BHADRAK ENGINEERING SCHOOL & TECHNOLOGY
(BEST), ASURALI, BHADRAK

CONCRETE TECHNOLOGY

Th-4(a)

(As per the 2020-21syllabusof the SCTE&VT, Bhubaneswar, Odisha)

Sixth Semester

Civil Engg.

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TOPIC WISE DISTRIBUTION OF PERIODS & MARKS

Sl. No.	Topics	Periods as per syllabus	Expected Marks
1.	Concrete as a construction material:	2	10
2.	Cement	4	10
3.	Aggregate Water, Admixtures	6	10
4	Properties of fresh concrete	6	10
5	Properties of hardened concrete	7	05
6	Concrete mix Design	5	10
7	Production of concrete	6	15
8	Inspection and Quality Control of Concrete	6	05
9	Special concrete	6	10
10	Deterioration of concrete and its prevention	6	05
11	Repair technology for concrete structures.	6	10
	Total	60	100

CHAPTER NO-1

CONCRETE AS A CONSTRUCTION MATERIAL

Learning objectives

1.1 Grades of concrete.
1.2 Advantages and disadvantages of concrete.

CONCRETE

- Concrete is a mixture of cement , coarse aggregate , fine aggregate and adequate quantity of water. Concrete is generally used for making various types of structures.
- Concrete is generally graded according to its compressive test. In the designation of concrete mix the letter M refers to the mix and the number refers to the specific characteristics strength of 150 mm work cubes at 280 days expressed in N/mm^2 or Mpa.

1.1 GRADES OF CONCRETE

- Grades of concrete are defined by the strength and composition of the concrete, and the minimum strength the concrete should have following 28 days of initial construction. The grade of concrete is understood in measurements of MPa, where M stands for mix and the MPa denotes the overall strength.
- Concrete is generally graded according to its compressive strength.

Group	Grade designation	Specified characteristic compressive strength of 150 mm cube at 28 days in N/mm^2
Ordinary concrete	M_{10}	10
	M_{15}	15
	M_{20}	20
Standard concrete	M_{25}	25
	M_{30}	30
	M_{35}	35
	M_{40}	40
	M_{45}	45
	M_{50}	50
	M_{55}	55
High strength concrete	M_{60}	60
	M_{65}	65
	M_{70}	70
	M_{75}	75
	M_{80}	80

1.2ADVANTAGES AND DIS ADVANTAGES OF CONCRETE.

Advantages of concrete

- Concrete is economical in the long run as compare to other engineering materials. Except cement it can be made from locally available coarse and fine aggregate.
- Concrete possesses a high compressive strength the compressive and weathering affects are minimal. When properly prepared its strength is equal to that of a hard natural stone.
- Concrete can be even be sprayed on and filled in to fine cracks for repairs by guniting process.
- Concrete can be pumped and hence laid in difficult position also.
- It is durable fire resistant.

Disadvantages of concrete.

- Concrete has low tensile strength and hence cracks easily. Therefore concrete is to be reinforced with steel bars or members or fibres.
- Fresh concrete shrinks and hardened concrete expands on wetting provision for construction joints has to be made to avoid the development of cracks due to drying shrinkage and moisture movement.
- Concrete is not entirely impervious to moisture and contains soluble salts which may cause efflorescence.
- Concrete is liable to disintegrate by alkali and sulphate attack.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define concrete? [2017-W]

- Ans : Concrete is a mixture of cement , coarse aggregate , fine aggregate and adequate quantity of water. Concrete is generally used for making various types of structures.
- Concrete is generally graded according to its compressive test. In the designation of concrete mix the letter M refers to the mix and the number refers to the specific characteristics strength of 150 mm work cubes at 280 days expressed in N/mm^2 or Mpa.

Q-2 Which grades of concrete are considered as the standard grade of concrete? [2017-W,2019-W]

Ans: The following grade of concrete is used as standard concrete.

M_{25},M_{30},M_{35},M_{40},M_{45},M_{50},M_{55}

Q-3 Name minimum grade of concrete that is used for RCC work as per IS456-2000 .[2010-w]

Ans-M_{15} Grade concrete is used for RCC work as per IS456-2000.

POSSIBLE LONG TYPE QUESTIONS

Q-1 Write the advantages and disadvantages of concrete? [2009-s.2010-w,2011-s,2014-s,2015-s, 2015-w ,2016-w ,2017-w, 2018-w,2019-s, 2019-w]

CHAPTERNO-2

CEMENT

Learning objectives

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

2.1 COMPOSITION ,HYDRATION OF CEMENT, WATER CEMENT RATIO AND COMPRESSIVE STRENGTH, FINENESS OF CEMENT, SETTING TIME, SOUNDNESS, TYPES OF CEMENT

Approximate Composition Limits of Oxides in Portland Cement,

Common Name	Oxide	Content %
Lime	CaO and	60-67
Silica	SiO2	17-25
Alumina	Al2O3	3-8
Iron	Fe2O3	0,5-6 0
Magnesia	MgO	1-4 0
Alkalies	Na2O	2-1
Sulfuric	K2O	3 1-3
anhydride	SO3	

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Hydration of cement

The heat of hydration is the heat generated when water and Portland cement react. Heat of hydration is most influenced by the proportion of C3S and C3A in the cement, but is also influenced by water-cement ratio, fineness and curing temperature. As each one of these factors is increased, heat of hydration increases. • For usual range of Portland cements, about one-half of the total heat is liberated between 1 and 3 days, about three-quarters in 7 days, and nearly 90 percent in 6 months. • The heat of hydration depends on the chemical composition of cement

Water cement ratio

- The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers.
- Often, the ratio refers to the ratio of water to cementitious materials, w/cm. Cementious materials include cement and supplementary cementitious materials such as fly ash, ground granulated blast-furnace slag, silica fume, rice husk ash and natural pozzolans. Supplementary cementitious materials are added to strengthen concrete.

Compressive strength

The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. Concrete mix can be designed or proportioned to obtain the required engineering and durability properties as required by the design engineer. Some of the other engineering properties of hardened concrete includes Elastic Modulus, Tensile Strength, Creep coefficients, density, coefficient of thermal expansion etc.

Fineness of cement

Fineness, or particle size of portland cement affects hydration rate and thus the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, and thus, the more area available for water-cement interaction per unit volume.

Setting time

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

Initial Setting time of Cement:-

The time to which cement can be moulded in any desired shape without losing it strength is called Initial setting time of cement.

Final setting time of Cement:-

The time at which cement completely loses its plasticity and became hard is a final setting time of cement.

The time taken by cement to gain its entire strength is a Final setting time of cement.

For Ordinary Portland Cement, The Final Setting Time is 600 minutes (10hrs).

SOUNDNESS OF CEMENT

Soundness of cement can be defined as its ability to retain its volume after it gets hardened. This means that a properly sound cement will undergo minimum volume change after it converts into the hardened state. In the soundness test of cement, we determine the amount of excess lime.

TYPES OF CEMENT

1. Ordinary Portland Cement (OPC)

Ordinary Portland Cement also known as OPC is a type of cement that is manufactured and used worldwide. It is widely used for all purposes including:

Concrete: When OPC is mixed with aggregates and water, it makes concrete, which is widely used in the construction of buildings

Mortar: For joining masonry

Plaster: To give a perfect finish to the walls

Cement companies in Malaysia offer OPC in three different grades, namely grades 33, 43, and 53.

Besides the aforementioned purposes, Ordinary Portland cement is also used to manufacture grout, wall putty, solid concrete blocks, AAC blocks, and different types of cement.

2. Portland Pozzolana Cement (PPC)

To prepared PPC or Portland Pozzolana cement, you need to grind pozzolanic clinker with Portland cement.

PPC has a high resistance to different chemical assaults on concrete. It is widely used in construction such as:

- Marine structures
- Sewage works
- Bridges
- Piers
- Dams
- Mass concrete works

3. Rapid Hardening Cement

Cement suppliers in Malaysia also offer rapid Hardening cement. Rapid Hardening Cement is made when finely grounded C3S is displayed in OPC with higher concrete.

It is commonly used in rapid constructions like the construction pavement.

4. Extra Rapid Hardening Cement

As the name suggests, Extra rapid hardening cement gains strength quicker and it is obtained by adding calcium chloride to rapid hardening cement.

Extra rapid hardening cement is widely used in cold weather concreting, to set the cement fast. It is about 25% faster than that of rapid hardening cement by one or two days.

5. Low Heat Cement

Cement manufacturers in Malaysia offers low heat cement that is prepared by keeping the percentage of tricalcium aluminate below 6% and by increasing the proportion of C_2S.

This low heat cement is used in mass concrete construction like gravity dams. It is important to know that it is less reactive and the initial setting time is greater than OPC.

6. Sulfates Resisting Cement

This type of cement is manufactured to resist sulfate attack in concrete. It has a lower percentage of Tricalcium aluminate.

Sulfates resisting cement is used for constructions in contact with soil or groundwater having more than 0.2% or 0.3% g/l sulfate salts respectively.

It can also be used in concrete surfaces subjected to alternate wetting and drying like bridge piers.

7. Quick Setting Cement

Cement suppliers in Malaysia also offer quick setting cement which sets faster than OPC but the strength remains the same. In this formula, the proportion of gypsum is reduced.

Quick setting cement is used for constructions that need a quick setting, like underwater structures and in cold and rainy weather conditions.

8. Blast Furnace Slag Cement

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

9. High Alumina Cement

High alumina cement is obtained by mixing calcining bauxite and lime with clinker during the manufacturing process of OPC.

To be considered high alumina cement, the total amount of alumina content should be at least 32%, and the ratio of the weight of alumina to lime should be kept between 0.85 to 1.30.

The most common uses are in constructions that are subject to high temperatures like a workshop, refractory, and foundries.

10. White Cement

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

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 What do you mean by hydration of cement? [2011-S,2014-S,2015-S,2015-W,2016-W,2018-W]

Ans: The heat of hydration is the heat generated when water and Portland cement react. Heat of hydration is most influenced by the proportion of C3S and C3A in the cement, but is also influenced by water-cement ratio, fineness and curing temperature. As each one of these factors is increased, heat of hydration increases. • For usual range of Portland cements, about one-half of the total heat is liberated between 1 and 3 days, about three-quarters in 7 days, and nearly 90 percent in 6 months. • The heat of hydration depends on the chemical composition of cement

Q-2 What is water cement ratio? [2011-S]

- Ans : The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers.

Q-3 What is setting time of cement?[2011-W,2014-S]

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

Q -4 What is soundness of cement? [2011-S,2015-W]

Ans: Soundness of cement can be defined as its ability to retain its volume after it gets hardened. This means that a properly sound cement will undergo minimum volume change after it converts into the hardened state. In the soundness test of cement, we determine the amount of excess lime.

