curing of concrete all of which contribute towards making impervious concrete.
- Some type of waterproofing admixtures may contain butyl stearate, the action of which is similar to soaps, but it does not give frothing action.
- Butyl stearate is superior to soap as water repellent material in concrete.
- Heavy mineral oil free from fatty or vegetable oil has been proved to be effective in rendering the concrete waterproof.
- The use of Asphalt Cut-back oils have been tried in quantities of 2 1/2, 5 and 10 per cent by weight of cement. Strength and workability of the concrete was not seriously affected.
- Production of concrete of low permeability depends to a great extent on successful uniform placing of the material.
- An agent which improves the plasticity of a given mixture without causing deleterious effects or which limits bleeding and thereby reduces the number of large voids, might also be classified as a permeability reducing admixture.
- Air entraining agents may also be considered under this, since they increase workability and plasticity of concrete and help to reduce water content and bleeding.
- An air entrained concrete has lower absorption and capillarity till such time the air content do not exceed about 6 per cent.
- Among many other aspects, the w/c ratio used in the concrete, the compaction, curing of concrete, the

admixture used to reduce the w/c ratio, the heat of hydration, the micro-cracking of concrete and many other facets influence the structure of hardened cement paste and concrete, which will have direct bearing on permeability, damp-proofing and waterproofing.

5. Explain in detail about the GGBS and Metakaoline? (April/May 2019)

Metakaolin

- Considerable research has been done on natural pozzolans, namely on thermally activated ordinary clay and kaolinitic clay.
- These unpurified materials have often been called ―Metakaolin�. Although it showed certain amount of pozzolanic properties, they are not highly reactive.
- Highly reactive metakaolin is made by water processing to remove unreactive impurities to make 100% reactive pozzolanic.
- Such a product, white or cream in colour, purified, thermally activated is called High Reactive Metakaolin (HRM).
- High reactive metakaolin shows high pozzolanic reactivity and reduction in Ca(OH)2 even as early as one day. It is also observed that the cement paste undergoes distinct densification. The improvement offered by this densification includes an increase in strength and decrease in permeability.
- The high reactive metakaolin is having the potential to compete with silica fume. Metakaolin is not a byproduct as any other pozzolanic material it is a specially manufactured material with definite properties.

Ground Granulated Blast Furnace Slag (GGBS) (April/May 2019)

- Ground granulated blast-furnace slag is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases.
- The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material.
- The granulated material when further ground to less than 45 micron will have specific surface of about 400 to 600 m^2 / kg. The chemical composition of Blast Furnace Slag (BFS) is similar to that of cement clinker.
- The blast furnace slag is mainly used in India for manufacturing slag cement. There are two methods for making Blast Furnace Slag Cement.
- In the first method blast furnace slag is interground with cement clinker along with gypsum. In the second method blast furnace slag is separately ground and then mixed with the cement.
- Clinker is hydraulically more active than slag. It follows then that slag should be ground finer than clinker, in order to fully develop its hydraulic potential.
- Inter-grinding seriously restricts the flexibility to optimize slag level for different uses.
- The hydraulic potential of both the constituent's clinker and slag can be fully exploited if they are ground separately.
- The level of fineness can be controlled with respect to activity, which will result in energy saving.

- The present trend is towards separate grinding of slag and clinker to different levels.
- Fly ash is used as an admixture in making concrete Ground Granulated Blast-furnace Slag popularly called GGBS is used as an admixture in making concrete.
- In other countries its use as an admixture is more common than its use as slag cement.

6. What is fly ash and explain the importance and uses.(April/May 2019)

- Fly ash is finely divided residue resulting from the combustion of powdered Coal and transported by the flue gases and collected by electrostatic precipitator.
- In U.K. it isreferredaspulverised fuel ash (PFA).Fly ash is the most widely used pozzolanic material all overtheworld.
- One of the well known engineers, E.A.Abdun-Nur has said the following in 1984."In the real world of modern concrete, fly ash is as essential an ingredient of the mixturesarePortland cement, aggregate, water and chemical admixtures.
- In most concretes, I useit in largeramounts (by volume) thanPortland cement, and therefore it is not an admixture. An addition to the mixture. Concrete without fly ash and chemical admixture should onlybefound in museum showcases."
- Fly ash was first used in large scale in the construction of Hungry Horse Dam in America in the year 1948 in the approximate amount of 30 percent by weight of cement.
- Later on it was used in Canyon and Ferry dam’s etc. In India, Fly ash was used in Rihand dam construction replacing cement upto about 15 percent.In the recent time.
- The importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete particularly for making high strength and high performance concrete. Extensive research has been done all over the world on the benefits that could be accrued in the utilisation of fly ash as a supplementary cementitious material. High volume fly ash concrete is a subject of current interest all over the world.
- The use of fly ash as concrete admixture not only extends technical advantages to properties of concrete but also contributes to the environmental pollution control.
- In India alone we produce more than about 100 million tons of fly ash per year; the disposal of which has become a serious environmental problem.
- The effective utilization of fly ash in concretemaking is therefore.Attracting serious considerations of concrete technologist’sa governmentdepartments Secondlycement is the backbone for global infrastructural development.
- It was estimate that global consumption of cement is about 2.2 billion tonnes in 2005. Production of every tone of cement emits carbon dioxide to the tune of about 0.87 tonne.

- Expressing it in another Way, it can be said that 7% of the world's carbon dioxide emission is attributable to Portland cement industry.
- Because of the significant contribution to the environmental pollution and to the high consumption of natural resources like limestone etc. we cannot go on produce more and more cement. There is a need to economise the use of cement. One of the practical solutions to economise cement is to replace cement with supplementary cementitious material like fly ash and slag.
- In India the total production of fly ash is more than 100 million tons. Fly ash is only about 20% of the production. Therefore the use of fly ash mustpopularize for more than one reason.

6. Discuss the effects of adding fly ash, silica fume and GGBFS in concrete (Mineral Admixtures). (Nov/Dec 2016, 2017) (May/June 2016)(April/May 2017, 2018)(Nov/Dec 2019)

Fly ash

- The most important benefit is reduced permeability to water and aggressive chemicals. Properly cured concrete made with fly ash creates a denser product because the size of the pores is reduced.
- This increases strength and reduces permeability. The use of fly ash can result in better workability, pumpability, cohesiveness, finish, ultimate strength, and durability.
- The fine particles in fly ash help to reduce bleeding and segregation and improve pumpability and finishing, especially in lean mixes.

Silica fume

- Workability: With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition.
- Although the slump decreases, the mix remains highly cohesive.
- Segregation and bleeding: Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases.
- Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

GGBS

- GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials.
- Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.
- Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement,

depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions.

- This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.
- Use of GGBS significantly reduces the risk of damages caused by alkali silica reaction (ASR), provides higher resistance to chloride ingress reducing the risk of reinforcement corrosion and provides higher resistance to attacks by sulphate and other chemicals.

7. What are the Factors Affecting Air Entraining Admixtures?(May/June 2016)

- The first and the main factor is the time which it took during mixing with concrete. If mixing with concrete takes longer time then as we know hydration starts at the same time when water mix up with cement.
- So if longer mixing time then this air entrains will not being entrained in hydrated product and then in severe condition there is not protection for that particular part.
- Amount of fine aggregates is the 2nd major factor which influences the amount air entrained.
- If amount of fine aggregates is higher than empty spaces in concrete will be less available and this reduces the amount of air entrained during mixing.
- If this happens then against frost action, protection will be less. If amount of sand is higher than in the same proportion will be the amount of air entrained, because we know sand is a cohesion free material.
- Temperature also affects the amount of air entrained in concrete. If temperature is higher than less will the amount of air entrained in fresh concrete.
- Slump value also has a positive effect on amount of air entrained. If value of slump will be higher than air content will be more as compared to normal slump value.
- If vibration is produced during mixing for better solution than this vibration removes air bubbles from fresh concrete and decreases the resistance against frost action.
- The air-void system created by using air-entraining agents in concrete is also influenced by concrete materials and construction practice.
- Concrete materials such as cement, sand, aggregates and other admixtures play an important role in maintaining the air-void system in concrete.
- Fine aggregate serves as a three-dimensional screen and traps the air; the more median sand there is in the total aggregate, the greater the air content of the concrete.
- Gradation has more influence in leaner mixes. Median sand ranging from the No. 30 sieve to the No. 100 is the most effective at entraining air.
- Excessive fines, minus No. 100 material, cause a reduction in air entrainment.

- Because the use of chemical and mineral admixtures in addition to air-entraining agents has become common practice, concrete users are always concerned about the effects of these admixtures on the air-void system and durability of concrete.
- When lignosulfonate water reducers are used, less air-entraining agent is required because the lignosulfonate have a moderate air-entraining capacity, although alone they do not react as air-entraining agents.
- For a fixed amount of air-entraining agent, the effect of added calcium chloride is to slightly increase the air content.
- The effect is more pronounced as amounts greater than 1% of the weight of cement is used. Some HRWR (superplasticizers) interact with cements and air-entraining agents, resulting in reductions in specific surfaces and increases in air-void spacing factors.
- Mineral admixtures such as fly ash and silica fume also affect the formation of void systems in concrete.
- Temperature can also have a significant effect on air entrainment. Air entrainment varies inversely with temperature. The same mix will entrain more air at 50 F (10C) than at 100F (38C).
- Air Content Control. Measurement of air content is an important checking "sensor" for the concrete user to know whether concrete will resist freeze-thaw damage.
- Because average void spacing decreases as air content increases, an "optimum" air content at which void spacing will prevent the development of excessive pressure due to freezing and thawing will exist.
- It is important to check the air content of fresh concrete regularly for control purposes. Air content should be tested not only at the mixer but also at the point of discharge into the forms, because of losses of air entrainment due to handling and transportation.

8. Explain in detail about the fly ash. (Nov/Dec 2017)(April/May 2019)

- Fly ash is a fine powder which is a byproduct from burning pulverized coal in electric generation power plants.
- Fly ash is a pozzolanic, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement.
- The fly ash produced by coal-fired power plants provide an excellent prime material used in blended cement, mosaic tiles, and hollow blocks among others.
- Fly ash can be an expensive replacement for Portland cement in concrete although using it improves strength, segregation, and ease of pumping concrete.
- The rate of substitution typically specified is 1 to 1 ½ pounds of fly ash to 1 pound of cement. Nonetheless, the amount of fine aggregate should be reduced to accommodate fly ash additional volume.

Fly Ash Types

- Currently, more than 50 percent of the concrete placed in the U.S. contains fly ash.
- Dosage rates vary depending on the type of fly ash and its reactivity level.
- Typically, Class F fly ash is used at dosages of 15 to 25 percent by mass of cementitious material, and Class C fly ash at 15 to 40 percent.
- Class F fly ash, with particles covered in a kind of melted glass, greatly reduces the risk of expansion due to sulfate attack as may occur in fertilized soils or near coastal areas.
- Class F are generally low-calcium fly ashes with carbon contents less than 5 percent but sometimes as high as 10 percent.
- Class C fly ash is also resistant to expansion from chemical attack, has a higher percentage of calcium oxide, and is more commonly used for structural concrete.
- Class C fly ash is typically composed of high-calcium fly ashes with carbon content less than 2 percent.

Fly Ash Applications

- Fly ash can be used as prime material in blocks, paving or bricks; however, one the most important applications is PCC pavement.
- PCC pavements use a large amount of concrete and substituting fly ash provides significant economic benefits.
- Fly ash has also been used for paving roads and as embankment and mine fills.

Fly Ash Drawbacks

- Slower strength gain.
- Seasonal limitation.
- Increase in air entraining admixtures.
- An increase of salt scaling produced by higher fly ash.

Fly Ash Benefits

- Fly ash can be a cost-effective substitute for Portland cement in some markets.
- In addition, fly ash could be recognized as an environmentally friendly product because it is a byproduct and has low embodied energy.
- It's also is available in two colors, and coloring agents can be added at the job site.
- In addition, fly ash also requires less water thanPortland cement and it is easier to use in cold weather.

Other benefits include:

- Produces various set times.
- Cold weather resistance.
- Higher strength gains, depending on its use.
- Can be used as an admixture.
- Can substitute for Portland cement.
- Considered a non-shrink material.
- Produces denser concrete and a smoother surface with sharper detail.
- Great workability.
- Reduces crack problems, permeability and bleeding
- Reduces heat of hydration.
- Produces lower water/cement ratio for similar slumps when compared to no fly ash mixes.
- Reduces CO2 emissions.

9. Write the benefits of using silica fume in concrete.(April/May 2017, 2019)(Nov/Dec 2019)

Silica Fume

- Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete.
- Because of its chemical and physical properties, it is a very reactive pozzolanic. Concrete containing silica fume can have very high strength and can be very durable.
- Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

1. Reduce of Concrete Permeability

- For provision of a concrete resistant to the most aggressive environment, the most important property is the permeability.
- Lower the ingress of movement of water or chemicals; lower the deterious reactions such as sulphate attack, reinforcement corrosion.
- The reaction between Silica Fume and the calcium hydroxide, released as the cement hydrates, provides a dense impermeable pore structure.
- Although the total porosity of the Silica Fume concrete is similar to the OPC concrete the average pore size is much finer, conducting to a large reduction of permeability.

2. Improvement of concrete mechanical Performances

- The Silica Fume reacts with the cement paste to form additional strong Calcium Silicate Hydrate (CSH) providing higher strength.
- Silica Fume reduces bleeding and enhances the cement paste bond to the aggregates. Thanks to its pozzolanic effect (reaction with $Ca(OH)_2$), and therefore to the strength improvement, Silica Fume can be used to reduce to the cement content of the mix.
- In addition of the cost saving benefit, this will reduce the total heat of hydration and can improve the performances of the concrete in terms of chemical resistance.

3. Improvement of Concrete Sulfate resistance

- Prior to develop the advantages of using Silica Fume to improve the concrete sulfate resistance, it may be interesting to highlight the basics form of sulfate attacks and the properties of sulfate resisting cement.
- The use and deterioration of concrete in environments containing sulfates has led to the development of special sulfate resisting cements.
- It has also spawned significant research into the use of supplementary cementitious materials to improve sulphate resistance.
- The utility of Silica Fume for enhancing the resistance of concrete to sulfate attack has been widely studied. Sulphate resisting cements have a low C_3A content to minimize the risk off sulfate attack.
- However, this does not necessarily provide immunity:as certain sulphate reacts with hydrated lime and the calcium silicate hydrates the sulfate resisting cement provide less protection than expected.
- Low C_3A cements are more susceptible to reinforcement corrosion attack.

The basic forms of sulfate attack are the following:

- The reactive aluminates in the cement will react with the gypsum in cement during hydration.
- If the quantity of reactive aluminates in the cement is too high, then their hydrate form will be available to react with 72sulphates after the cement has hardened. This will produce expansive ettringite and cracking of the concrete.

Aluminate Hydrate + Calcium Hydroxide + sulfate + water =>Ettringite

The second principle cause attack is the acid interaction of sulfates ions and calcium hydroxide, causing gypsum formation.

Calcium Hydroxide + sulfate + water => Gypsum

- It has been shown that the cation (calcium, Magnesium, Aluminium, Ammonium) of the sulfate salt affects the type and the severity of the attack.

4. Improvement of Reinforcement Corrosion Protection

- In a marine structure, the performances of the concrete in terms of sulfate resistance must be taken into consideration for concrete design but the resistance to chlorides diffusion through the concrete is generally a main concern as well.
- Type 1 cements (with high C3A content) blended with Silica Fume used in combination with a high range water reducer provide high durable performance against chloride-induced reinforcement corrosion and against sulfate attack.

The main reasons of this result can be summarize as follows:

- Silica Fume reduces the permeability of the concrete. Water and chemicals ingress are thus reduced.
- The ability of high C3A cement to complex with chlorides results in the formation of insoluble compound, able to reduce the mobility of free chloride ion to the reinforcement-concrete surface.

10. Explain in detail about the GGBFS.(Nov/Dec 2017) (April/May 2019)

- The ground granulated blast furnace slag (GGBFS) is a by-product of iron manufacturing which when added to concrete improves its properties such as workability, strength and durability.
- This material is obtained by the heating of iron ore, limestone and coke at a temperature about 1500 degree Celsius. The process is carried out in a blast furnace.
- The formation of GGBFS is not direct. The by-product of iron manufacturing is a molten slag and molten iron. The molten slag consists of alumina and silica, also with the certain amount of oxides.
- This slag is later granulated by cooling it. For this, it is allowed to pass through a high-pressure water get. This result in quenching of the particles which results in granules of size lesser than 5mm in diameter.
- The main constituents of blast furnace slag are CaO, SiO2, Al2O3 and MgO. These are the minerals that are found in most of the cementitious substances.
- The particles are further dried and ground in a rotating ball mill to form a fine powder, known as ground granulated blast furnace slag cement. Now different methods can be employed to perform the main process called as the quenching.
- Based on what method is employed, it can be known as palletized slag, foamed or expanded slag, GGBFS or air-cooled blast furnace slag (ACBFS).

<u>Composition of Ground Granulated Blast Furnace Slag (GGBFS)</u>

The difference in mineralogical composition in GGBFS compared to Portland cement is shown in the table below.

Mineral	**GGBFS**	**Portland Cement**

CaO	30-50%	55-66%
SiO_2	28-40%	20-24%
Al_2O_3	8-24%	0-8%
MgO	1-18%	5%

- Another significant difference in GGBFS is that some of the metals within it have not undergone complete oxidation. This change will be reflected in the structural formation in concrete when compared with Portland cement.
- From the above two differences in composition compared with the Portland cement, would show changes in the hydration reaction as well as the hydration products that are given GGBFS.

Physical Properties of Ground Granulated Blast Furnace Slag (GGBFS)

- Ground granulated blast furnace slag has a color nearly white in appearance.
- Hence the use of GGBFS in concrete manufacture would give a light and brighter color to concrete unlike the dark grey color of ordinary cement concrete structures. This is an added advantage of GGBFS in terms of aesthetics.

The typical properties of GGBS

Physical properties of GGBFS

Property	**Value**
Physical Form	Off white powder
Bulk density (kg/m^3)	1200
Specific Gravity	2.9
Specific surface (m^2/kg)	425 – 470

Particle Size Distribution of Ground Granulated Blast Furnace Slag

- It is observed that the particle size of GGBFS varies with the grinding techniques used during its manufacture.

- It is also observed that the product from ball mill has wide particles and narrow particles for the one grounded in airflow mill. Those grounded in vibro-mill have spherical shaped particles.

Using GGBFS cement

- In the concrete manufacturing plant, the GGBFS can be added along with the Portland cement, water and aggregates. The normal ratio of the mixture remains the same.
- The GGBFS can be replaced from 30 to 85 % of the cement weight. Most of the instances we replace 40 to 50%.

Advantages of GGBFS in concrete

The incorporation of ground granulated blast furnace slag in concrete manufacture gains many advantages which are mentioned below:

- GGBFS in concrete increases the strength and durability of the concrete structure.
- It reduces voids in concrete hence reducing permeability
- GGBFS gives a workable mix.
- It possesses good pumpable and compaction characteristics
- The structure made of GGBFS constituents help in increasing sulphate attack resistance.
- The penetration of chloride can be decreased.
- The heat of hydration is less compared to conventional mix hydration.
- The alkali-silica reaction is resisted highly.
- These make the concrete more chemically stable
- Gives good surface finish and improves aesthetics
- The color is more even and light.
- Lower chances of efflorescence
- The maintenance and repair cost of structures are reduced thus increasing the life cycle of concrete structures.
- Unlike cement, GGBFS does not produce carbon dioxide, sulphur dioxide or nitrogen oxides.
- It is found that working with GGBFS is easy as it has greater mobility characteristics. This is due to its fineness and the particle shape of the GGBFS particles. These also possess a lower relative density.
- The GGBFS particles have a very glassy texture that makes them increase the workability. This can help in reduction of water as well as Superplasticizers to get adequate workability in common situations.
- They also have fewer chances to get segregated during handling as well as pumping of the material. Pumping is facilitated by the lower relative density and flowing ability of the mix, that is owned by GGBFS.
- The usage of GGBFS in concrete provides a certain unique feature that differs from the ordinary Portland cement concrete. The concrete made from GGBFS sets slowly when compared to ordinary Portland cement mix.

- More the GGBFS amount more will be the time taken for its setting. But the strength is gained with time. This slow setting would help in the formation of cold joints. But the situations where faster setting time is required cannot go for this replacement.
- The GGBS composition stays plastic for a longer period that would help in making a smoother finish for the contractor.
- The sustainability factor of GGBFS is proved from the above-mentioned advantages. The product itself is a by-product that is used for a greater recognition. The reduction of carbon dioxide in the structure makes them more sustainable.

Effects of GGBS on fresh concrete

- ❖ The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump.
- ❖ Thisreduction of unit water content will be more pronounced with increase in slag content and also on the fineness of slag.
- ❖ This is because of the surface configuration and particle shape ofslag being different than cement particle.
- ❖ In addition, waterused for mixing is not immediately lost, as the surface hydration of slag is slightly slower than that of cement.
- ❖ Reduction of bleeding is not significant with slag of4000 cm^2/g fineness.
- ❖ But significant beneficial effect is observed with slag fineness of 6000 cm^2/g and above.

Effects of GGBS on hardened concrete

The use of slag leads to the enhancement of intrinsic properties of concrete in both fresh and hardened conditions.The major advantages recognized are:

- ❖ Reduced heat of hydration
- ❖ Refinement of pore structures
- ❖ Reduced permeability to the external agencies
- ❖ Increased resistance to chemical attack

11. Describe the role of accelerators in concrete with its advantages and disadvantages. (Nov/Dec 2019)

Refer Q.No:2

Accelerating Admixtures: Advantages

- ➢ Shortens the setting time of cement and therefore increases the rate of gain of strength.
- ➢ Enables earlier release from precast moulds thus speeding production.
- ➢ Reduces segregation and increase density and compressive strength.
- ➢ Cures concrete faster and therefore uniform curing in winter and summer can be achieved.
- ➢ Reduces water requirements, bleeding, shrinkage and time required for initial set.

Accelerating Admixtures: Disadvantages

- It has increased drying shrinkage.
- It offers reduced resistance to sulphate attack.
- CaCl2 high risk of corrosion of steel – not permitted in reinforced **concrete**.
- It is more expensive and less effective.

PART A

1. **Define proportioning of concrete mix. (April/May 2019) (Nov/Dec 2019)**
   - Proportioning of concrete mix is defined as the art of obtaining a suitable ratio of the various ingredients of concrete with the required properties at the lowest cost.
2. **What are the factors affecting mix proportioning?**
   - Environmental exposure conditions
   - Grades of concrete
   - Type of cement
   - Type and size of aggregates
   - Nominal maximum size of aggregates
   - Maximum and minimum cement content
   - Maximum free water cement ratio by weight
   - Degree of workability
   - Air entrained agent
   - Types of admixtures used if any
   - Maximum/ minimum density of concrete
   - Maximum/ minimum temperature of fresh concrete
   - Type of curing and mixing
   - Source of water
3. **Write any four methods of proportioning. (Nov/Dec 2016)**
   - Arbitrary Method
   - Fineness Modulus Method
   - Minimum Void Method
   - Maximum Density Method
   - Water cement Ratio Method
4. What are the factors to be considered in the choice of mix proportioning?

   The mix proportion of concrete mix may be based on the following factors:
   - Grade designation
   - Type of cement
   - Maximum nominal size of aggregates
   - Minimum water-cement ratio
   - Workability
   - Minimum cement content.
5. **Define Concrete mix design.**
   - Mix design can be defined as the process of selectingsuitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

6. What are the basic assumptions made in design of concrete mixes?

- The compressive strength of concrete is governed by its water-cement ratio.
- For a given aggregate characteristics, the workability ofconcrete is governed by its water content.

7. What are the advantages of concrete mix design? (Nov/Dec 2013)

- Best use of available materials.
- It has desired concrete properties.
- It saves up to 15% of cement for M20 grade of concrete.
- It produces good quality concrete.

8. What are the disadvantages of concrete mix design? (Apr/May 2010)

- If we made any material replacement this design methodology can't able to adopt.
- The effects of climate changes are not considered.

9. What are most important properties of concrete on whichevery concrete technologist should have familiarization?

Every concrete technologist should familiarize themselves withthe most important properties of concrete:

- Workability
- Durability
- Strength
- Volume change
- Air entrainment
- Density

10. What are the factors that affect the workability ofconcrete?(Nov/Dec 2011)

The factors that affect the workability of concrete are:

- Size distribution of the aggregate,shape of the aggregate particles,
- Gradation and relative proportions of the fine and coarseaggregate,
- Plasticity,
- Cohesiveness, and
- Consistency of the mix.

11. Mention some of the physical properties of materials required for mix design.

- Strength / grade of cement
- Initial and final setting time of cement
- Gradation of fine aggregates
- Specific gravity of fine aggregates
- Silt content by weight
- Maximum size of coarse aggregate
- Grading of coarse aggregate
- Shape of coarse aggregate
- Strength of coarse aggregate
- Aggregate absorption

12. What are the ways in which concrete mix can be designed?

A mix design can be designed in two ways as below:

- Nominal mix

- Design mix

13. Mention the types of Concrete Mixes. (Nov/Dec 2019)

- Nominal Mixes
- Standard mixes
- Designed Mixes

14. What is nominal mix?

- In this type of mix, all the ingredients are prescribed and their proportions are specified.
- It is used for relatively unimportant and simpler concrete works. Therefore there is scope for any deviation by the designer.
- Nominal mix concrete is used for concrete of M20 or lower.

15. What is design mix?(Apr/May 2010, Nov/Dec 2011)

- The concrete mix produced under quality control by considering the strength, durability and workability is called design mix.
- Design mix concrete is used for concrete above M20.

16. Define Standard Mix.(Apr/May 2013)

- Standard mix is defined as concrete mixed in the proportions of 1 part of cement, 2 parts of Fine aggregate and 4 parts of coarse aggregate.

17. Distinguish between Design mix and Nominal mix.(May/June 2016) (Nov/Dec 2017, 2019) (April/May 2018, 2019)

Design Mix	Nominal Mix
The concrete mix produced under quality control by considering the strength, durability and workability is called design mix.	In this type of mix, all the ingredients are prescribed and their proportions are specified.
Design mix has weigh batching	Nominal Mix has volumetric batching

18. What are the four variables which influence concrete mix design, in general?(April/May 2018, 2019)

- Water/cement ratio
- Cement content
- Relative proportion of fine and coarse aggregates
- Use of admixtures

19. What are the objectives of mix design?(May/June 2016)

- The basic objective of concrete mix design is to find the most economical proportions.
- To achieve the desired end results strength, cohesion, workability, and durability.

20. Why honeycombingisto beprevented?

- It is essential that freshly mixed concrete should be eliminatedfrom air pockets and secured maximumdensity in the structure.
- The Engineer must prevent theoccurrence of loosely textured or porous concrete matrix, which iscalled "honeycombing" to achieve maximum strength anddensity.

21. What is the principal reason for entraining air inconcrete?

- The principal reason for entraining air in concrete is to increaseresistance to the destructive effects of freezing and thawingand melting salts.
- The entrainment of air also increases theworkability of the concrete for placement purposes andpermits a reduction in the sand and water contents of the mix.

22. What are the factors that contribute to the concretedensity?

The factors that contribute to density for all types of concreteare:

- Use of well-graded aggregate of the largest possible maximumsize.
- Minimum water content consistent with good workability.
- Minimum air content consistent with adequate durability.
- Thorough consolidation during placement.

23. What are the factors affect the properties of concrete?(Apr/May 2010)

There are various factors which affect the properties ofconcrete:

- The quality and quantity of cement water and aggregates
- Batching
- Transportation
- Placing
- Compaction
- Curing

24. Mention some of the methods of mix design.

- Arbitrary proportion
- Fineness modulus method
- Maximum density method
- Surface area method
- Indian Road Congress, IRC 44 method
- High strength concrete mix design
- Mix design based on flexural strength
- Road note No .4 (Grading curve method)
- ACI Committee 211 method
- Department of Environment method (DoE method)
- Mix design for pumpable concrete
- Indian Standard recommended method (BIS method)

25. Which methods of mix design are commonly used?

- ACI Committee 211 method.
- Department of Environment method (DOE method).
- Indian Standard recommended method (BIS method) is commonly used.

26. Mention the basic steps in the mix design.

- To find the target mean strength.
- To determine the curve of cement based on its strength.
- To determine water/cement ratio.
- To determine cement content.
- To determine fine aggregate proportions
- To determine coarse aggregate proportions

27. What are the variable factors to be considered in connection with specifying a concrete mix?

- Water cement ratio
- Cement content or cement – aggregate ratio
- Gradation of the aggregates
- Consistency

28. Define statistical quality control.

- Statistical quality control refers to the use of statistical method in the monitoring and maintaining of the quality of products and services.

29. What are the common terminologies used in the statistical quality control?

- Mean strength

- Variance
- Standard deviation
- Coefficient of variation

30. How will you calculate the standard deviation?

It is the root mean square deviation of all the results. This is denoted by σ.

$$\sigma = \sqrt{\sum \frac{(X-\overline{X})^2}{\sqrt{n-1}}}$$

Where

σ-Standard deviation,

n-Number of observations,

X -particular value of observations

$\bar{X}$-arithmetic mean

31. What are the requirements of concrete mix design?

The requirements which form the basis of selection andproportioning of mix ingredients are:

- The minimum compressive strength required fromstructural consideration.
- The adequate workability necessary for full compactionwith the compacting equipment available.
- Maximum water-cement ratio and/or maximum cementcontent to give adequate durability for the particular siteconditions.
- Maximum cement content to avoid shrinkage cracking dueto temperature cycle in mass concrete.

32. List out the advantages of Design mix. (Nov/Dec 2013)

- Properties of all materials are used.
- Cement content is low and hence the mix design is economical.

33. List out the disadvantages of nominal mix. (Apr/May 2013)

- Nominal mix does not say which type of sand, cement, aggregate to be used.
- High cement is required which leads to high cost.

34. What are the data used for ACI? (Nov/Dec 2011)

- Fineness modulus
- Unit weight of dry rodded coarse aggregate
- Specific gravity of cement, coarse and fine aggregate
- Absorption characteristic of coarse and fine aggregate

35. What is meant by grading of aggregates?

- Grading of aggregate means particle size distribution of the aggregate.
- If all the particle of an aggregate were of one size, more voids will be left on the aggregate mass.
- Properly graded aggregate produces dense concrete and needs smaller quantities of fine aggregate and cement.
- Grading determines the workability of the mix, which controls segregation, bleeding, water-cement ratio, handling, placing, and other characteristics of the mix.

36. On what circumstances high grade concretes are utilized effectively? (Nov/Dec 2016, April/May 2017)

- To open early traffic on concrete pavements (as low as 3 days).
- To satisfied specific needs of special applications such as durability, modulus of elasticity and tensile strength. Example: dams, marine foundations, heavy industrial floor etc.
- HSC reduces column and beam dimensions in a building. Lower dead loads results in reducing the loads results in reducing the loads associated with foundations.
- HSC reduce slab depth and therefore a building's overall height.
- HSC are used in precast elements and concrete element requiring post tensioning.

37. Write any four grades of cement concrete. (April/May 2017)

- M10
- M15
- M20
- M25
- M30

38. What is the minimum grade of concrete to be used as per IS 456-2000?

IS 456-2000 has recommended that minimum grade of concrete shall be not less than M-20 in reinforced concrete work.

39. Define the terms: Standard deviation and Coefficient of variation. (April/May 2019)

Standard deviation (S)for **concrete**, the target mean strength is calculated as the sum of characteristic strength of **concrete** and 1.65 times the **standard deviation** of the sample.

Coefficient of variation (V) - the sample standard deviation expressed as a percentage of the average strength is called the coefficient of variation.