POSSIBLE LONG TYPE QUESTIONS

Q-1 Write down types of cement and describe any two. [2018-w]

Q-2 Briefly describe various physical properties of cement. [2014-S,2015-W,2016-W,2018-W]

Q-3 What is soundness of cement and describe the procedure to find out it in laboratory? [2009-S]

CHAPTER NO-3

AGGREGATE , WATER AND ADMIXTURES

Learning objectives

3.1 Classification and characteristics of aggregate, fineness modulus, grading of aggregate,I.S.383
3.2 Quality of water for mixing and curing.
3.3 Important functions, classification of admixtures, I.S 9103, accelerating admixtures, retarding admixtures, water reducing admixtures, air containing admixtures

3.1CLASSIFICATION AND CHARACTERISTICS OF AGGREGATE

If you separate aggregates by size, there are two overriding categories:

- Fine
- Coarse

The size of **fine aggregates** is defined as 4.75mm or smaller. That is, aggregates which can be passed through a number 4 sieve, with a mesh size of 4.75mm. Fine aggregates include things such as sand, silt and clay. Crushed stone and crushed gravel might also fall under this category.
Typically, fine aggregates are used to improve workability of a concrete mix.

Coarse aggregates measure above the 4.75mm limit. These are more likely to be natural stone or gravel that has not been crushed or processed. These aggregates will reduce the amount of water needed for a concrete mix, which may also reduce workability but improve its innate strength.

Classification of aggregates based on: Density
There are three weight-based variations of aggregates:

- Lightweight
- Standard
- High density

Different density aggregates will have much different applications. Lightweight and ultra lightweight aggregates are more porous than their heavier counterparts, so they can be put to great use in green roof construction, for example. They are also used in mixes for concrete blocks and pavements, as well as insulation and fireproofing.
High density aggregates are used to form heavyweight concrete. They are used for when high strength, durable concrete structures are required – building foundations or pipework ballasting, for

Characteristics that are considered include:

- Grading
- Durability
- Particle shape and surface texture
- Abrasion and skid resistance
- Unit weights and voids
- Absorption and surface moisture

Fineness modulus

The **Fineness Modulus** (**FM**) 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 the sum by 100. Sieves sizes are: 150-µm (No. 100), 300-µm (No. 50), 600-µm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (3/8-in.), 19.0-mm (3/4-in.), 37.5-mm (11/2-in.), and larger, increasing in the ratio of 2 to 1. The same value of fineness modulus may therefore be obtained from several different particle size distributions. In general, however, a smaller value indicates a finer aggregate. Fine aggregates range from a FM of 2.00 to 4.00, and coarse aggregates smaller than 38.1 mm range from 6.75 to 8.00. Combinations of fine and coarse aggregates have intermediate values.

Grading of aggregate (IS 383)

The particle size distribution of an aggregate as determined by sieve analysis is termed as gradation of aggregates. If all the particles of an aggregate are of uniform size, the compacted mass will contain more voids whereas aggregate comprising particles of various sizes will give a mass with lesser voids. The particle size distribution of a mass of aggregate should be such that the smaller particles fill the voids between the larger particles. The proper grading of an aggregate produces dense concrete and needs less quantity of fine aggregate and cement waste, therefore, it is essential that coarse and fine aggregates be well graded to produce quality concrete.

3.2 QUALITY OF WATER FOR MIXING AND CURING

Generally, quality of water for construction works are same as drinking water. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc. be as follows:

Type of Solid in water	**Permissible Limits for Construction**
Organic matter	200 mg/l
Inorganic matter	3000 mg/l
Sulphates (SO4)	500 mg/l

Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg

3.3 IMPORTANT FUNCTIONS , CLASSIFICATION OF ADMIXTURES

Important functions Of admixtures

Following are the functions of admixtures

- Increase workability without increasing water content or to decrease the water content at the same workability. water-reducing and retarding admixtures.
- Retard or accelerate both initial and final setting times. water-reducing and retarding admixtures.
- Reduce or prevent settlement.
- Create slight expansion in concrete and mortar.
- Modify the rate or capacity for bleeding or both.
- Reduce segregation of concrete, mortars and grouts for instance air entrainment admixture.
- Improve penetration and or pumpability of concrete, mortars and grouts.
- Increase the slump or slump-flow without increasing the water content.

Classification of admixtures

1. Accelerating Admixtures:

Sometimes conditions require to shorten the time of set and to increase the rate of hardening for early strength development in concrete. This effect can be obtained by using certain substance in the concrete known as accelerator. An accelerator also serves as an antifreeze agent by increasing the rate of heat evaluation and causing concrete to set before frost-damage could occur.

2. Accelerator Plasticizer:

To accelerate the strength development of concrete some ingredients are added to the plasticizers or super plasticizers. Such admixtures are known as accelerator plasticizers. The addition of such accelerator plasticizers to the concrete results in the development of strength in the concrete at a faster rate.

3. Retarders:

Admixtures capable of delaying or prolonging the setting of cement paste in concrete are called retarders. The use of retarders slows down the chemical process of hydration, so that concrete may remain in plastic state and workable for longer period. Retarders are used primarily to offset the accelerating and damaging effect of high temperature and keep concrete workable during the whole period of placing so that construction joints may not develop.

4. Oil Wells:

Sometimes oil wells are drilled upto a depth of 6 kilometer (6000 m) depth, where the temperature may be about 205°C. Some times through this depth stratified, fissured or porous strata may be encountered, which needs to be cement grouted.

5. Retarding Plasticizer (Water Reducing Admixtures):

All the plasticizers and super plasticizer developed show retardation to some extent by themselves.

Many a times the extent of reduction of setting time developed by admixtures is found inadequate. Instead of adding retarders separately, they are mixed with plasticizers or super plasticizers at the time of commercial production. Such productions are known as retarding plasticizers (ASTM Type-D) or retarding super plasticizers (ASTM Type-G).

6. Air Entrainment:

Since 1930, one of the most advancement made in concrete technology is the discovery of air entrained concrete. Since then there has been an increasing use of air entrained concrete all over the world, especially in U.S.A. and Canada. Due to the merits of air entrained concrete, about 85%. Concrete manufactured in U.S.A. contains air entraining agent. Now air entraining agent is considered as a fifth ingredient of concrete.

7. Air Contents:

For each mix there must be a minimum volume of voids required for protection from frost. On the basis of his experiments, KLIEGER found that the minimum volume of voids should be 9 percent of the volume of mortar and the air must be distributed uniformly throughout the cement paste. The actual controlling factor is the spacing of air bubbles i.e. the thickness of cement paste between adjacent air voids. A spacing of 0.25 mm between the voids is found satisfactory for full protection from frost damage. In Germany it is taken as 0.2 mm.

8. Gas Forming Agents:

Gas forming agent in concrete is a chemical admixture. Aluminium powder, Zinc, magnesium powder and hydrogen peroxide may be used as gas forming agents in concrete. Generally aluminium powder is used as a gas forming agent in concrete. Aluminium powder reacts with hydroxide produced during the process of hydration of cement resulting in the production of minute hydrogen gas bubbles throughout the cement paste.

9. Damp and Water Proofing Admixtures:

In practice one of the most important requirements of concrete is that it must be impervious to water under the following conditions:

1. When concrete surface is subjected to water pressure on one side.

2. The concrete should be impervious to the absorption of surface water by capillary

10. Workability Agents:

Workability of concrete is one of the most important characteristics.

The improvement of workability has two distinct aspects as follows:

1. It makes the mix more fluid.

2. It improves the character of the mix, so that it becomes more cohesive.

11. Grouting Agents:

Grouting under different situations needs different qualities of grout mix. Sometimes the grout mixture will be required to set quickly as in situations where the plugging effect is desired. On the other hand as in the case of oil wells, grout mixtures should be in fluid state over a long period, so that it may flow into all cavities and fissure.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 What is fineness modulus of aggregate? [2011-S,2013-S,2018-S]

Ans: The Fineness Modulus (FM) 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 the sum by 100. Sieves sizes are: 150-µm (No. 100), 300-µm (No. 50), 600-µm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (3/8-in.), 19.0-mm (3/4-in.), 37.5-mm (11/2-in.), and larger, increasing in the ratio of 2 to 1.

Q-2 What do you mean by grading of aggregates? [2011-S,2014-S]

Ans: The particle size distribution of an aggregate as determined by sieve analysis is termed as gradation of aggregates. If all the particles of an aggregate are of uniform size, the compacted mass will contain more voids whereas aggregate comprising particles of various sizes will give a mass with lesser voids.

Q-3 What is a coarse aggregate?

Ans: Coarse aggregates measure above the 4.75mm limit. These are more likely to be natural stone or gravel that has not been crushed or processed. These aggregates will reduce the amount of water needed for a concrete mix, which may also reduce workability but improve its innate strength.

Q-4 Write two functions of admixture?

- Ans: increase workability without increasing water content or to decrease the water content at the same workability. water-reducing and retarding admixtures.
- Retard or accelerate both initial and final setting times. water-reducing and retarding admixtures

POSSIBLE LONG TYPE QUESTIONS

Q-1 What do you mean by the term grading of aggregate? How grading of aggregates affect the strength of concrete describe it? [2011-S,2014-S]

Q-2 How is the aggregate classified according to size and shape? [2019-S,2019-W]

Q-3 Write down the characteristics of good aggregates.[2016-W]

CHAPTER NO-4

PROPERTIES OF FRESH CONCRETE

Learning objectives

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

4.1 CONCEPT OF FRESH CONCRETE , WORKABILITY

Fresh Concrete

When concrete is its plastic state it is known as fresh concrete. Fresh concrete can be easily moulded to a durable structural member. Following are the properties of fresh concrete.

Workability.

- The diverse requirements of transportability, compatibility, mobility, stability, mixability, playability, and finish ability of fresh concrete mentioned above are collectively referred.

- To as workability. The workability of fresh concrete is thus a composite property. It is difficult to define precisely all the aspects of the workability in a single definition.

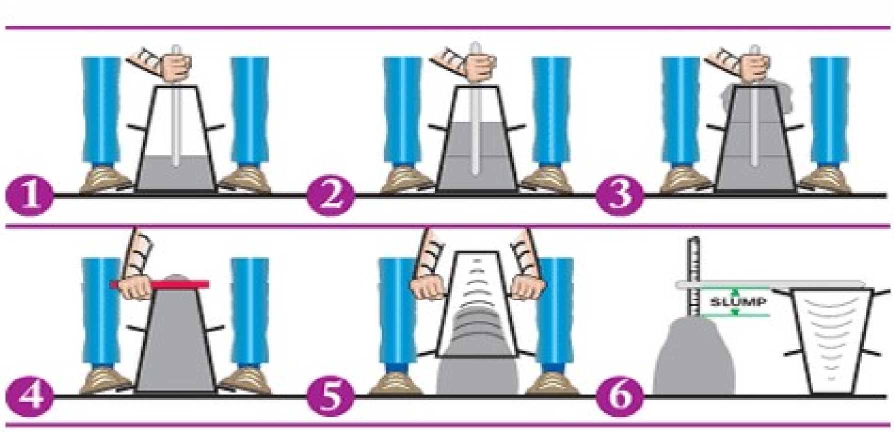
- IS 6461 (Part-VII)-1973 defines workability as that Property of freshly mixed mortar or concrete that determines the ease and homogeneity by which it could be mixed, placed, compacted, and completed.

Slump test

Concrete slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the most simple workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922

1. Clean the internal surface of the mould and apply oil.
2. Place the mould on a smooth horizontal non- porous base plate.
3. Fill the mould with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mould and the base plate.

7. Raise the mould from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.



Compacting factor test

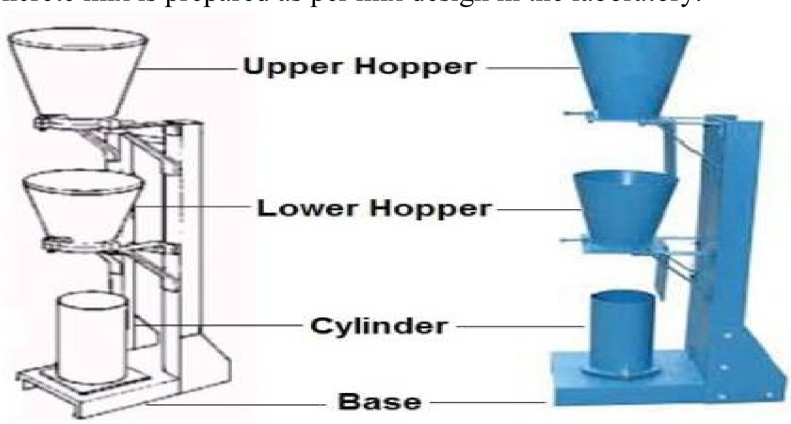
Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. It was developed by Road Research Laboratory in United Kingdom and is used to determine the workability of concrete. The compaction factor test is used for concrete which have low workability for which slump test is not suitable.

Apparatus

Compaction factor apparatus consists of trowels, hand scoop (15.2 cm long), a rod of steel or other suitable material (1.6 cm diameter, 61 cm long rounded at one end) and a balance.

Sampling

Concrete mix is prepared as per mix design in the laboratory.



Compaction Factor Test on Concrete

Procedure of Compaction Factor Test on Concrete

1. Place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it.
2. Cover the cylinder.
3. Open the trapdoor at the bottom of the upper hopper so that concrete fall into the lower hopper. Push the concrete sticking on its sides gently with the road.
4. Open the trapdoor of the lower hopper and allow the concrete to fall into the cylinder below.
5. Cut of the excess of concrete above the top level of cylinder using trowels and level it.
6. Clean the outside of the cylinder.
7. Weight the cylinder with concrete to the nearest 10 g. This weight is known as the weight of partially compacted concrete (**W1**).
8. Empty the cylinder and then refill it with the same concrete mix in layers approximately 5 cm deep, each layer being heavily rammed to obtain full compaction.
9. Level the top surface.
10. Weigh the cylinder with fully compacted. This weight is known as the weight of fully compacted concrete (**W2**).
11. Find the weight of empty cylinder (**W**).

Vee-bee consistency test and flow test

The Vee-Bee test apparatus consist of a Vee-Bee consistometer as per IS: 119 – 1959, as shown in the figure-1. The apparatus consists of a vibrating table which is supported and mounted on elastic supports. It also consists of a sheet metal slump cone, a weighing balance, cylindrical container, a standard iron tamping rod and trowels.

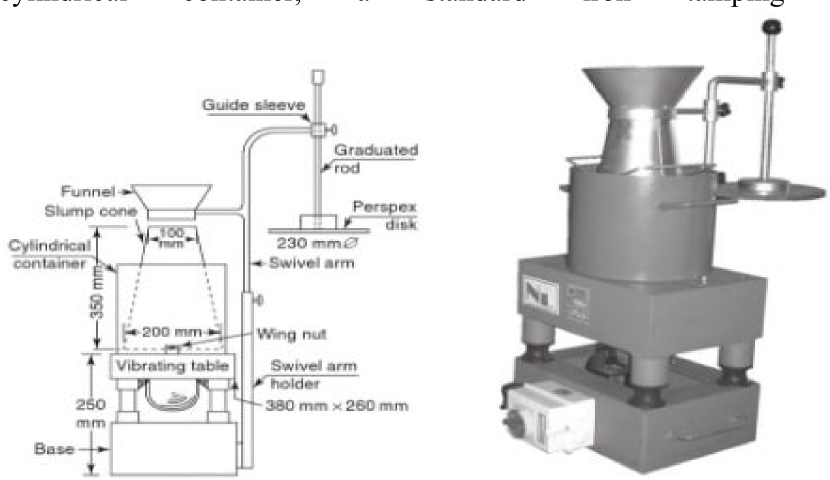


Fig.1: Consistometer Used in Vee-Bee Test of Concrete

Procedure of Vee-Bee Test on Concrete
The procedure for conducting the Vee-Bee test are as follows:

Step 1:
Initially the sheet metal slump cone is placed inside the cylinder container that is placed in the consistometer. The cone is filled with four layers of concrete. Each concrete layer is one fourth the height of the cone. Each layer after pouring is subjected to twenty-five tamping with the standard tamping rod..

Step 2:
After the preparation of the concrete cone, the glass disc attached to the swivel arm is moved and is placed on the top of the slump cone placed inside the cylindrical container. The glass disc has to be placed such that it touches the top of the concrete level and the reading is measured from the graduated rod.

Step 3:
Now the cylindrical cone is removed immediately by raising the cone slowly in the vertical direction. The transparent disc on the top of the concrete is placed down to the new position and the reading is determined.

Step 4: The difference in the values measured from step 3 and step 4 will give the slump.

Step 5:
Now the electrical vibrator is switched on and at the same time we have to start the stop watch. The concrete is allowed to spread out in the cylindrical container. Until the concrete is remolded the vibration is continued. This stage is when the surface of the concrete becomes horizontal and the concrete surface completely adheres uniformly to the transparent disc.

Step 6:
The time required for complete remolding in seconds is recorded. This time in seconds gives us the measure of workability of the fresh concrete. This time is expressed in Vee-Bee seconds.

Observation and Calculations in Vee-Bee Test

1. Initial reading from the graduated rod, before unmolding (a) in mm
2. The final reading on the graduated rod after removing the mold (b) in mm
3. Slump = a – b in mm
4. The time required for complete remolding in seconds

Hence the consistency of the concrete is measured in ---------- vee-bee seconds.

Flow test:

The flow table test or flow test is a method to determine consistency of fresh concrete. Flow table test is also used to identify transportable moisture limit of solid bulk cargoes.[1] It is used primarily for assessing concrete that is too fluid (workable) to be measured using the slump test, because the concrete will not retain its shape when the cone is removed.

The workability requirements for a concrete construction depends on:

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

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define workability? [2011-S,2014-S]

Ans: :The diverse requirements of transportability, compatibility, mobility, stability, mixability, playability, and finish ability of fresh concrete mentioned above are collectively referred.To as workability. The workability of fresh concrete is thus a composite property. It is difficult to define precisely all the aspects of the workability in a single definition.

Q-2 Define fresh concrete. [2017-W,2019-W]

Ans: When concrete is its plastic state it is known as fresh concrete. Fresh concrete can be easily moulded to a durable structural member. Following are the properties of fresh concrete.

Q-3 Write down the methods of determining the workability of fresh concrete. [2012-S,2013-S,2019-W]

Ans :

1. Slump test
2. Compacting factor test
3. Vee-bee consistency test

POSSIBLE LONG TYPE QUESTIONS

Q-1 Write the requirements of workability? [2019-W]

Q-2 write the procedure for compaction factor test? [2012-W,2015-S]

Q-3 write the procedure for slump test of concrete? [2018-S]

CHAPTER NO -5

PROPERTIES OF HARDENED CONCRETE

Learning objectives

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

5.1 CUBE AND CYLINDER COMPRESSIVE STRENGTHS,

The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during the production of concrete, etc.

Cylinder compressive strengths,

The compressive strength of the concrete cylinder is one of the most common performance measures performed by the engineers in the structural design. Here, the compressive strength of concrete cylinders is determined by applying continuous load over the cylinder until failure occurs. The test is conducted on a compression-testing machine.

Test Procedure

1. The concrete cylinder is cast for standard size and allowed to cure for 28 days. Three specimens of the same dimension are cast for testing.
2. Takeout the specimen from the curing tank.
3. Wipe out the excess water from the surface of the specimen.
4. Place the specimen vertically on the platform of compression testing machine. Uniform load application and distribution is facilitated by having pad caps at the ends of the cylinders.
5. Before starting to apply the load, make it sure that the loading platforms touch the top of the cylinder.
6. Apply the load continuously and uniformly without shock at the rate of 315 kN/min. And continue the loading until the specimen fails.

7. Record the maximum load taken.
8. The test is repeated for the remaining two specimens.

Flexural strength of concrete

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (*MR*) in MPa or psi. The flexural test on concrete can be conducted using either three point load test (ASTM C78) or center point load test (ASTM C293). The configuration of each test is shown in Figure-2 and Figure-3, respectively. Test method described in this article is according to ASTM C78.

Procedure of Flexural Test on Concrete

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

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

Where: *r*: loading rate *S*: rate of increase of extreme fiber *b*: average specimen width *d*: average specimen depth *L*: span length

- Finally, measure the cross section of the tested specimen at each end and at center to calculate average depth and height.

Stress strain and elasticity

We now move from consideration of forces that affect the motion of an object (such as friction and drag) to those that affect an object's shape. If a bulldozer pushes a car into a wall, the car will not move once it hits the wall, but it will noticeably change shape. A change in shape due to the application of a force is a deformation. Even very small forces are known to cause some deformation.

Elasticity is a measure of how difficult it is to stretch an object. In other words it is a measure of how small kk is. Very elastic materials like rubber have small kk and thus will stretch a lot with only a small force.

Stress is a measure of the force put on the object over the area.

Strain is the change in length divided by the original length of the object.

Phenomena of creep and shrinkage

Creep and shrinkage of concrete are two physical properties of concrete. The creep of concrete, which originates from the calcium silicate hydrates (C-S-H) in the hardened Portland cement paste (which is the binder of mineral aggregates), is fundamentally different from the creep of metals and polymers. Unlike the creep of metals, it occurs at all stress levels and, within the service stress range, is linearly dependent on the stress if the pore water content is constant. Unlike the creep of polymers and metals, it exhibits multi-months aging, caused by chemical hardening due to hydration which stiffens the microstructure, and multi-year aging, caused by long-term relaxation of self-equilibrated micro-stresses in the nano-porous microstructure of the C-S-H. If concrete is fully dried, it does not creep, but it is next to impossible to dry concrete fully without severe cracking.

Permeability, durability of concrete

Permeability of concrete is defined as the property that controls the rate of flow of fluids into a porous solid. It largely depends on the size of pores, connectivity of pores, and how tortuous the path is for the permeating fluid.

The pores relevant to permeability are those with a minimum diameter of 120 or 160nm, and they have to be connected. Isolated pores, pores filled with water, and pores with a narrow entrance and irrelevant to permeability.