40. Calculate the cement and water content for M335 design mix as per IS specifications. (Nov/Dec 2019)

Given data:

Grade of Concrete: M35

Characteristic Strength (Fck) : 35 Mpa

Standard Deviation: 1.91 Mpa*

Target Mean Strength: T.M.S.=Fck +1.65 x S.D.

(From I.S 456-2000) = 35+ 1.65×1.91= 38.15 Mpa

Solution:

Select Water Cement Ratio = 0.43 for concrete grade M35
(From Fig 2. of I.S. 10262- 1982)

Select Water Content = 172 Kg

(From IS: 10262 for 20 mm nominal size of aggregates Maximum Water Content = 186 Kg/ $M^{3)}$

Hence, Cement Content= 172 / 0.43 = 400 Kg / M^3

PART – B & C

1. Write short note on principles of concrete mix design and what are the factors consider in mix design? (Nov/Dec 2017)

CONCRETE MIX DESIGN

- Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

The selection and proportioning of materials depend on:

- The structural requirements of the concrete
- The environment to which the structure will be exposed
- The job site conditions especially the methods of concrete
  - Production
  - Transport
  - Placement
  - Compaction
  - Finishing,
- The characteristics of the available raw materials.

PRINCIPLES OF CONCRETE MIX DESIGN

- Estimating the required batch weights for the concreteinvolves whetherbased on a series of trial mixes, computer simulations, soundrule of thumb advice or a combination of all three.
- The following parameters need to be specified in design for a particularpurpose; maximum water-cement (w/c) ratio, minimum cementcontent, air content, slump, maximum size of aggregate, andstrength requirement.
- An essential part of mix design is to minimizevoids in concrete.
- Therefore, the principle of design of concrete mixesinvolves determination of the proportions of the given constituents,namely, cement, water, fine and coarse aggregates andadmixtures which would produce concrete possessingspecified properties both in the fresh and hardened states withthe maximum overall economy.
- Workability isthe important property of concretein the fresh state and compressive strength and durability are important for hardened state.
- The mix design iscarriedout for a particular compressive strength of concrete with adequateworkability so that fresh concrete can be properly placed andcompacted, and to achieve the required durability.

The following basic assumptions are made in design of plasticconcrete mixes of medium strength:

- The compressive strength of concrete is governed by itswater-cement ratio, andfor a given aggregate characteristics, the workability ofconcrete is governed by its water content.

FACTORS IN THE CHOICE OF MIX PROPORTIONING

The mix proportion of concrete mix is based on thefollowing factors:

- Grade designation,
- Type of cement,
- Maximum nominal size of aggregates,
- Minimum water-cement ratio,
- Workability, and
- Minimum cement content.

2. What are the Factors affecting the proportioning of concrete mix? (May/June 2016) (Nov/Dec 2019)

The various factors affecting the mix design are:

Compressive strength

- It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete.
- The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix.
- The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction.
- According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

Workability

- The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used.
- For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort.
- This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

Durability

- The durability of concrete is its resistance to the aggressive environmental conditions.
- High strength concrete is generally more durable than low strength concrete.
- In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

Maximum nominal size of aggregate

- In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate.
- However, the compressive strength tends to increase with the decrease in size of aggregate.
- IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

Grading and type of aggregate

- The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio.
- Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.
- The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio.
- An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

Quality Control

- The degree of control can be estimated statistically by the variations in test results.
- The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing.
- The lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required.
- The factor controlling this difference is termed as quality control.

3. Explain briefly about the nominal mix and design mix?

NOMINAL MIX AND DESIGN MIX

Mix design is a process of selecting suitable ingredientsand determining their relative proportions with the objective ofproducing concrete of having certain minimum workability, strength and durability as economically as possible.

A mix design can be designed in two ways as explainedbelow:

- Nominal mix
- Design mix

Nominal mix

- It is used for relatively unimportant and simpler concreteworks.
- In this type of mix, all the ingredients are prescribed andtheir proportions are specified.
- Therefore there is no scope forany deviation by the designer.
- Nominal mix concrete may beused for concrete of M20 or lower.
- The various ingredients are**taken** as given in the Table

Table 3.1 Various ingredients for nominal mix

Grade	Maximum quantity of dry aggregates per 50 kg of cement	Fine aggregate to Coarse aggregate ratio by mass	Maximum quantity of water in litres
M 5	800	Generally 1:2 but may varies from 1: 1.50 to 1: 2.50	60
M 7.5	625		45
M 10	480		34
M 15	330		32
M 20	250		30

Design mix:

- It is a performance based mix where choice of ingredients and proportioning are left to the designer to be decided.
- The user has to specify only the requirements of concrete in fresh as well as hardened state.
- The requirements in fresh concrete are workability and finishing characteristics, whereas in hardened concrete these are mainly the compressive strength and durability.

4. What are the objectives of mix design and factors affect the properties of concrete?

CONCRETE MIX DESIGN METHODS

- The design of concrete mix is not a simple task on account of the widely varying properties of concrete constituent materials, the conditions that prevail at the site of work, in particular the exposure condition, and the conditions that are demanded for a particular work for which the mix is designed.
- Design of concrete mix requires complete knowledge of various properties of concrete constituent materials, the implications in case of change on the conditions at thesite, the impact of the properties of plastic concrete on the hardened concrete and the complicated inter-relationship between the variables.
- All these make the task of mix design more complex and difficult.

Objective of mix design

- The basic objective of concrete mix design is to find the most economical proportions.
- To achieve the desired end results strength, cohesion, workability, and durability.

As mentioned earlier the proportioning of concrete is based on certain material properties of cement, sand and aggregates. Concrete mix design is basically a process of taking trials with certain proportions.

Factors affect the properties of concrete

There are various factors which affect the properties of concrete:

- The quality and quantity of cement water and aggregates
- Batching

- Transportation
- Placing
- Compaction
- Curing etc.

Therefore, the specific relationships that are used in proportioning concrete mixes should be considered only as the basis for trial, subject to modifications in the light of experience as well as for the particular materials used at the site in each case.

5. What are the methods of mix design and basic steps in mix design?(Nov/Dec 2013)

Methods of mix design

- Methods have been developed to arrive at the proportions in a scientific manner.
- No mix design method directly gives the exact proportions that will most economically achieve end results.
- The methods are only serve as a base to start and achieve the end results in the fewest possible trials.

The code of practice for mix design IS: 10262 clearly states following:

- The basic assumption made in mix design is that the compressive strength of workable concretes, by and large, governed by the water/cement ratio.
- Another most convenient relationship applicable to normal concrete is that for a given type, shape, size and grading of aggregates, the amount of water determines its workability.

Different mix design methods helps to arrive at the trial mix that will give required strength, workability, cohesion etc.These mix design methods have same common threads in arriving at proportions but their method of calculation is different. Several of methods of mix proportioning are suggested and followed by many people and some of the methods are mentioned below:

- Arbitrary proportion
- Fineness modulus method
- Maximum density method »
- Surface area method
- Indian Road Congress, IRC 44 method
- High strength concrete mix design
- Mix design based on flexural strength
- Road note No.4 (Grading curve method)
- ACI Committee 211 method
- Department of Environment method (DoE method)
- Mix design for pumpable concrete
- Indian Standard recommended method (BIS method)

Out of the above methods, some of them are not very widely used now days because of some difficulties or drawbacks in the procedures for arriving at the satisfactory proportions. ACI committee method, DoE method and BIS methods are commonly used.

Basic steps in mix design

- To find the target mean strength.
- To determine the curve of cement based on its strength.
- To determine water/cement ratio.

- ❖ To determine cement content.
- ❖ To determine fine aggregate proportions.
- ❖ To determine coarse aggregate proportions.

6. What is all the information required for mix design? (April/May 2019) Refer Code book (IS: 10262)

Information required for mix design or Requirements of concrete mix design. (Nov/Dec 2019)

For the design of concrete mix, the following information is required:

- ✓ Grade of concrete
- ✓ Degree of workability
- ✓ Maximum temperature of fresh concrete
- ✓ Type of cement
- ✓ Minimum cement content
- ✓ Maximum water cement ratio
- ✓ Type of aggregates
- ✓ Maximum nominal size of aggregate
- ✓ Type of admixtures, if required
- ✓ Level of quality assurance
- ✓ Exposure condition
- ✓ Method of placing
- ✓ Degree of supervision

7. Explain the design procedure of ACI method of mix design?

- The ACI Committee mix design method assumes certain basic facts which have been substantiated by field experiments or large works. They are:

(a) The method makes use of the established fact, that over a considerable range of practical proportions, fresh concrete of given slump and containing a reasonably well graded aggregate of given maximum size will have practically a constant total water content regardless of variations in water/cement ratio and cement content, which are necessarily interrelated.

(b) It makes use of the relation that the optimum dry rodded volume of coarse aggregate per unit volume of concrete depends on its maximum size and the fineness modulus of the fine aggregate as indicated in Table 11.4 regardless of shape of particles. The effect of angularity is reflected in the void content, thus angular coarse aggregates require more mortar than rounded coarse aggregate.

(c) Irrespective of the methods of compaction, even after complete compaction is done, a definite percentage of air remains which is inversely proportional to the maximum size of the aggregate.

The following is the procedure of mix design in this method:

(a) Data to be collected:

(i) Fineness modulus of selected F.A.

(ii) Unit weight of dry rodded coarse aggregate.

(iii) Sp. gravity of coarse and fine aggregates in SSD condition

(iv) Absorption characteristics of both coarse and fine aggregates.

(v) Specific gravity of cement.

(b) From the minimum strength specified, estimate the average design strength either by using standard deviation or by using coefficient of variation.

(c) Find the water/cement ratio from the strength point of view. Find also the water/cement ratio from durability point of view. Adopt lower value out of strength consideration and durability consideration.

(d) Decide maximum size of aggregate to be used. Generally for RCC work 20 mm and prestressed concrete 10 mm size are used.

(e) Decide workability in terms of slump for the type of job in hand.

(f) The total water in kg/m^3 of concrete is read from table 11.8 entering the table with the selected slump and selected maximum size of aggregate. Table 11.8 also gives the approximate amount of accidentally entrapped air in non-air-entrained concrete.

(g) Cement content is computed by dividing the total water content by the water/cement ratio.

(h) The bulk volume of dry rodded coarse aggregate per unit volume of concrete is selected, for the particular maximum size of coarse aggregate and fineness modulus of fine aggregate.

(j) The weight of C.A. per cubic meter of concrete is calculated by multiplying the bulk volume with bulk density.

(k) The solid volume of coarse aggregate in one cubic meter of concrete is calculated by knowing the specific gravity of C.A.

(l) Similarly the solid volume of cement, water and volume of air is calculated in one cubic meter of concrete.

(m) The solid volume of sand is computed by subtracting from the total volume of concrete the solid volume of cement, coarse aggregate, water and entrapped air.

(n) Wight of fine aggregate is calculated by multiplying the solid volume of fine aggregate by specific gravity of F.A.

8. Write the step by step procedure of BIS method of mix design. (Apr/May 2018, 2019) (Nov/Dec 2013, 2017, 2019)

BIS method of mix design

- Indian Standard IS 10262:2002 provides the guide lines of proportioning concrete mixes as per the requirements using the concrete making materials including other supplementary materials identified for this purpose.
- The proportioning is carried out to achieve specified characteristics at specified age, work ability of fresh concrete and durability requirements.
- This standard is applicable for ordinary and standard concrete grades only.

Step by step procedure

Step 1.Target mean strength for fix design

In order that not more than the specified proportions of test results are likely to fall below the characteristic strength, the concrete mix has to be proportioned for higher target mean compressive strength (f_{ck}). The margin over characteristic strength is given by the following relation as given in equation 3.1.

$$f'_{ck} = f_{ck} + t x S \qquad ...3.1$$

Where,

f'_{ck} = target average compressive strength at 28 days,

f_{ck}= characteristic compressive strength at 28 days,

t=a statistic, according to IS 456 :2000, the characteristic strength is defined as that value below which not more than 5% (1 in20) results are expected to fall. Therefore, in such case, the value of't' can be taken as 1.65 as per IS 10262, Table 2.

S = standard deviation

If, t = 1.65, then the above equation (3.1) will reduce to equation 3.2.:

$$f'_{ck} = f_{ck} + 1.65\ S \qquad ...3.2$$

Note: Standard deviation for each grade of concrete shall be calculated separately.

Assumed standard deviation

- Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in Table 3.2may be assumed for the proportioning of mix in the first instance.
- As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix proportioned properly.
- However, when adequate past records for a similar grade exist and justify to the designer a value of standard deviation different from thatshown Table 3.2, it shall be permissible to use that value.

Table 3.2 Assumed standard deviation as per IS 456: 2000

Grade of concrete	Assumed standard deviation (N/mm^2)
M10	3.50
M15	
M20	4.00
M25	
M30	5.00
M35	
M40	
M45	
M50	

Step 2 Selection of water / cement ratio

- Different cements, supplementary cementitious materials and aggregates of different maximum size, grading, surface texture, shape and other characteristics may produce concretes of different compressive strength for the same free water-cement ratio.
- Therefore, the relationship between strength and free water-cement ratio should preferably be established for the materials actually to be used.
- In the absence of such data, the preliminary free water-cement ratio (by mass) corresponding to the target strength at 28 days may be selected from the established relationship, if available.
- Otherwise, the water-cement ratio given in Table 5 of IS 456 for respective environment exposure conditions may be used as starting point.

The free water-cement ratio selected according to the above should be checked against the limiting water-cement ratio for the requirements of durability and the lower of the two values adopted. In the absence of such data, the preliminary free water-cement ratio(by mass) corresponding to the target strength at 28 days may be selected from the relationships shown in Figure. 3.1

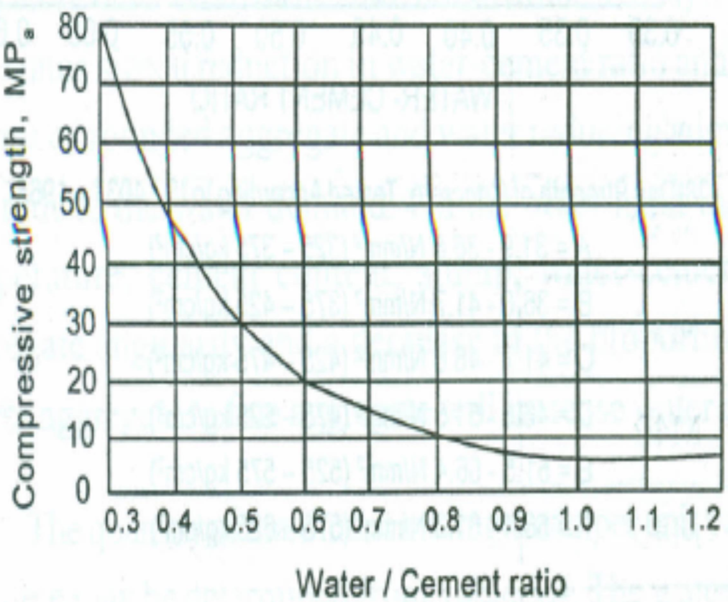


Figure generalized relation between free water cement ratio and compressive strength of concrete

- Alternately, the preliminary free water-cement ratio (by mass) corresponding to the target average strength, may be selected from the relationships shown in Figure. 3.2 using the curve corresponding to the 28 days cement strength to be used for the purpose.

Note: The free water-cement ratio selected should be checked against the limiting water-cement ratio for the durability requirement and the lower of the two values should be adopted.

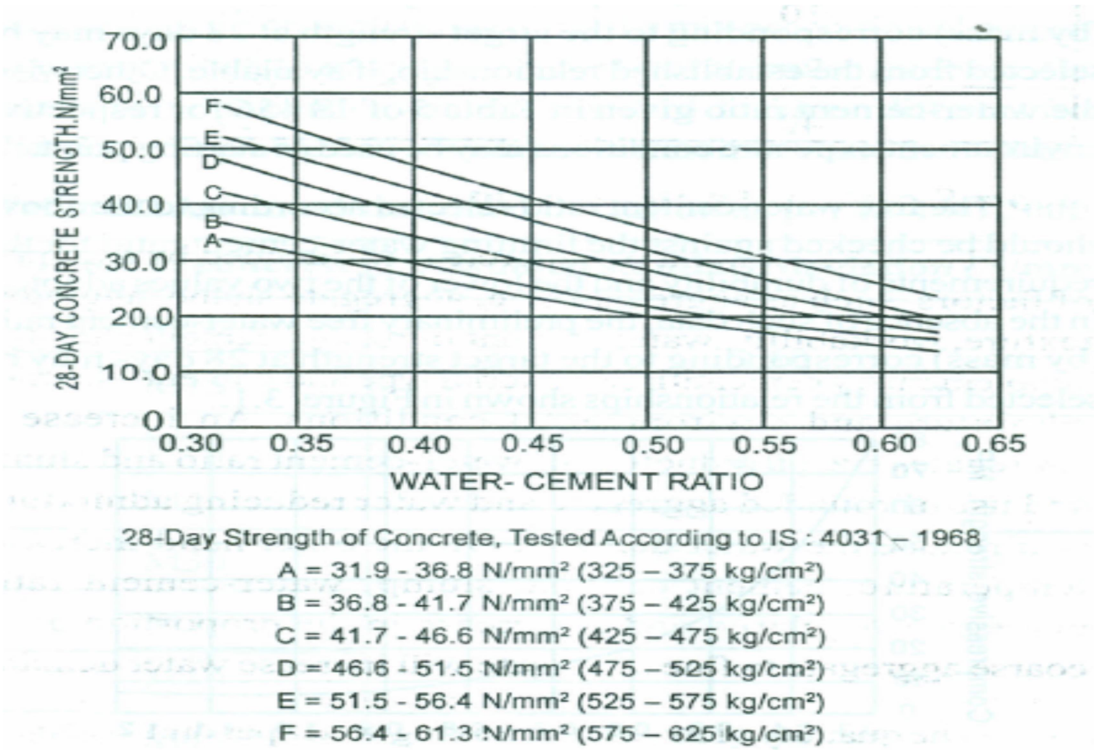


Figure 3.2 Relation between free water-cement ratio and concrete strength for different cement strengths

Step 3. Estimation of entrapped air

Approximate amount of entrapped air to be expected innormal (non-air-entrained) concrete is given in Table 3.3.

Table 3.3 Approximate entrapped air content

Nominal maximum sizeof aggregate	Entrapped air, as % of* volume of concrete
10	3.0
20	2.0
40	1.0

Step 4 Selection of water content

- The water content of concrete is influenced by a number of factors, such as aggregate size, aggregate shape, aggregate texture, workability, water-cement ratio, and cement and other supplementary cementitious material type and content, chemical admixture and environmental conditions.
- An increase in aggregates size, a reduction in water-cement ratio and slump, and use of rounded aggregate and water reducing admixtures will reduce the water demand. On the other hand increased temperature, cement content, slump, water-cement ratio, aggregate angularity and a decrease in the proportion of the coarse aggregate to fine aggregate will increase water demand.
- The quantity of maximum mixing water per unit volume of concrete may be determined from Table 3.4.
- The water content in Table 3.4 is for angular coarse aggregate and for 25 to50 mmslump range.
- The water estimate in Table 3.4 can be reduced by approximately 10 kg for sub-angular aggregates, 20 kg for gravel with some crushed particles and 25 kg for rounded gravel to produce same workability.
- For the desired workability (other than25 to 50 mm slump range), the required water content may be established by trial or an increase by about 3 % for every additional 25mm slump or alternatively by use of chemical admixturesconforming to IS 9103.
- This illustrates the need for trial batch testing of local materials as each aggregate source is different and can influence concrete properties differently.

Water reducing admixtures or super plasticizing admixtures usually decrease water content by5 to 10 % and 20 % and above respectively at appropriate dosages.

Table 3.4 Maximum water content per m^3 of concrete for nominal maximum size of aggregate

Nominal maximum size of aggregate (mm)	Maximum water content (kg) per m^3
10	208
20	186
40	165

Step5. Selection of water content and fine to total aggregate ratio

For the desired workability, the quantity of mixing water per unit volume of concrete and the ratio of fine aggregate to total aggregate by absolute volume are to be estimated from Tables 3.5 or 3.6 as applicable, depending upon the nominal maximum size and type of aggregates.

Table 3.5 Approximate sand and water contents per m³ of concrete for grades up to M35

Nominal maximum size of aggregate (mm)	Water content* per m³ of concrete	Sand as percent of total aggregate by absolute volume
10	208	40
20	186	35
40	165	30

* Water content corresponding to saturated surface dry aggregate

Table 3.6 Approximate sand and water contents per m³ of concrete for grades above M35

Nominal maximum size of aggregate (mm)	Water content* per m³ of concrete	Sand as percent of total aggregate by absolute volume
10	208	40
20	186	35
40	165	30

* Water content corresponding to saturated surface dry aggregate

Table 3.5 is to be used for concrete grade upto M35 is based on the following conditions :

- Crushed (angular) coarse aggregate, conforming to IS:383-1970*,
- Fine aggregate consisting of natural sand conforming tograding zone II of Table 4 of IS: 383-1970*,
- Water-cement ratio of 0.60 (by mass), and
- Workability corresponding to compacting factor of 0.80.

For other conditions of workability, water-cement ratio, grading of fine aggregate, and for rounded aggregates, certain adjustments in the quantity of mixing water and fine to total aggregate ratio given in Tables 3.5 and 3.6 are to be made, according to Table 3.7.

Table 3.6 is to be used for concretes grades above M35and is based on the following conditions:

- ✓ Crushed (angular) coarse aggregate, conforming to IS383:1970,
- ✓ Fine aggregate consisting of natural sand conforming to grading zone II of Table 4 of IS 383:1970,
- ✓ Water - cement ratio of 0.35 (by mass), and
- ✓ Workability corresponding to compactions factor of 0.80.

Table 3.7 Adjustment of values in water content and sand percentage for other conditions

Change in conditions stipulated for Tables 3.5 and 3.6	Adjustment required in	
	Water content	% sand in total aggregate
For sand confirming to grading zone I, III or zone IV of Table 4, IS 383:1970	0	+ 1.5 % for zone I - 1.5 % for zone III - 3 % for zone IV
Increase or decrease in the value of compacting factor by 0.1	± 3 %	0
Each 0.05 increase or decrease in water-cement ratio	0	± 1 %
For rounded aggregate	-15 kg	-7 %

Step6. Calculation of cement content

The cement content per unit volume of concrete may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete (Cement by mass = water content / water cement ratio). The cement content so calculated shall be checked against the minimum cement content for the requirements of durability and the greater of the two values adopted.

Step 7.Calculation of aggregate content

With the quantities of water and cement per unit volume of concrete and the ratio of fine to total aggregate already determined, the total aggregate content per unit volume of concrete may be calculated from the following equations 3.3 and3.4 respectively for fine aggregate and coarse aggregate.

$$V = \left[w + \frac{C}{S_c} + \frac{1}{p} \cdot \frac{f_a}{S_{fa}} \right] \times \frac{1}{1000} \quad \ldots 3.3$$

$$V = \left[w + \frac{C}{S_c} + \frac{1}{1-p} \cdot \frac{C_a}{S_{ca}} \right] \times \frac{1}{1000} \quad \ldots 3.4$$

Where,

V = absolute volume of fresh concrete, which is equal to gross volume (m^3) minus the volume of entrapped air,

W = mass of water (kg) per m^3 of concrete,

C = mass of cement (kg) per m^3 of concrete,

S_c = specific gravity of cement,

p = ratio of fine aggregate to total aggregate by absolute volume,

f = total mass of fine aggregate (kg)per m^3 of concrete,

C = total mass of coarse aggregate (kg) per $m^3$of concrete,

S_{fa}=specific gravity of saturated surface dry fine aggregate,

S_{ca}= specific gravity of saturated surface dry coarse aggregate.

Step8 Combination of different coarse aggregate fractions

The coarse aggregate used should conform to 18383:1970.Coarse aggregates of different sizes should be combined in suitable proportions so as to result in an overall grading conforming to Table 2 of IS 3 83:1970 for the particular nominal maximum size of aggregate.

Step9 Calculation of batch masses

The masses of the various ingredients for concrete of a particular batch size may be calculated. The calculated mix proportions shall be checked by means of trial batches.

9. Illustrate the mix design for a concrete of M20 grade (Design stipulations and test data of materials are to be given). (Apr/**May 2010, April/May 2017, 2019) (May/June 2016) (Nov/Dec 2016, 2017)**

MIX DESIGN EXAMPLE

Example 1: Illustrating the mix design for a concrete of M 20grade is given below:

Design stipulations

Characteristic compressive strength required in the field at 28 days: 20 N/mm^2

Maximum size of aggregate: 20 mm angular

Degree of workability :0.90 compacting factor

Degree of quality control: good

Type of exposure : Mild

Test data for materials

Cement used -ordinary Portland cement satisfying the requirements of IS	:	269-1989
Specific gravity of cement	:	3.15
Specific gravity of fine aggregate	:	2.60
Specific gravity of coarse aggregate	:	2.60
Water absorption of fine aggregate	:	1.00 percent
Water absorption of coarse aggregate	:	0.50 percent
Free (surface) moisture of fine aggregate	:	2.00 percent
Free (surface) moisture of coarse aggregate	:	Nil

Sieve analysis for fine aggregate

Sieve sizes	% passing	Remarks
4.75 mm	100	Confirming to grading Zone III of Table 4 of IS: 383: 1970
2.36 mm	100	
1.18 mm	93	
600 micron	60	
300 micron	12	
150 micron	2	

Sieve analysis for coarse aggregate

Sieve sizes (mm)	Analysis of coarse aggregate fractions (% passing)		Percentage of different fractions			Remarks
	I	II	I (60)	II (60)	Combined 100 %	
20	100	100	60	40	100	Confirming to Table 2 of IS 383:1970
10	0	71.20	0	28.50	28.50	
4.75	-	9.40	-	3.70	3.70	
2.36	-	-	-	-	-	

Solution

Step 1: Target mean strength of concrete

For tolerance factor of 1.65 and assumed standard deviation using Table 3.2, the target mean strength for specified characteristics cube strength is 20+ 4x 1.65 = 26.6 N/mm^2.

Step 2: Selection of water - cement ratio

From Figure 3.1, the free water - cement ratio required for the target mean strength of is 0.50. This is lower than the maximum value of 0.55 prescribed for mild exposure in Table 5» of IS 456: 2000.

Step 3: Selection of water and sand content

From Table 3.5, for 20 mm nominal maximum size aggregate and sand conforming to grading zone II, water content per cubic meter of concrete = 186 kg and sand content as percentage to total aggregate by absolute volume = 35 percent.

Step 4: Adjustment required if any,

In this example, for change in values in water - cement ratio, compacting factor and sand belonging to zone III, the following adjustment is required:

(i) For water content percent:

For decrease in water - cement ratio by (0.60 - 0.50) that is 0.10 = 0%

For increase in compacting factor (0.90 - 0.80) that is 0.60 = +3%

For sand conforming to zone III of Table 4 of IS 383: 1970 = 0%

Total +3%

$\therefore$ Required water content = 186 + 3% of 186

$$= 186 + \frac{3}{100} \times 186$$

$$= 186 + 5.5$$

$$= 191.6 \text{ kg/m}^3 \text{ (or) lit/m}^3 \text{ (or) l/m}^3$$

(ii) For sand in total aggregate

For decrease in water-cement ratio by (0.60 - 0.50) that is 0.10	= -2.0%
For increase in compacting factor (0.90 - 0.80) that is 0.10	= 0%
For sand conforming to zone III of Table 4 of IS: 383 - 1970	= -1.5%
Total	-3.5%

Therefore, required sand content as percentage of total aggregate by absolute volume = 35 - 3.5 = 31.5 percent.

Step 5: Determination of cement content

Water cement ratio = 0.50

Water = 191.6 litres

$$\text{Cement} = \frac{191.6}{0.50} = 383 \text{ kg/m}^3$$

This cement content is adequate for mild exposure condition, according to Table 5 of IS 456: 2000.

Step 6: Determination of fine and coarse aggregate content

From Table 3.3, for specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2 percent. Taking this into account and applying equations from 3.3 and 3.4,

$$0.98 = \left(191.6 + \frac{383}{3.15} + \frac{1}{0.315} \times \frac{f_a}{2.60}\right) \times \frac{1}{1000}$$

$$f_a = 546\,\mathrm{kg/m^3} \text{ and}$$

$$0.98 = \left(191.6 + \frac{383}{3.15} + \frac{1}{1-0.315} \times \frac{C_a}{2.60}\right) \times \frac{1}{1000}$$

$$C_a = 1188\,\mathrm{kg/m^3}$$

Step 7: Mix Proportion

From the above steps 1 to 6, the mix proportion then becomes:

	Water	Cement	Fine aggregate	Coarse aggregate
	191.60 kg	383 kg	546 kg	1188 kg
(or)	0.50	1	1.42	3.10

Step 8: Actual quantities of materials required

(i) Water

For water-cement ratio of 0.50 quantity of water = 191.60 lit

Add extra quantity of water to be added for absorption in case of coarse aggregate, at 0.50

percent by mass, $\frac{0.50}{100} \times 1188$ = +5.94 lit

Deduct quantity of water for free moisture present in sand, at

2 percent by mass, $\frac{2}{100} \times 546$ = -10.92 lit

Therefore, actual quantity of water to be added = 186.62 lit

(ii) Fine aggregate (sand)

As per original calculation fine aggregate = 546 kg

Add 2 percent for free moisture = 10.92 kg

Actual quantity of sand required after allowing for mass of free moisture = 556.92 kg

(iii) Coarse aggregate (20 mm)

As per original calculation = 1188 kg

deduct 0.50% for water absorption = –5.94 kg

$\frac{0.50}{100} \times 1188$

Total aggregate = 1182 kg

Fraction I (60%) = $\frac{60}{100} \times 1182$ = 709.20kg

Fraction II (40%) = 472.80 kg

Step 9: Actual quantities required for the mix without adjustments

The mix 1: 1.42: 3.10: 0.50 (by mass), the mix quantity different materials are:

Cement	: 383 kg
Sand	: 546 kg
Coarse aggregate	: 1188 kg (Fraction I = 712.80 kg)
	(Fraction II = 475.20 kg)
Water	: 191.60 kg.

Step 10: Actual quantities required for the mix with adjustments: (Ratio: 1: 1.45: 3.08: 0.487)

Cement	: 383 kg
Sand	: 556.92 kg
Coarse aggregate	: 1182 kg (Fraction I = 709.20 kg)
	(Fraction II = 472.80 kg)
Water	: 186.62 lit

Step 11: Actual quantities required for the mix per 50 bag of cement:

Cement	: 50 kg
Sand	: 72.50 kg
Coarse aggregate	: 154.00 kg (Fraction I = 92.58 kg)
	(Fraction II = 61.72 kg)
Water	: 24.35 kg

Example 2: The mix proportioning for a concrete of M 40 grade

Stipulations for proportioning

Grade designation	:	M40
Type of cement	:	OPC 43 grade conforming to IS 8112
Maximum nominal size of aggregate	:	20 mm
Minimum cement content	:	320 kg/m^3
Maximum Water - cement content	:	0.45
Workability	:	100 mm (slump)
Exposure Condition	:	Severe (for reinforced concrete)
Method of concrete placing	:	Pumping
Degree of supervision	:	Good
Type of aggregate	:	Crushed angular aggregate
Maximum cement (OPC) content	:	450 kg/m^3
Chemical admixture type	:	Super plasticizer

Test data for materials

Cement used	:	OPC 43 grade conforming to IS 8112
Specific gravity of cement	:	3.15

Chemical admixture	:	Super plasticizer conforming to IS 9103
Specific gravity of fine aggregate	:	2.74
Specific gravity of Coarse aggregate	:	2.74
Water absorption of Fine aggregate	:	1.0 percent
Water absorption of Coarse aggregate	:	0.5 percent
Free (surface) moisture of Fine aggregate	:	Nil
Free (surface) moisture of Coarse aggregate	:	Nil

Sieve analysis for fine aggregate : Conforming to grading zone 1 of Table 4 of IS 383:1970

Sieve analysis for coarse aggregate:

Sieve Size (mm)	Analysis of coarse aggregate fractions (% passing)		Percentage of different fractions			Remarks
	I	II	I(60)	II(60)	Combined 100%	
20	100	100	60	40	100	Confirming to Table 2 of IS 383:1970
10	0	71.20	0	28.50	28.50	
4.75	-	9.40	-	3.70	3.70	
2.36	-	-	-	-	-	

Solution

Step 1: Target mean strength of concrete

For tolerance factor of 1.65 and assumed standard deviation using Table 3.2, the target mean strength for specified characteristics cube strength is $40 + 5 \times 1.65 = 48.25\ N/mm^2$.