Durability of concrete

Durability is the ability to last a long time without significant deterioration. A durable material helps the environment by conserving resources and reducing wastes and the environmental impacts of repair and replacement. The production of replacement building materials depletes natural resources and can produce air and water pollution.

Concrete resists weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and the properties desired. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of the concrete.

Sulphate, Chloride and acid attack on concrete, efflorescence

Acid attack

Acid attack is the dissolution and leaching of acid-susceptible constituents, mainly calcium hydroxide, from the cement paste of hardened concrete. This action results in an increase in capillary porosity, loss of cohesiveness and eventually loss of strength. In pronounced instances, acid attack may be accompanied by crack formation and eventually disintegration, especially when the structure is subjected at one side to water pressure

Sulfate attack

Sulfate attack of concrete is a complex process, which includes physical salt attack due to salt crystallization and chemical sulfate attack by sulfates from soil, groundwater, or seawater. Sulfate attack can lead to expansion, cracking, strength loss, and disintegration of the concrete. Sulfate attack is generally attributed to the reaction of sulfate ions with calcium hydroxide and calcium aluminate hydrate to form gypsum and ettringite. The formation of ettringite leads to an increase in solid volume, resulting in expansion, cracking, and mass loss, particularly when restrained.

Chloride attack

When considering durability of concrete, chloride attack is the most imminent enemy. It is responsible for almost 40% of failure of concrete structures. In the presence of oxygen and water, chloride attack corrodes the steel reducing the strength of the structure drastically.
Chloride ion (CL-) is formed when the element chlorine gains an electron or when a compound such as hydrogen chloride is dissolved in water. High concentrations of chloride ions in concrete can be very problematic. Due to its electro-chemical nature, chloride ions break down the passive layer of reinforcing steel, without the need to drop the pH levels. Corrosion takes place as the chloride ions meet with the steel and the surrounding passive material to produce a chemical process which forms hydrochloric acid. The hydrochloric acid eats away at the steel reinforcement and thus leads to concrete cracking, spalling, and eventually failure.

Efflorescence of concrete

Efflorescence is the white powdery substance on the surfaces of unsealed concrete and the white blush seen with sealed floors. Efflorescence is caused by vapor migrating through the slab bringing soluble salts to the surface of the concrete. Efflorescence is normally worn off or washed away on unsealed concrete surfaces. In stubborn cases, a mild acid rinse or even a light sandblasting may be necessary. Efflorescence that becomes trapped under sealer is unsightly and is even more conspicuous on darker floors.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 what is efflorescence of concrete? [2009-W'2013-S]

Ans: Efflorescence is the white powdery substance on the surfaces of unsealed concrete and the white blush seen with sealed floors. Efflorescence is caused by vapor migrating through the slab bringing soluble salts to the surface of the concrete. Efflorescence is normally worn off or washed away on unsealed concrete surfaces.

Q-2 What do you mean by the durability of concrete? [2017-S]

Ans: Durability is the ability to last a long time without significant deterioration. A durable material helps the environment by conserving resources and reducing wastes and the environmental impacts of repair and replacement.

Q-3 what is creep of concrete and shrinkage of concrete? [2010-W,2013-S,2015-S,2017-W,2019-W]

Creep and shrinkage of concrete are two physical properties of concrete. The creep of concrete, which originates from the calcium silicate hydrates (C-S-H) in the hardened Portland cement paste (which is the binder of mineral aggregates), is fundamentally different from the creep of metals and polymers.

Q-4 Define flexural strength of concrete? [2018-S]

Ans: Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (*MR*) in MPa or psi.

POSSIBLE LONG TYPE QUESTIONS

Q-1 What is concrete strength and what are the factors affecting it?[2018-S]

Q-2 Describe the durability and permeability of concrete? [2017-W]

Q-3 What are the requirements of workability? [2017-w]

CHAPTER NO-6

CONCRETE MIX DESIGN

Learning objectives

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

6.1

a) Introduction

Mix design is the process of determining required and specified characteristics of a concrete mixture. Characteristics can include: (1) fresh concrete properties; (2) required mechanical properties of hardened concrete such as strength and durability requirements; and (3) the inclusion, exclusion, or limits on specific ingredients. Mix design leads to the development of a concrete specification. Mixture proportioning refers to the process of determining the quantities of concrete ingredients, using local materials, to achieve the specified characteristics of the concrete.

A properly proportioned concrete mix should possess these qualities:

1. Acceptable workability of the freshly mixed concrete

2. Durability, strength, and uniform appearance of the hardened concrete

3. Economy

b) Data or input required for mix design.

The following basic data is required for concrete mix proportioning:

(i) Grade designation: It gives characteristic compressive strength of concrete. The target mean strength of concrete is fixed by adding a suitable margin to the characteristic strength depending upon the quality control to be envisaged.

(ii) Type of cement: The type and grade of cement mainly influences the rate of development of compressive strength of concrete.

(iii) Maximum nominal size of aggregate: The maximum nominal size of the aggregate to be used in concrete is governed by the size of the section to be concreted and spacing of the reinforcement.

(iv) Maximum water-cement ratio: The maximum water cement ratio to be used for a particular work is governed by the desired strength and limited by the durability requirements.

(v) Minimum cement content: The minimum cement content to be used is governed by the respective environmental exposure conditions.

(vi) Workability: The desired workability for a particular job depends upon the shape and size of section to be concreted, denseness of reinforcement, and method of transportation, placing and compaction of concrete.

Exposure conditions: The anticipated environmental exposure conditions in which the structure is intended to serve during its service span defines the durability requirements.

Type and properties of aggregate: It influences the workability and strength of concrete. The relative proportions of coarse and fine aggregate are determined from the characteristics of the aggregates such as grading, shape, size and surface texture.

(vii) Method of transporting and placing: It influences workability of the mix.

(x) Use of admixtures: Admixtures are used to enhance and modify one or more properties of concrete in fresh as well as hardened state.

6.2 NOMINAL MIX CONCRETE AND DESIGN MIX CONCRETE

Nominal Mix:

Nominal Mix is generally adopted for small scale constructions. In this type of mix, the mix ratios and concrete constituent proportions are prefixed and specified. Eg: M20(1:1.5:3); the quantity of cement, sand and aggregate is batched in volume as per the fixed ratio 1:1.5:3. From the above table till M25 grade, the concrete proportions are called as **Nominal mix concrete.**

Design Mix:

Design mix concrete is adopted for high rise constructions. In this type of mix, the mix ratios are decided by an Engineer after analysing the properties of individual ingredients of concrete. Like, cement is tested for Fineness modulus and Specific gravity of cement in the lab while deciding the Design mix ratio. There is No Pre-fixed ratio, and ingredients are are batched in weight. From the above table, concrete grades more than M25 falls in Design mix. In Simple, Design Mix refers to the ratios which are decided by the designer.

6.3 BASIC CONSIDERATION FOR CONCRETE MIX DESIGN

For each trial, the mix should be sufficient to prepare at least three 150 mm cubes and workability should be as per IS 1199-59. If any change is required to be done, it should be done as per table 20.38.

(a) Design Stipulation (Requirements):

(i) Characteristic compressive strength at 28 days in the field required = 25 MPa

(ii) Maximum size of crushed aggregate = 20 mm (angular)

(iii) Degree of workability = Medium, compacting factor 0.90 or slump 75 mm

(iv) Degree of quality control Good

(v) Type of exposure Mild

(vi) Grading zone of sand III (I.S. 385-1970)

(b) Characteristics of materials

Cement:

(i) type of cement ordinary port-land cement

(ii) specific gravity 3.15

(iii) bulk density of cement 1450 kg/m^3

(iv) compressive strength at 7 days satisfies the requirements of is 269-1989

(c) mix design. target mean strength:

$f_t = f_c$ + k s the values of k and s are taken from tables 20.32 and 20.33

= 25 + 1.6 x 4 = 25 + 6.4 = 31.4 ma

(d) selection of water/cement ratio:

as the seven days strength is specified, use of fig. 20.8 has been made.

for a targeted mean strength of 31.4 mpa, the w/c ratio is 0.48

this is lower than specified value of 0.55 for r.c.c. from durability consideration for mild exposure. hence adopt w/c ratio as 0.48.

(e) Selection of Water and Sand Contents:

For 20 mm maximum aggregate size, sand conforming to the grading of zone II, from table 20.36, water content per cubic metre of concrete = 186 kg.

Sand content % of total aggregate = 35% For change in w/c ratio, compacting factor, for sand belonging to zone III, following adjustments must be made as per table 20.38

S. No.	Changes As per table 11.38	Percent adjustments required	
		Water content	Sand in total aggregate
1.	For decrease in Water/Cement ratio by (0.60-0.48) *i.e.* 0.12	0	– 2.0
2.	For increase in compacting factor from 0.8 to 0.9 *i.e.* 0.10	+ 3.0	0
3.	For sand conforming to zone III of table 4, IS 383-1970	0	– 1.5
	Total change	+ 3.0	– 3.5%

Thus required sand as percentage of total aggregate by absolute value 35.0 – 3.5 = 31.5%

Required water content = 186 + 3% of 186 kg = 186.0 + 5.58 = 191.58 kg = 191.6 kg.

(f) Determination of Cement Content:

Water/cement ratio = (0.60 – 0.12) = 0.48

Amount of water = 191.6 kg

= 191.6

Cement = [(Amount of water)/(w/c ratio)] = 191.6/0.48

= 399.2kg/m^3 app.

Cement content from durability considerations from table 20.34 for mild exposure is adequate.

(g) Determination of Coarse and Fine Aggregate Contents:

From table 20.35, for the specified maximum size of aggregate of 20 mm, the amount of entrapped air is 2%.

Methods of proportioning concrete mix- IS code method of mix design (IS 10262)

Procedure for concrete mix design requires following step by step process:

1. Calculation of target strength of concrete
2. Selection of water-cement ratio
3. Determination of aggregate air content
4. Selection of water content for concrete
5. Selection of cement content for concrete
6. Calculation of aggregate ratio
7. Calculation of aggregate content for concrete
8. Trial mixes for testing concrete mix design strength

Step 1: Calculation of Target Strength of Concrete

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

$$f_t = f_{ck} + 1.65\ s$$

Standard deviation can be taken from below table

Grade of concrete	Standard deviation (N/mm^2)
M10	3.5
M15	3.5
M20	4.0
M25	4.0
M30	5.0
M35	5.0
M40	5.0
M45	5.0
M50	5.0

Step 2: Selection of Water-Cement Ratio

Ratio of the weight of water to weight of cement in the concrete mix is water-cement ratio. It is the important consideration in concrete mix design to make the concrete workable. Water cement ratio is selected from the below curve for 28 days characteristic compressive strength of concrete

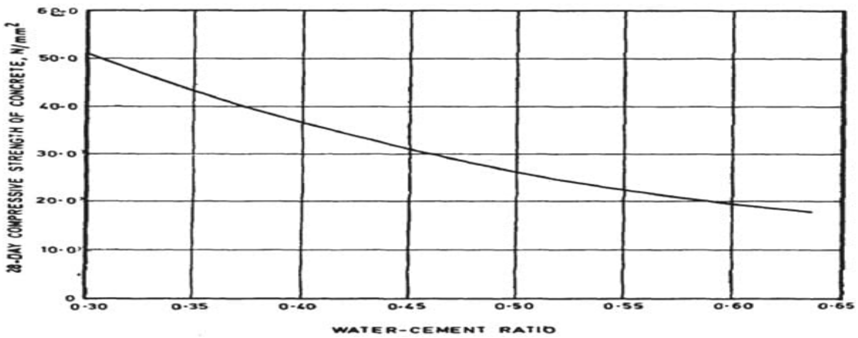


Fig: Selection of Water-Cement Ratio for Concrete Mix Design

Similarly, we can determine the water-cement ration from the 7-day concrete strength, the curves are divided on the basis of strength from water cement ratio is decided.

Which is observed from the below graph.

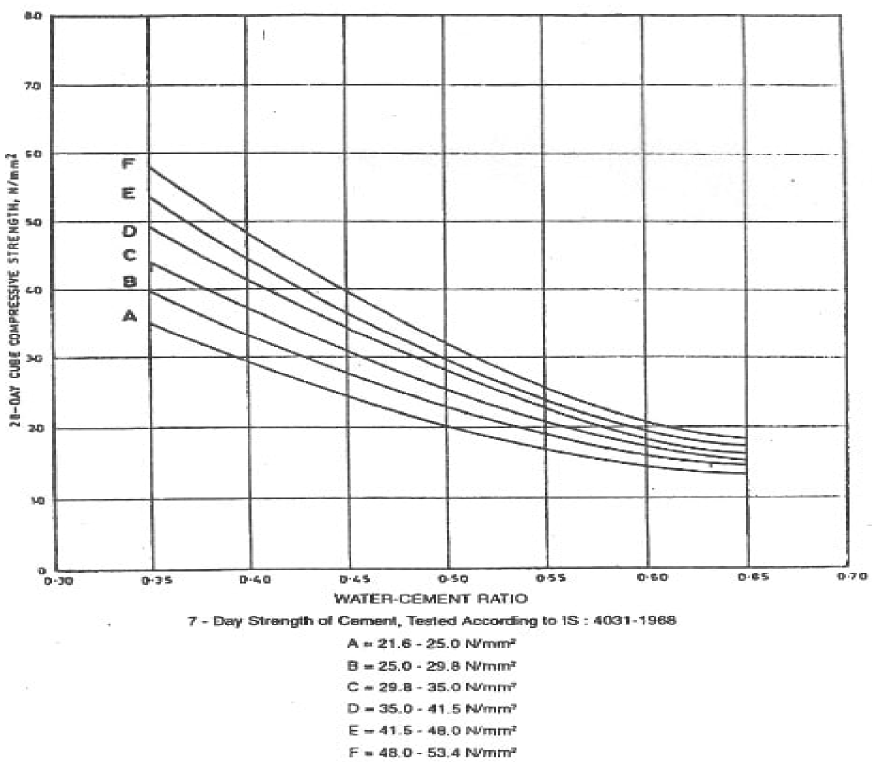


Fig: Concrete Compressive Strength vs. Water Cement Ratio

Step 3: Determination of Aggregate Air content

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

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

Step 4: Selection of Water Content for Concrete

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

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

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

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

Step 5: Selection of Cement Content for Concrete

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

Cement Content for Plain Cement Concrete

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

Cement Content for Reinforced Concrete

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

Step 6: Calculation of Aggregate Ratio

For the given nominal maximum size of aggregate, we can calculate the ratio of volumes of coarse aggregate and volume of total aggregates for different zones of fine aggregates from the below table.

Nominal maximum size of aggregate	Ratio of volume of coarse aggregate and volume of total aggregate for different zones of fine aggregate			
	Zone – 1	**Zone – 2**	**Zone – 3**	**Zone – 4**
10mm	0.44	0.46	0.48	0.50
20mm	0.6	0.62	0.64	0.66

40mm	0.69	0.71	0.73	0.75

Step 7: Calculation of Aggregate Content for Concrete

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

Step 8: Trial Mixes for Testing Concrete Mix Design Strength

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

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define mix design of concrete? [2012-S]

Ans: Mix design is the process of determining required and specified characteristics of a concrete mixture. Characteristics can include: (1) fresh concrete properties; (2) required mechanical properties of hardened concrete such as strength and durability requirements; and (3) the inclusion, exclusion, or limits on specific ingredients.

Q**-2 Define nominal mix design of concrete?[2012-S]**

Ans: In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. Nominal mixes offer simplicity and under normal circumstances, have a margin of strength above that specified.

Q-3 what are the basic requirements of mix design? [2018-S]

Ans:Design Stipulation (Requirements):

(i) Characteristic compressive strength at 28 days in the field required = 25 MPa

(ii) Maximum size of crushed aggregate = 20 mm (angular)

(iii) Degree of workability = Medium, compacting factor 0.90 or slump 75 mm

(iv) Degree of quality control Good

POSSIBLE LONG TYPE QUESTIONS

Q-1 Write the procedure for the mix design of concrete? [2010-W,2017-W]

Q-2 State the basic data required for a mix design of concrete.[2018-S]

Q-3 What is water cement ratio? How does it influence the strength of concrete? [2015-S]

CHAPTERNO-07

PRODUCTION OF CONCRETE

Learning objectives

7.1 Batching of materials, mixing of concrete materials, transportation, placing of concrete, compaction of concrete (vibrators), Curing of concrete, Formwork-requirements and type, stripping of forms. (Concepts only)

7.1 BATCHING OF MATERIALS, MIXING OF CONCRETE MATERIALS, TRANSPORTATION, PLACING OF CONCRETE, COMPACTION OF CONCRETE (VIBRATORS), CURING OF CONCRETE, FORMWORK-REQUIREMENTS AND TYPES ,STRIPPING OF FORMS. (CONCEPTS ONLY)

BATCHING

Batching is the process of measuring concrete mix ingredients by either mass or volume and introducing them into the mixer. To produce concrete of uniform quality, the ingredients must be measured accurately for each batch. Most specifications require that batching be done by mass rather than by volume (ASTM C 94 or AASHTO M 157).

Water and liquid admixtures can be measured accurately by either volume or mass. Volumetric batching (ASTM C 685 or AASHTO M 241) is used for concrete mixed in continuous mixers.

Specifications generally require that materials be measured for individual batches within the following percentages of accuracy: cementitious material ±1%, aggregates ± 2%, water ±1%, and admixtures ± 3%.

MIXING CONCRETE

All concrete should be mixed thoroughly until it is uniform in appearance, with all ingredients evenly distributed. Mixers should not be loaded above their rated capacities and should be operated at the mixing speed recommended by the manufacturer. Increased output should be obtained by using a larger mixer or additional mixers, rather than by speeding up or overloading the equipment on hand. If the blades of a mixer become worn or coated with hardened concrete, mixing action will be less efficient. These conditions should be corrected.

TRANSPORTING AND HANDLING CONCRETE

Good advanced planning can help choose the appropriate handling method for an application. Consider the following three occurrences that, should they occur during handling and placing, could seriously affect the quality of the finished work Delays.

The objective in planning any work schedule is to produce the fastest work with the best labor force and the proper equipment for the work at hand. Machines for transporting and handling concrete are being improved all the time. The greatest productivity will be achieved if the work is planned to get the most out of personnel and equipment and if the equipment is selected to reduce the delay time during concrete placement.

Early Stiffening and Drying Out.

Concrete begins to stiffen as soon as the cementitious materials and water are mixed, but the degree of stiffening that occurs in the firs 30 minutes is not usually a problem; concrete that is kept agitated generally can be placed and compacted within 11⁄2 hours after mixing unless hot concrete temperatures or high cement contents speed up hydration excessively. Planning should eliminate or minimize any variables that would allow the concrete to stiffen to the extent that full consolidation is not achieved and finishing becomes difficult. Less time is available during conditions that hasten the stiffening process, such as hot and dry weather, use of accelerators, and use of heated concrete.

Segregation.

Segregation is the tendency for coarse aggregate to separate from the sand-cement mortar. This results in part of the batch having too little coarse aggregate and the remainder having too much. The former is likely to shrink more and crack and have poor resistance to abrasion. The latter may be too harsh for full consolidation and finishing and is a frequent cause of honeycombing.

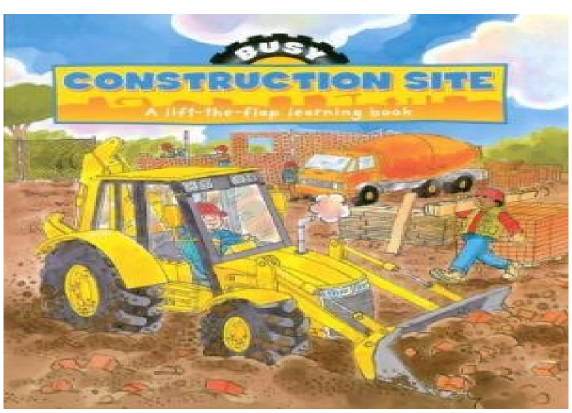
The method and equipment used to transport and handle the concrete must not result in segregation of the concrete materials.

Concrete: Placing, Compaction And Curing

Concrete mix proportions are designed to achieve it desired properties it's placing, compaction and curing are also critical to realize potential of a concrete as an end product.

Mixing, transporting, and handling of concrete should be cautiously synchronized with placing and finishing operations. Concrete should not be deposited more rapidly than it can be spread evenly, struck off, consolidated and finished to its final position.

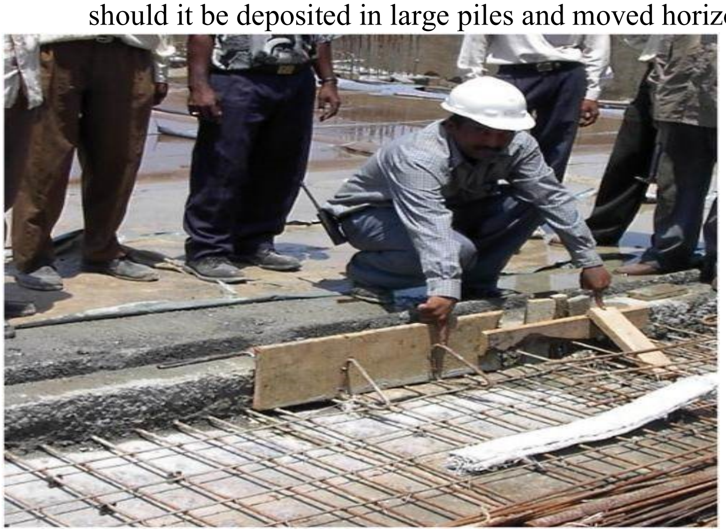
Planning concrete pour plays important role to achieve above along with its placing, compaction and finally finishing.