Step 2: Selection of water - cement ratio

From Table 5 of IS456: 2000, maximum water - cement ratio = 0.40

Step 3: Selection of water content

From Table 3.5, for 20 mm nominal maximum size aggregate maximum water content = 186 litre (for 25 to 50 mm slump range)

Estimated water content for 100 mm

$$\text{Slump} = 186 \times \frac{6}{100} \times 186$$

$$= 197 \text{ litre}$$

As super plasticizer is used, the water content can be reduced up 20 percent and above. Assume in this case 29% reduction.

$$\text{Hence, the arrived water content} = 197 - \frac{29}{100} \times 197$$

$$= 140 \text{ litre}$$

Step 4: Calculation of cement content

water - cement ratio = 0.40

$$\text{cement content} = \frac{140}{0.40} = 350\ \text{kg/m}^3$$

From Table 5 of IS: 456, minimum cement content

for severe exposure condition, $= 320\ \text{kg/m}^3$

$$350\ \text{kg/m}^3 > 320\ \text{kg/m}^3$$

hence, OK.

Step 5: Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS 10262 : 2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone I) for water - cement ratio of 0.50 is equal to 0.60.

In this problem, water - cement ratio is 0.40,

Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water - cement ratio is lower by 0.10; the proportion of volume of coarse aggregate is increased by 0.02

(at the rate of -/+ 0.01 for every ± 0.05 change in water - cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water - cement ratio of 0.40 = 0.62.

For pumpable concrete these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = $0.62 \times 0.9 = 0.56$

volume of fine aggregate

content $= 1 - 0.56 = 0.44$.

Step 6: Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

Volume of concrete $= 1\text{m}^3$

$$\text{Volume of cement} = \frac{\text{mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$$

$$= \frac{350}{3.15} \times \frac{1}{1000} = 0.111\text{m}^3$$

$$\text{Volume of water} = \frac{\text{mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$$

$$= \frac{140}{1} \times \frac{1}{1000} = 0.140\text{m}^3$$

Volume of chemical admixture (@ 2% by mass of cementitious

$$\text{materials)} = \frac{\text{mass of chemical admixture}}{\text{Specific gravity of admixture}} \times \frac{1}{1000}$$

$$= \frac{7}{1.145} \times \frac{1}{1000} = 0.006\text{m}^3$$

$\therefore$ Volume of all in aggregate

$$= 1-(0.111 + 0.140 + 0.006)$$

$$= 0.743\text{m}^3$$

mass of coarse aggregate = volume of all in aggregate × volume of coarse aggregate × specific gravity of coarse aggregate × 1000

$= 0.743 \times 0.56 \times 2.74 \times 1000$

$= 1140 \text{kg}$

mass of fine aggregate = volume of all in aggregate × volume of fine aggregate × specific gravity of fine aggregate × 1000

$= 0.743 \times 0.44 \times 2.74 \times 100$

$= 896 \text{ kg}$

Step 7: Mix Proportions for trial

Cement $= 350 \text{ kg/m}^3$

Water $= 140 \text{ kg/m}^3$

Fine aggregate $= 896 \text{ kg/m}^3$

Coarse aggregate $= 1140 \text{kg/m}^3$

Chemical admixture $= 7 \text{kg/m}^3$

Water - cement: 0.40

Example 3: The mix proportioning for a concrete of M40 using fly ash.

Stipulations for proportioning

Grade designation	:	M40
Type of cement	:	OPC 43 grade conforming to IS 8112
Maximum nominal size of aggregate	:	20mm
Minimum cement content	:	320 kg/m^3
Maximum Water - cement content	:	0.45
Workability	:	100 mm (slump)
Exposure Condition	:	Severe (for reinforced concrete)
Method of concrete placing	:	Pumping
Degree of supervision	:	Good
Type of aggregate	:	Crushed angular aggregate
Maximum cement (OPC) content	:	450 kg/m^3
Chemical admixture type	:	Super plasticizer
Type of mineral admixture	:	Fly ash conforming to IS 3812 (part - I)

Test data for materials

Cement used	:	OPC 43 grade conforming to IS 8112
Specific gravity of cement	:	3.15
Chemical admixture	:	Super plasticizer conforming to IS 9103
Specific gravity of fine aggregate	:	2.74
Specific gravity of Coarse aggregate	:	2.74
Water absorption of Fine aggregate	:	1.0 percent
Water absorption of Coarse aggregate	:	0.5 percent
Free (surface) moisture of Fine aggregate	:	Nil
Free (surface) moisture of Coarse aggregate	:	Nil
Fly ash	:	conforming to IS 3812 (part - I)
Specific gravity of fly ash	:	2.20

Sieve analysis for fine aggregate: Conforming to grading zone 1 of Table 4 of IS 383:1970

Sieve analysis for coarse aggregate:

Sieve Size (mm)	Analysis of coarse aggregate fractions (% passing)		Percentage of different fractions			Remarks
	I	II	I(60)	II(60)	Combined 100%	
20	100	100	60	40	100	Confirming to Table 2 of IS 383:1970
10	0	71.20	0	28.50	28.50	
4.75	-	9.40	-	3.70	3.70	
2.36	-	-	-	-	-	

Solution:

Step 1: Target mean strength of concrete

For tolerance factor of 1.65 and assumed standard deviation using Table 3.2, the target mean strength for specified characteristics cube strength is $40 + 5 \times 1.65 = 48.25$ N/mm².

Step 2: Selection of water - cement ratio

From Table 5 of IS 456: 2000, maximum water - cement ratio = 0.40

Step 3: Sele ction of water content

From Table 3.5, for 20 mm nominal maximum size aggregate maximum water content = 186 litre (for 25 to 50 mm slump range)

Estimated water content for 100 mm

$$\text{Slump} = 186 \times \frac{6}{100} \times 186$$
$$= 197 \text{ litre}$$

As super plasticizer is used, the water content can be reduced up 20 percent and above. Assume in this case 29% reduction.

$$\text{Hence, the arrived water content} = 197 - \frac{29}{100} \times 197$$
$$= 140 \text{ litre}$$

Step 4: Calculation of cement content

water - cement ratio = 0.40

$$\text{cement content} = \frac{140}{0.40} = 350 \text{ kg/m}^3$$

From Table 5 of IS: 456, minimum cement content

for severe exposure condition, $= 320 \text{ kg/m}^3$

$$350 \text{ kg/m}^3 > 320 \text{ kg/m}^3$$

hence, OK.

Step 5: Calculation of fly ash content

Decide the percentage of fly ash to be used based on project requirement and quality of materials. In certain situations increase in cementitious material content may be warranted. The decision on increase in cementitious material content and its percentage may be based on experience and trial.

In this example, increase of 10% cementitious material content is considered.

$$\therefore \text{ cementitious material content} = 350 \times \frac{10}{100} \times 350$$

$$= 385 \text{ kg/m}^3$$

$$\text{water content} = 140 \text{ kg/m}^3$$

$$\text{So, water - cement ratio} = \frac{140}{385} = 0.364$$

Fly ash at 30% of total cementitious material content

$$= 385 \times \frac{30}{100} = 115 \text{ kg/m}^3$$

$$\text{cement (OPC) content} = 385 - 115 = 270 \text{ kg/m}^3$$

Step 6: Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS 10262 : 2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone I) for water - cement ratio of 0.50 is equal to 0.60.

In this problem, water - cement ratio is 0.40,

Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water - cement ratio is lower by 0.10; the proportion of volume of coarse aggregate is increased by 0.02

(at the rate of -/+ 0.01 for every ± 0.05 change in water - cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water - cement ratio of 0.40 = 0.62.

For pumpable concrete these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = 0.62 × 0.9 = 0.56

volume of fine aggregate content = 1-0.56 = 0.44.

Step 7: Mix calculation

The mix calculations per unit volume of concrete shall be as follows:

Volume of concrete $= 1m^3$

$$\text{Volume of cement} = \frac{\text{mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$$

$$= \frac{270}{3.15} \times \frac{1}{1000} = 0.086m^3$$

$$\text{volume of flyash} = \frac{\text{mass of flyash}}{\text{Specific gravity of flyash}} \times \frac{1}{1000}$$

$$= \frac{115}{2.20} \times \frac{1}{1000}$$

$$= 0.052m^3$$

$$\text{Volume of water} = \frac{\text{mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$$

$$= \frac{140}{1} \times \frac{1}{1000} = 0.140\ m^3$$

Volume of chemical admixture at 2% by mass of cementitious

$$\text{material} = \frac{\text{mass of chemical admixture}}{\text{Specific gravity of admixture}} \times \frac{1}{1000}$$

$$= \frac{7}{1.145} \times \frac{1}{1000}$$

$$= 0.006 m^3$$

Volume of all in aggregate

$$= 1-(0.086+0.052+0.140+0.006)$$

$$= 0.716 m^3$$

Mass of coarse aggregate = Volume of all in aggregate × volume of coarse aggregate × Specific gravity of coarse aggregate × 1000

$$= 0.716 \times 0.56 \times 2.74 \times 1000$$

$$= 1098\ kg$$

Mass of fine aggregate = Volume of all in aggregate × volume of fine aggregate × Specific gravity of coarse aggregate × 1000

$$= 0.716 \times 0.44 \times 2.74 \times 1000$$

$$= 863\ kg$$

Step 8: Mix Proportions for trial

- Cement = 270 kg/m³
- Fly ash = 115 kg/m³
- Water = 140 kg/m³
- Fine aggregate = 863 kg/m³
- Coarse aggregate = 1098 kg/m³
- Chemical admixture = 7 kg/m³
- Water - cement ratio = 0.364

Problem 2

Design of M30 concrete mix as per IS: 10262-2009, Concrete mix proportioning-guidelines (First revision). The following are the design stipulations for proportioning:

Grade designation	: M30
Type of cement	: OPC 43 grade confirming to IS 8112
Maximum nominal size of aggregates	: 20 mm
Minimum cement content	: 350 kg/m^3
Maximum water cement ratio	: 0.50
Workability	: 25 - 50 mm (slump)
Exposure condition	: Moderate
Degree of supervision	: Good
Type of aggregate	: Crushed angular aggregate
Maximum cement content	: 450 kg/m^3
Chemical admixture	: Not recommended

TEST DATA FOR MATERIALS

Cement used		: OPC 43 grade confirming to IS 8112
Specific gravity of cement		: 3.15
Specific gravity of		
	Coarse aggregate	: 2.68
	Fine aggregate	: 2.65
Water absorption		
	Coarse aggregate	: 0.6 percent
	Fine aggregate	: 1.0 percent
Free (surface) moisture		
	Coarse aggregate	: Nil (absorbed moisture full)
	Fine aggregate	: Nil

Coarse aggregate : Conforming to Table 2 of IS: 383

Fine aggregate : Conforming to Zone I of IS: 383

TARGET STRENGTH FOR MIX PROPORTIONING

$$\boxed{f'_{ck} = f_{ck} + 1.65\ S}$$

Where

f'_{ck} = Target average compressive strength at 28 days

f_{ck} = Characteristic compressive strength at 28 days

S = Standard deviation

From Table 1 of IS: 10262-2009, standard deviation, S = 5 N/mm^2

Therefore target strength = $30 + 1.65 \times 5 = 38.25\ N/mm^2$

SELECTION OF WATER CEMENT RATIO

From Table 5 of IS: 456-2000, maximum water cement ratio = 0.50 (Moderate exposure)

Based on experience, adopt water cement ratio as 0.45 as the cement is 53 grade

$0.45 \leq 0.5$, hence ok

SELECTION OF WATER CONTENT

From Table-2 of IS: 10262-2009, maximum water content = 186 litres

(For 25–50mm slump range and for 20 mm aggregates)

Estimated water content for 25-50 mm slump = 186 litres

CALCULATION OF CEMENT CONTENT

Water cement ratio = 0.45

Cement content = $186/0.45 = 413\ kg/m^3 > 350\ kg/m^3$ (Given)

From Table 5 of IS: 456–2000, minimum cement content for moderate exposure condition = 300 kg/m^3. Hence OK

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3 of IS: 10262-2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 = 0.60.

In the present case w/c = 0.45. The volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As w/c ratio is lower by 0.10, increase the coarse aggregate volume by 0.02 (at the rate of -/+ 0.01 for every +/- 0.05 change in water cement ratio). Therefore corrected volume of coarse aggregate for w/c of 0.45 = 0.61.

The new volume of coarse aggregate is 0.61. Volume of fine aggregate is 0.39.

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete $= 1\ m^3$

b) Volume of cement $= \dfrac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \dfrac{1}{1000}$

$= [413/3.15] \times [1/1000]$

$= 0.131\ m^3$

c) Volume of water $= \dfrac{\text{Mass of water}}{\text{Specific gravity of water}} \times \dfrac{1}{1000}$

$= [186/1] \times [1/1000]$

$= 0.186\ m^3$

d) Volume of all in aggregates (z) $= a - (b + c)$

$= 1 - (0.131 + 0.186)$

$= 0.683\ m^3$

e) Mass of coarse aggregates $= z \times \text{Volume of CA} \times \text{specific gravity of CA} \times 1000$

$= 0.683 \times 0.61 \times 2.68 \times 1000$

$= 1117$ kg

f) Mass of fine aggregates $= z \times \text{Volume of FA} \times \text{specific gravity of FA} \times 1000$

$= 0.683 \times 0.39 \times 2.65 \times 1000$

$= 706$ kg

MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement = 413 kg/m^3

Water = 186 kg/m^3

Fine aggregate = 706 kg/m^3

Coarse aggregates = 1117 kg/m^3

Water cement ratio = 0.45

Aggregates are assumed to be in saturated surface dry condition. Otherwise corrections are to be applied while calculating the water content. Necessary corrections are also required to be made in mass of aggregates. Trial mixes are studied in laboratory.

10. Design a concrete mix for reinforced concrete work for the following requirements using IS; 10262-2009 code. (May/June 2016) (Nov/Dec 2019)

(b) Design a concrete mix for reinforced concrete work for the following requirements using IS: 10262-2009 code.

Characteristic strength at 28 days : 35 MPa

Exposure condition: severe

Degree of workability: slump = 50 mm

Quality control : very good

Cement: OPC (specificgravity = 3.15)

Fine aggregate : zone II sand (specific gravity = 2.64)

Coarse aggregate : maximum size = 20mm (specific gravity

Water absorption of coarse aggregate = 1 %

Free surface moisture in sand = 2%

Assume any data required.

TEST DATA FOR MATERIALS

S.Q.9

Cement used: OPC 43 Grade

Specific Gravity of cement: 3.15

Specific Gravity of

Coarse aggregate	:	2.7
Fine aggregate	:	2.64

Water absorption

Coarse aggregate	:	1%
Fine aggregate	:	NIL

Free surface moisture

Coarse aggregate	:	NIL (absorbed moisture full)
Fine aggregate	:	2%

Sieve Analysis

Coarse aggregate	:	Conforming to Table 2 of IS: 383
Fine aggregate	:	Conforming to Zone II of IS: 383

Target Strength for Mix Proportioning

$$\boxed{f'_{ck} = f_{ck} + 1.65\,S}$$

Where

f'_{ck} = Target average compressive strength at 28 days

f_{ck} = Characteristic compressive strength at 28 days

S = Standard deviation

From Table 1 of IS: 10262 – 2009,

Standard derivation, $S = 5\ N/mm^2$

Therefore target strength $= 35 + (1.65 \times 5)$

$= 43.25\ N/mm^2$

Selection of Water Cement Ratio

From Table 5 of IS: 456 – 2000, maximum water cement ratio = 0.45 (severe exposure).

Based on experience, adopt water cement ratio as 0.40 as the cement is 43 grade

0.4 < 0.45, hence ok.

Selection of Water Content

From Table 2 of IS; 10262 – 2009,

Maximum water content = 186 liters

(For 25 – 50 mm slump range and for 20 mm aggregates)

$$\left.\begin{array}{r}\text{Estimated water content}\\ \text{for 25 – 50 mm slump}\end{array}\right\} = 186 \text{ litres.}$$

Calculation of Cement Content

Water cement ratio = 0.4

$$\text{Cement content} = \frac{186}{0.4} = 465 \text{ kg/m}^3$$

From Table 5 of IS: 456 – 2000, minimum cement content for severe exposure condition = 320 kg/m^3.

$$465 \text{ kg/m}^3 > 320 \text{ kg/m}^3$$

Hence ok.

Proportion of volume of Coarse Aggregate and Fine Aggregate Content

From Table3 of IS: 10262 – 2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone II) for water – cement ratio of 0.5 = 0.62.

In the present case W/C = 0.4. The volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As W/C ratio is lower by 0.10, increase the coarse aggregate volume by 0.02 (at the rate of –/+ 0.01 for every +/– 0.05 change is water cement ratio). Therefore corrected volume of coarse aggregate for W/C of 0.4 = 0.64

The new volume of coarse aggregate is 0.64. Volume of fine aggregate is 0.36.

Mix calculation

The mix calculations per unit volume of concrete shall be as follows.

a) Volume of concrete = 1 m^3

b) $$\text{Volume of cement} = \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$$

$$= \frac{465}{3.15} \times \frac{1}{1000}$$

$$= 0.148 \text{ m}^3$$

c) $$\text{Volume of water} = \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$$

$$= \frac{186}{1} \times \frac{1}{1000}$$

$$= 0.186 \text{ m}^3$$

d) $$\left.\begin{array}{c}\text{Volume of all}\\ \text{in aggregates (z)}\end{array}\right\} = a - (b + c)$$

$$= 1 - (0.148 + 0.186)$$

$$= 0.666 \text{ m}^3$$

e) $$\left.\begin{array}{c}\text{Mass of coarse}\\ \text{aggregates}\end{array}\right\} = z \times \text{Volume of CA} \times \text{specific gravity of CA} \times 1000$$

$$= 0.666 \times 0.64 \times 2.7 \times 1000$$

$$= 1150.85 \text{ kg}$$

f) $$\left.\begin{array}{c}\text{Mass of fine}\\ \text{aggregates}\end{array}\right\} = z \times \text{Volume of FA} \times \text{specific gravity of FA} \times 1000$$

$$= 0.666 \times 0.36 \times 2.64 \times 1000$$

$$= 632.97 \text{ kg}$$

MIX PROPORTIONS FOR TRIAL NUMBER 1

Cement = 465 kg/m³

Water = 186 kg/m³

Fine aggregate = 632.97 kg/m³

Coarse aggregate = 1150.85 kg/m³

Water cement ratio = 0.4

M45 CONCRETE MIX DESIGN BY IS METHOD (Nov/Dec 2019)

<u>A-1) Design stipulations</u>

Characteristics compressive strength 28 days : **45N/mm^2**

Target mean strength : $f'_{ck} = f_{ck} + 1.65\ s$ **(s= 5; from is 10262 table 1)**

$f'_{ck} = 45+1.65 \times 5 = 53.25 N/mm^2$

Maximum size of aggregates : **20 mm**

Workability, slump : **50 to 75mm**

Type of exposure : **moderate**

Aggregate surface condition : **All aggregates are in surface dried Condition**

A-2) Test data for materials

Type of cement :ACC 43 grade (OPC)

Specific gravity of cement :3.15

Specific gravity of admixture :1.07

Specific gravity of coarse aggregates :2.54

Specific gravity of fine aggregates :2.47

Table for densities of materials used

materials	**Specific gravity**	**X 1000**	**Specific weight(kg/m^3)**
Water	1	1000	1000
Cement	3.155	1000	3155
Surface dried fine aggregates	2.47	1000	2470
Surface dried coarse aggregates	2.54	1000	2540
admixture	1.07	1000	1070

A-3) Selection of water/cement ratio

From is 456-2000 table 5 maximum W/C ratio =0.35

Based on trials adopted w/c ratio=0.34<0.35 hence ok

Hence selected W/C ratio is = 0.34

A-4)Estimation of mixing water

a) Weight of water for 20 mm aggregates and slump 25-50 mm = 186 litre.

b) Weight of water for 50-75 mm slump **(increased by 3% for additional 25 mm slump as per is 10262 clause 4.2) = 191.58 litre.**

Note: on adding super plasticizer @ 0.9% water content reduces by 20%

Net water volume =191.58X0.8=litre =153.26 litre

A-5) estimation of weight of cement

Wt. of cement=wt. of water/water cement ratio

Wt. of cement=153.26/0.34 =450.76kg/m^3

Min. content as per is 456 for moderate exposure =360kg

450.76> 360kg hence ok

A-6) Estimation of weight of admixture

Weight of admixture @0.9% of weight of cement=0.9x 450.36/100 =4.05kg

Volume of admixture (E)=wt. of admixture/specific weight

=4.05/1070 = 0.00378 m^3

A-7) Calculating proportion of coarse and fine aggregates

From is-10262 table 3

Volume of coarse aggregates corresponding to 20mm size and fine aggregates zone 1=o.60

Volume of fine aggregates =(1-0.60)= 0.40

A-8) mix calculations

a) Volume of concrete =1m^3

b) Volume of cement = (mass of cement/specific gravity)x(1/1000)

= (450.76/3.155)x(1/1000) =0.1428 m^3

c) Volume of water =(mass of water/specific gravity)x(1/1000)

= (153.36/1.00)x(1/1000) =0.153 m^3

d) Volume of admixture = (mass of admixture/specific gravity)x(1/1000)

=(4.05/1.07)x(1/1000) =0.00378 m^3

e) Volume of all in aggregates= {a-(b+c+d)}= 1-(0. 1428+0.153+0.00378) =0.70042

f) Weight o coarse aggregates = 0.7057x0.63x specific gravity of coarse aggregates x 1000

=0.7004x0.60x2.54 x 1000 =1067.44 kg

g) Weight of fine aggregates = 0.7004 x0.40x 2.47 x 1000 =691.99kg

A-9) proportion ratio

Cement: coarse aggregates: fine aggregates = 1:1.53: 2.36

A-10) Table of ingredients

Ingredients	Surface dried weights
cement	450.76 kg
Coarse aggregates	1067.44 kg
Fine aggregates	691.99 kg
water	153 litre.
Admixture	4.05 kg
Water cement ratio	0.34

PART A

1. Define workability. (April/May 2010) (Nov/Dec 2019)

- Workability is the property of concrete which determines the amount of internal work necessary to produce full compaction.

- It is a measure with which concrete can be handled from the mixer stage to its final fully compacted stage.

2. List out the requirements of fresh concrete.

a. Mix ability

b. Stability

c. Mobility

d. Compact ability

e. Finish ability

3. List out the Factors affecting of Workability.(Nov/Dec 2017) (April/May 2018)

a. Water content e. Surface texture
b. Mix proportion f. Grading
c. Size of aggregate g. Admixture
d. Shape of aggregate

4. Mention the methods to measure the workability.

a. Slump Test
b. Compaction Factor
c. Vee-Bee Consistometer
d. Kelly Ball Penetration test
e. Flow table Test
f. Vibrating table

5. Mention the values of different type of slump. (Or) what kinds of slump observed in slump cone test? (April/May 2019)

- True slump -up to 125mm from top
- Shear slump -up to 150 mm from top
- Collapse slump -150-225mm

6. List out the usage of slump values.

- slump 0 – 25 mm are used in road making
- 10 – 40 mm are used for foundations with light reinforcement
- 50 -90 for normal reinforced concrete placed with vibration

7. State, how the grading of aggregates effect the workability?

- Grading of aggregates has the maximum influence on workability.
- The better the grading, the less is the amount of void in it.
- When total void are less, excess paste is available to give better lubricating effect.
- With excess amount of paste the mixture becomes cohesive and fatty which prevents segregation of particles and least amount of compacting efforts is required to compact the concrete.

8. Define compaction factor.

- Compaction Factor is the ratio of the weight of partially compacted concrete to the weight of the concrete when fully compacted in the same mould.

9. Define Vee- bee consistometer.

- Consistometer is based on consistency test which is a mechanical variation of the simple slump test which includes determination of the workability of concrete.
- Measures consistency of concrete in terms of time required to transform by vibration a frustum of fresh concrete sample into a cylinder. This time is called VB time.

10. What is the use of Kelly Ball Penetration test?

- Kelly Ball Penetration method is used to determine the penetration of a hemispherical metal weight into freshly mixed concrete, which is related to the workability of the concrete.

11. What is the use of flow table method?

- Flow table indicates consistency and proneness to segregation.
- It is used for aggregate of size <40mm. The flow is determined by = {D-250/250}*100.

12. Mention the test conducted to test the properties of hardened concrete. (April/May 2018)

a. Compression Testing Machine
b. Flexure Strength Testing Machine
c. Lateral Extensometer
d. Split Tensile Test
e. Shear strength
f. Bond strength

13. List out the factors affecting the results of strength test.

a. Size and shape of aggregate
b. Condition of casting
c. Moisture condition
d. Bearing condition
e. Rate of loading

14. What are the steps adopted to control bleeding?

- By adding more cement
- By using more finely ground cement
- By using little air entraining agent
- By increasing finer part of fine aggregate
- By properly designing the mix and using minimum quantity of water.

15. Define Segregation.

- The tendency of separation of coarse aggregate grains from the concrete mass is called segregation.

16. Mention the types of segregation in concrete technology in general.

- In concrete technology, segregation can be divided by two types.
- Firstly the coarse aggregate may separate from the main mass of concrete in its plastic state.
- Secondly, the grout (cement +paste) may separate from the mix.
- The second one is generally occurs if a concrete is too wet.

17. What are the three types of separation in concrete?

- Type - 1: Coarse aggregate separating out or settling down from rest of the matrix.
- Type -2: The paste separating away from coarse aggregate.
- Type -3: Water being lowest in specific gravity, separating out from the rest of the material.(Bleeding)

18. Suggests some remedies for segregation.

- By correctly proportioning the mix,
- By proper handling,
- By proper transporting,
- By proper placing,
- By proper compacting and
- By proper finishing.

19. Definebleeding.(Nov/Dec 2016) (April/May 2017)

- The tendency of water rising above the surface of freshly laid concrete is known as bleeding.

20. What are the steps adopted to control bleeding?

- By adding more cement
- By using more finely ground cement
- By using little air entraining agent
- By increasing finer part of fine aggregate
- By properly designing the mix and using minimum quantityof water.

21. What are factors which influence strength of concrete when tested for compressive strength? (Nov/Dec 2017)

- Shape and size of test specimens
- Height to diameter ratio

- Rate of application of load
- Moisture content in the test specimen
- Material used for capping

22. What is batching?

- Batching is the correct measurement of various materials used in the concrete mix. It can be either volume or by weight.

23. How is weight batching is obtained?

Weight batching is more accurate and hence preferred weighing can be done by

a. Simple spring balance
b. Platform weighing machines
c. Automatic weighing machines

24. How mixing operation is done in concrete?

a. Hand
b. Machine
    a) Tilting type
        1. Charging by hand
        2. Charging by machine
    b)Non tilting type
        1. Continuous mixer
        2. Pan mixer
        3. Truck mixer

25. What is the purpose of compaction?

- Compaction is done to eliminate air voids in concrete.

26. What is hardened concrete and mention the factors influence its strength?

Hardened concrete gives an overall idea about the quality of concrete. It depends on

a. Water cement ratio
b. Degree of compaction
c. Age of concrete
d. Richness of mix
e. Curing of concrete
f. Temperature of concrete.

27. Define curing.

- Curing is the process of maintaining satisfactory moisture content and temperature in freshly cast concrete for a definite period of time immediately following placement.

28. Define shrinkage.

- Volume change due to loss of moisture affects durability and strength, causes cracks in concrete at different stage due to alkali aggregate reaction, sulphate action, and settlement of fresh concrete is shrinkage.

29. Define creep.

- When a concrete member is loaded it deforms to a certain extent as soon as the load is applied. When the load is kept constant, the deformation increases with time.
- This increase in strain under sustained stress is called creep of concrete.

30. List the methods of curing.

- Water curing
  1. Immersion
  2. Ponding
  3. spraying
- Membrane curing
- Application of heat

31. Mention the two major purposes of curing.

- It prevents or replenishes the loss of moisture from the concrete;
- It maintains a favorable temperature for hydration to occur for a definite period

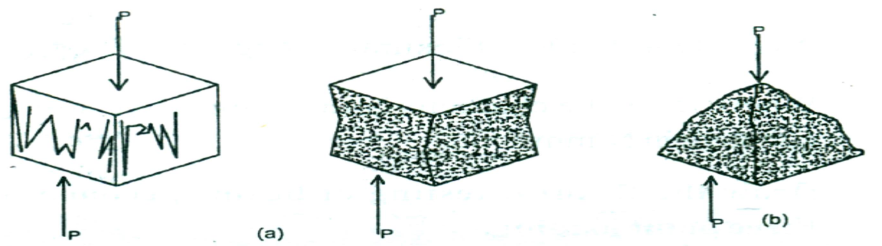
32. How shrinkage is classified?

1. Plastic shrinkage
2. Drying shrinkage
3. Autogeneous shrinkage
4. Carbonation shrinkage
5. Thermal shrinkage

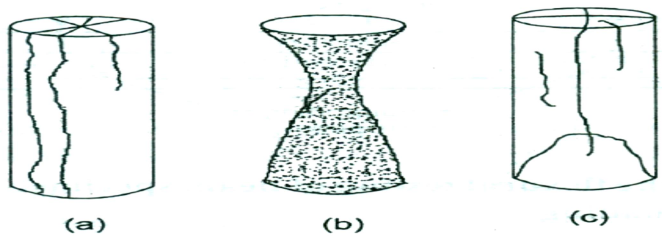
33. What are the factors influencing the strength of concrete.(April/may 2017)

- The characteristics of cement.
- The characteristics and properties of aggregates.
- The degree of compaction
- The efficiency of curing
- Age at the time of testing.
- Conditions of testing.

34. Draw the typical pattern of concrete cube specimen failure under compression.



35. Draw the typical pattern of concrete cylinder specimen failure under compression.



36. Write the higher and lower ranges of flexural strength of concrete compare to compressive strength.

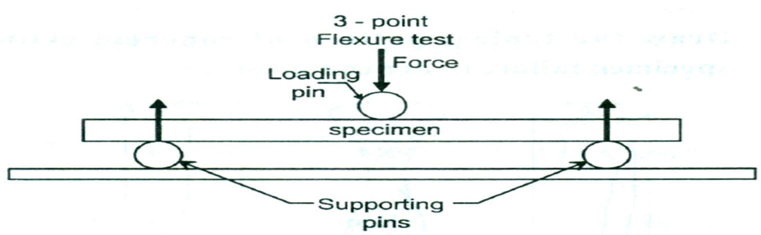
The flexural strength of concrete was found to be 8 to 11 per cent of the compressive strength of the concrete for higher ranges of concrete strength (greater than 25 N/mm^2) and 9 to 13 per cent for lower ranges of concrete strength (less than 25 N/mm^2) approximately.

37. Write the relationship between the compressive strength and flexural strength as per IS 456:2000.

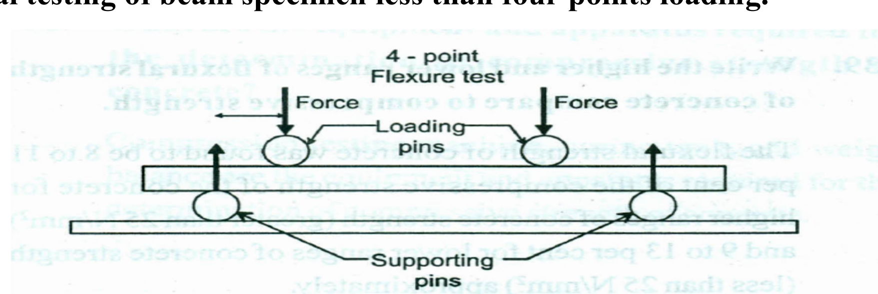
As per IS 456:2000, Flexural Strength = $0.7\sqrt{fck}$

Where, f_{ck} is the characteristic compressive strength of concrete in N/mm^2

38. Draw the flexural testing of beam specimen under three point loading.



39. Draw the flexural testing of beam specimen less than four points loading.



40. What are the advantages of ring tension test? (April/May 2017) (Nov/Dec 2016)

- Same type and same specimen can also be used for compression test.

- It is simple to perform and it gives uniform results than other tension test.

41. Which are controls the property of concrete? (April/May 2012)

The relative quantities of cement, aggregates and water mixed together are controls the properties of concrete in the wet state as well as in the hardened state.

42. How will you ensure that the ingredients of concrete are proper?

The right proportions of aggregate, sand, cement, water in concrete are ensured by experience in volumetric proportion.

43. What are the disadvantages of adding more water to concrete?

- Increased quantity of water may cause bleeding in concrete
- Cement slurry also escapes through the joints of formwork
- Strength of concrete may reduce.

44. List the advantages of using bigger sizes of aggregates compare to smaller sizes.

- It has less surface area
- Requires less amount of water for wetting surface
- Requires less amount of paste for lubricating the surface

45. How will you decide the maximum size of aggregate to be used in concrete in practical?

- The handling,
- Mixing and
- Placing equipment,
- Thickness of section and
- Quantity of reinforcement.

46. What are all the shapes of aggregate available in general? (Nov/Dec 2012)

- Angular aggregate
- Flaky aggregate
- Elongated aggregate
- Rounded aggregate
- Sub-rounded aggregate
- Cubical aggregate etc.

47. What are the advantages for application of heat?

- Concrete is vulnerable to damage only for short time.
- Concrete member can be handled very quickly.
- A smaller curing tank will be sufficient.
- Pre-stressing bed can be released early for further casting.

48. List out the terms in exposure of concrete in higher temperature.

- Steam curing at ordinary temperature.
- Steam curing at high pressure.
- Curing by infrared radiation.
- Electrical curing.

49. What are the considerations involved in steam curing?

- ❖ An initial delay prior to steaming.
- ❖ A period for increasing the temperature.
- ❖ A period for decreasing the temperature.
- ❖ A period for retaining the temperature.

50. List the advantages derived from high pressure curing process.

- ❖ In exhibits higher resistance to sulphate attack, freezing and thawing action and the chemical action.
- ❖ In also exhibits lower drying shrinkage, and moisture movement.

51. What are the methods for making high strength concrete?

- ❖ Seeding
- ❖ Re-vibration
- ❖ Use of admixtures
- ❖ High speed slurry mixing.

52. What are the techniques adopted in high strength of concrete?

- ❖ Compaction by pressure
- ❖ Helical binding
- ❖ Reactive powder concrete
- ❖ Polymerization in concrete

53. Mention the test conducted to test the properties of hardened concrete.

- ❖ Compression Testing Machine
- ❖ Flexure Strength Testing Machine
- ❖ Lateral Extensometer
- ❖ Split Tensile Test
- ❖ Shear strength
- ❖ Bond strength

54. List out the factors affecting the results of strength test.

- ❖ Size and shape of aggregate
- ❖ Condition of casting
- ❖ Moisture condition
- ❖ Bearing condition
- ❖ Rate of loading

55. How will you find the flexural strength of concrete?

- ❖ It's expressed as the moulds of rupture f_b.

$$f_b = \frac{Pl}{bd^2}$$

- ❖ P-load in kN
- ❖ l- Length of specimen in mm
- ❖ b- Breadth of specimen in mm
- ❖ d- Depth of specimen in mm

56. Why does a concrete cylinder fail at a lower stress than a concrete cube? (May/June 2016)

- ❖ Contact area of a standard cube mould with the upper platen in the testing machine is more which results in more confinement.
- ❖ More confinement resists against specimen expansion resulting in more compressive strength.

57. What are the effects on water cement ratio on concrete? (May/June 2016)

- ❖ The strength and workability of concrete depend to a great extent on the amount of water used.
- ❖ For a given proportion of the materials, there is an amount of water which gives the greatest strength.

58. When we can say that the concrete is workable? (Apr/May 2010)

- ➢ It can be handled without segregation
- ➢ It can be placed without loss of homogeneity
- ➢ It can be compacted with specified effort
- ➢ It can be finished easily

59. **What are the things should be kept in mind while specifying the workability?**

- ➢ Type of construction work
- ➢ Method of mixing
- ➢ Thickness of section
- ➢ Extent of reinforcement
- ➢ Mode of compaction
- ➢ Distance of transporting
- ➢ Method of placing
- ➢ Environmental condition

60. What are the important parameters of workability? Or state the importance of controlling workability. (April/May 2019)

- ➢ Fully compaction of concrete
- ➢ Lubrication to the concrete properties
- ➢ Without segregation
- ➢ For placing without loss of homogeneity.

61. How will you ensure that the ingredients of concrete are proper?

- ❖ The right proportions of aggregate, sand, cement, water in concrete are ensured by experience in volumetric proportion.

62. Give the description of slump test apparatus.

The apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions of bottom diameter200 mm, top diameter 100 mm and height 300 mm respectively.

63. What are all the patterns normally appear in slump test? (Apr/May 2010)

- ➢ True slump
- ➢ Shear slump
- ➢ Collapse slump

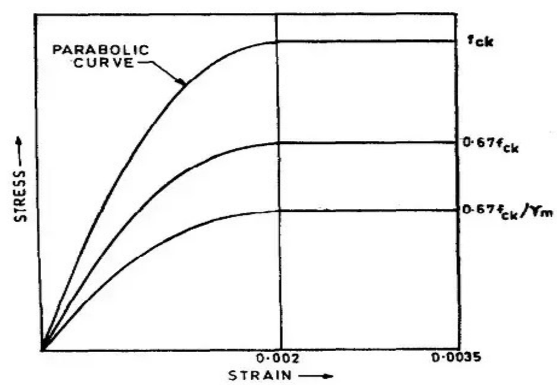
64. State the characteristics of different pattern of slump.

- The pattern of slump indicates the characteristics of concrete in addition to the slump value.
- If the concrete slumps evenly it is called true slump.
- If one half of the cone slides down, it is called shear slump.
- Shear slump also indicates that the concrete is non-cohesive and shows the characteristic of segregation.

65. Mention the advantages of slump test.

- It grants the facility to easily detect the difference in water content of successive batches of concrete of the same identical mix,
- The apparatus is cheap, portable and convenient to be used at site.

66. Draw the Stress-Strain curve for concrete. (April/May 2019) (Nov/Dec 2019)



67. Define durability of concrete. (Nov/De 2019)

- Durability of concrete is its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration.
- When exposed to environment durable concrete is likely to retain its original form, quality and serviceability during its lifetime.

68. **Define: Permeability**.

- Permeability is the ease with which liquids or gases can travel through concrete.
- This property is of interest in relation to the water-tightness of liquid retaining structures and to chemical attack.

69. **What is water absorption in hardened concrete?**

- The water absorption is determined by measuring the decrease in mass of a saturated and surface-dry sample after oven drying for 24 hours.
- The amount of water absorbed depends on the order of feeding the ingredients into the mixer and on the coating of coarse aggregate with cement paste.

70. What are the causes of bleeding and segregation? (Nov/Dec 2019)

<u>Causes of segregation</u>

- Poorly graded aggregate & excessive water content is the major cause of segregation.

- A badly proportioned mix, where sufficient matrix is not there to bond and contain the aggregate cause aggregates to settle down.
- Insufficiently mixed concrete with excess water content shows a higher tendency for segregation.

Causes of bleeding

- Bleeding is a form of segregation in which water present in the concrete mix is pushed upwards due to the settlement of cement and aggregate.
- The specific gravity of water is low, due to this water tends to move upwards.
- Bleeding ordinarily occurs in the wet mix of concrete.

PART B& C

1. Define workability. Explain the factors affecting workability.(May/June 2016) (Nov/Dec 2017)

Workability

- The lubrication required for handling concrete without segregation, for placing without loss of homogeneity, for compacting with the amount of efforts forth-coming and to finish it sufficiently easily, the presence of a certain quantity of water is of vital importance.

- The quality of concrete satisfying the above requirements is termed as workable concrete.

Factors Affecting Workability

- Workable concrete is the one which exhibits very little internal friction between particle and particle or which overcomes the frictional resistance offered by the formwork surface or reinforcement contained in the concrete with just the amount of compacting efforts forthcoming.
- The factors helping concrete to have more lubricating effect to reduce internal friction for helping easy compaction are given below:

  (a) Water Content (b) Mix Proportions

  (c) Size of Aggregates (d) Shape of Aggregates

  (e) Surface Texture of Aggregate (f) Grading of Aggregate

  (g) Use of Admixtures.

(a) Water Content:

- Water content in a given volume of concrete, will have significant influences on the workability.
- The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability.

(b) Mix Proportions*:*

- Aggregate/cement ratio is an important factor influencing workability. The higher the aggregate/cement ratio, the leaner is the concrete.
- On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

(c) Size of Aggregate:

- The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction.

(d) Shape of Aggregates:

- The shape of aggregates influences workability in good measure. Angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded aggregates or cubical shaped aggregates.
- Contribution to better workability of rounded aggregate will come from the fact that for the given volume or weight it will have less surface area and less voids than angular or flaky aggregate.

(e) Surface Texture:

- The influence of surface texture on workability is again due to the fact that the total surface area of rough textured aggregate is more than the surface area of smooth rounded aggregate of same volume.

- A reduction of inter particle frictional resistance offered by smooth aggregates also contributes to higher workability.

(f) Grading of Aggregates:

- This is one of the factors which will have maximum influence on workability. A well graded aggregate is the one which has least amount of voids in a given volume.
- Aggregate particles will slide past each other with the least amount of compacting efforts. The better the grading, the less is the void content and higher the workability. The above is true for the given amount of paste volume.

(g) Use of Admixtures:

- Of all the factors mentioned above, the most import factor which affects the workability is the use of admixtures.
- It is to be noted that initial slump of concrete mix or what is called the slump of reference mix should be about 2 to 3 cm to enhance the slump many fold at a minimum doze. One should manipulate other factors to obtain initial slump of 2 to 3 cm in the reference mix.
- Without initial slump of 2 –n 3 cm, the workability can be increased to higher level but it requires higher dosage – hence uneconomical.
- Use of air-entraining agent being surface-active, reduces the internal friction between the particles. They also act as artificial fine aggregates of very smooth surface.

2. Explain the test for workability (or) how do you determine the fresh concrete properties? Explain any two in detail.(Nov/Dec 2016, 2017, 2019)(May/June 2016) (April/May 2018, 2019)

Measurement of Workability

- Workability of concrete is a complex property. Numerous attempts have been made by many research workers to quantitatively measure this important and vital property of concrete.
- Some of the tests measure the parameters very close to workability and provide useful information. The

following tests are commonly employed to measure workability

(a) Slump Test

(b) Compacting Factor Test

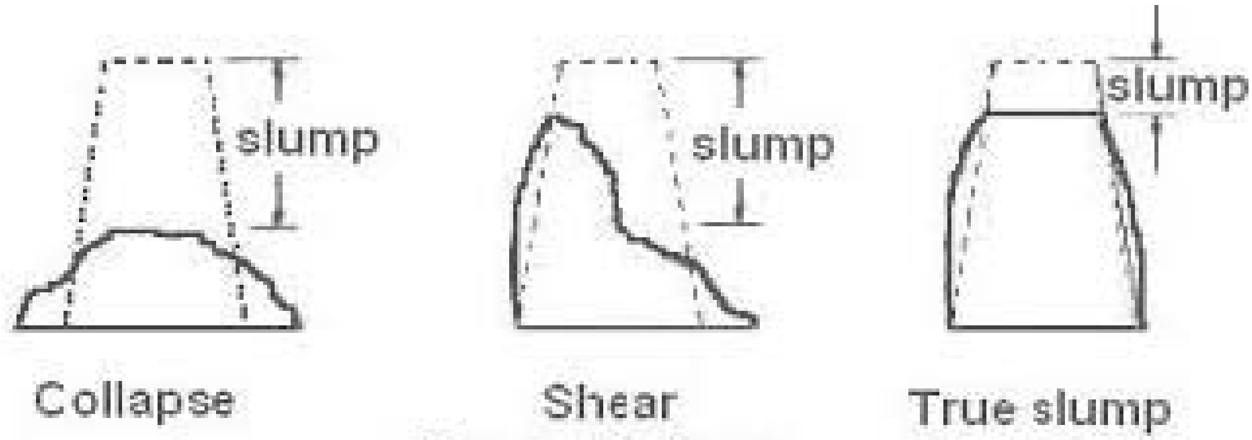
(c) Flow Test

(d) Kelly Ball Test

(e) Vee Bee Consistometer Test.

Slump Test

- Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete.
- It does not measure all factors contributing to workability, nor is it always representative of the place ability of the concrete.
- Repeated batches of the same mix, brought to the same slump, will have the same water content and water cement ratio; provided the weights of aggregate, cement and admixtures are uniform and aggregate grading is within acceptable limits.
- Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps.
- Quality of concrete can also be further assessed by giving a few tamping or blows by tamping rod to the base plate.
- The deformation shows the characteristics of concrete with respect to tendency forsegregation.
- The apparatus for conducting the slump test essentially consists of ametallic mould in the form of a frustum of a cone having the internal dimensions asunder:
  - Bottom diameter r: 20 cm
  - Top diameter : 10 cm
  - Height: 30 cm



Types of slump

- The thickness of the metallic sheet for the mould should not be thinner than 1.6 mm. Sometimes the mould is provided with suitable guides for lifting vertically up. For tamping the concrete, a steel tamping rod 16 mm dia, 0.6 meter along with bullet end is used.
- The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test.
- The mould is placed on a smooth, horizontal, rigid and non-absorbent surface the mould is then filled in four layers, each approximately 1/4 of the height of the mould.
- Each layer is tamped 25 times by the tamping rod takingcare to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod.
- The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subsidence is referred as SLUMP of concrete.
- The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm. is taken as Slump of Concrete.
- Shear slump also indicates that the concrete is non-cohesive and shows the characteristic of segregation. It is seen that the slump test gives fairly good consistent results for a plastic-mix.
- This test is not sensitive for a stiff-mix. In case of dry-mix, no variation can be detected between mixes of different workability.
- In the case of rich mixes, the value is often satisfactory, their slump being sensitive to variations in workability.

<u>K-SLUMP TESTER</u>

- It can be used to measure the slump directly in one minute after the tester is inserted in the fresh concrete to the level of the floater disc. This ester can also be used to measure the relative workability.
- Chrome plated steel tube with external and internal diameters of 1.9 and 1.6 cm respectively. The tube is 25 cm long and its lower part is used to make the test.
- The length of this part is 15.5 cm which includes the solid cone that facilitates inserting the tube into the concrete.
- Two types of openings are provided in this part: 4 rectangular slots 5.1 cm long and 0.8 cm wide and 22 round holes 0.64 cm in diameter; all these openings are distributed uniformly in the lower part.
- A disc floater 6 cm in diameter and 0.24 cm in thickness which divides the tube into two parts: the upper part serves as a handle and the lower one is for testing as already mentioned.
- The disc serves also to prevent the tester from sinking into the concrete beyond the preselected level.A hollow plastic rod 1.3 cm in diameter and 25 cm long which contains a graduated scale in centimeters.
- This rod can move freely inside the tube and can be used to measure the height of mortar that flows into the tube and stays there. The rod is plugged at each end with a plastic cap to prevent concrete or any other material from seeping inside.
- An aluminium cap 3 cm diameter and 2.25 cm long which has a little hole and a screw that can be used to set and adjust the reference zero of the apparatus.
- There is also in the upper part of the tube, a small pin which is used to support the measuring rod at the beginning of the test. The total weight of the apparatus is 226 g.

The following procedure is used:

(a) Wet the tester with water and shake off the excess.

(b) Raise the measuring rod, tilt slightly and let it rest on the pin located inside the tester.

(c) Insert the tester on the leveled surface of concrete vertically down until the disc float rests at the surface of the concrete. Do not rotate while inserting or removing the tester.

(d) After 60 seconds, lower the measuring rod slowly until it rests on the surface of the concrete that has entered the tube and read the K-Slump directly on the scale of the measuring rod.

(e) Raise the measuring rod again and let it rest on its pin.

(f) Remove the tester from the concrete vertically up and again lower the measuring rod slowly till it touches the surface of the concrete retained in the tube and read workability (W) directly on the scale of the measuring rod.

- The K-slump apparatus is very simple, practical, and economical to use, both in the field and the laboratory. The K-slump tester can be used to measure slump in one minute in cylinders, pails,buckets, wheel-barrows, slabs or any other desired location where the fresh concrete is placed.

Advantages of slump test

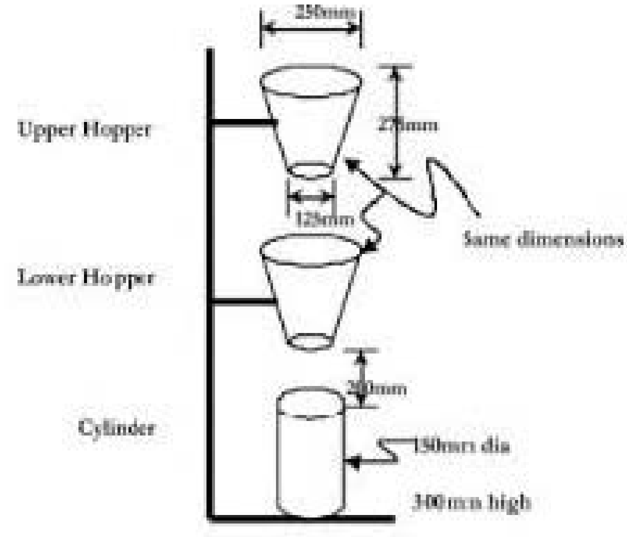
- ❖ It grants the facility to easily detect the difference in water content of successive batches of concrete of the same identical mix.
- ❖ The apparatus is cheap, portable and convenient to be use at site.

Limitation of slump test

- ❖ As such, there is no direct relationship between the workability and the value of slump.
- ❖ It is not suitable for a concrete in which maximum size of the aggregate exceeds 40 mm.
- ❖ There are chances of many shapes of slump to occur and it is difficult to decide which the correct value is.
- ❖ The slump occurs only in case of plastic mixes. It does not occur in case of dry mixes.

COMPACTING FACTOR TEST

- The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field.
- It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concrete are insensitive to slump test.
- The degree of compaction, called the compacting factor is measured by the density ratio i.e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.
- The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap-door is opened so that the concrete falls into the lower hopper.
- Then the trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. In the case of a dry-mix, it is likely that the concrete may not fall on opening the trap-door.
- In such a case, a slight poking by a rod may be required to set the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blades supplied with the apparatus.
- The outside of the cylinder is wiped clean. The concrete is filled up exactly upto the top level of the cylinder. It is weighed to the nearest 10 grams.
- This weight is known as ―Weight of partially compacted concrete.

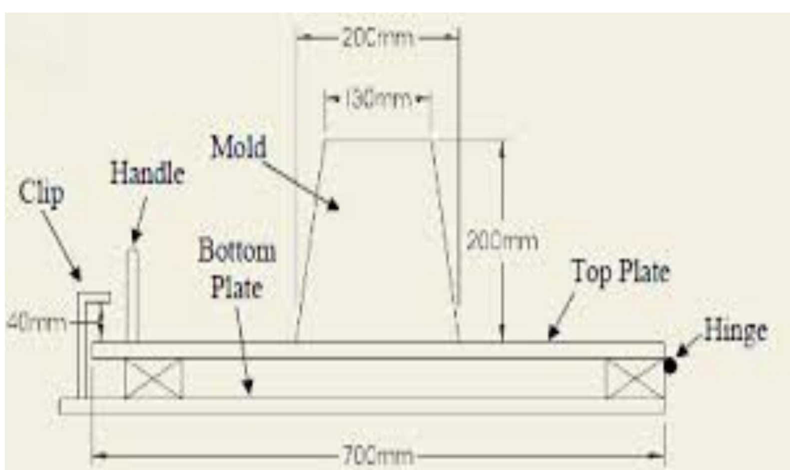


- The cylinder is emptied and then refilled with the concrete from the same sample in layers approximately 5 cm deep. The layers are heavily rammed or preferably vibrated so as to obtain full compaction.
- The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighed to the nearest 10 gm. This weight is known as Weight of fully compacted concrete.

The compaction factor =
$$\text{The compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

FLOW TEST (May/June 2016, Nov/Dec 2016)

- This is a laboratory test, which gives an indication of the quality of concrete with respect to consistency, cohesiveness and the proneness to segregation.
- In this test, a standard mass of concrete is subjected to jolting. The spread or the flow of the concrete is measured and this flow is related to workability.



Flow Table Test Apparatus

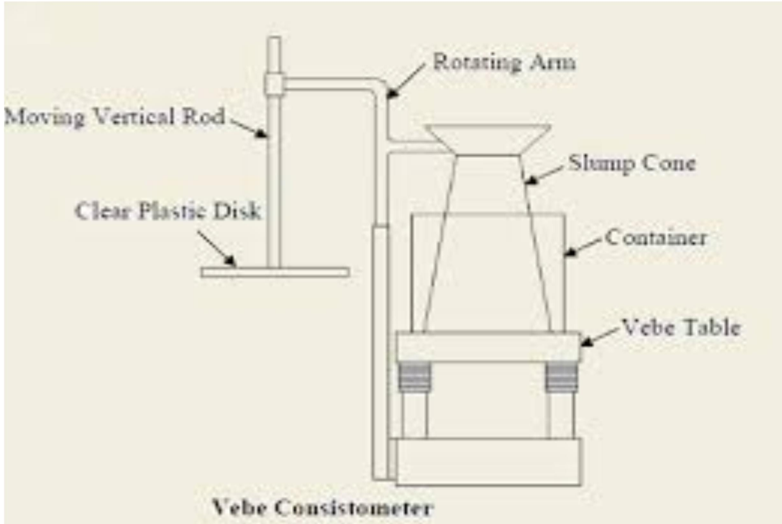
- It can be seen that the apparatus consists of flow table, about 76 cm. in diameter over which concentric circles are marked.
- A mould made from smooth metal casting in the form of a frustum of a cone is used with the following internal dimensions.
- The base is 25 cm. in diameter, upper surface 17 cm. in diameter, and height of the cone is 12 cm. The table top is cleaned of all gritty material and is wetted.
- The mould is kept on the centre of the table, firmly held and is filled in two layers. Each layer is rodded 25 times with a tamping rod 1.6 cm in diameter and 61 cm long rounded at the lower tamping end.
- After the top layer is rodded evenly, the excess of concrete which has overflowed the mould is removed.
- The mould is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped
- 12.5 mm 15 times in about 15 seconds. The diameter of the spread concrete is measured in about 6 directions to the nearest 5 mm and the average spread is noted.
- The flow of concrete is the percentage increase in the average diameter of the spread concrete over the base diameter of the mould

$$\textbf{Flow per cent} = \frac{\textbf{Spread diameter in cm} - 25}{25} \times 100$$

- The value could range anything from 0 to 150 per cent. A close look at the pattern of spread of concrete can also give a good indication of the characteristics of concrete such as tendency for segregation.

VEE BEE CONSISTOMETER TEST

- This is a good laboratory test to measure indirectly the workability of concrete. This testconsists of a vibrating table, a metal pot, a sheet metal cone, a standard iron rod.
- Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the consistometer.
- The glass disc attached to the swivel armis turned and placed on the top of the concrete in the pot.
- The electrical vibrator is then switched on and simultaneously a stop watch started.



- The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes a cylindrical shape.
- This can be judged by observing the glass disc from the top for disappearance of transparency. Immediately when the concrete fully assumes a cylindrical shape, the stop watch is switched off.
- The time required for the shape of concrete to change from slump cone shape to cylindrical shape in seconds is known as Vee Bee Degree.
- This method is very suitable for very dry concrete whose slump value cannot be measured by Slump Test but the vibration is too vigorous for concrete with a slump greater than about 50 mm.

3. Explain segregation and Bleeding.(Nov/Dec 2017) (April/May 2019)

Segregation

- Segregation can be defined as the separation of the constituent materials of concrete. A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture.
- If a sample of concrete exhibits a tendency for separation f say, coarse aggregate from the rest of the ingredients, then, that sample is said to be showing the tendency for segregation. Such concrete is not only going to be weak; lack of homogeneity is also going to induce all undesirable properties in the hardened concrete.
- A well made concrete, taking into consideration various parameters such as grading, size, shape and surface texture of aggregate with optimum quantity of waters makes a cohesive mix. Such concrete will not exhibit any tendency for segregation.
- The cohesive and fatty characteristics of matrix do not allow the aggregate to fall apart, at the same time; the matrix itself is sufficiently contained by the aggregate. Similarly, water also does not find it easy to move out freely from the rest of the ingredients.

- The conditions favorable for segregation are the badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates.
- Insufficiently mixed concrete with excess water content shows a higher tendency for segregation.
- Dropping of concrete from heights as in the case of placing concrete in column concreting will result in segregation.
- When concrete is discharged from a badly designed mixer, or from a mixer with worn out blades, concrete shows a tendency for segregation.
- Conveyance of concrete by conveyor belts, wheel barrow, long distance haul by dumper, long lift by skip and hoist are the other situations promoting segregation of concrete. Vibration of concrete is one of the important methods of compaction.
- It should be remembered that only comparatively dry mix should be vibrated. It too wet a mix is excessively vibrated; it is likely that the concrete gets segregated.
- A cohesive mix would reduce the tendency for segregation. For this reason, use of certain workability agents and pozzolanic materials greatly help in reducing segregation.
- The use of air-entraining agent appreciably reduces segregation.
- Segregation is difficult to measure quantitatively, but it can be easily observed at the time of concreting operation.
- The pattern of subsidence of concrete in slump test or the pattern of spread in the flow test gives a fair idea of the quality of concrete with respect to segregation.

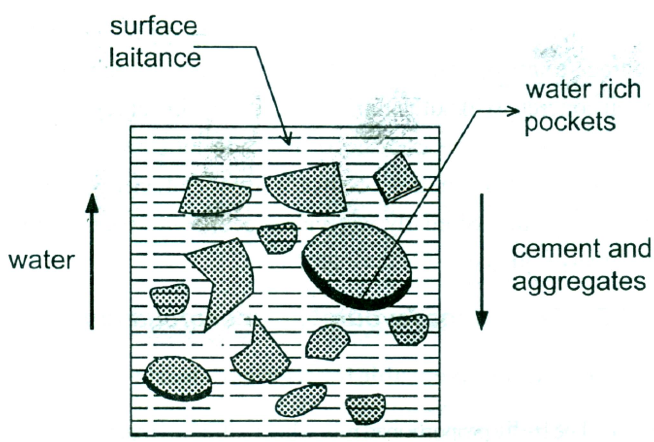


Figure 4.6 Theory behind segregation of concrete

The separation can be of three types as mentioned below:

- Coarse aggregate separating out or settling down from rest of the matrix (Type-l segregation).
- The paste separating away from coarse aggregate (Type-2 segregation) ,
- Water being lowest in specific gravity, separating out from the rest of the material (Type-3 segregation, called Bleeding)

Remedies for segregation

- By correctly proportioning the mix,
- By proper handling,
- By proper transporting,
- By proper placing,
- By proper compacting and
- By proper finishing.

At any stage, if segregation is observed, remaining for a short time would make the concrete again homogeneous.

As mentioned earlier, a cohesive mix would reduce the tendency for segregation. For this reason, use of certain workability agents and pozzolanic materials greatly help in reducing segregation.

The use of air-entraining agent appreciably reduces segregation.

Bleeding

- Bleeding is sometimes referred as water gain. It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete.
- Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete.
- In thin members like roof slab or road slabs and when concrete is placed in sunny weather show excessive bleeding. Due to bleeding, water comes up and accumulates at the surface.
- Sometimes, along with this water, certain quantity of cement also comes to the surface. When the surface is worked up with the trowel and floats, the aggregate goes down and the cement and water come up to the top surface.
- This formation of cement paste at the surface is known as Laitance. Water while traversing from bottom to top, makes continuous channels. If the water cement ratio used is more than 0.7, the bleeding channels will remain continuous and unsegmented by the development of gel. These continuous bleeding channels are often responsible for causing permeability of the concrete structures.
- While the mixing water is in the process of coming up, it may be intercepted by aggregates. The bleeding water is likely to accumulate below the aggregate.
- This accumulation of water creates water voids and reduces the bond between the aggregates and the paste. The above aspect is more pronounced in the case of flaky aggregate.
- Similarly, the water that accumulates below the reinforcing bars, particularly below the cranked bars, reduces the bond between the reinforcement and the concrete.

- The poor bond between the aggregate and the paste or the reinforcement and the paste due to bleeding can be remedied by revibration of concrete.
- The formation of laitance and the consequent bad effect can be reduced by delayed finishing operations.
- Bleeding rate increases with time up to about one hour or so and thereafter the rate decreases but continues more or less till the final setting time of cement.Bleeding is an inherent phenomenon in concrete.
- All the same, it can be reduced by proper proportioning and uniform and complete mixing.
- The bleeding is not completely harmful if the rate of evaporation of water from the surface is equal to the rate of bleeding.

Method of Test for Bleeding of Concrete

- This method covers determination of relative quantity of mixing water that will bleed from a sample of freshly mixed concrete A cylindrical container of approximately 0.01 m^3 capacity, having an inside diameter of 250 mm and inside height of 280 mm is used.
- A tamping bar similar to the one used for slump test is used. A pipette for drawing off free water from the surface, a graduated jar of 100 cm^3 capacities is required for test.
- A sample of freshly mixed concrete is obtained. The concrete is filled in 50 mm layer for a depth of 250 ± 3 mm (5 layers) and each layer is tamped by giving strokes, and the top surface is made smooth by toweling.
- The test specimen is weighed and the weight of the concrete is noted. Knowing the total water content in 1 m^3 of concrete quantity of water in the cylindrical container is also calculated.
- The cylindrical container is kept in a level surface free from vibration at a temperature of 27°C ± 2°C. It is covered with a lid.
- Water accumulated at the top is drawn by means of pipette at 10 minutes interval for the first 40 minutes and at 30 minutes interval subsequently till bleeding ceases.
- To facilitate collection of bleeding water the container may be slightly tilted. All the bleeding water collected in a jar.

Bleeding water percentage = Total quantity of bleeding water X 100
Total quantity of water in concrete

Effects* of *bleeding on concrete

- ❖ Due to bleeding concrete loses its homogeneity.
- ❖ Bleeding is responsible for causing permeability in concrete.

- ❖ In the process of bleeding (i.e. while water is in the process of coming towards top) sometimes gets accumulated below the aggregate.
- ❖ This accumulation of water creates a water voids and reduces bond between the aggregate and cement past. So the strength of concrete reduces (Note:This aspect is more pronounced in case of flaky aggregates).
- ❖ Similarly, water that accumulates below the reinforcing bars, particularly below the cranked bars, reduces the bond between the reinforcement and concrete.
- ❖ If a slip form paver is used for construction of concrete pavement, the bleeding water causes very serious problems.
- ❖ If too much of bleeding water accumulates on the surface of pavement slab, the bleeding water flows at over the unsupported side which. Causes collapsing of sides.
- ❖ In pavement construction bleeding water delays surface finishing and application of curing compound.