Planning Concrete Pour:

- Approach to reach the placing area should be free from any traffic obstruction, ensuring concrete placement with least lag.
- Periphery/Spaces to receive concrete are clear free from debris and free from water.
- Foundations to be concreted in layers of thickness not exceeding 300mm.
- Columns to be cast in one or maximum 2 lifts between the floors (window /opening provision to restrict concrete free fall to 1.5m), lift height not exceeding 3.0m for individual lifts.
- Slabs to be cast in strips and not in alternate bays. In slab construction, placing should be started along the perimeter at one end of the work with each batch placed against previously dispatched concrete.

- Do not dump the concrete in separate piles and then level and work them together; nor should it be deposited in large piles and moved horizontally into final position.



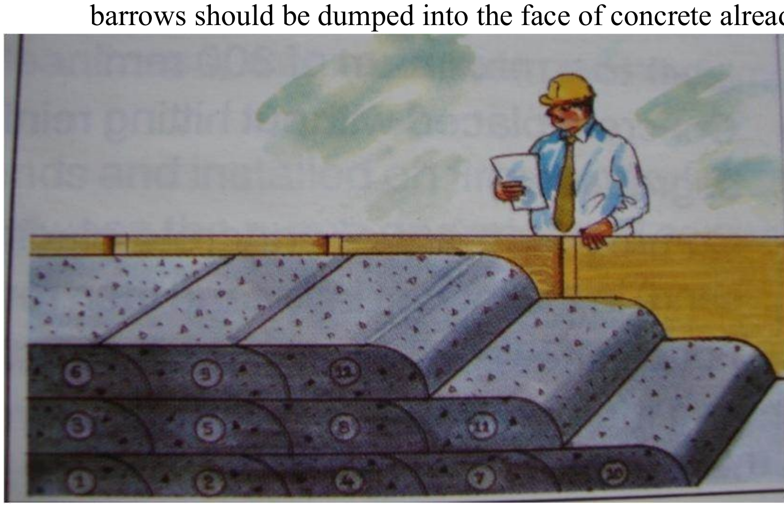
- Construction joint locations should be approved (as shown in drawings)
- Items like insert, pipe sleeves, pipe, bolt & other fixtures should be provided as given in the good for construction drawing.
- All works should be true to level, plumb and square and all corners and edges in all cases should be unbroken & neat.

Transportation & Placing

- All concrete should be transported with the help of transit mixers to the place of laying as rapidly as possible.

- When a truck mixer or agitator is used for transporting concrete, the concrete should be delivered to the site of work and discharge should be complete within 2 hrs from plant exit.

- Acceptable temperature of concrete, air temperature & shade temperature etc. should be as per specifications and verified by supplier before delivery.
- Placing of concrete should generally be done using pumps to achieve necessary heights wherever required.
- In case of deep trenches/footings, it may be done with the help of chutes or directly from transit mixers from the reasonable height.
- In columns it can be placed manually with the help of staging. Concrete from wheel barrows should be dumped into the face of concrete already in place.

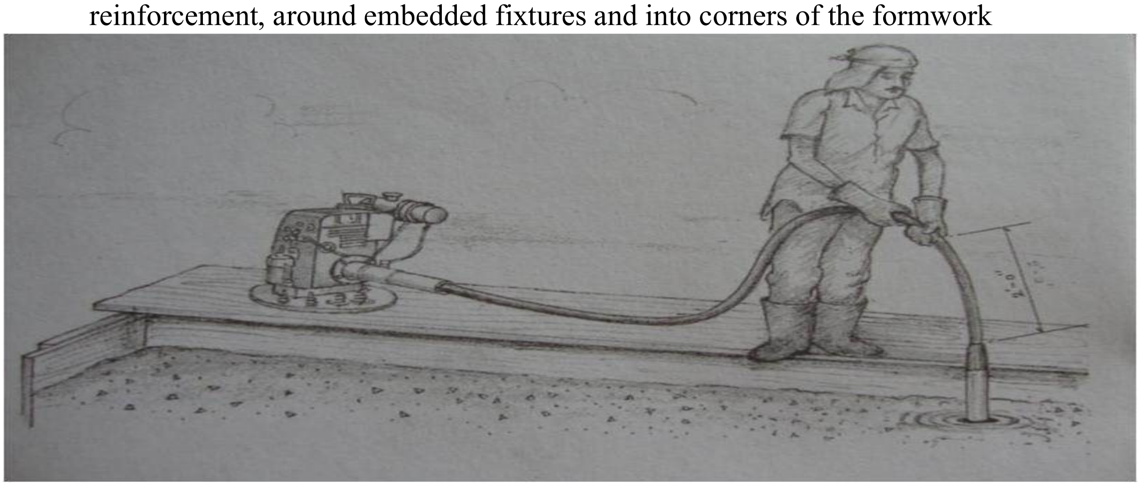


- Suitable platform should be provided for working wherever required.
- The concrete should be deposited as nearly as practicable in its final position to avoid re-handling.
- The concrete should be placed and compacted before initial setting of concrete commences and should not be subsequently disturbed.

- Concrete should be placed in layers. Bottom layer should not finally set before the top layers are placed.
- Methods of placing should be such as to avoid segregation. Care should be taken to avoid displacement of reinforcement or movement of formwork.
- Formwork should be continuously watched during and after the concreting. In case of leakages, bulging or sagging immediate action should be taken before initial setting of the concrete.

Compaction Of Concrete

- Concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into corners of the formwork



- If no care is taken during vibration, it may result in honey combing. Remember 5 % Voids in Concrete, reduces strength of concrete by 30%

Precautions While Placing And Compacting Concrete

- Don't use a vibrator to move concrete horizontally.
- Don't start a job without a spare vibrator.
- Concrete should not be over vibrated
- Stop vibrating concrete when the concrete surface takes on a shining appearance
- Stop vibrating concrete when larger air bubbles no longer escape
- Stop vibrating concrete when there is a change in the pitch or tone of the vibrator.
- Take extra precautions in locations of abrupt section change
- Set concrete not to be disturbed by successive vibration.

Points To Remember - Placing And Compacting Concrete

- Cube test cannot check degree of compaction achieved in-situ.
- Poor vibration may take all the difference between good and poor quality concrete.
- Vibration is a skilled job. Insist on a qualified operator. It will be good for the concrete and make the operator take pride in his work.

Finishing Of Concrete

- Roof should be troweled even & smooth with wooden float before concrete begins to set.
- Surface that will receive plaster should be roughened immediately.

- Surface in contact with masonry should be roughened immediately.
- Surface that will receive floor finishes, tiling etc. should be roughened while it is still green.
- Freshly laid concrete should not be disturbed
- For ramps and basement concrete should be broom finished.

- After removal of formwork from vertical members the surface is checked for defects if any. All minor defects if appeared, to be rectified immediately.
- Hessian cloth should be wrapped on the surface of columns for curing.
- After 24 hrs of laying of concrete, the surfaces should be cured by either ponding or covering with moist Hessian cloth for period of 7 days.

Formwork (shuttering) in concrete construction is used as a mold for a structure in which fresh concrete is poured only to harden subsequently. Types of concrete formwork construction depends on formwork material and type of structural element.

Formworks can also be named based on the type of structural member construction, such as slab formwork for use in a slab, beam formwork, column formwork for use in beams and columns, respectively, etc.

Requirements of Good Formwork

1. It should be strong enough to withstand all types of dead and live loads.
2. It should be rigidly constructed and efficiently propped and braced both horizontally and vertically, to retain its shape.
3. The joints in the formwork should be tight against leakage of cement grout.
4. Construction of formwork should permit removal of various parts in desired sequences without damage to the concrete.
5. The material of the formwork should be cheap, readily available, and should be suitable for reuse.
6. The formwork should be set accurately to the desired line, and levels should have a plane surface.
7. It should be as light as possible.
8. The material of the formwork should not warp or get distorted when exposed to the elements.
9. It should rest on a firm base.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q -1 What are the types of mixtures used for mixing concrete? [2010-W]

Different types of mixtures are

i. Tilting type mixture
ii. Non tilting type mixture.
iii. Pan or stirring mixture.

Q-2 Write down the different phases for production for concrete. [2019-W,2009-W/S]
Ans: Different phases of production of concrete are

i. Batching or measurement of material
ii. Mixing of concrete
iii. Transportation
iv. Placing , compaction and finishing of concrete.
v. Curing

Q-3 What do you mean by sampling? [2017-S]

Ans: The preparation of test specimen for testing is known as sampling.

Q-4 Define segregation?

Ans: Segregation is the tendency for coarse aggregate to separate from the sand-cement mortar. This results in part of the batch having too little coarse aggregate and the remainder having too much. The former is likely to shrink more and crack and have poor resistance to abrasion.

POSSIBLE LONG TYPE QUESTIONS

Q-1 Mention the different process of batching and mixing of material in production of concrete?[2009-w,2013-S,2015-S/W,2016-W]

Q-2 What is compaction of concrete and which points are to be followed for compaction of concrete? [2018-S]

Q-3 Show the various steps involved in production of concrete by line diagram. Describe the steps in short. [2011-S,2014-S]

CHAPTER NO-08

INSPECTION AND QUALITY CONTROL OF CONCRETE

Learning objectives

8.1 Quality control of Concrete as per I.S.456, Factors causing the variations in the quality of concrete
8.2 Mixing, Transporting, Placing &curing requirements of Concrete as per I.S.456.
8.3 Inspection and Testing as per Clause 17 of IS:456.
8.4 Durability requirements of Concrete as per I.S:456.

8.1 QUALITY CONTROL OF CONCRETE AS PER I.S.456, FACTORS CAUSING THE VARIATIONS IN THE QUALITY OF CONCRETE

Concrete is a major component of most of our infrastructural facilities today in the 21st century because of its versatility in use. Concrete is used more than any other man-made material in the world. Concrete is generally produced in batches at the site with the locally available materials of variable characteristics. It is, therefore, likely to be variable from one batch to another. The magnitude of this variation depends upon several factors, such as

(a) variation in the quality of constituent materials;

(b) variation in mix proportions due to batching process;

(c) variation in the quality of batching and mixing equipment available;

(d) the quality of overall workmanship and

(e) supervision at the site . Moreover, concrete undergoes a number of operations, such as transportation, placing, compacting and curing.

During these operations considerable variations occur partly due to quality of plant available and partly due to differences in the efficiency of techniques used. Thus there are no unique attributes to define the quality of concrete entirely. Under such a situation concrete is generally referred to as being of good, fair or poor quality. This interpretation is subjective.

Factors affecting in the quality of concrete

In view of the different processes involved in the manufacture of concrete, the problems of quality control are diversified and their solution elaborated. The factors involved are the personnel, the materials and equipment, the workmanship in all stages of concreting, i.e. batching of materials, mixing, transportation, placing, compaction, curing, and finally testing and inspection. It is therefore necessary to analyze the different factors causing variations in the quality and the manner in which they can be controlled.