4. Explain the properties of fresh and hardened concrete.

PROPERTIES OF FRESH CONCRETE (April/May 2018)

- The fresh concrete or plastic concrete is the initial stage of concrete period and it is counted from the mixing stage till it is transported, placed, compacted and finished in the position.
- The fresh concrete must satisfy the following requirements. Ideal Requirements of Fresh Concrete

i. Mixability

- The mix should be able to produce a homogeneous and uniform fresh concrete from the constituent materials of each batch under the action of mixing forces.

ii. Stability

- The mix should be stable meaning thereby it should not segregate during transporting and placing and also the tendency of the bleeding should be minimum.

iii. Mobility/Flow ability

- The mix should be mobile enough to surround all reinforcement without leaving any voids behind as well as to completely fill the formwork.

iv. Compact ability

- The mix should be amenable to proper and thorough minimum compaction into a dense compact concrete under the existing facilities of compaction at site.

v. Finishability

- It should be able to obtain a uniform and satisfying surface finish.

PROPERTIES OF HARDENED CONCRETE (Nov/Dec 2017)(Nov/Dec 2018)

- The concrete is a basic prime building material because of various properties being possessed during its hardened state which starts from the day it attains the full designed strength to the end of its life.
- For hardened concrete, the various properties which need consideration are as follows.

(A) STRENGTH

a. Compressive strength

b. Tensile strength

c. Flexural strength

d. Shear strength

e. Bond strength

(B) Durability

(C) Impermeability

(D) Dimensional Changes

(a) Elasticity

(b) Shrinkage

(c) Creep

(d) Thermal expansion

(e) Fatigue

(E) Fire Resistance

STRENGTH OF CONCRETE

- The strength of concrete is the most important property as far as structural designs are concerned. Indirectly, it gives the idea of other properties (Impermeability, durability, wear resistance etc) also.
- A strong concrete is more dense, compact, impermeable and resistant to weathering and chemical attacks. Meaning thereby, the strength of concrete gives an overall idea of its quality.
- Strength of concrete is defined as the ability to resist force and for structural purposes, it is taken as the unit force required to cause rupture which may be caused by compressive stress, tensile stress, flexural stress, shear stress, bond stress etc.

Compressive Strength of Concrete

- The compressive strength of concrete is considered the basic character of the concrete.
- Consequently, it is known as the **characteristic compressive strength of concrete (fck)** which is defined as that value below which not more than five percent of test results are expected to fall based on

IS: 456-2000. In this definition the test results are based on 150 mm cube cured in water under temp. Of 27 ± 2°C for 28 days and tested in the most saturated condition under direct compression.

- Other strength viz, direct tensile stress, flexural stress, shear stress and bond stress also are directly proportional to the compressive stress. Higher is the compressive stress, higher is other stresses also.
- Not only stresses, other properties for example modulus of elasticity, abrasion and impact resistances, durability are also taken to be related to the compressive strength, hence, the compressive strength is an index of overall quality of concrete.

5. Explain the factors influencing the strength of concrete.(April/May 2017, 2019)(Nov/Dec 2016)

Factors Affecting Compressive Strength

- Among the materials and mix variables, **water -cement ratio** is the most important parameter governing the compressive strength.
- Besides W/C ratio, following factors also affect the compressive strength.
  - The characteristics of cement.
  - The characteristics and properties of aggregates.
  - The degree of compaction
  - The efficiency of curing
  - Age at the time of testing.
  - Conditions of testing.

Water -Cement Ratio

- The water -cement ratio, defined as the ratio of the mass of free water (i.e. excluding that absorbed by the aggregate) to that of cement in a mix, is the most important factor that controls the strength and many other properties of concrete.
- In practice, this ratio lies generally in the range of 0.35 to 0.65, although the purely chemical requirement (for the purpose of complete hydration of cement) is only about 0.25.
- The compressive strength of concrete at a given age and under normal temperature, depends primarily on w/c ratio; lower the w/c ratio, greater is the compressive strength and vice versa.
- This was first enunciated by Abrams as S = where S is the compressive strength, w/c is water -cement ratio of a fully compacted concrete mix, K 1 and K 2 are empirical constants.
- In day-to-day practice, the constants K 1 and K2 are not evaluated, instead the relationship between compressive strength and w/c ratio are adopted which are supposed to be valid for a wide range of conditions.

- Effect of water -cement ratio on compressive strength at different ages. A reduction in the water cement ratio generally results in an increased quality of concrete in terms of strength, density, impermeability, reduced shrinkage and creep etc.
- The probable reason, why lower w/c ratio gives higher strength of concrete may be found by considering the cement forms a paste with water and it is this paste that binds the different particles of aggregates.
- So thicker is the consistency of the paste, greater is its binding property. Another reason is that the quantity of water required for chemical combination is very small (about 25% of the weight of cement) compared with that required for workability and the excess water ultimately on evaporation leaves pores.
- The greater is the excess of water, greater is loss of strength and water -tightness. The tensile strength and bond strength with steel do not decrease with increase in w/c ratio to the same extent as compressive strength does. Say with increase in w/c ratio from 0.5 to 0.6, the decrease in tensile strength and bond strength is 10% but decrease in compressive strength is about 25%.

Characteristics and properties of cement

- The type of cement and fineness of cement affect the strength of concrete. With respect to Ordinary Portland cement (OPC), Rapid Hardening Portland Cement (RHPC) and Low Heal Portland Cement (141-1PC) give higher and lower strength respectively.
- The rate of gain of strength depends entirely upon fineness of the cement. Finer cement increases the rate of hydration and hydrolysis which results in early development of strength though the ultimate strength is not affected.

Characteristics and Properties of Aggregates

The strength of concrete is governed by

  - strength of aggregate
  - strength of mortar
  - bond strength between mortar and aggregate

- The strength of aggregate is normally greater than the strength of mortar and bond between mortars and aggregate.
- The strength of mortar depends upon w/c ratio whereas bond between mortar and aggregate depends upon the strength of mortar and the size, shape, texture and grading of aggregate.
- Larger maximum size of coarse aggregate gives lower compressive strength of concrete. The reasons behind may be stated as follows.

- The larger maximum size aggregate gives lower surface area for development of gel bond which is responsible for lower strength. Aggregates of smaller size, angular aggregate and aggregate of rough surface texture provides more surface area and more consumption of cement and hence more bond strength.
- Bigger aggregate size causes a more heterogeneity in the concrete and this prevents uniform distribution of load when stressed.
- For larger size aggregate the transition zone becomes much weaker due to development of micro cracks which result in lower compressive strength.

The degree of compaction

- Higher is the compaction of freshly mixed concrete, more is the reduction of the voids and consequently greater is the compressive strength of concrete.

The efficiency of curing

- Curing is the name given to procedures used for promoting the hydration of cement, and consists of a control of temperature and of the moisture movement from and into the concrete.
- Hydration of cement takes place in capillaries filled with water.
- By keeping concrete saturated, loss of water by evaporation from the capillaries is prevented and loss of water by self desiccation (due to the chemical reactions of hydration of cement) from outside.
- Cuing should be continued until the originally water filled space in the fresh cement paste has been filled by product of hydration to the desired extent. Curing temperature should be from 23° to 30°C (27°C average).
- The curing must be adequate at favorable temperature for sufficient period which helps in attaining the maximum strength and other desirable properties.
- Age of Concrete the strength of concrete increases with age as the hydration of cement prolongs for a considerable time.

Conditions of Testing

- After adequate curing, the concrete mould is tested in the moist saturated condition with surface wiped out under direct compression.
- The strength of concrete is influenced by moisture content at the time of testing, because moisture content in concrete provides lubrication effect and reduces the strength when compared with dry sample.
- Strength in dry sample = 1.10 to 1.20 times the strength of the saturated sample.

Strength of Prism Vs 150 mm Strength

- The characteristic strength of concrete (fck) is based on 150 mm cube but if it is tested on the prism mould the strength of prism specimen decreases with increase in height to the side ratio and stabilizes when this ratio is 5.

- Variation in Strength with Size of Cubes The characteristic strength of concrete is based on 150mm cube but the strength of concrete determined through the cube specimen varies with the size of cubes.
- The strength of specimen increases with decrease in size and vice -versa as indicated in the Cube (150 mm) Strength Vs Cylinder (150 mm dia, 300 mm ht) Strength If the concrete is tested on cylinder having 150 mm diameter and height 300 mm instead of 150 mm cube, the cube strength can be estimated as Cylinder strength (fcu) = 0.80 * cube strength (fck)

TENSILE STRENGTH (May/June 2016)

- Tensile strength of concrete under direct tension is very small and generally neglected in normal design practice. Although the value ranges from 8 to 12% of its compressive strength.
- An average value 10% is the proper choice. The direct tension method suffers the problem like holding the specimen properly in the testing machine and the application of uniaxial tensile load not being free of eccentricity.
- The tensile strength can be calculated indirectly by loading a concrete cylinder to the compressive force along the two opposite ends (with its axis horizontal)
- Due to uniform tensile stress acting horizontally along the length of cylinder, the cylinder splits into two halves.
- The magnitude of this tensile stress (acting in a direction perpendicular to the line of action of applied compression) is given by

  S = 2 where; S = Tensile stress in kg/cm 2 P = load causing rupture in kg

  D = Dia in cm (15 cm)

  L = Length in cm (30 cm)

- The indirect tensile stress is known as SPLITTING TENSILE STRENGTH.

FLEXURAL STRENGTH

- The maximum tensile stress resisted by the plain concrete in flexure (bending) is called FLEXURAL STRENGTH (MODULUS OF RUPTURE) expressed in N/mm^2 or kg/m^2.
- The most common plain concrete subjected to flexure is a highway/runway pavement. The strength of pavement concrete is evaluated by means of bending test on beam specimen.

- The flexural strength (modulus of rupture) is determined by testing standard test specimens of 150 mm x 150 mm x 700 mm over a span of 600 mm or 100 mm x 100 mm x 500 mm over a span of 400 min. under symmetrical two point loading

SHEAR STRENGTH

- Shear strength is the capacity of concrete to resist the sliding of the section over the adjacent section.
- A good amount of shear strength capacity is possessed by concrete depending upon the grade of concrete and percentage of tensile reinforcement in the section.
- It is difficult to obtain shear strength of concrete but I.S. code suggests the value for different grade of concrete.

BOND STRENGTH

- Bond strength is the shear stress at the interface of reinforcement bar and surrounding concrete developed to resist any force that tries slippage of the reinforcement to its surrounding concrete.
- It is determined by PULL OUT TEST. The av. bond strength is 10% of compressive strength of concrete the bond strength depends upon grade of concrete, higher the grade, higher is the value of bond strength.

6) Explain in detail about the determination of Compressive and Flexural strength of concrete. (April/May 2017, 2018) (Nov/Dec 2017, 2018)

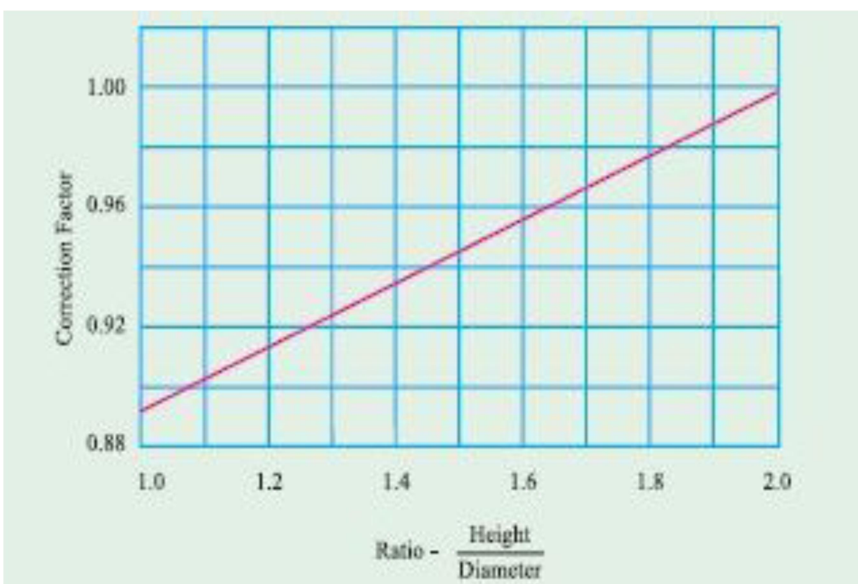
Compression Test

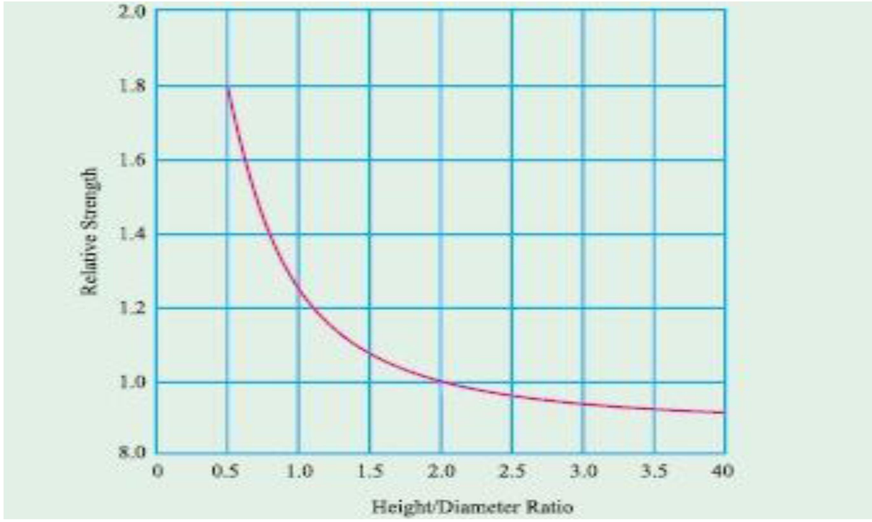
- Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

- The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm, 10 cm size cubes may also be used as an alternative. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long. Smaller test specimens may be used but a ratio of the diameter of the specimen to maximum size of aggregate, not less than 3 to 1 is maintained.

Failure of Compression Specimen

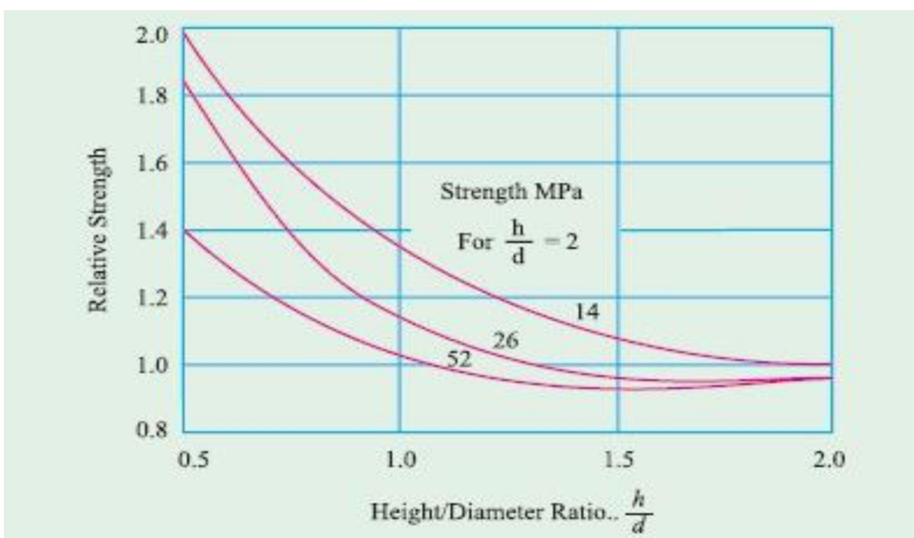
- Due to compression load, the cube or cylinder undergoes lateral expansion owing to the Poisson's ratio effect. The steel plates do not undergo lateral expansion to the some extent that of concrete, with the result that steel restrains the expansion tendency of concrete in the lateral direction.
- This induces a tangential force between the end surfaces of the concrete specimen and the adjacent steel plates of the testing machine. It has been found that the lateral strain in the steel plates is only 0.4 of the lateral strain in the concrete.
- Due to this the platen restrains the lateral expansion of the concrete in the parts of the specimen near its end. The degree of restraint exercised depends on the friction actually developed.
- When the friction is eliminated by applying grease, graphite or paraffin wax to the bearing surfaces the specimen exhibits a larger lateral expansion and eventually splits along its full length.
- With friction acting i.e., under normal conditions of test, the elements within the specimen is subjected to a shearing stress as well as compression.
- The magnitude of the shear stress decreases and the lateral expansion increases in distance from the platen. As a result of the restraint, in a specimen tested to destruction there is a relatively undamaged cone of height equal to √ 3/2 d.
- But if the specimen is longer than about 1.7 d, a part it of will be free from the restraining effect of the platen. Specimens, whose length is less than 1.5 d, show a considerably higher strength than those with a greater length.





Effect of the Height/Diameter Ratio on Strength:

- Normally, height of the cylinder ―h is made twice the diameter d, but sometimes, particularly, when the core is cut from the road pavements or airfield pavements or foundations concrete, it is not possible to keep the height/diameter ratio of 2:1.
- The diameter of the core depends upon the cutting tool, and the heightof the core will depend upon the thickness of the concrete member. If the cut lengthof the core is too long.
- It can be trimmed to h/d ratio of 2 before testing. But withtoo short a core, it is necessary to estimate the strength of the same concrete, as ifit had been determined on a specimen with h/d ratio equal to 2.
- High strength concrete is less affected than the low strength concrete. Figure shows the influence of h/d ratio on the strength of cylinder for different strength levels.



- Figure shows the general pattern of influence of h/d ratio on the strength of cylinder. It is interesting to note that the restraining effect of the platens of the testing machine extends over the entire height of the cube but leaves unaffected a part of test cylinder because of greater height.

- It is, therefore, the strength of the cube made from identical concrete will be different from the strength of the cylinder.
- Normally strength of the cylinder is taken as 0.8 times the strength of the cube, but experiments have shown that there is no unique relationship between the strength of cube and strength of cylinder.
- It was seen that the strength relation varies with the level of the strength of concrete. For higher strength, the difference between the strength of cube and cylinder is becoming narrow. For 100 MPa concrete the ratio may become nearly 1.00.

7. Discuss in detail about the flexural strength of concrete. (May/June 2016) (April/May 2018)

The Flexural Strength of Concrete:

- Concrete is relatively strong in compression and weak in tension.
- In reinforced concrete construction the strength of the concrete in compression is only taken into consideration.
- The tensile strength of concrete is generally not taken into consideration.
- A concrete road slab is called upon to resist tensile stresses from two principal sources - wheel loads and volume change in the concrete.
- Wheel loads may cause high tensile stresses due to bending, when there is an inadequate sub grade support.
- Volume changes, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the sub grade.
- Stresses due to volume changes alone may be high.
- The longitudinal tensile stress in the bottom of the pavement caused by restraint and temperature warping frequently amounts to as much as 2.5 N/mm- at certain periods of the year and the corresponding stress in the transverse direction is approximately 0.9 N/rnm^2.
- These stresses are additive to those produced by wheel loads on unsupported portions of the slab.
- Therefore, it is necessary to assess the flexural strength of concrete either from the compressive strength or independently.
- As measurements and control of compressive strength in field are easier and more convenient, it has been customary to find out the compressive strength for different conditions and to correlate this compressive strength to flexural strength.
- Having established a satisfactory relationship between flexural and compressive strength, pavement, can be designed for a specified flexural strength value, or this value could be used in any other situations when required.

- Strength of concrete in compression and tension (both direct tension and flexural tension) are closely related, but the relationship is not of the type of direct proportionality.
- The ratio of the two strengths depends on general level of strength of concrete. In other words, for higher compressive strength concrete shows higher tensile strength, but the rate of increase of tensile strength is of decreasing order.
- The flexural strength of concrete was found to be 8 to 11 per cent of the compressive strength of the concrete for higher ranges of concrete strength (greater than 25 N/rnm^2) and 9 to 13 per cent for lower ranges of concrete strength (less than 25 N/rnm^2) approximately.
- The flexural to compressive strength ratio was higher with aggregate of 40 mm maximum size than with those of 20 mm maximum size.
- In general the ratio was found to be slightly higher in the case of natural gravel as compared to crushed stone.
- There are number of empirical relationships connecting tensile strength and compressive strength of concrete.
- One of the common relationships is shown below.

  Tensile Strength = K (Compressive Strength) x n

- Where, value of K varies from 6.2 for gravels to 10.4 for crushed rock (average value is 8.3) and value of''n' may vary from 0.5 to 0.75.
- The Indian Standard IS: 456 of2000 give the following relationship between the compressive strength and flexural strength

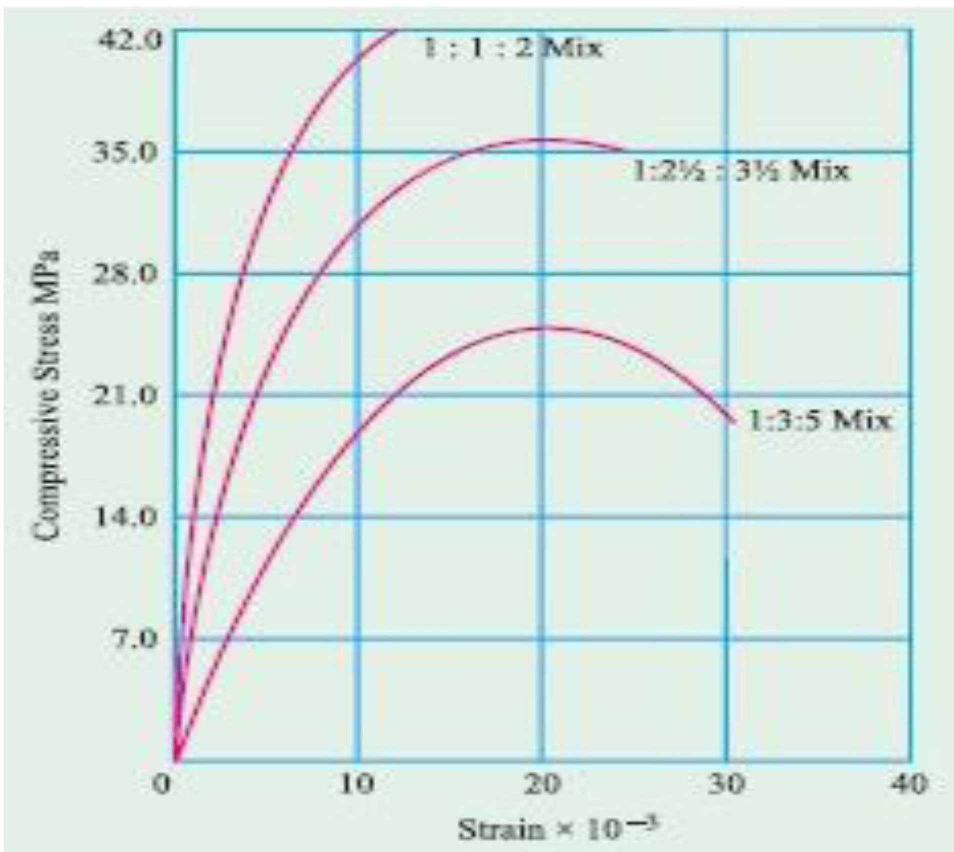
  Flexural strength = 0.7 $\sqrt{fck}$

  Where, fck is the characteristic compressive strength of concrete in N/mm^2.

8. Explain in detail about the determination of Young's Modulus and Stress-strain curve for concrete. (Nov/Dec 2017, 2019)

- When reinforced concrete is designed by elastic theory it is assumed that a perfect bond exists between concrete and steel.
- The stress in steel is m times the stress in concrete where m is the ratio between modulus of elasticity of steel and concrete, known as modular ratio.
- The accuracy of design will naturally be dependent upon the value of the modulus of elasticity of concrete, because the modulus of elasticity of steel is more or less a definite quantity.
- The modulus of elasticity is determined by subjecting a cube or cylinder specimen to uniaxial compression and measuring the deformations by means of dial gauges fixed between certain gauge lengths.

- Dial gauge reading divided by gauge length will give the strain and load applied divided by area of cross section will give the stress. A series of readings are taken and the stress-strain relationship is established.
- The modulus of elasticity can also be determined by subjecting a concrete beam to bending and then using the formulae for deflection and substituting other parameters.
- The modulus of elasticity so found out from actual loading is called static modulus of elasticity. It is seen that even under short term loading concrete does not behave as an elastic material.
- However, up to about 10-15% of the ultimate strength of concrete, the stress-strain graph is not very much curved and hence can give more accurate value. For higher stresses the stress-strain relationship will be greatly curved and as such it will be inaccurate



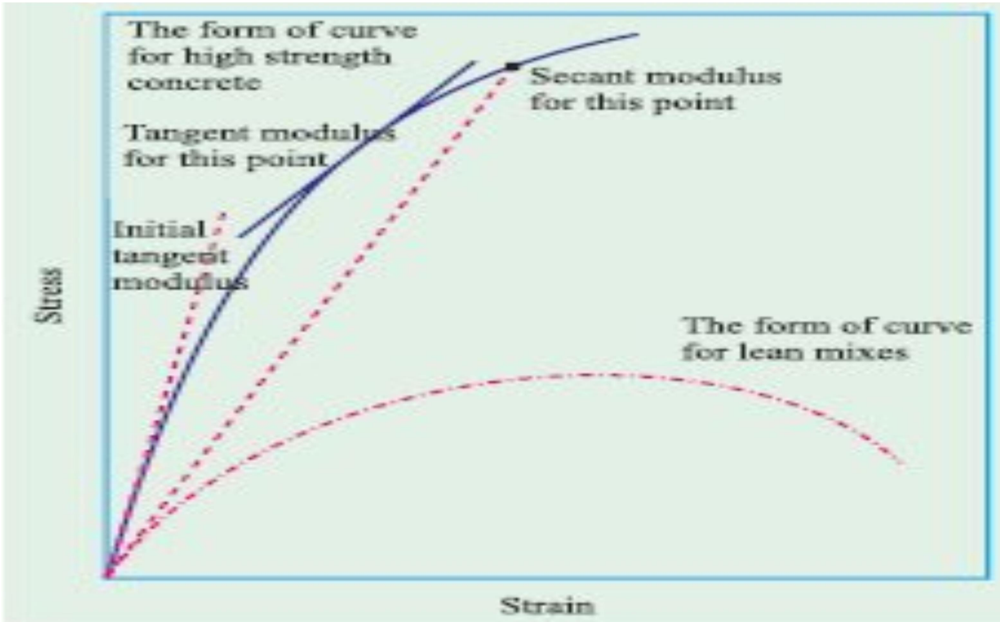


Figure shows stress strain relationship for various concrete mixes.

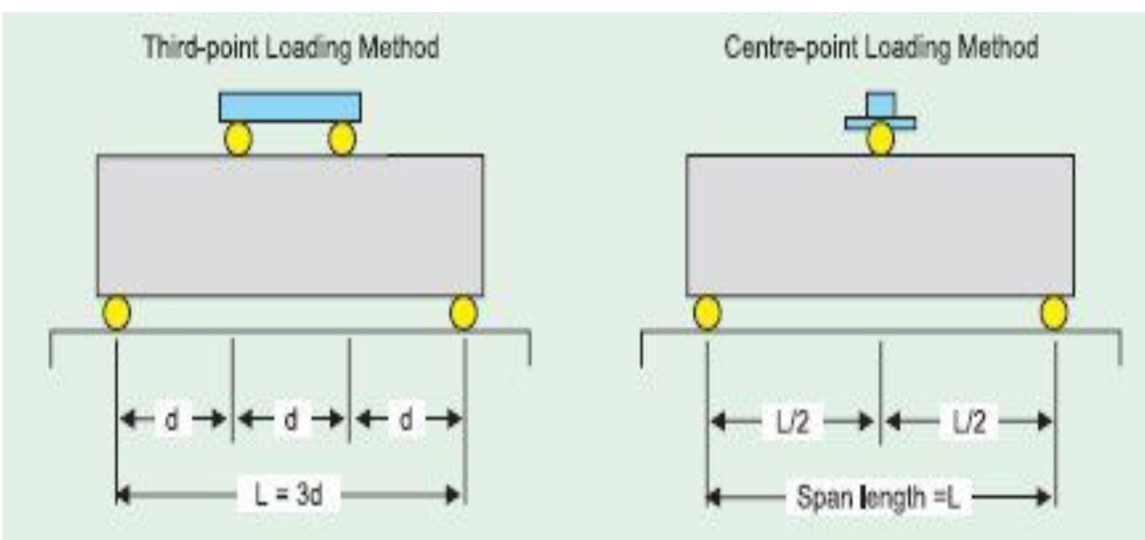
- In view of the peculiar and complex behavior of stress-strain relationship, the modulus of elasticity of concrete is defined in somewhat arbitrary manner.
- The modulus of elasticity of concrete is designated in various ways and they have been illustrated on the stress-strain curve in Fig.
- The term Young‘s modulus of elasticity can strictly be applied only to the straight part of stress-strain curve. In the case of concrete, since no part of the graph is straight, the modulus of elasticity is found out with reference to the tangent drawn to the curve at the origin.
- The modulus found from this tangent is referred as initial tangent modulus. This gives satisfactory results only at low stress value. For higher stress value it gives a misleading picture. Tangent can also be drawn at any other point on the stress-strain curve.
- The modulus of elasticity calculated with reference to this tangent is then called tangent modulus. The tangent modulus also does not give a realistic value of modulus of elasticity for the stress level much above or much below the point at which the tangent is drawn.
- The value of modulus of elasticity will be satisfactory only for stress level in the vicinity of the point considered.
- A line can be drawn connecting a specified point on the stress-strain curve to the origin of the curve. If the modulus of elasticity is calculated with reference to the slope of this line, the modulus of elasticity is referred as secant modulus.
- If the modulus of elasticity is found out with reference to the chord drawn between two specified points on the stress-strain curve then such value of the modulus of elasticity is known as chord modulus.

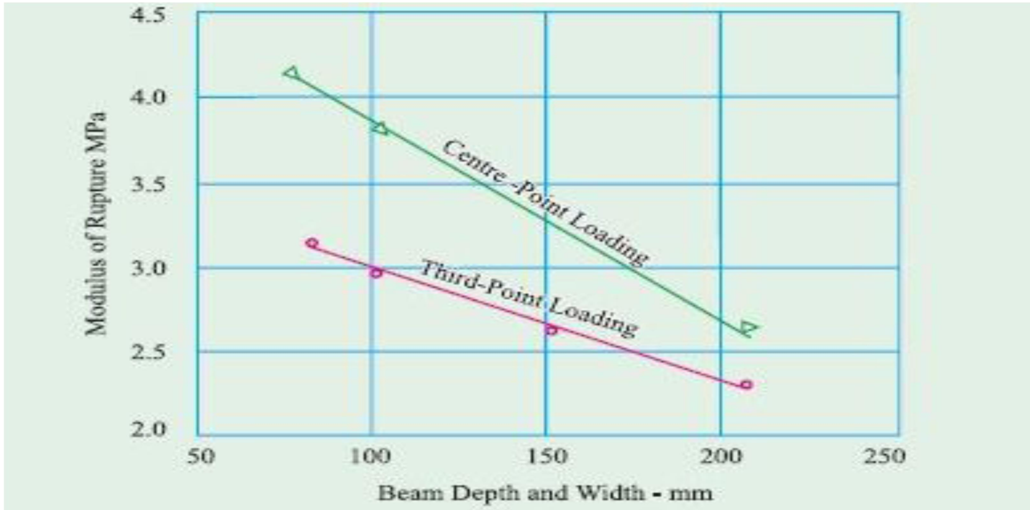
- The modulus of elasticity most commonly used in practice is secant modulus. There is no standard method of determining the secant modulus.
- Sometime it is measured at stresses ranging from 3 to 14 MPa and sometime the secant is drawn to point representing a stress level of 15, 25, 33, or 50 per cent of ultimate strength.
- Since the value of secant modulus decreases with increase in stress, the stress at which the secant modulus has been found outshould always be stated.
- Modulus of elasticity may be measured in tension, compression or shear. The modulus in tension is usually equal to the modulus in compression.
- It is interesting to note that the stress-strain relationship of aggregate alone shows a fairly good straight line. Similarly, stress-strain relationship of cement paste alone also shows a fairly good straight line.
- But the stress-strain relationship of concrete which is combination of aggregate and paste together shows a curved relationship. Perhaps this is due to the development of micro cracks at the interface of the aggregate and paste.
- Because of the failure of bond at the interface increases at a faster rate than that of the applied stress, the stress-strain curve continues to bend faster than increase of stress. Figure shows the stress-strain relationship for cement paste, aggregate and concrete.

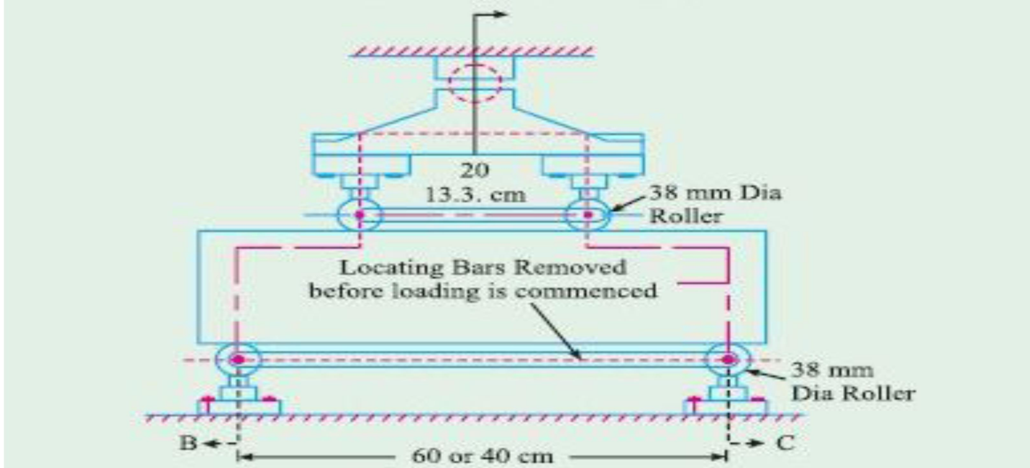
9. **Discuss in detail about the tensile strength of concrete. (April/May 2017) (May/June 2016)**

Determination of Tensile Strength:

- Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied to the concrete.
- While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure flexural strength property of concrete.







Procedure:

- Test specimens are stored in water at a temperature of 24° to 30°C for 48 hours before testing.
- They are tested immediately on removal from the water whilst they are still in a wet condition.
- The dimensions of each specimen should be noted before testing. No preparation of the surfaces is required.

Placing the Specimen in the Testing Machine:

- The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers.
- The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surfaces of the specimen and the rollers.
- The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 0.7 kg/sq cm/min that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

- The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded.
- The appearance of the fractured faces of concrete and any unusual features in the type of failure is noted.
- The flexural strength of the specimen is expressed as the modulus of rupture $f_b$which if _a‘ equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, is calculated to the nearest 0.05 MPa as follows:

$$f_b = \frac{P \times l}{b \times d^2}$$

When _a‘ is greater than 20.0 cm for 15.0 cm specimen or greater than 13.3 cm for a 10.0 cm specimen, or

$$f_b = \frac{3p \times a}{b \times d^2}$$

when _a‘ is less than 20.0 cm but greater than 17.0 cm for 15.0 specimen, or lessthan 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen where

b = measured width in cm of the specimen,
d = measured depth in cm of the specimen at the point of failure,
l = length in cm of the span on which the specimen was supported, and
p = maximum load in kg applied to the specimen.

If _a‘is less than 17.0 cm for a 15.0 cm specimen, or less than 11.0 cm for a 10.0 cm specimen, the results of the test be discarded.

- As mentioned earlier, it is difficult to measure the tensile strength of concrete directly. of late some methods have been used with the help of epoxy bonded end pieces to facilitate direct pulling.
- Attempts have also been made to find out direct tensile strength of concrete by making briquette of figure shape for direct pulling but this method was presenting some difficulty with grip and introduction of secondary stresses while being pulled.
- Whatever may be the methods adopted for finding out the ultimate direct tensile strength, it is almost impossible to apply truly axial load. There is always some eccentricity present. The stresses are changed due to eccentricity of loading.
- These may introduce major error on the stresses developed regardless of specimen size and shape. The third problem is the stresses induced due to the grips.
- There is a tendency for the specimen to break near the ends. This problem is always overcome by reducing the section of the central portion of the test specimen.
- The method in which steel plates are glued with the epoxies to the ends of test specimen, eliminates stresses due to griping, but offers no solution for the eccentricity problem. All direct tension test methods require expensive universal testing machine.

10. Explain durability of concrete, water absorption, permeability, concrete test, acid resistance. (Nov/Dec 2019).

DURABILITY OF CONCRETE:

Durability of concrete is defined as the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties.

Concrete will remains durable if,

- The cement paste structure is dense and of low permeability.
- Under extreme condition, it has entrained air to resist freeze- thaw cycle.
- It is made with graded aggregate that are strong and inert.
- The ingredients in the mix contains minimum impurities such as alkalis, chlorides, sulphates and silt.

Factors affecting durability of concrete:

Durability of concrete depends upon the following factors

1. Cement content:

- Mix must be designed to ensure cohesion and prevent segregation and bleeding.
- If cement is reduced, then a fixed w/c ratio the workability will be reduced leading to inadequate compaction.
- However, if water is added to improve workability, water/cement ratio increases and resulting in highly permeable material.

2. Compaction:

- The concrete as a whole contain voids can be caused by inadequate compaction.
- Usually it is being governed by the compaction equipment used, type of formworks, and density of the steelwork.

3.Water cement ratio:

- Water cement ratio is the most important parameter governing compressive strength.
- A lower ratio leads to higher strength and durability, however it may create the mix difficult to mould.
- It can be resolved by using suitable plasticizers or super plasticizers.

4. Absorption and curing:

- It is very important to permit proper strength development aid moisture retention and to ensure hydration process occur completely.

5. Cover:

- Thickness of concrete cover must follow the limits set in codes.

6. Permeability:

- It is considered the most important factor for durability.
- It can be noticed that higher permeability is usually caused by higher porosity.
- Therefore, a proper curing, sufficient cement, proper compaction and suitable concrete could provide a low permeability concrete.

Types of Durability:

There are many types but the major ones,

1. Physical Durability:

- Physical durability is the property of concrete against the action of freezing and thawing action, water **permeability and temperature stresses.**

2. Chemical Durability:

- Chemical durability is the property of concrete against the action of alkali aggregate reaction, sulphate attack, chloride ingress and corrosion of reinforcement.

Causes for the lack of durability in concrete:

1. External causes:

- Extreme weathering conditions
- Extreme temperature
- Extreme humidity
- Abrasion
- Electrolytic action
- Attack by a natural or industrial liquids or gases

2. Internal causes:

(a) Physical factors:

- Volume change due to difference in thermal properties of aggregate and cement paste.
- Frost action

(b) Chemical factors:

- Alkali aggregate reactions
  - i. Alkali silica reaction
  - ii. Alkali silicate reaction
  - iii. Alkali carbonate reaction
- Corrosion of steel

<u>WATER ABSORPTION:</u>

- Durability of concrete is dependent on the capacity of a fluid to penetrate the concretes microstructure, which was called permeability.
- Surface water absorption is higher than internal water absorption regardless of curing conditions.

- Permeability mainly depends on the surface water absorption of concrete, and there is a significant direct relation between permeability and surface water absorption.

Water absorption test for concrete:

- Dry the concrete specimen and weight (W1)
- Immerse it in water for specified amount of time (say 24 hours), and weighting it again (W2).
- The increase in weight as a percentage of the original weight is expressed as its absorption (in %).
  Water absorption % = $(W!1-W2)W1\ X\ 100$
- The average absorption of the test samples shall not be greater than 5% with no individual unit greater than 7%.

PERMEABILITY:

- Permeability is defined as the property of concrete that governs the rate of flow of a fluid into pores and voids present in the hardened concrete.
- Both the cement paste and aggregate contains pores.
- The concrete as a whole contains voids due to improper compaction.
- These voids can be reduced by vibration.
- The cement paste enveloped the aggregate, contains pores. The pores in the cement concrete are

1. Capillary pores (with a diameter varying between 0.01 and 10 microns**)** in the cement and the paste which combines the aggregates.

2. Large micro voids, between 1 mm to 10 mm, which are caused by faulty compaction of fresh concrete.

Causes of permeability:

- Water cement ratio
- Compaction
- Curing
- Long term drying, micro cracks from in concretes, cause deterioration of concrete.
- Weathering effect, the cracks also develop due to structural stresses.
- Unequal thermal stresses causes rupture of bond between concrete constituents.
- Entrapped air in concrete due to poor compaction of concrete, this causes environment to have undue defects in concrete.
- Various other reasons cause volume change of concrete, and permit the flow of water.

Reduced the permeability:

- Reducing water cement ratio to optimum value.
- Compacting concrete thoroughly but not in excess.
- Using pozzolanic material.
- Use of air entrained concrete up to certain level.
- Using dense aggregate.

CORROSION TEST:

- Measurement of steel reinforcement corrosion in concrete is essential to analyze the strength and durability of structure.

- There is no instrument or technique available to measure the extent of corrosion of steel.
- However, measurement of concrete properties, such as resistivity and potential of concrete can assess the probability of corrosion of reinforcement steel.
- Resistivity meter and corrosion analysing instrument, which are easily available, can measure these properties.

Resistivity meter for measuring corrosion:

- The corrosion of steel in concrete is an electro- chemical reaction, which generates a flow of current. Resistivity of the concrete influence the flow of this current.
- The lower the electric resistance, the more easily corrosion current flow through the concrete and the greater is the probability of corrosion.
- Thus, the resistivity of concrete is a good indication of probability of corrosion.

Resistivity level (Kilo-ohm /cm)	**Possible corrosion rate**
<5	Very high
5 to 10	High
10 to 20	Moderate to low
>20	Insignificant

PART A

1. Define: Special concrete. (April/May 2012)

- Special concrete is defined as concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices.

2. Define: Lightweight concrete. (April/May 2010) (Nov/Dec 2017)

- Lightweight concrete may be defined as the concrete of substantially lower unit weight than that made from gravel or crushed stone.
- The light-weight concrete density varies from 300 to 1850 kg/m. If the concrete density is less than 2000 kg/m^3 can also be called as lightweight concrete.

3. What is the result of lightweight concrete?

- Lightweight concrete not only results in reducing dead weights on structure, but also has a better insulation against heat and sound.

4. What are the ways to achieve lightweight concrete in actual practice?

Lightweight concrete can be achieved in actual practice by three different ways.

- By replacing the usual mineral aggregate by cellular porous or lightweight aggregate.

- By introducing gas or air bubbles in mortar. This is known as aerated concrete.
- By omitting sand fraction from the aggregate. This is called 'no-fines' concrete.

5. Classify the lightweight concrete on the purpose for which it is used.

Lightweight concrete can also be classified on the purpose for which it is used, such as:

- Structural light weight concrete,
- Non-load bearing concrete and
- Insulating concrete.

6. Classify the lightweight aggregate.

- Natural lightweight aggregates
- Artificial lightweight aggregates

7. Name some of the natural light weight aggregate

a. Pumice
b. Diatomite
c. Scoria
d. Volcanic cinders
e. Saw dust
f. Rice husk

8. Explain pumice.

- Pumice is usually light coloured or nearly white and has a fairly even texture of interconnected cells of aggregate.
- Pumice is the one of the oldest light weight aggregates which has been used roman structures.

9. Define Diatomite.

This is hydrated amorphous silica derived from the remains of microscopic aquatic plants called as Diatomite.

10. Explain scoria.

- Scoria is also light weight aggregate of volcanic origin which isusually dark in color and contains larger and irregularly shapedcells unconnected with each other.
- It is slightly weaker than pumice.

11. Define volcanic cinders.

Volcanic cinders are also loose volcanic product resembling artificialcinders.

12. Explain sawdust.

- Saw dust is manufactured by soft wood.
- The addition of lime to mix in an amount to equal to about 1/3 to1/2the volume of cement will counteract this.
- The shrinkage of moisture movement of saw dust is also high.
- The practical mixes of the ratio of 1:2 to 1:3 i.e., cement saw dust by volume.

13. Explain rice husk.

- Limited use of ricehusk, groundnut husk and bagasse have beenused as light weight aggregates for the manufacture of lightweight concrete for special purposes.

14. Name some of the artificial light weight aggregate.

a. Brick bat
b. Foamed slag
c. Cinder, clinker
d. Bloated clay
e. Sintered fly ash
f. Exfoliated vermiculite
g. Expanded perlite

15. Describe brick bats.

- Brick bats are one of the types of aggregates used in certain places where natural aggregates are not available or costly.
- The brick bat aggregate cannot be really brought under lightweight aggregates because the concrete made with this aggregate will not come under the category of light weight concrete.

16. Describe cinder, clinker and breeze.

- The term of cinder, clinker and breeze are used to cover the material partly fused or sintered particles arising from the combustion of coal.
- These days the use of these materials as light weight aggregate in the form of coarse or fine aggregate is getting abated owing to the wider use of pulverized coal rather than lumps of coal.

17. Explain foamed slag.

- Foamed slag is of the most important types of light weight aggregates.
- It is made by rapidly quenching blast furnace slag, a by-product, produced in the manufacture of iron.

18. What are the properties of foamed slag?

- Free from contamination of heavy impurities.
- Free from volatile impurities such as coke or coal.
- Free from excess of sulphate.

19. Define bloated clay.

- When certain glass and shale's are heated to the point ofincipient fusion, they expand or what is termed as bloat to manytimes their original volume on account of the formation of gaswithin the mass at the fusion temperatures.
- The cellular structure so formed is retained on cooling and theproduct is used as light weight aggregates.

20. Describe sintered fly ash.

- The fly ash is mixed with limited amount of water and is firstmade into pellets and then sintered at a temperature of 1000°C to1200° C.
- The fly ash may contain some un-burnt coal which may vary from2 to 15 % or more depending upon the efficiency of burning.

21. Describe exfoliation.

- Raw vermiculate is a micaceous mineral and has a laminar structure.
- When heated with certain percentage of water it expands bydelamination in the same way as that of slate or shale.
- This type of expansion is known as "exfoliation".

22. Describe Exfoliated vermiculite.

Due to exfoliation the vermiculite which may have expanded even as much as 30 times will have a density of only 60 to 130 kg/m3.

23. Describe expanded perlite.

- Perlite is the one of the volcanic gases like pumice.
- This when crushed and heated to the point of incipient fusion at a temperature of about 900 to 1100°C it expands from a light cellular material with density of about 30 to 240 kg/m3

24. What are the Advantages of light weight concrete?

- Rapid and relatively simple construction.
- Economical in terms of transportation as well reduction in man power.
- Most of the light weight concrete has better nailing and sawing properties.
- Significant reduction of overall weight and results in saving structural frames, footings and piles.

25. Define: Aerated concrete

Aerated concrete may be defined as concrete made very light and cellular by the addition of prepared foam or by generation of gas within the unhardened mixture. It is also termed as cellular concrete and foamed concrete.

26. What are the uses of aerated concrete?

Aerated concrete is used for the following purpose:

- Partitions for heat insulation because of its low thermal conductivity and weight
- In fire proofing because of its better fire resistivity
- Floor construction and light insulation

27. Define Guniting or Shotcrete.(Apr/May 2010) (April/May 2018)

- It is defined as a mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface.

28. Define Polymer concrete. (May/June 2016)

- Polymer concrete is part of group of concretes that use polymers to supplement or replace cement and uses polymer as a binder.

i. polymer impregnated concrete
ii. Polymer cement concrete (pcc)
iii. Polymer concrete

29. State the advantages of polymer concrete. (May/June 2016)

Advantages:

- Rapid curing at ambient temperature.
- Lighter weight (only somewhat less dense than traditional concrete, depending on the resin content of the mix)
- Mines, tunnels, and highways.
- Pump manufacturing and chemical processing.
- Industries

30. Define High-Performance concrete.(May/June 2016)

- Recently a new term "High performance concrete" is used for concrete mixture which possesses high workability, high strength, and high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack.
- High-performance concrete (HPC) is also, a high-strength concrete but it has a few more attributes specifically designed as mentioned above.

31. How Geopolymer concrete is more advantages than cement concrete in construction industry? (Nov/Dec 2016)(April/may 2017)

- Geopolymer concrete has significantly higher resistance to acid then ordinary concrete
- 80% reduction in CO_2 footprint comparing to OPC, opportunity to obtain tradable CO_2 certificates.
- Can be used in a wide range of ready-mix, pre-cast, and pre-stressed/pre-cast applications
- Excellent fire and heat resistance. It has the ability to remain stable in temperatures of more than $1200\ ^{o}C$.

32. List the various types of polymer concrete. (April/May 2019)

i) Polymer impregnated concrete (PIC)

ii) Polymer cement concrete (PCC)

iii) Polymer Concrete (PC)

iv) Partially impregnated and surface coat

v) Polymer Concrete.

vi)Polymer impregnated concrete (PIC)

33. Describe polymer impregnated concrete (PIC).

- ❖ Polymer impregnated concrete is the one of the widely used in polymer composite.
- ❖ It is nothing but a precast conventional concrete, cured and dried oven, or by dielectric heating from which is the air in the open cell is removed by vacuum.

34. Mention the types of manometers are used in Polymer impregnated concrete (PIC).

- ❖ Methyl methacrylate (MMA)
- ❖ Styrene
- ❖ Acrylonitrile
- ❖ t- butyl styrene
- ❖ Other thermo plastic manometers.

35. Mention the types manometers are used in polymer cement concrete.

- ❖ Polyester styrene
- ❖ Epoxy styrene
- ❖ Furnas
- ❖ Vinylidene chloride.

36. Write the Disadvantages of polymer concrete.

- ➢ More expensive
- ➢ The monomers can be volatile, combustible and toxic.
- ➢ Initiators which are used as catalyst are combustible and harmful to human skin

37. Write the advantages of polymer concrete.

- ➢ It has high impact resistance and high compressive strength.
- ➢ Polymer concrete is highly resistant to freezing and thawing.
- ➢ Highly resistant to chemical attack and abrasion.

4. Permeability is lower than other conventional concrete.

38. Mention the Application Of Polymer Concrete. (Nov/Dec 2019)

Polymer concrete is broadly utilizing in several circumstances as following

- ➢ Nuclear power plants.
- ➢ Kerbstones.
- ➢ Prefabricated structural element.
- ➢ Precast slabs for bridge decks.
- ➢ Roads.

- Marine Works.
- Prestressed concrete.
- Irrigation works.
- Sewage works.
- Waterproofing of buildings.
- Food processing buildings etc.

39. Define the term 'high strength concrete'.(April/May 2010)

- The term "high strength concrete" is obviously a relative term. High strength concrete may be defined as concrete with specified characteristic cube strength between 60 and 100 N/mm^2.
- There is no exact point of separation between "normal- strength" and "high-strength" concrete. According to the American Concrete Institute, high strength is defined as that over 41 N/mm^2 compressive strength.

40. What are the main applications of high strength concrete?

The main applications for high strength concrete in- situ concrete construction are in:

- Offshore structures,
- Columns for tall buildings,
- Long-span bridges and
- Other highway structures

41. What is the main advantage of high strength concrete?

- The main advantage is the reduction in size of compression elements and or the amount of longitudinal reinforcement required.

42. Mention some of the special methods for making high strength concrete.

There are some special methods of making high strength concrete and they are as follows:

- Seeding
- Re-vibration
- High speed slurry mixing
- Use of admixtures
- Inhibition of cracks
- Sulphur Impregnation
- Use of cementitious aggregates

43. What are the materials used for high strength concrete?

- Fly ash
- Ground granulated blast furnace slag (GGBS)
- Silica fume
- Super plasticizers
- Aggregates

44. What are the properties of high strength concrete?

- ❖ Higher flow ability (when used with super plasticizers),
- ❖ Higher elastic modulus,
- ❖ Higher flexural strength, Low permeability,
- ❖ Improved abrasion resistance and
- ❖ Better durability.

45. What are the disadvantages of high strength concrete?

- ❖ Expansive: High initial cost.
- ❖ Risk of lung cancer in the manufacturing phase.

46. Mention some applications of high strength concrete.(April/May 2018)

- ❖ Bridges
- ❖ High-rise buildings
- ❖ Concrete piles
- ❖ Bed of machines
- ❖ Dam spillway
- ❖ Industrial floors
- ❖ Hume pipes and
- ❖ Concrete sleepers

47. Why high strength concrete is used for concrete repairs?

- High strength concrete for concrete repair is used to provide a concrete with improved resistance to chemical attack, better abrasion resistance, improved resistance to freezing and thawing and reduced permeability.

48. Define SIFCON. (Nov/Dec 2016) (April/may 2017)

- Slurry Infiltrated Fibrous Reinforced Concrete (SIFCON) is a relatively new high performance and advanced material and can be considered as a special type of Steel Fiber Reinforced Concrete (SFRC).
- The technique of infiltrated layers of steel fibers with Portland cement based. Steel fibre bed is prepared and cement slurry is infiltrated.
- With these techniques macro-fibre content up to about 20% by volume can be achieved.

49. What is Geopolymer concrete? (Apr/May 2010)

- Geopolymer concrete is concrete based on an inorganic binder polymerized from Al-Si rich materials of geological or industrial origin, such as fly-ash. Geopolymer is used as the binder, instead of cement paste, to produce concrete.

50. Define Ready-mix concrete. (Apr/May 2011)

- Concrete which is mixed in a stationary mixer in a central batching plant or in truck mixer and supplied in fresh condition to the purchaser either at site or into purchaser vehicle is called ready mix concrete.

51. Write the important Properties of ready mixed concrete.

- Good durability,
- High strength,
- Water tightness,
- Resistance to abrasion.

52. Where ready mixed concrete will be used?

Ready mixed concrete will be used where there is shortage of space for the procurement of the material and where the site is very congested.

53. What are the types of ready mixed concrete?

- Plant mixed concrete
- Shrink mixed concrete
- Transit mixed concrete

54. Define Fibre reinforced concrete.

- Fibre reinforced concrete is defined as the composite material consists of mixture of cement, mortar or concrete and discontinuous, discrete uniformly dispersed suitable fibres.

  <u>NATURAL FIBRES</u>

  Coconut fibre, Sugarcane, Straw, Jute fibres

  <u>SYNTHETIC FIBRES</u>

  Glass, carbon, steel, polypropylene, nylon

55. What are the common fibres generally used?

The common fibers generally used are nylon, coir, jute, asbestos, glass and steel.

56. Mention some of the basic requirements of fibres.

- High tensile strength,
- High modulus of elasticity,
- Adequate extensibility,
- Good bond at the interface,
- Chemical stability,
- Durability,
- Energy absorption,
- Resistance to shock and dynamic loading, impact and fatigue strength.

57. Mention some of the properties of FRC.

- It has an ability to stop or delay the propagation of crack
- It get stretched more than concrete under loading

- It has an ability to resist corrosion
- It enhances the tensile strength of concrete
- It enhances the shear strength of concrete
- It enhances the compressive strength of concrete etc.

58. List some of the factors affecting FRC.

- Type of Fibre
- Fibre geometry
- Fibre content
- Volume fraction
- Distribution of fibre
- Fibre aspect ratio
- Shape and bond at fibre matrix interface
- Mixing technique of concrete
- Compaction technique of concrete
- Size of aggregate
- Orientation of fibre
- Shape of aggregate

59. What is volume fraction of fibres?

It is the ratio of volume of fibre to the total volume of matrix.

60. What is fibres aspect ratio? (Nov/Dec 2011)

It is the ratio of length to diameter of the fibres.

61. List some of the types of fibres used in FRC as reinforcing materials.

- AcrylicAsbestos
- CarbonPolyester
- CoirPolyethylene
- CottonPoly propylene rayon
- GlassRock wool
- NylonSteel

62. Mention some of the most practiced fibre reinforced concrete (FRC).

- Steel fibre reinforced concrete
- Glass fiber reinforced concrete (GFRC)
- Synthetic fibers
- Natural fibre reinforced concrete

63. Write the benefits of steel fibers.

- Improve structural strength
- Reduce steel reinforcement requirements
- Improve ductility

- ❖ Reduce crack widths and control the crack widths tightly, thus improving durability
- ❖ Improve impact- and abrasion-resistance
- ❖ Improve freeze-thaw resistance

64. Mention some of the applications of FRC.

- ❖ Residential, Commercial
- ❖ Warehouse / Industrial
- ❖ Highways / Roadways / Bridges
- ❖ Ports and Airports
- ❖ Waterways
- ❖ Mining and Tunneling
- ❖ Elevated Decks
- ❖ Agriculture
- ❖ Precast Concrete and Products

65. What are the disadvantages of FRP? (Apr/May 2013)

- ❖ Increase in specific gravity of the concrete.
- ❖ Proportioning the exact amount of fibres in the batch of concrete.
- ❖ Higher cost because of its control issues as well as the cost of raw material is high.
- ❖ Corrosion of steel fibres.

66. What do you mean by critical length of fibre? (Apr/May 2012)

Critical length of fibre defined as the maximum embedded fibre length for a fibre to be pulled out from a matrix without rupture.

67. Define Ferro cement. (Nov/Dec 2017, 2019)

- Ferro cement is a relatively new material consisting of wire meshes and cement mortar.
- It consists of closely spaced wire meshes which are impregnated with rich cement mortar mix.

68. Write about the reinforcing wires used in Ferrocement.

- It is important to get a good distribution of wire mesh throughout the cement mortar to limit cracking.
- Wire meshes come in a wide variety of types, diameters, stiffness's, and strengths. For large tanks, welded

- ❖ It's strength to weight ratio higher than RCC.
- ❖ It has less thermal conductivity as compared to RCC.
- ❖ It is thin and more aesthetic.

69. What is High Performance Concrete? (May/June 2016)

- ❖ High performance Concrete (HPC) is known as a180igh-tech construction material, proving to be very cost effective, reliable, and having long-term durability in natural environment.
- ❖ The definition ofHPC is based on establishing value of workability, strength and durability.

70. How high performance concrete helps in construction site?

(i) it can remain in liquid state for a longer duration,

(ii) it can be prepared with very small quantity of water, and

(iii) it can also gulp waste materials having pozzolanic reactivity like fly ash, Ground Granulated Blast furnace Slag, Silica fume, Rice Husk ash etc. to give itself strength and increased life.

71. Write short notes on shortcrete. (April/May 2018)

Shortcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregates. Therefore, in general, the concrete in which mortar or concrete is pneumatically projected at high velocity on the backup surface is known as shortcrete or gunite.

72. What are the applications of light weight concrete? (April/May 2019)

- ➢ Decks of long span bridges.
- ➢ Fire and corrosion production
- ➢ Heat insulation on roofs
- ➢ Insulation of water pipes

73. State the advantages of Ready mixed concrete. (April/May 2019)

- ➢ Speed in construction
- ➢ Elimination of storage needs
- ➢ Uniform and assured quantity of concrete
- ➢ Reduction in wastage
- ➢ RMC is eco-friendly
- ➢ Documentation of mix design
- ➢ Easy addition of admixtures

74. Write the advantages of SIFCON. (Nov/Dec 2019)

- ➢ SIFCON possess excellent durability, energy absorption capacity, impact and abrasion resistance and toughness.
- ➢ Modulus of elasticity (E) values for SIFCON specimens is more compared with plain concrete.
- ➢ SIFCON exhibits high ductility.
- ➢ The limitation in SFRC that is balling problem of steel fibers with increase in fiber volume is overcomes by SIFCON, because of its fiber alignment.

75. Define Laitance. (Nov/Dec 2019)

An accumulation of fine particles on the surface of fresh concrete due to an upward movement of water. (as when excessive mixing water is used)

76. List the two application of heavy weight concrete. (April/May 2018)

- For radiation shielding (medical or nuclear)
- For ballasting of pipelines

77. What is self-compacting concrete (SSC)?

- Making concrete structure without vibration, have been done in the past.
- For examples, placement of concrete under water is done by the use of tremie without vibration.
- Mass concrete and shaft concrete can be successfully placed without vibration.
- But the above examples of concrete are generally of lower strength and difficult to obtain consistent quality.

78. Define: Vacuum concrete.

- Vacuum concrete is the type of concrete in which the excess water is removed for improving concrete strength. The water is removed by use of vacuum mats connected to a vacuum pump.

74. Define: Foam concrete.

- **Foam concrete** is also known as **aircrete**, **foamed concrete**, **foamcrete**, **cellular lightweight concrete** or **reduced density concrete**, is defined as a cement based slurry, with a minimum of 20% (per volume) foam entrained into the plastic mortar.
- As mostly no coarse aggregate is used for production of foam concrete the correct term would be called mortar instead of concrete; it may be called "foamed cement" as well.

PART B& C

1. Explain the Ready Mix Concrete. (May/June 2016) (Nov/Dec 2016)

Ready Mix Concrete

- Concrete which is mixed in a stationary mixer in a central batching plant or in truck mixer and supplied in fresh condition to the purchaser either at site or into purchaser vehicle is called ready mix concrete.
- The age of fresh concrete is 2 to 3 hours and should be delivered within 30 to 60 minutes.
- Concrete itself is a mixture of Portland cement, water and aggregates comprising sand and gravel or crushed stone.
- In traditional work sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete.
- Ready Mixed Concrete is bought and sold by volume -usually expressed in cubic meters.
- The first ready-mix factory was built in the 1930s, but the industry did not begin to expand significantly until the 1980s, and it has continued to grow since then.
- The capacity is about 1.52 m^3.
- The output of ready mix concrete is 30.58 $m^{3/}$hr and can supply to a maximum of 1.33 m^3 for six times daily

Process:

- A ready-mix concrete plant consists of silos that contain cement, sand, gravel and storage tanks of additives such as plasticizers, as well as a mixer to blend the components of concrete.
- These components are gravity fed into the preparation bin. The quality of concrete should be maintained.
- The water dosage in particular must be very precise and the mixing itself must remain continuous and consistent.
- Finally, the concrete prepared in a batch plant is loaded into a mixer truck, also known as a transit mixer, which delivers it to the construction site. A concrete factory must be located within a radius of 20 to 30 km from the work site, depending on traffic conditions.

Storage silo → Belt conveyor → mixing plant → transit mixer or

Or machine or batching

Components of RMC Plant:

- RMC Plant with Auxiliary or supporting equipment‘s.
- Transit mixer.
- Site equipment for handling concrete. (concrete pump)

Supporting equipment’s:

- Cement silos
- Cement weight hopper
- Aggregate bins
- Conveyor

Properties:

- Good durability,
- High strength,
- Water tightness,
- Resistance to abrasion.

Advantages

- Speed in construction
- Elimination of storage needs
- Uniform and assured quantity of concrete
- Reduction in wastage
- RMC is eco-friendly
- Documentation of mix design
- Easy addition of admixtures

Disadvantages

- The materials are batched at a central plant, and the mixing begins at that plant, so the travelling time from the plant to the site is critical over longer distances.
- Generation of additional road traffic. Furthermore, access roads and site access have to be able to carry the greater weight of the ready-mix truck plus load.
- Concrete’s limited time span between mixing and going-off means that ready-mix should be placed within 90 minutes of batching at the plant.
- Modern admixtures can modify that time span precisely, however, so the amount and type of admixture added to the mix is very important.