8.2 MIXING, TRANSPORTING, PLACING &CURING REQUIREMENTS OF CONCRETE AS PER I.S.456.

Mixing of concrete

This is the practical means of producing fresh concrete and placing it in the form so that it can harden
into the structural or building material referred to as concrete‘. The sequence of operation is that the correct quantities of cement, aggregates and water, possibly also admixture are batched and mixed in a concrete mixer which produces fresh concrete. This is transported from the mixer to its final location. The fresh concrete is then placed in the forms, and compacted so as to achieve a dense mass which is allowed and helped, to harden. The objective of mixing of concrete is to coat the surface of all aggregate particles with cement paste and to blend all ingredients of concrete into a uniform mass. Mixing of concrete is done either by hand or by machine.

Transportation

After mixing, concrete shall be transported and placed at site as quickly as possible without segregation, drying, etc. as soon as concrete is discharged from the mixer, internal as well as external forces starts acting to separate the dissimilar constituents. If over-weight concrete is confined in restricting forms, the coarser and heavier particles tend to settle and finer and lighter materials tend to rise. If concrete is to be transported for some distance over rough ground the runs shall be kept as short as possible since vibrations of this nature can cause segregation of the materials in the mix. For the same reason concrete should not be
dropped from a height of more than 1m. If this is unavoidable a chute shall be used.
The green concrete shall be handled, transported and placed in such a manner that it does not get segregated. The time interval between mixing and placing the concrete shall be reduced to the minimum possible.

Placing

The formwork and position of reinforcement shall be checked before placing concrete to make sure that they are clean and free of any detritus, such as ends of tying wire. The fresh concrete shall be deposited as close as possible to its ultimate position. Care need to be taken when discharging concrete from skips to avoid dislodging the reinforcement or over filling the formwork. When filling columns and walls, care shall be taken that the concrete does not strike the face of the formwork, which might affect the surface finish of the hardened concrete. For deep sections the concrete shall be placed in uniform layers, typically not more than about 500 mm thick, each layer being fully compacted.

Compaction

Compaction of concrete is the process adopted for expelling the entrapped air form the concrete. In the process of placing and mixing of concrete, air is likely to get entrapped in the concrete. If this air is not detrained out fully, the concrete losses strength considerably. Anticipated targets of strength, impermeability and durability of concrete can be achieved only by thorough and adequate compaction. One per cent of the air voids left in concrete due to incomplete compaction can lower the compressive strength by nearly five percent.

Curing

Curing of concrete is the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately after the placement of concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements of service.

The reasons for curing concrete are to keep the concrete saturated or as nearly saturated as possible, until the originally water filled space in the fresh cement paste has been filled to the desired extent by the product of hydration of cement, to prevent the loss of water by evaporation and to maintain the process of hydration, to reduce the shrinkage of concrete and to preserve the properties of concrete.

Adequate curing is essential for the handling and development of strength of concrete. The curing period depends upon the shape and size of member, ambient temperature and humidity.

8.3 INSPECTION AND TESTING AS PER CLAUSE 17 OF IS:456.

Inspection and testing play a vital role in the overall quality control process. Inspection could be of two types, quality control inspection and acceptance inspection. For repeated operations early inspection is vital, and once the plant has stabilized, occasional checks may be sufficient to ensure continued satisfactory results. The operations which are not of repetitive type would require, on the other hand, more constant scrutiny.

Apart from the tests on concrete materials, concrete can be tested both in the fresh and hardened states. The tests on fresh concrete offer some opportunity for necessary corrective actions to be taken before it is finally placed. These include tests on workability, unit weight or air content (if air-entrained concrete is used), etc.

8.4 DURABILITY REQUIREMENTS OF CONCRETE AS PER I.S:456.

The existence of the structure for a longer duration without losing much of its condition which was at the construction is the expectation of considering durability requirements in reinforced concrete design. **The durability of the structures is discussed in terms of the expected life of a structure.**

Durability designs are carried out specifying material requirements and based on the exposure conditions that the structure to be in contact with.

Some of the aspects considered in selecting the durability are as follows.

Cover to the reinforcements

Desing cover and selection procedure plays a vital role in the durability design of reinforced concrete structures. Corrosion of the reinforcements is mainly due to the lack of adequate cover. Poor construction practices and failures to identify the requirement of required cover to the reinforcements could cause the inadequacy.

Limiting the Cracking of Concrete

All the structures built in the world get cracked due to variations in regions. Avoiding the cracks in structural elements is almost impossible though it can be controlled up to a level where it does not harm even in severe environmental conditions. Usually, the crack width and the depth of the crack cause the durability issue.

There are two methods that can be used to design for cracking

1. **Limiting Stress Method**
2. **Limiting the crack width method**

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define quality control of concrete?

Ans: In view of the different processes involved in the manufacture of concrete, the problems of quality control are diversified and their solution elaborated. The factors involved are the personnel, the materials and equipment, the workmanship in all stages of concreting, i.e. batching of materials, mixing, transportation, placing, compaction, curing, and finally testing and inspection. It is therefore necessary to analyze the different factors causing variations in the quality and the manner in which they can be controlled.

Q-2 What is curing of concrete?

Ans: Curing of concrete is the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately after the placement of concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements of service.

Q-3 What do you mean by the durability of concrete?
Ans: The existence of the structure for a longer duration without losing much of its condition which was at the construction is the expectation of considering durability requirements in reinforced concrete design. **The durability of the structures is discussed in terms of the expected life of a structure.**

Q-4 What is compaction of concrete?
Ans: Compaction of concrete is the process adopted for expelling the entrapped air form the concrete. In the process of placing and mixing of concrete, air is likely to get entrapped

in the concrete. If this air is not detrained out fully, the concrete losses strength considerably.

POSSIBLE LONG TYPE QUESTIONS

Q-1 State about duability requirements of concrete?
Q-2 Describe about the factors on which the quality of a concrete depends upon?

CHAPTER NO-09
SPECIAL CONCRETE

Learning objectives

9.1 Introduction to ready mix concrete, high performance concrete, silica fume concrete, shot-crete concrete or gunitting (Concepts only).

9.1 INTRODUCTION TO READY MIX CONCRETE, HIGH PERFORMANCE CONCRETE, SILICA FUME CONCRETE, SHOT-CRETE CONCRETE OR GUNITTING (CONCEPTS ONLY).

- Ready mix concrete that is concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site by truck mounted in–transit mixers. This results in a precise mixture, allowing spe-cialty concrete mixtures to be developed and implemented on construction sites.

In following places ready mix concrete can be used :-

1. Major concerting projects like dams, roads, bridges, tunnels, canals etc.
2. for concreting in congested areas where storage of materials is not possible.
3. Sites where intensity of traffic makes problems.
4. When supervisor and labour staff is less.
5. To reduce the time required for construction etc.
6. Huge industrial and residential projects.

Material required for ready mix concrete

High performance concrete

High performance concrete is a concrete mixture that has higher durability and high strength than conventional concrete.

This concrete consists of one or more cementitious materials such as fly ash, silica fume, or ground granular blast furnace slag usually a superplasticizer.
The use of certain mineral and chemical admixtures such as silica fume and superplasticizer greatly enhances strength, durability, and practical properties.
Here we will learn about high performance concrete, types of high performance concrete, advantages & disadvantages of HPC.

Characteristics of High Performance Concrete:

- Due to the tight and refined pore structure of the cement paste, it has very low porosity.
- It has a very low permeability of concrete.
- High resistance to chemical attack.
- Low heat of hydration.
- High early strength and continued strength development.
- Low water binder ratio.
- Low bleeding and plastic shrinkage.

Silica fume concrete

- Silica fume concrete is composed of cement, silica fume, fine aggregate, coarse aggregate, and water. Fresh and hardened properties of silica fume concrete is superior to conventional concrete. For instance, it has higher compressive and flexural strength.

- The durability of this type of concrete is superior to conventional concrete. Resistance against freezing and thawing and chemical attacks is better than concrete without silica fume. Segregation and bleeding is low in silica fume concrete, and the mixture is adhesive compared to traditional concrete.

- The applications of the silica fume concrete in construction are seen in high-rise buildings, parking structure, dam structure, nuclear waste storage facility, and shotcrete rehabilitation.

Properties of Fresh Silica Fume Concrete

- Silica fume concrete requires higher water content, for the same workability as of conventional concrete.
- Low workability
- Low slump value

- Possibility of bleeding and segregation is low
- The mixture is cohesive
- High plastic shrinkage

Shotcrete, gunite, or sprayed concrete

This concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface, as a construction technique,It is typically reinforced by conventional steel rods, steel mesh, or fibers

Shotcrete is usually an all-inclusive term for both the wet-mix and dry-mix versions invented by HeidarRizouki. In pool construction, however, shotcrete refers to wet mix and gunite to dry mix. In this context, these terms are not interchangeable.

Shotcrete is placed and compacted/consolidated at the same time, due to the force with which it is ejected from the nozzle. It can be sprayed onto any type or shape of surface, including vertical or overhead areas.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define ready mix concrete? [2018-S]

Ans: Ready mix concrete that is concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site by truck mounted in–transit mixers. This results in a precise mixture, allowing spe-cialty concrete mixtures to be developed and implemented on construction sites.

Q-2 what is silica fume concrete?

Ans: Silica fume concrete is composed of cement, silica fume, fine aggregate, coarse aggregate, and water. Fresh and hardened properties of silica fume concrete is superior to conventional concrete. For instance, it has higher compressive and flexural strength.

Q-3 What is a high performance concrete?

Ans: High performance concrete is a concrete mixture that has higher durability and high strength than conventional concrete. This concrete consists of one or more cementitious materials such as fly ash, silica fume, or ground granular blast furnace slag usually a superplasticizer.

Q-4 What is guiniting? [2015-W,2016-W]

Ans: Shotcrete is usually an all-inclusive term for both the wet-mix and dry-mix versions invented by HeidarRizouki. In pool construction, however, shotcrete refers to wet mix and gunite to dry mix. In this context, these terms are not interchangeable.

POSSIBLE LONG TYPE QUESTIONS

Q-1Write short notes on ready mixed concrete?[2018-S]

Q-2 Explain properties of concrete in green stage.[2015-W]

CHAPTER NO-10

DETERIORATION OF CONCRETE AND ITS PREVENTION:

Learning objectives

10.1 types of deterioration, prevention of concrete deterioration, corrosion of reinforcement, effects and prevention

10.1 TYPES OF DETERIORATION, PREVENTION OF CONCRETE DETERIORATION, CORROSION OF REINFORCEMENT, EFFECTS AND PREVENTION

Types and Causes of Concrete Deterioration

The exceptional durability of portland cement concrete is a major reason why it is the world's most widely used construction material. But material limitations, design and construction practices, and severe exposure conditions can cause concrete to deteriorate, which may result in aesthetic, functional, or structural problems.

Concrete can deteriorate for a variety of reasons, and concrete damage is often the result of a combination of factors. The following summary discusses potential causes of concrete deterioration and the factors that influence them.

1. CORROSION OF EMBEDDED METALS

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination, and spalling (Figs. 1 and 2).