2. Explain the Light Weight Concrete.(April/May 2017, 2018, 2019) (Nov/Dec 2017)

- Light weight concrete is produced by including large quantities of air in the aggregate, in the matrix or in between the aggregate particles, or by a combination of processes. Aggregate that weight less than about 1000kg/m^3 are used.

- The light weight is due to the cellular structure or highly porous microstructure.
- **Natural light weight aggregates** are made by processing igneous volcanic rocks such as pumice, scoria and tuff.
- **Synthetic light weight aggregates** can be manufactured by thermal treatment from a variety of materials such as clay, shale, slate fly ash pallets, blast furnace slag.

Making:

- The mixing procedure for light weight concrete is the same as for normal concrete and is produced in the same type of mixer or mixing plant.
- In first stage, the mortar is mixed i.e., cement, sand, admixtures, and about two-third of mixing water.
- In the second stage, the coarse aggregate is added with the rest of the water and final mixing is done. At times, light weight dry fines cause the material to form balls in the mixer.
- It can be avoided if less water is added at the start and then the amount is increased gradually .the size of the aggregate should be less than 8 or 10 mm.

Classification of light weight concretes:

- ✓ By using porous light weight aggregate of low apparent specific gravity, i.e. lower than 2.6. This type of concrete is known as light weight aggregate concrete.
- ✓ By introducing large voids within the concrete or mortar mass; these voids should be clearly distinguished from the extremely fine voids produced by air entertainment. This type of concrete is variously known as aerated, cellular, foamed or gas concrete.
- ✓ By omitting the fine aggregate from the mix so that large amount of interstitial voids is present; normal weight coarse aggregate is generally used. This concrete is known as no-fine concretes.

Properties:

- ➢ Low compressive strength
- ➢ High water absorption and moisture content.
- ➢ High creep and shrinkage.
- ➢ Good thermal insulation due to air filled voids.
- ➢ Low thermal expansion.

Advantages

- Rapid and relatively simple construction.
- Economical in terms of transportation as well reduction in man power
- Most of the light weight concrete has better nailing and sawing properties.
- Significant reduction of overall weight and results in saving structural frames, footings and piles.

Disadvantages:

- Inability to provide high compressive strength
- Less density
- Very sensitive to moisture content
- Mixing time is longer than conventional concrete to obtain proper mixing.

3. List out some of the Natural Light weight aggregate and Artificial Light weight aggregate and discuss.

NATURAL AGGREGATES

- Natural lightweight aggregates are not found in many places and they are also not of uniform quality.
- These are not used vary widely in making lightweight concrete.
- Out of the natural lightweight aggregates pumice is the only one which is used rather widely.

Pumice stone

- It is also a suitable material to produce lightweight concrete, provided it is free from volcanic dust or clay etc.
- Bulk density of pumice ranges from 500 to 800 kg/m^3 and it gives concrete having density 800 to 1100 kg/m^3, has a high thermal insulation and its strength about 15 to 40 N/mm^2 .
- These are rocks of volcanic origin which occur in many parts of the world.
- They are light enough and yet strong enough to be used as lightweight aggregate.
- Their lightness is due to the escaping of gas from the molten lava when erupted from deep beneath the earth's crest.

Diatomite

- This is hydrated amorphous silica derived from there mains of microscopic aquatic plants called diatoms.
- It is also known as Kieselguhr.
- The deposits of these aquatic plants are formed beneath the deep ocean bed.

- Subsequently when the ocean bed is raised and becomes continent, the diatomaceous earth becomes available on land.
- In pure form diatomite has an average weight of 450 kg/m^3.
- But due to impurities, the naturally available diatomite may weight more than 450 kg/m^3.

Scoria

- Scoria is also lightweight aggregate of volcanic origin which is usually dark in colour and contains larger and irregularly shaped cells unconnected with each other.
- Therefore, it is slightly weaker than pumice.

Volcanic cinders

- These are also loose volcanic product resembling artificial cinder.

Saw dust

- Sometimes saw dust is used as a lightweight aggregate in flooring and in the manufacture of precast products.
- Saw dust concrete has been used in the manufacture of precast concrete products, joint less flooring and roofing tiles.
- It is also used in concrete block for holding the nail well.
- Wood aggregate also has been tried for making concrete.
- The wood wool concrete is made by mixing wood shavings with Portland cement or gypsum for the manufacture of precast blocks.
- This has been used as wall panels for acoustic purposes.

Rice husk ash (RHA)

- Limited use of the rice husk, groundnut husk and bagasse have been used as light weight aggregate for the manufacture of lightweight concrete for special purposes.
- RHA, produced after burning of rice husks (RH) has high reactivity and pozzolanic property. Chemical compositions of RHA are affected due to burning process and temperature.
- Silica content in the ash increases with higher the, burning temperature.
- Research shows that RHA produced by burning rice husk between 600°C and 700°C temperatures for 2 hours, contains 90-95% $Si0_2$, 1-3% K_20 and < 5% un burnt carbon.
- Under controlled burning condition in industrial furnace, RHA contains silica in amorphous and highly cellular form, with 50-1000 m^2/g surface area.

Coconut shell (CS)

- Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to normal aggregate.
- Coconut shells can be grouped under light weight aggregate.
- Moisture retaining and water absorbing capacity of CS are more compared to conventional aggregate.
- The presence of sugar in the coconut shell as long as it is not in a free sugar form, it is not going to affect the setting and strength of concrete.
- The 28days air dry densities of coconut shell concrete (CSC) is less than 2000 kg/m^3 and these are within the range of structural lightweight concrete.
- Coconut shell concrete has better workability because of the smooth surface on one side of the shells and the size of CS crushed to 12.5 mm maximum in any direction.

Oil palm shell (OPS)

- OPS are hard in nature and do not deteriorate easily once bound in concrete and therefore, it does not contaminate or leach to produce toxic substances.
- Unlike artificially produced aggregates or industrial by-products, OPS do not need to be processed or require any chemical pretreatment before it is used.
- The bulk density of OPS is about 500 to 600 kg/m^3, producing concretes of about 1900 kg/m^3 in density, which makes them lightweight.
- OPS concrete fulfills the requirement of structural concrete achieving good workability.

ARTIFICIAL AGGREGATES

Brick bats

- Brick bats are one of the types of aggregates used in certain places where natural aggregates are not available or costly.
- The brick bat aggregates cannot be really brought under lightweight aggregates because the concrete made with this aggregate will not come under the category/of lightweight concrete. However since the weight of such concrete will be less than the weight of normal concrete it is included here.
- Wherever brick bat aggregates are used, the aggregates are made from slightly over burnt bricks, which will be hard and absorb less water.

- Brick bat aggregates are also sometimes used in conjunction with high alumina cement for the manufacture of heat resistant concrete.

Breeze or Clinker

- These aggregates are obtained from coal and are very light. Some types of coal produce clinker which expands on coming in contact with water and is injurious to concrete causing it to crack.
- The more the combustible matter remaining in the clinker, the more moisture movement is there.
- It should not be used in reinforced concrete where the steel is liable to get corroded. The crushing strength of this concrete is 15 to 30N/mm^2 and its density varies from 800 to 1000 kg/m^3.

Foamed slag

- Foamed slag is also used for preparing lightweight concrete. It is obtained by rapidly quenching the blast furnace slag in water.
- It should be free from combustible materials like coke and sulphur.
- It also shows expansion on getting moist. It produces concrete having a density of about 1300 to 1450 kg/m^3.
- It has a high crushing strength.

Expanded vermiculite slate

- This aggregate is obtained by heating some natural products like vermiculite (a mica product) to suitable temperatures.
- By heating its volume increases several times and forms a light weight aggregate.
- The weight of this concrete may be as 600 kg/m^3

Bloated clay

- When certain glass and shale's are heated to the point of incipient fusion, they expand or what is termed as bloat to many times their original volume on account of the formation of gas within the mass at the fusion temperatures.
- The cellular structure so formed is retained on cooling and the product is used as lightweight aggregate.
- Central Building Research Institute of India: (CBRI) has also 'developed a process technique for the manufacture of bloated clay for structural use.

Sintered fly ash (Pulverized fuel ash)

- Fly ash is finely divided residue, comprising of spherical glassy particles, resulting from the combustion of powdered coal.
- The fly ash is mixed with limited amount of water and is first made into pellets and then sintered at a temperature of 1000° to 1200°C.
- The sintering process is nearly similar to that used in the manufacture of Portland cement.
- The fly ash may contain some un burnt coal which may vary from 2 to 15 % or more depending upon the efficiency of burning.

Expanded Perlite

- This when crushed and heated to the point incipient fusion at a temperature of about 900 to 1100℃ it expands to form a light cellular material with density of about 30 to 240 kg/m^3.
- This light material is crushed carefully to various sizes and used in concrete.
- Due to its very low density this is also 'used for insulation grade concrete.

4. What is aerated concrete? How will you produce it? What is no- fines concrete? Explain in detail. (Apr/May 2010)

<u>Aerated concrete</u>

- Aerated concrete may be defined as concrete made very light and cellular by the addition of prepared foam or by generation of gas within the unhardened mixture.
- It is also termed as cellular concrete and foamed concrete.

By generation* of *gas

- The addition of powdered aluminum or zinc to the cement causes evolution of hydrogen gas on addition of water.
- The powdered metal is added to the cement in dry state in the ratio of 1: 1000.
- After thorough mixing in the dry state, water is mixed.
- This cause the evolution of gases and the process goes on for an hour or so.
- This concrete is quite impervious to water but has a high drying shrinkage.
- So each block or unit should be fully cured and dried, before being used to eliminate any subsequent shrinkage.
- The density of this concrete is about 650 to 950 kg/m^{3}and its strength about 15 to 30 N/mm^2

By use of foaming agents

- Sometimes ordinary concrete can be made light by adding foaming agents like resin soaps.

- These agents develop bubbles inside the concrete and its density is reduced.
- The ordinary heavy aggregates are also sometimes replaced by wooden fibers, chips and saw dust etc. this also helps to reduce the weight of concrete.
- Use of foam concrete has gained popularity not only because of the low density but also because of other properties mainly the thermal insulation property.
- Aerated concrete is made in the density range from 300kg/m^{3}to about 800kg/m^3, Lower density grades are used for insulation purposes, while medium density grades are used for the manufacture of building blocks or load bearing walls and comparatively higher density grades are used in the manufacture of prefabricated structural members in conjunction with steel reinforcement.

Use* of *aerated concrete

- Aerated concrete is used for the following purpose:
- Partitions for heat insulation because of its low thermal conductivity and weight
- In fire proofing because of its better fire resistivity

No Fines concrete

- No fines concrete may be defined as concrete mixtures containing little or no fine aggregate.
- No-fines concrete is becoming popular because of some of the advantages it possesses over the conventional concrete.
- The single sized aggregates make a good no-fines concrete, which in addition.
- To having large voids and hence light in weight, also offers architecturally attractive look.
- The fine aggregate is not added in this concrete.
- So that there are voids left in the coarse aggregate.
- The coarse aggregate may be any of the usual type or the light weight aggregate.
- The coarse aggregate used should be finer than 20 mm size and not more than 10% should pass the 10mm sieve.
- The usual proportion of cement to aggregate is 1:l0 in case of heavy aggregate and 1:6 in case of light aggregate.
- The water/cement ratio for satisfactory consistency will vary between a narrow-range of 0.38 and 0.52. Water/cement ratio must be chosen with care.
- If too Iowa water/cement ratio is adopted, the paste will be so dry that aggregates do not get properly smeared with paste which results in insufficient adhesion between the particles.

- On the other hand, if the water/cement ratio is too high, the paste flows to the bottom of the concrete, particularly when vibrated and fills up the voids between the aggregates at the bottom and makes that portion dense.
- Therefore, the amount of water should be just sufficient to give a coating of cement paste on all particles.
- Too little water may leave loose aggregate inside the concrete and too much of water may cause the cement paste to flow and segregate.
- It is better to wet the aggregate before adding cement and water.
- The concrete should then be mixed thoroughly till all the particles are coated.
- Properly prepared concrete will not segregate during placing.
- It does not need any water tight forms also.
- No-fines concrete, when conventional aggregates are used, may show a density of about 1600 to 1900 kg/m^3, but when no-fines concrete is made by using light weight aggregate, the density may come to about 360 kg/m^3.
- No fines concrete does not pose any serious problem for compaction.
- Uses of mechanical compaction or vibratory methods are not required. Simple rodding is sufficient for full compaction.
- However, formwork may be required to be kept for a longer time, when used as a structural member, as the strength of concrete is comparatively less.
- The compressive strength of no-fines concrete varies between 1.4 N/mm^{2}to about 14 N/rnm^2

Properties* of *no fines concrete

- It does not segregate.
- The density varies with the grading of aggregates
- Water cement ratio of this concrete varies from 0.38 to0.52
- Its strength increases with time
- There is very little cohesiveness, necessitating longer duration of form work removal.
- Shrinkage of this concrete is lower than normal concrete and its thermal expansion is about 0.6 to 0.8 of normal concrete.

Limitations* of *no fines concrete

- It disintegrates rapidly.

- It is unsuitable for foundations and in places continuously in touch with moisture, because of its high absorption quality.
- It is also not suitable for reinforced concrete.

Application* of *no fines concrete

- It is used in large scale for load bearing cast in-situ external walls for single storey and multi storied buildings.
- This type of concrete has been used for temporary structures because of low initial cost
- Also for the ease with which it can be broken and reused as aggregate.
- Architects consider this as an attractive construction material.
- Owing to its slightly higher thermal insulating property, it can be used for external walls for heat insulation.
- Because of rough texture, it gives a good base for plastering.
- Even if the outside surface of the no-fines concrete wall is subjected to rain beating, the inside of the wall will be free from dampness because of low capillary action on account of large voids.

5. Explain polymer concrete.(April/May 2010)(Nov/Dec 2011, 2017, 2019) (April/May 2017, 2018, 2019)

- **Polymer concrete** is part of group of concretes that use polymers to supplement or replace cement and uses polymer as a binder.

Process:

- The main technique in producing PC is to minimize void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregates.
- This is achieved by properly grading and mixing the aggregates to attain the maximum density and minimum void volume.
- The graded aggregates are prepacked and vibrated in a mould. Monomer is then diffused up through the aggregates and polymerization is initiated by radiation or chemical means.
- A silane coupling agent is added to the monomer to improve the bond strength between polymer and the aggregate.
- In polyester resins are used no polymerization is required. Polymer concrete can develop compressive strengths of the order of 140 MPa (20,000 psi) within hours or even minutes.

- Such polymer concretes tend to be brittle and it is reported that dispersion of fibre reinforcement would improve the toughness and tensile strength of the material.
- The use of fibrous polyester concrete in the compressive region of reinforced concrete beams provides a high strength, ductile concrete at reasonable cost.

  The types include

  - ✓ Polymer-impregnated concrete
  - ✓ Polymer concrete
  - ✓ Polymer-Portland-cement concrete.

Properties: (Nov/Dec 2019)

- ➢ High tensile, flexural, and compressive strengths
- ➢ Good adhesion to most surfaces
- ➢ Good long-term durability with respect to freeze and thaw cycles
- ➢ Low permeability to water and aggressive solutions
- ➢ Good chemical resistance
- ➢ Good resistance against corrosion

Advantages:

- ➢ Rapid curing at ambient temperature.
- ➢ Lighter weight (only somewhat less dense than traditional concrete, depending on the resin content of the mix)
- ➢ Mines, tunnels, and highways.
- ➢ Pump manufacturing and chemical processing.
- ➢ Industries

Disadvantages

- ➢ More expensive
- ➢ The monomers can be volatile, combustible and toxic.
- ➢ Initiators which are used as catalyst are combustible and harmful to human skin

A. POLYMER IMPREGNATED CONCRETE

- PIC is a hardened Portland cement concrete that has been impregnated with a monomer (low viscosity liquid organic material) and subsequently polymerized insitu.
- In this case the cement concrete is cast and cured in the conventional manner. After the concrete product gets hardened and dried, air from the voids is removed under partial vacuum and low viscosity monomer (styrene, vinyl chloride) is diffused through the pores of the concrete.
- The concrete product is then finally subjected to polymerization by radiation or by heat

treatment thereby converting the monomer filled in the voids into solid plastic.

Application:

- Precast slabs for bridge decks,
- Roads,
- Marine structures
- Food processing buildings

B. POLYMER CEMENT CONCRETE (PCC)

- PCC is produced by incorporating an emulsion of a polymer or a monomer in ordinary Portland cement concrete.
- The ingredients comprising cement, aggregate and monomer are mixed with water and monomer in the concrete mix in the concrete is polymerized after placing concrete in position. The resultant concrete has improved:
  - Strength,
  - Adhesion
  - Chemical resistance
  - Impact and abrasion résistance
  - Increased impermeability
  - Reduced absorption

Application:

- Marine Works

C. POLYMER CONCRETE

- In polymer concrete polymer /monomer is used to act as binder in place of cement. The monomer and aggregate are mixed together and the monomer is polymerized after placement of concrete in position.
- It is imperative to pre-heat the coarse and fine aggregates while mixing monomer.

Application:

- Irrigation Works

6. Explain Fibre reinforced concrete. (Nov/Dec 2016, 2017, 2019)(April/May 2017, 2018)

- Fibre reinforced concrete is defined as the composite material consists of mixture of cement, mortar or concrete and discontinuous, discrete uniformly dispersed suitable fibres.

- Plain cement concrete, due to its low tensile strength and impact resistance is considered to be o brittle material.
- However, marked improvement in these properties can be brought about by the addition of small diameter, short length, and randomly distributed fibres.
- The fibres can be imaginated as an aggregate with an extreme deviation in shape from the rounded smooth aggregate. The fibres interlock and entangle around aggregate particles and considerably reduce the workability, while the mix becomes more cohesive and less prone to segregation.
- The fibres suitable for reinforcing the concrete have been produced from steel, glass and organic polymers.

The major factors affecting the characteristics of fibre reinforced concrete are:

- Water cement ratio;
- Size of coarse aggregate
- Mixing
- Percentage of fibres;
- Aspect ratio
- Diameter and length of fibres

- The location and extent of cracking under load will depend upon the orientation and number of fibres in the cross section.
- The fibre stress strains the shrinkage and creep movements of unreinforced matrix. However fibres have been found to be more effective in controlling compression creep than tensile creep of unreinforced matrix.

Properties:

- Increased tensile and bending strength coir
- Improved ductility and resistance to cracking
- High impact strength and toughness
- Spalling resistance
- High energy absorption capacity

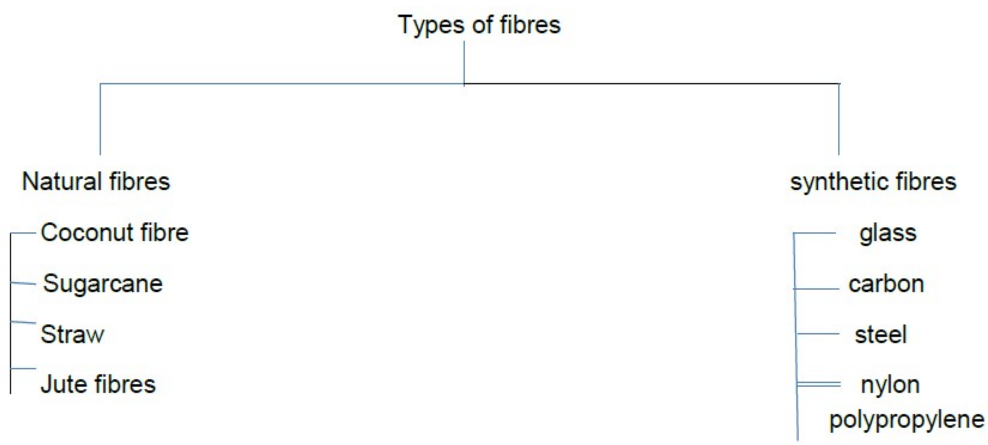
Application:

- Hydraulic structures
- Airfield and highway pavement
- Bridge decks

- ➢ Tunnel lining
- ➢ Heavy duty floors

Disadvantage:

- ➢ The main **disadvantage** associated with the fiber reinforced concrete is Fabrication. The process of incorporating fibers into the cement matrix is labor intensive.
- ➢ Costlier than the production of the plain concrete.



SYNTHETIC FIBRES:

Steel fibre reinforced concrete

- This type of concrete is formed by adding steel fibres in the ingredients of concrete. Round steel fibres are commonly used.
- The typical diameter lies in the range of .25 to .75 mm, by addition of 2 to 3 percent of fibre (by volume).
- It is possible to achieve two or three times increase in the flexural strength of concrete and substantial increase in explosion resistance, crack resistance etc.

Application:

- ➢ Construction of pavement
- ➢ Bridge decks,
- ➢ Pressure vessels,
- ➢ Tunnel lining

Glass fibre reinforced concrete:

- Glass fibres are made up from 200 to 400 individual filaments which are highly bonded to make up a strand.

- These strands can be chopped into various lengths or combined into make cloth,mat or tape.
- The process of manufacture of glass-fibre cement products may involve spraying, premixing or incorporation of continuous rovings.
- It has been observed that addition of 10% of glass fibres by volume brings almost two folds increase in tensile strength and substantial increase in impact resistance of concrete.

Application:

- Used in sewer lining
- Roofing elements, swimming pool, tanks etc.
- Polypropylene and nylon fibres.
- Increase the impact strength.
- Possess very high tensile strength

Asbestos:

- It is a mineral fibre
- Tensile strength varies between 560 and 980 N/mm^2.

Carbon fibres:

- Possess a tensile strength of 2110 to 2815N/ mm^2.
- Used in cladding, panels, shells

NATURAL FIBRES:

Coconut fibre as reinforcement

- Natural reinforcing materials can be obtained at low cost and low levels of energy using local manpower and technology.
- Utilization of natural fibres as a form of concrete enhancement is of Particular interest to less developed regions where conventional construction materials are not readily available or are too expensive.
- Coconut and sisal-fibre reinforced concrete have been used for making roof tiles, corrugated sheets, pipes, silos and tanks.
- The dry cement and aggregates were mixed for two minutes by hand in a 0.1m3 laboratory mixer pan.
- The mixing continued for further few minutes while about 80% of the water was added.

- The mixing was continued for another few minutes and the fibres were fed continuously to the concrete for a period of 2–3 min while stirring.
- Finally, the remaining water along with super -plasticizer was added and the mixing was continued for an additional two minutes.
- This ensured a complete distribution of fibres throughout the concrete mix. For each mix, a total of six cylinders with dimension of 100×200mm and three cubes of 100mm were cast.

Effects of fibers in concrete

- Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage.
- They also reduce the permeability of concrete and thus reduce bleeding of water.
- Toughness is defined as the area under a load-deflection (or stress-strain) curve.
- As it can be seen from Figure 5.9, adding fibers to concrete greatly increases the toughness of the material.
- That is, fiber-reinforced concrete is able to sustain load at deflections or strains much greater than those at which cracking first appears in the matrix.
- The amount of fibers added to a concrete mix IS expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%.

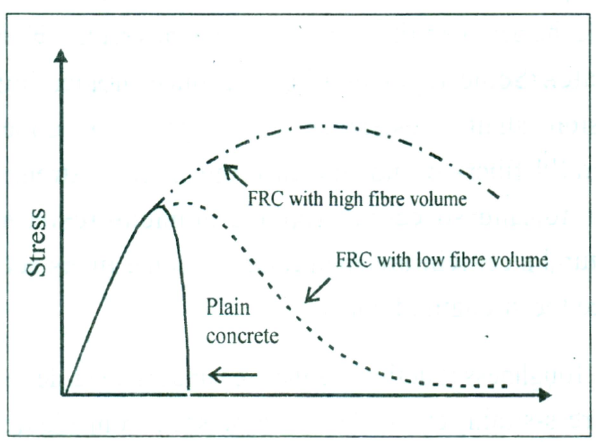


Figure 5.9 Typical stress-strain curves for fiber-reinforced concrete

Types of fibre reinforced concrete

Steel fibre reinforced concrete

- Steel fiber-reinforced concrete is basically a cheaper and easier to use form of rebar reinforced concrete.
- Rebar reinforced concrete uses steel bars that are laid within the liquid cement, which requires a great deal of preparing work but make for a much stronger concrete.
- Steel fiber-reinforced concrete uses thin steel wires mixed in with the cement.
- This imparts the concrete with greater structural strength, reduces cracking and helps protect against extreme cold.
- Steel fiber is often used in conjunction with rebar or one of the other fiber types.

Glass fiber reinforcement concrete (GFRC)

- Glass fiber-reinforced concrete uses fiber glass, much like you would find in fiberglass insulation, to reinforce the concrete.
- The glass fiber helps insulate the concrete in addition making it stronger.
- Glass fiber also helps prevent the concrete from cracking over time due to mechanical or thermal stress.
- In addition, the glass fiber does not interfere with radio signals like the steel fiber reinforcement does.

Synthetic fibers

- Synthetic fiber-reinforced concrete uses plastic and nylon fibers to improve the concrete's strength.
- In addition, the synthetic fibers have a number of benefits over the other fibers.
- While they are not as strong as steel, they do help improve the cement pump ability by keeping it from sticking in the pipes.

Natural fiber reinforced concrete

- Historically, fiber-reinforced concrete have used natural fibers, such as hay or hair.
- While these fibers help the concrete's strength they can also make it weaker if too much is used.
- In addition, if the natural fibers are rotting when they are mixed in then the rot can continue while in the concrete.
- This eventually leads to the concrete crumbling from the inside, which is why natural fibers are no longer used in construction.

Advantages of different fibres

Polypropylene and Nylon fibers can

- Improve mix cohesion, improving pump ability over long distances
- Improve freeze-thaw resistance
- Improve resistance to explosive spalling in case of a severe fire
- Improve impact resistance
- Increase resistance to plastic shrinkage during curing

Steel fibers can

- Improve structural strength
- Reduce steel reinforcement requirements
- Improve ductility
- Reduce crack widths and control the crack widths tightly, thus improving 'durability
- Improve impact- and abrasion-resistance
- Improve freeze-thaw resistance

Applications of FRC

- **Residential:** including driveways, sidewalks, pool construction with shotcrete, basements, colored concrete, foundations, drainage, etc.
- **Commercial:** exterior and interior floors, slabs and parking areas, roadways etc.
- **Warehouse / Industrial:** light to heavy duty loaded floors and roadways
- **Highways / Roadways / Bridges:** conventional concrete paving, , white-toppings, barrier rails, curb and gutter work, pervious concrete, sound attenuation barriers, etc.
- **Ports and Airports:** runways, taxiways, aprons, seawalls, dock areas, parking and loading ramps.
- **Waterways:** dams lock structures, channel linings, ditches, storm-water structures, etc.
- **Agriculture:** farm and animal storage structures, walls, silos, paving, etc.
- **Precast Concrete and Products:** architectural panels, tilt-up construction, walls, fencing, septic tanks, burial vaults, grease trap structures, bank vaults and sculptures.

7. Explain

(i) High strength concrete (Nov/Dec 2016) (April/May 2017, 2019)

(ii) High performance concrete (Nov/Dec 2016, 2017, 2019) (April/May 2017, 2019)

(iii) Geo polymer concrete (May/June 2016) (Nov/Dec 2016)(April/may 2017)

(iv) Ferro cement (May/June 2016) (Nov/Dec 2016, 2019) (April/May 2017)

High strength concrete

- The manufacture of high strength concrete will grow to find its due place in concrete construction for all the obvious benefits.
- In the modern batching plants high strength concrete is produced in a mechanical manner. Of course, one has to take care about mix proportioning, shape of aggregates, use of supplementary cementitious materials, silica fume and super plasticizers.
- With the modern equipments, understanding of the role of the constituent materials, production of high strength concrete has become a routine matter.
- There are special methods of making high strength concrete. They are given below.
    - Seeding
    - Revibration
    - High speed slurry mixing;
    - Useofadmixtures
    - Inhibitionofcracks
    - Sulphurimpregnation
    - Use of cementitious aggregates.

Seeding:

- This involves adding a small percentage of finely ground, fully hydrated Portland cement to the fresh concrete mix.
- The mechanism by which this is supposed to aid strength development is difficult to explain. This method may not hold much promise.

Revibration:

- Concrete undergoes plastic shrinkage. Mixing water creates continuous capillary channels, bleeding, and water accumulates at some selected places.
- All these reduce the strength of concrete. Controlled revibration removes all these defects and increases the strength of concrete.

High Speed slurry mixing:

- This process involves the advance preparation of cement-water mixture which is then blended with aggregate to produce concrete.
- Higher compressive strength obtained is attributed to more efficient hydration of cement particles and water achieved in the vigorous blending of cement paste.

Use of Admixtures:

- Use of water reducing agents are known to produce increased compressive strengths.

Inhibition of cracks:

- Concrete fails by the formation and propagation of cracks. If the propagation of cracks is inhibited, the strength will be higher.
- Replacement of 2– 3% of fine aggregate by polythene or polystyrene ―lenticules 0.025 mm thick and 3 to 4 mm in diameter results in higher strength.
- They appear to act as crack arresters without necessitating extra water for workability. Concrete cubes made in this way have yielded strength upto 105 MPa.

Sulphur Impregnation:

- Satisfactory high strength concrete has been produced by impregnating low strength porous concrete by sulphur.
- The process consists of moist curing the fresh concrete specimens for 24 hours, drying them at 120°C for 24 hours, immersing the specimen in molten sulphur under vacuum for 2 hours and then releasing the vacuum and soaking them for an additional ½ hour for further infiltration of sulphur.
- The sulphur-infiltrated concrete has given strength upto 58 MPa.

Use of Cementitious aggregates:

- It has been found that use of cementitious aggregates has yielded high strength. Cement found is kind of clinker.
- This glassy clinker when finely ground results in a kind of cement. When coarsely crushed, it makes a kind of aggregate known as ALAG.
- Using Alag as aggregate, strength upto 125 MPa has been obtained with water/cement ratio 0.32.

High performance concrete:

- High Performance Concrete (HPC) is a specialized series of concretes designed to provide several benefits in the construction of concrete structures.
- High performance concrete possesses high level of all characteristics of concrete, strength, durability, all service life for durability of concrete.
- Conventional concrete designed on the basis of compressive strength does not meet any functional requirements such as impermeability, resistance to frost, thermal cracking etc.

- While high strength concrete aims at enhancing strength. The term high performance concrete is used to refer concrete of required performance for the majority of construction applications.

Making:

- The mixing sequence of high performance concrete is as follows. Loading of the aggregates and water, addition of the air entraining agent and mixing to develop a satisfactory air bubble system and stabilizing it. Mixing of cement. Addition of super plasticizer and mixed finally.

Properties:

- High workability.
- High durability
- Resistance to chemical attack.
- High modulus of elasticity
- High strength

Advantage:

- Ease of placement and consolidation without affecting strength
- Long-term mechanical properties
- Early high strength
- Toughness
- Volume stability
- Bridge decks, pavements and paving structures
- Longer life in severe environments

Disadvantage:

- Highly expensive
- Proportion of admixtures should be accurate otherwise the properties get changed.

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GEOPOLYMER CONCRETE:

- Geopolymer concrete is concrete based on an inorganic binder polymerized from Al-Si rich materials of geological or industrial origin, such as fly-ash.
- Geopolymer is used as the binder, instead of cement paste, to produce concrete. The Geopolymer paste binds the loose coarse aggregates, fine aggregates and other unreacted materials together to form the geopolymer concrete.
- The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.
- As in the Portland cement concrete, the aggregates occupy the largest volume, that is, approximately 75 to 80% by mass, in geopolymer concrete.

- The silicon and the aluminum in the fly ash are activated by a combination of sodium hydroxide and sodium silicate solutions to form the geopolymer paste that binds the aggregates and other unreacted materials.

PROCESS:

Materials

- The materials needed to manufacture the geopolymer concrete are the same as those for making Portland cement concrete, except for the Portland cement.
- Low calcium (class F) dry fly ash obtained from a local power station was used as the source material.
- For the alkaline activator, a combination of sodium hydroxide solution and sodium silicate solution was used.
- The sodium hydroxide solution was prepared by dissolving the sodium hydroxide solids, either in the form of pellets or flakes, in water.
- Extra water and Naphthalene Sulfonate-based superplasticizer were also added to improve the workability of the fresh fly ash-based geopolymer concrete.
- The sodium silicate solution used contained Na_2O=14.7%, SiO_2=29.4%, and 55.9% of water, by mass. All the liquids were mixed together before adding to the solids.

Mixing and Compacting

- The aggregates in saturated surface dry condition and the dry fly ash were mixed in a pan mixer for 3-4 minutes.
- At the end of this mixing, the liquid component of the Geopolymer concrete mixture, i.e. the combination of the alkaline solution, the super plasticizer and the extra water, was added to the solids, and the mixing continued for a specified period of time.
- In this study, the wet mixing period was designated as the mixing time.
- The fresh concrete had a stiff consistency and was glossy in appearance.
- The fresh concrete was then cast in moulds.
- Compaction was performed using the usual practice, either by applying strokes or using vibration or a combination of both.

- After casting, the concrete samples were cured at an elevated temperature for a specified period of time.

Curing

- Curing was carried out at a specified elevated temperature, either in an oven (dry curing) or in a steam chamber.
- At the end of the curing period, the test specimens were left in the mold for about six hours.
- The samples were then removed from the molds, and left to air dry in the room temperature before testing at a specified age

ENGINEERING PROPERTIES

- Compressive strengths ranging from 20-30MPa to 80-100MPa Ref. 1.
- Flexural strengths typically 2-3MPa higher than for OPC concrete at the same compressive strength
- Hardening in 5-7 days vs. 28 days for OPC concrete at ambient temperature.
- Does not generate any heat of hydration during curing due to the polymerization nature of its chemistry.
- Low specific creep: typ. 25-30 micro strains at 40% load, vs. 50-60 for OPC concrete.
- Low drying shrinkage: typ. 100-150 micro strains @ 1 yr., vs. 500-800 forOPC concrete.
- Excellent resistance to freeze-thaw cycles
- Adhesion to fresh and old concrete substrates, steel, glass, ceramics.
- Inherent protection of steel reinforcing due to low chloride diffusion rates.

SUPERIOR DURABILITY:

1) High level of resistance to a range of acids and salt solutions
   - Na2SO4, MgSO4, NaCl, Sulfuric Acid, Hydrochloric Acid
   - Resistant to seawater corrosion
2) Not subject to deleterious alkali-aggregate reactions.
3) Impervious to water.
4) Fire resistance
   - No water molecules present in the geopolymer structure hence does not spall at high temperatures, unlike OPC concrete.
5) Does not burn or release toxic fumes, unlike organic polymers.

APPLICATIONS:

- Metro/railroad systems,
- Highways, bridges,
- Marine infrastructure,
- Dams, canal linings,
- Water and sewage pipes,
- Mine tailings.

ADVANTAGES:

- Geopolymer concrete has significantly higher resistance to acid then ordinary concrete
- 80% reduction in CO2 footprint comparing to OPC, opportunity to obtain tradable CO2 certificates.
- Can be used in a wide range of ready-mix, pre-cast, and pre-stressed/pre-cast applications
- Excellent fire and heat resistance. It has the ability to remain stable in temperatures of more than 1200 ^{o}C

DISADVANTAGES

- Activator is necessary to start the geopolymerisation process.
- Due to the dangers of handling chemicals and the liability issues that ensue, geopolymer concrete is generally sold as a pre-cast or pre-mixed material

FERROCEMENTCONCRETE:

- It is well known that conventional reinforced concrete members are too heavy, brittle, cannot be satisfactorily repaired if damaged, develop cracks and reinforcements are liable to be corroded.
- The above disadvantages of normal concrete make it inefficient for certain types of work.
- Ferrocement is a relatively new material consisting of wire meshes and cement mortar.
- It consists of closely spaced wire meshes which are impregnated with rich cement mortar mix.
- The wire mesh is usually of 0.5 to 1.0 mm diameter wire at 5 mm to 10 mm spacing and cement mortar is of cement sand ratio of 1: 2 or 1: 3 with water/cement ratio of 0.4 to 0.45.
- The Ferro cement elements are usually of the order of 2 to 3 cm. in thickness with 2 to 3 mm external cover to the reinforcement.
- The steel content varies between 300 kg to 500 kg per cubic meter of mortar.
- The basic idea behind this material is that concrete can undergo large strains in the neighborhood of the reinforcement and the magnitude of strains depends on the distribution and subdivision of reinforcement throughout of the mass of concrete.

Materials used for Ferro cement

The reinforcing wire

- It is important to get a good distribution of wire mesh throughout the cement mortar to limit cracking.
- Wire meshes come in a wide variety of types\ diameters, stiffness, and strengths.
- For large tanks, welded meshes made from the larger diameters of wire (above 4mm) welded at 100 mm to 200mm spacing to a square or rectangular grid are often used to provide a strong reinforcing frame, which is then covered with smaller sizes of mesh or netting.

Wire netting

- Wire netting, often called 'chicken wire of mesh', is very useful for distributing loads through the mortar and into the larger diameter reinforcing wires.
- It is easily moulded to form spherically shaped surfaces, such as arched roofs to tanks.

The cement mortar

- Cement mortar is a mixture of sand, cement, and water.
- The strength of the mortar depends on these raw materials, the mix ratio, and the workmanship of those who mix and use the mortar.

Sand

- Clean, dry sand should be used.
- It should be well graded, comprising particles of different sizes.
- The importance of good, clean, well graded sand cannot be over emphasized if one is to make the high grade impervious mortar required for boatbuilding.

Cement

- Cement should have been recently manufactured and have been protected from water vapour during storage and transport.

Water

- The water used in the mix needs to be clean, preferably of drinking-water quality.

The cement: sand ratio

- The usual ratio of cement to dry sand is 1:3 by volume.
- To achieve the desired ratio, a bucket can be used to accurately measure out the proportions of sand and cement.

The water: cement ratio

- The ratio of water to cement has an important effect on the final strength of the mortar.
- A ratio of about 0.4: 1 to 0.5:1 (ratio of water: cement by weight) is an ideal, which is equivalent to between 20 to 25 litres of water to each 50 kg bag of cement.

Mixing for Ferro cement

- It is preferable to use a concrete mixer.
- Where this is not possible, mix the right ratios of sand and cement on a hard, clean surface until the mixture is of uniform colour.
- Cast a mixing slab if necessary, or use a portable mixing trough to prevent loss of cement and to prevent soil contaminating the mortar.

Curing for Ferro cement

- Once the mortar has set, keep it damp for at least two weeks and preferably longer.
- This curing is important for the proper gaining of strength and the prevention of cracking.
- It can be assisted by wetting the surfaces and covering them with polythene sheeting or wet sacking.
- It will still be necessary to periodically wet the surfaces before they can be allowed to dry.

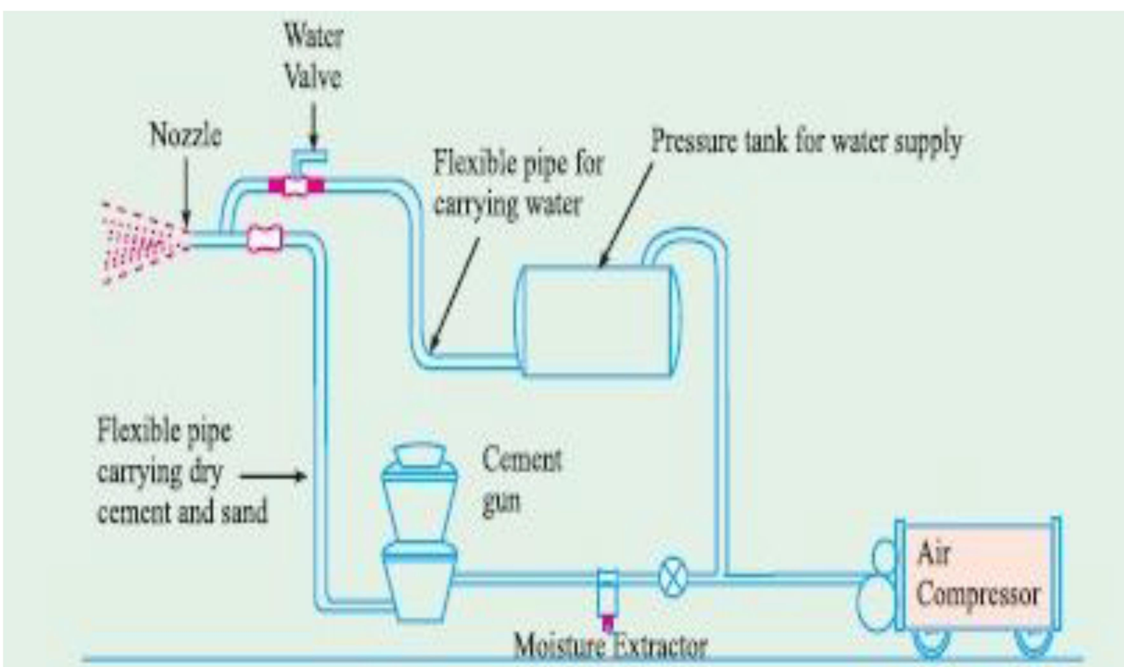
6. Describe in detail about Shotcrete and its advantages. (May/June 2016)(April/May 2017, 2019) (Nov/Dec 2017, 2019)

- Shotcrete or Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface.
- Recently the method has been further developed by the introduction of small sized coarse aggregate into the mix deposited to obtain considerably greater thickness in one operation and also to make the process economical by reducing the cement content.
- Normally fresh material with zero slumps can support itself without sagging or peeling off.
- The force of the jet impacting on the surface compact the material. Sometimes use of set accelerators to assist overhead placing is practiced.
- The newly developed Redi-set cementcan also be used for shotcreting process.
- There is not much difference between guniting and shotcreting.

- Gunite was first used in the early 1900 and this process is mostly used for pneumatically application of mortar of less thickness, whereas shotcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregates.
- There are two different processes in use, namely the Wet-mix process and the dry-Mix process. The dry mix process is more successful and generally used.

Dry-mix Process

- The dry mix process consists of a number of stages and calls for some specialized plant. A typical small plant set-up is shown in Fig The stages involved in the dry mix process is given below:
- Cement and sand are thoroughly mixed.
- The cement/sand mixture is fed into a special air-pressurized mechanical feeder termed as gun‘.
- The mixture is metered into the delivery hose by a feed wheel or distributor within the gun.
- This material is carried by compressed air through the delivery hose to a special nozzle.
- The nozzle is fitted inside with a perforated manifold through which water is sprayed under pressure and intimately mixed with the sand/cement jet.
- The wet mortar is jetted from the nozzle at high velocity onto the surface to be gunited.



The Wet-mix Process

- In the wet-mix process the concrete is mixed with water as for ordinary concrete before conveying through the delivery pipe line to the nozzle, at which point it is jetted by compressed air, onto the work in the same way, as that of dry mix process.

- The wet-mix process has been generally discarded in favour of the dry-mix process, owing to the greater success of the latter.
- The dry-mix methods make use of high velocity or low velocity system. The high velocity Gunite is produced by using a small nozzle and a high air pressure to produce a high nozzle velocity of about 90 to 120 metres per second.
- This results in exceptional good compaction. The lower velocity Gunite is produced using large diameter hose for large output.
- The compaction will not be very high.

Advantages of Wet and Dry Process

- Although it is possible to obtain more accurate control of the water/cement ratio with the wet process the fact that this ratio can be kept very low with the dry process largely overcomes the objection of the lack of accurate control.
- The difficulty of pumping light-weight aggregate concrete makes the dry process more suitable when this type of aggregate is used.
- The dry process on the other hand, is very sensitive to the water content of the sand; too wet a sand causes difficulties through blockade of the delivery pipeline, a difficulty which does not arise with the wet process.
- The lower water/cement ratio obtained with the dry process probably accounts for the lesser creep and greater durability of concrete produced in this way compared with concrete deposited by the wet process, but air-entraining agents can be use to improve the durability of concrete deposited by the latter means.
- Admixtures generally can be used more easily with the wet process except for accelerators. Pockets of lean mix and of rebound can occur with the dry process.
- It is necessary for the nozzle man to have an area where he can dump unsatisfactory shotcrete obtained when he is adjusting the water supply or when he is having trouble with the equipment.
- These troubles and the dust hazard are less with the wet process, but wet process does not normally give such a dense concrete as the dry process.
- Work can be continued in more wind weather with the wet process than with the dry process, Owing to the high capacities obtainable with concrete pumps, a higher rate of laying of concrete

can probably be achieved in the wet process than with the dry process.

7. Describe in detail about SIFCON and its advantages. (May/June 2016)

SLURRY INFILTRATED FIBROUS REINFORCED CONCRETE (SIFCON)

- Slurry Infiltrated Fibrous Reinforced Concrete (SIFCON) is a relatively new high performance and advanced material and can be considered as a special type of Steel Fiber Reinforced Concrete (SFRC).
- SIFCON is unique construction material possessing high strength as well as large ductility and far excellent potential for structural applications when accidental (or) abnormal loads are encountered during services SIFCON also exhibit new behavioral phenomenon, that of ”Fiber lock” which believed to be responsible for its outstanding stress-strain properties.
- The matrix in SIFCON has no coarse aggregates, but a high cementitious content. However, it may contain fine (or) coarse sand and additives such as fly ash, micro silica and latex emulsions.
- The matrix fineness must be designed so as to properly infiltrate the fiber network placed in moulds, since otherwise, large pores may form leading to substantial reduction in properties.
- A controlled quantity of high range water reducing admixtures (super plasticizer) may be used for improving flowing characteristics of SIFCON.
- All steel fiber types namely straight, hooked and crimped can be used. The fibers are subjected to frictional and mechanical interlock in addition to the bond with the matrix.
- The matrix plays the role of transferring the forces between fibers by shear, but also acts as bearing to keep fibers interlock.

COMPOSITION OF SIFCON

- Proportions of cement and sand generally used for making SIFCON are 1:1, 1:1.5 (or) 1:2 cement slurry alone have some applications.

- Generally, fly ash (or) silica fume equal to 10 to 15% by weight of cement is used in mix. Water cement ratio varies between 0.3 to 0.4.
- Percentage of super plasticizers varies from 2 to 5% by weight of cement.
- The percentage of fibers by volume can be anywhere from 4 to 20% even though the current practical ranges from 4 to 12%.

PROCESS OF MAKING SIFCON

- The process of making SIFCON is different, because of high steel fiber content. While in SFRC the steel fibers are mixed intimately with wet (or) dry mix of concrete, prior to mix being poured into forms.
- SIFCON is made by infiltrating low viscosity cement slurry in to a bed of steel fibers "pre packed" in forms (or) moulds.

DESIGN PRINCIPLES

- The design methods for SIFCON members must take into account their application (or) end, the property that needs to be enhanced, minimum proportion, strength as well as its constructability and service life.
- In general, a high strength SIFCON mix can easily be designed and obtained with virtually any type of steel fibers available today, if slurry is also of high strength like conventional concrete.
- The strength of slurry is a function of water-cement ratio, because the slurry mixes used in SIFCON usually contain significant percentages of fly ash (or) silica fume (or) both.
- The term "water-cement plus admixtures" is used when designing slurry mix.
- In addition, the ratio of "admixtures to cement" is also an important parameter in design of SIFCON higher volume percentages of fibers need lower viscosity slurry to infiltrate the fibers thoroughly.
- Generally, higher the slurry strength greater is SIFCON strength.

FACTORS AFFECTING THE EFFICENCY OF SIFCON

There are four variables to consider when evaluating a SIFCON specimen. They are:-

(1) Slurry strength

(2) Fiber volume

(3) Fiber alignment

(4) Fiber type

- "Cement slurry" greatly affects the behavior of SIFCON specimens because the slurry is the back bone of specimen. The elastic moduli, tensile strength and compressive strength of slurry affect the behavior of composite SIFCON matrix. Fiber pullout strength is lest one variable that depends upon slurry compressive strength.
- "Fiber volume" depends upon fiber type and vibration effort. Smaller (or) shorter fibers will pack denser than longer fibers. Higher fiber volume can be achieved with added vibration time.
- "Fiber alignment" greatly affects the behavior of a SIFCON specimen. Fibers can be aligned normal to loading (or) parallel to loading. The ultimate strength, ductility and energy absorption are all affected by fiber alignment.

"Fiber types" are mainly 2 types. They are:-

(1) Steel fibers
(2) (2) Glass fibers

- Steel fibers come in three main shapes and several sizes and strengths. The shapes are hooked, crimped and deformed with various aspect ratios (l/d).
- The most popular steel fiber is Dramix fiber (hooked) made by Bekaert Corporation.
- Glass fibers were generally rod like in shape with various lengths, diameters and strengths.

ADVANTAGES OF SIFCON

- SIFCON possess excellent durability, energy absorption capacity, impact and abrasion resistance and toughness.
- Modulus of elasticity (E) values for SIFCON specimens is more compared with plain concrete.
- SIFCON exhibits high ductility.
- The limitation in SFRC that is balling problem of steel fibers with increase in fiber volume is overcomes by SIFCON, because of its fiber alignment.
- Deflection for SIFCON will be very less compared to conventional and will act as rigid body.

DISADVANTAGES OF SIFCON

- Uniformity and quality control of fiber distribution in addition to high placement cost associated with manual addition of fibers, restricted wide applications of these composites.

USAGE /APPLICATION AREA

SIFCON has properties like ductility, crack resistance, penetration and impact resistance very high compared to other materials like SFRC, concrete it is best suited to applications in following areas:-

(1) Pavement rehabilitation and pre cast concrete products.
(2) Overlays, bridge decks and protective revetments.
(3) Seismic and explosive resistant structures.
(4) Security concrete applications.(safety vaults, strong rooms)
(5) Refractory applications. (soak-pit covers, furnace lintels, saddle piers)
(6) Sea protective works.
(7) Military applications such as anti-missile hangers, underground shelters.
(8) Aerospace launching platforms.
(9) Repair, rehabilitation and strengthening of structures.
(10) Concrete mega structures like offshore and long span structures, solar towers.

8. Explain the properties of geo polymer concrete and mention the economic benefits, advantages of geo polymer and its applications.

Properties of geopolymer concrete

- The behavior and failure mode of fly ash-based geopolymer concrete in compression is similar to that of Portland cement concrete.
- Modulus of elasticity increased as the compressive strength of geopolymer concrete increased.
- Poisson's ratio of fly ash-based geopolymer concrete was in the range 0.12 and 0.16.
- The tensile splitting strength of geo polymer concrete is only a fraction of the compressive strength, as in the case of Portland cement concrete.
- The unit-weight of the low-calcium fly ash- based geopolymer concrete is similar to that of Portland cement concrete.

- Compressive strength increased with age in the order of 10 to 20 percent when compared to the 7th day compressive strength.
- Heat-cured fly ash based geopolymer concrete undergoes very little drying the order of about 100micro strains after one year.
- This value is significantly smaller than the range of 500 to 800 micro strains experienced by Portland cement concrete.
- Heat-cured low-calcium fly ash based geopolymer concrete has an excellent resistance to sulfate attack.
- There was no damage to the surface of test specimens after exposure to sodium sulfate solution up to one year.
- There were no significant changes in the mass and the compressive strength of test specimens after various periods of exposure up to one year.
- The behavior and failure modes of reinforced geopolymer concrete columns were similar to those observed in the case of reinforced Portland cement concrete columns.
- The behavior and failure mode of reinforced geopolymer concrete beams were similar to those observed in the case of reinforced Portland cement concrete beams.

Economics benefits

- Fly ash-based geopolymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete.
- The very little drying shrinkage, the low creep, the excellent resistance to sulfate attack, and good acid resistance offered by the heat-cured low-calcium fly ash-based geopolymer concrete may yield additional economic benefits when it is utilized in infrastructure applications.

Advantages of geopolymer

Compared with Portland cement, geo polymer possesses the following characteristics:

- **Abundant raw materials resources**: Any pozzolanic compound or source of silicates or almino-silcates that is readily dissolved in alkaline solution will suffice as a source of the production of geopolymer.
- **Energy saving and environment protection:** Geopolymer do not require large energy consumption and a little CO2 is emitted.

- **Simple preparation technique:** Geo polymer can be synthesized simply by mixing alumina-silicate reactive materials and strongly alkaline solutions, then curing at room temperature. In a short period, a reasonable strength will be gained.
- **Good volume stability**: Geopolymer have 4/5 lower shrinkage than Portland cement
- **Reasonable strength gain in a short time:** Geopolymer can obtain 70% of the final compressive strength in the first 4 hours of setting.
- **Ultra-excellent durability:** Geo polymer concrete or mortar can withdraw thousands of years weathering attack without too much function loss.
- **High fire resistance and low thermal conductivity:** Geopolymer can withdraw 10000C to 12000C without losing functions. The heat conductivity of geo polymer varies from *0.24w/mk, (Watts per meter-Kelvin)* to *0.3w/mk,* compared well with lightweight refractory bricks *(0.3 w/mk*to 0.438 *w/mk).*

Applications of geo polymer

- Geopolymer, with properties such as abundant raw resource, little CO2 emission, less energy consumption, low production cost; high early strength, fast setting properties make geo polymer find great applications in many fields of industry such as civil engineering, automotive and aerospace industries, non-ferrous foundries and metallurgy, plastics industries, waste management, art and decoration, and retrofit of buildings.
- Geopolymer yield synthetic mineral products with such properties as high mechanical performance, hard surface, thermal stability, excellent durability, and high acid resistance and therefore any current building component such as bricks, ceramic tiles and cement could be replaced by geo polymer.
- At present, some geo polymer products have been used in aircraft to eliminate cabin fire in aircraft accidents.

Partially impregnated and surface coated concrete

- Partial impregnation may be sufficient in situations where the major requirement is surface resistance against chemical and mechanical attack in addition to strength increase.
- Even with only partial impregnation, significant increase in the strength of original concrete has been obtained.
- The partially impregnated concrete could be produced by initially soaking the dried specimens in liquid monomer like methyl methacrylate, then sealing them by keeping them under hot water at 70°C to prevent or minimize loss due to evaporation.

- The polymerization can be done by using thermal catalytic method in which three per cent by weight of benzoyl peroxide is added to the monomer as a catalyst.
- It is seen that the depth of monomer penetration is dependent upon following:
    - Pore structure of hardened and dried concrete
    - The duration of soaking
    - The viscosity of the monomer.
- The potential application of polymer impregnated concrete surface treatment (surface coated concrete) is in improving the durability of concrete bridge decks.
- Bridge deck deterioration is a serious problem everywhere, particularly due to a abrasive wear, freeze-thaw deterioration, spalling and corrosion of reinforcement.
- Excellent penetration has been achieved by Ponding the monomer on the concrete surface.
- Due care should be taken to prevent evaporation of monomer when ponded on concrete surface.
- The application of monomer for field application like in bridge decks poses more problems than laboratory application.
- A typical surface treatment in the field can be done in the following manner.
- The surface is dried for several days with electrical heating blanket.
- Remove the heating blanket and cover the slab with 0.64 m^3 oven-dried light-weight aggregate per 100 m^2
- Apply initially 2,000 to 3,000 ml of the monomer system per m^2.
- Cover the surface with polyethylene to retard evaporation.
- Shade the surface to prevent temperature increase which might initiate polymerization pre maturely that may reduce penetration into the concrete.
- Add periodically additional monomer to keep the aggregate moist for minimum soak time of 8 hours.
- Apply heat to polymerize the monomer.
- Heating blanket, steam or hot water can be used for this purpose.

Some of the promising monomer systems for this purpose are:

- Methyl methacrylate (MMA), 1% Benzoyl peroxide (BP), 10% Tri Methyl propane Tri Methacrylate (TMPTMA).
- Isodecyl methacrylate (IDMA), 1% BP 10%TMPTMA,
- Isobutyl methacrylate (IBMA), 1% BP 10% TMPTMA,

BP acts as a catalyst and TMPTMA is a cross linking agent which helps in polymerization at low temperature of 52°C.

9. Explain

(i) Foam concrete
(ii) Self compacting concrete (SCC) (April/May 2019) (Nov/Dec 2019)
(iii) Vaccum concrete

FOAM CONCRETE

- Light weight concrete also known as foamed concrete, foam concrete, cellular light weight concrete or reduced density concrete
- It is defined as a cement based slurry, with a minimum of 20%(per volume) foam entrained into the plastic mortar.
- As mostly no coarse aggregate is used for production of foam concrete the correct term would be called mortar instead of concrete.
- Sometimes it may be called as „foamed cement" because of mixture of only cement&foa without any fine aggregate.
- The density foam concrete usually varies from 400 kg/m3 to 1600 kg/m3.
- The density of normal concrete usually varies but around 2400 kg/m3
- The density is normally controlled by substituting fully or part of the fine aggregate with foam.

Manufacturing:

- Foamed concrete typically consists of slurry of cement and fly ash or sand and water, although some suppliers recommend pure cement and water with the foamed agent for very light weight mixes.
- This slurry is further mixed with synthetic aerated foam in a concrete mixing plant. The foam is created using a foaming agent, mixed with water and air foam a generator.
- The foaming agent used must be able to produce air bubbles with a high level of stability, resistant to the chemical processes of mixing, placing and hardening.
- Foamed concrete mixture may be poured or pumped into moulds, or directly into structural elements.
- The foam enables the slurry to flow freely due to thixotropic behavior of the foam bubble, allowing it to be easily poured into the chosen foam or mould.

- The viscous material requires up to 24hours to solidify (or as two hours if steam cured with temperatures up to 700 C to accelerate the process.) depending on variables including abient temperature and humidity.
- Once solidified produce may be releasing foam its mould.

Properties:

- Foam concrete is a versatile building material with a simple production method that is relatively inexpensive compared to autoclave aerated concrete.
- Foam concrete compounds utilizing fly ash in the slurry mix is cheaper still, and has less environment impact.
- Foam concrete is produced in a variety of densities from 200 kg/m3 to 1600kg/m3 depending on the application. Lighter density products may be cut into different sizes.
- While the product is considered a foam of concrete (with air bubbles replacing aggregate), its high thermal and acoustical insulating qualities make it a very different application than conventional concrete.

- **Strength:**
  - As with dense concrete, the compressive strength of foamed concrete will depend on the density, cement content, and water/cement ratio properties of aggregates, methods of manufacturing and curing.
  - The density of foam concrete within the range 400-1600 kg/m3 and can be produce at a compressive strength of 05 to 10 N/mm2
- **Fire resistance:**
  - Foam concrete is an inorganic material and therefore unlikely to catch fire.
  - Test carries out in several countries, including tests to ASTM standards, show that a load bearing foam concrete slab wall, 15cm thick, has a fire resistance exceeding 7 hours.
- **Thermal conductivity**
- **Shock- Absorption**

Advantages:

- Weight reduction of super structure using foam concrete walls.
- Less steel reinforcement requires for slabs, column, beams and foundation due to lesser load.

- Earthquake resistant due to lesser weight of building built using foam concrete walls in multistory buildings.
- Reduced cost of raw materials: by adding air, enclosed in foam bubbles, the volume of concrete can be increased at very low cost.
- Cost reduction for transportation and storage.
- Faster construction using cast in situ application.
- Improve thermal insulation
- Improve fire production.
- Easy to use/produce/handle
- Low investment
- High flowing capacity
- Low water absorption.
- Low weight and easily workable.
- Low weight for earthquake protection
- Eco-friendly

Disadvantages:

- It is very sensitive in water in its mixture.
- Its mixing time is longer than conventional concrete to assure proper mixing.
- Difficult to place & finish because of porosity and angularity.
- In some mixes cement mortar separates the aggregate and floats through surface.
- It takes more time in mixing for proper mixing because of finer particles and foam present in the mix.

SELF COMPACTING CONCRETE:

- Self-compacted concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of formwork under its self weight.
- It"s very flow able concrete with high workability that has ability to flow under its own weight with no need of vibration and no need of segregation and without the separation of the constituent material until it set.
- Thus SCC eliminates the vibration for the compacting of concrete without affecting its engineering properties.

- As of the year 2000,SCC used for prefabricated products (precast member) and ready mixed concrete (cast-in-situ) in JAPAN, USA, and later on INDIA etc.
- The creation of durable concrete structure requires adequate compaction by skilled workers.
- Solution for the achievement of durable concrete structures independent of the quality construction work is the use of SCC.
- Present day develop SCC can be classified as an advanced construction material.

Constituents of SCC

- SCC consists of the same components as conventionally vibrated concrete, which are
- Cement
- Aggregate
- Water
- Chemical admixtures i.e., super plasticizers and viscosity modifying agents.
- Mineral admixtures i.e., Fly ash, silica fume, GGBFS etc.,

Properties of SCC

- **Filling ability (excellent deformability)** – flows easily at suitable speed into formwork.
- **Passing ability (ability to pass reinforcement without blocking) -** passing through reinforcements without blocking.
- **High resistance to segregation** – the distribution of aggregate particles remains homogeneous in both vertical and horizontal directions.
- Static segregation due to gravity, vertical direction.
- Dynamic segregation due to flow, horizontal direction.

Measurements of SCC flow properties in fresh state:

- Slump flow test & T50 test
- L-Box test
- V-Funnel test

Test on hardened concrete:

- Compressive strength test
- Split tensile strength
- Flexural strength

Advantages of SCC

- Elimination of problems associated with vibration.
- Faster construction.

- Improves working condition and productivity in construction industry.
- Greater freedom in design.
- Less noise from vibrators and reduce dander from hand arm vibration
- Cost saving.
- Improve the quality, durability, and reliability of concrete structures due to better compaction and homogeneity of concrete.
- Reduce wear and tear on foams from vibration.
- Reduce permeability.

Disadvantages of SCC

- More precise measurements and monitoring of the constituent materials.
- Requires more trial batches at laboratory as well at ready- mixed concrete plants.
- Costlier than ready – mixed concrete based on concrete material cost (expectation to placement cost).
- Lack of globally accepted test standards and mix designs.
- More stringent requirements on the selection of material.

VACUUM CONCRETE:

- Vacuum concrete is the type of concrete in which the excess water is removed for improving concrete strength.
- Reducing the final water- cement ratio of concrete before setting to control strength and other properties of concrete.

Need for vacuum concrete:

- The chemical reaction of cement with water requires a water cement ratio of less than 0.38.
- But it is always taken more than 0.38.
- Workability is also important for concrete.
- Workability and high strength don‟t go together as their requirements are contradictory to each other.
- Vacuum concrete is the effective technique used to overcome this contradiction opposite requirements of workability and high strength.

Equipment use in vacuum concrete:

- Vacuum concrete with hose pipe.
- Filtering pad
- Screen board vibrator
- Water separator

- Power trowel
- Power floater

Procedure:

- With the help of screen vibrator the surface is vibrated.
- Vacuum pump is small but strong pump of 5 to 10 HP.
- The mats are placed over fine filter pads.
- Water from concrete is vacuum and stored in separator.
- About 3% reduction in concrete layer depth takes place.
- By the use of power trowel and power floater the surface is given and smooth finish.

Application of vacuum concrete:

- Industrial floor sheds like cold storage.
- Hydro power plant
- Bridges ports and harbour.
- Cooling tower

Advantages of vacuum concrete:

- Increase of final strength of concrete by about 25%.
- Sufficient decreasing in permeability of concrete.
- High density concrete.
- Increase of about 20% bond strength of concrete.
- Appreciable reduction of time for final finishing.
- Early removal of wall foams.
- Increase in durability.

Disadvantages of vacuum concrete:

- High initial cost.
- Need trained labor.
- Need specific equipments.
- Need power consumption.
- The porosity of concrete allows water/ oil and gases to seep through, consequently weakening the concrete.