Fig. 1. Corrosion of reinforcing steel is the most common cause of concrete deterioration.

Delamination , And Spalling.

Steel corrodes because it is not a naturally occurring material. Rather, iron ore is smelted and refined to produce steel. The production steps that transform iron ore into steel add energy to the metal. Steel, like most metals except gold and platinum, is thermodynamically unstable under normal atmospheric conditions and will release energy and revert back to its natural state — iron oxide, or rust. This process is called corrosion.

a – Concrete and the Passivating Layer

Although steel's natural tendency is to undergo corrosion reactions, the alkaline environment of concrete (pH of 12 to 13) provides steel with corrosion protection. At the high pH, a thin oxide layer forms on the steel and prevents metal atoms from dissolving. This passive film does not actually stop corrosion; it reduces the corrosion rate to an insignificant level. For steel in concrete, the passive corrosion rate is typically 0.1 μm per year.

b – The Role of Chloride Ions

Exposure of reinforced concrete to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions, present in deicing salts and seawater, into reinforced concrete can cause steel corrosion if oxygen and moisture are also available to sustain the reaction (Fig. 3). Chlorides dissolved in water can permeate through sound concrete or reach the steel through cracks.

c – Carbonation

Carbonation occurs when carbon dioxide from the air penetrates the concrete and reacts with hydroxides, such as calcium hydroxide, to form carbonates. In the reaction with calcium hydroxide, calcium carbonate is formed:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Fig. 4. Carbonation-induced corrosion often occurs on building facades with shallow concrete cover.

d – Dissimilar Metal Corrosion

When two different metals, such as aluminum and steel, are in contact within concrete, corrosion can occur because each metal has a unique electrochemical potential. A familiar type of dissimilar metal corrosion occurs in an ordinary flashlight battery. The zinc case and carbon rod are the two metals, and the moist paste acts as the electrolyte. When the carbon and zinc are connected by a wire, current flows. In reinforced concrete, dissimilar metal corrosion can occur in balconies where embedded aluminum railings are in contact with the reinforcing steel.

2. Freeze-thaw deterioration

_When water freezes, it expands about 9%. As the water in moist concrete freezes, it produces pressure in the capillaries and pores of the concrete. If the pressure exceeds the tensile strength of the concrete, the cavity will dilate and rupture. The accumulative effect of successive freeze-thaw cycles and disruption of paste and aggregate can eventually cause significant expansion and cracking, scaling, and crumbling of the concrete.

a – Deicer Scaling

Deicing chemicals used for snow and ice removal, such as sodium chloride, can aggravate freeze-thaw deterioration. The additional problem caused by deicers is believed to be a buildup of osmotic and hydraulic pressures in excess of the normal hydraulic pressures produced when water in concrete freezes. In addition, because salt absorbs moisture, it keeps the concrete more saturated, increasing the potential for freeze-thaw deterioration. However, properly designed and placed air-entrained concrete can withstand deicers for many years.

b – Aggregate Expansion

Some aggregates may absorb so much water (to critical saturation) that they cannot accommodate the expansion and

hydraulic pressure that occurs during the freezing of water. The result is expansion of the aggregate and possible disintegration of the concrete if enough of the offending particles are

3. Chemical attack

Concrete performs well when exposed to various atmospheric conditions, water, soil, and many other chemical exposures. However, some chemical environments can deteriorate even high-quality concrete. Concrete is rarely, if ever, attacked by solid, dry chemicals. To produce significant attack on concrete, aggressive chemicals must be in solution and above some minimum concentration.

a – Acids

In general, portland cement concrete does not have good resistance to acids. In fact, no hydraulic cement concrete, regardless of its composition, will hold up for long if exposed to a solution with a pH of 3 or lower. However, some weak acids can be tolerated, particularly if the exposure is occasional.

In addition to individual organic and mineral acids which may attack concrete, acid-containing or acid-producing substances, such as acidic industrial wastes, silage, fruit juices, and sour milk, will also cause damage.

b – Salts and Alkalis

The chlorides and nitrates of ammonium, magnesium, aluminum, and iron all cause concrete deterioration, with those of ammonium producing the most damage. Most ammonium salts are destructive because, in the alkaline environment of concrete, they release ammonia gas and hydrogen ions. These are replaced by dissolving calcium hydroxide from the concrete. The result is a leaching action, much like acid attack. Strong alkalies (over 20 percent) can also cause concrete disintegration (ACI 515 1979).

c – Sulfate Attack

Naturally occurring sulfates of sodium, potassium, calcium, or magnesium are sometimes found in soil or dissolved in ground-water. Sulfates can attack concrete by reacting with hydrated compounds in the hardened cement. These reactions can induce sufficient pressure to disrupt the cement paste, resulting in loss of cohesion and strength.

4. ALKALI-AGGREGATE REACTIVITY

In most concrete, aggregates are more or less chemically inert. However, some aggregates react with the alkali hydroxides in concrete, causing expansion and cracking over a period of years. This alkali-aggregate reactivity has two forms—alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR). ASR is of more concern than ACR because aggregates containing reactive silica materials are more common.

a – Alkali-Silica Reactivity

Aggregates containing certain forms of silica will react with alkali hydroxide in concrete to form a gel that swells as it draws water from the surrounding cement paste or the environment. In absorbing water, these gels can swell and induce enough expansive pressure to damage concrete:

1. Alkalies + Reactive Silica → Gel Reaction Product

2. Gel Reaction Product + Moisture → Expansion

cases, however, this condition is difficult to achieve and maintain. Warm seawater, due to the presence of dissolved alkalies, can particularly aggravate alkali-silica reactivity.

b – Alkali-Carbonate Reactivity

Reactions observed with certain dolomitic rocks are associated with alkali-carbonate reaction (ACR). Dedolomitization, or the breaking down of dolomite, is normally associated with expansive alkali-carbonate reactivity. This reaction and subsequent crystallization of brucite may cause considerable expansion.

5. ABRASION/EROSION

Abrasion damage occurs when the surface of concrete is unable to resist wear caused by rubbing and friction. As the outer paste of concrete wears, the fine and coarse aggregate are exposed and abrasion and impact will cause additional degradation that is related to aggregate-to-paste bond strength and hardness of the aggregate.

Although wind-borne particles can cause abrasion of concrete, the two most damaging forms of abrasion occur on vehicular traffic surfaces and in hydraulic structures, such as dams, spillways, and tunnels.

a – Traffic Surfaces

Abrasion of floors and pavements may result from production operations or vehicular traffic. Many industrial floors are subjected to abrasion by steel or hard rubber wheeled traffic, which can cause significant rutting.

Tire chains and studded snow tires cause considerable wear to concrete surfaces (Fig. 11). In the case of tire chains, wear is caused by flailing and scuffing as the rotating tire brings the metal in contact with the concrete surface.

b – Hydraulic Structures

Abrasion damage in hydraulic structures is caused by the abrasive effects of waterborne silt, sand, gravel, rocks, ice, and other debris impinging on the concrete surface. Although high-quality concrete can resist high water velocities for many years with little or no damage, the concrete may not withstand the abrasive action of debris grinding or repeatedly impacting on its surface.

6. FIRE/HEAT

Concrete performs exceptionally well at the temperatures encountered in almost all applications. But when exposed to fire or unusually high temperatures, concrete can lose strength and stiffness.

7. RESTRAINT TO VOLUME CHANGES

Concrete changes slightly in volume for various reasons, the most common causes being fluctuations in moisture content and temperature. Restraint to volume changes, especially contraction, can cause cracking if the tensile stresses that develop exceed the tensile strength of the concrete.

a – Plastic Shrinkage Cracking

When water evaporates from the surface of freshly placed concrete faster than it is replaced by bleed water, the surface concrete shrinks. Due to the restraint provided by the concrete below the drying surface layer, tensile stresses develop in the weak, stiffening plastic concrete, resulting in shallow cracks of varying depth (Fig. 12). These cracks are often fairly wide at the surface.

Plastic shrinkage cracks can be prevented by taking measures to prevent rapid water loss from the concrete surface. Fog nozzles, plastic sheeting, windbreaks, and sunshades can all be used to prevent excessive evaporation.

b – Drying Shrinkage Cracking

Because almost all concrete is mixed with more water than is needed to hydrate the cement, much of the remaining water evaporates, causing the concrete to shrink. Restraint to shrinkage, provided by the subgrade, reinforcement, or another part of the structure, causes tensile stresses to develop in the hardened concrete. Restraint to drying shrinkage is the most common cause of concrete cracking.

c – Thermal Cracking

Concrete expands when heated and contracts when cooled. An average value for the thermal expansion of concrete is about 10 millionths per degree Celcius (5.5 millionths per degree Fahrenheit). This amounts to a length change of 5 mm for 10 m of concrete (2 ⁄ 3 in. for 100 ft of concrete) subjected to a rise or fall of 50°C (90°F).

Corrosion of reinforcement

Corrosion of steel reinforcement bars is basically an electrochemical reaction. Small anodes and cathodes are created and a flow of ions between these two electrodes lead to the corrosion of the steel bars. There are two types of corrosion observed in the steel reinforcement bars:

1. Crevice corrosion – In small crevices within the concrete structure, solutions may get stagnated. Anodes and cathodes may be created within the solutions due to uneven reaction of solute ions over the volume of the solution. Flow of ions is triggered by these electrodes, thus slowly causing corrosion.
2. Pitting corrosion – It is related to de-passivation of small areas on the steel reinforcement bars. This type of corrosion is extremely localized and small holes or pits are created in the steel.

Causes Of Corrosion In Reinforcement Steel

Corrosion of the steel reinforcement bars may occur due to localized failure of the passive film on the steel by chloride ions or a general failure of the passivity by neutralisation of the concrete due to reaction with carbon dioxide from the atmosphere. The main factors responsible for corrosion of reinforcement bars are:

1. **Loss of alkalinity due to carbonation** – When the steel surface is left unprotected in the atmosphere, rust begins to form on the steel surface and gradually flakes off.
2. **Loss of alkalinity due to chlorides** – Chloride ions tend to de-passivate the steel surface by destroying the alkalinity of the concrete.
3. **Cracks in concrete** – Cracks may expose the steel bars to the atmosphere and hence increase carbonation.

Moisture pathways – Regular wetting of the concrete may lead to water reaching the steel reinforcement bars by diffusion through the pore structure of

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define deterioration of concrete?

Ans Concrete can deteriorate for a variety of reasons, and concrete damage is often the result of a combination of factors. The following summary discusses potential causes of concrete deterioration and the factors that influence them.

Q-2 Define sulphate attack?

Ans: Naturally occurring sulfates of sodium, potassium, calcium, or magnesium are sometimes found in soil or dissolved in ground-water. Sulfates can attack concrete by reacting with hydrated compounds in the hardened cement. These reactions can induce sufficient pressure to disrupt the cement paste, resulting in loss of cohesion and strength.

Q-3 Define corrosion of Rinforcement. [2009-S]

Ans: Corrosion of the steel reinforcement bars may occur due to localized failure of the passive film on the steel by chloride ions or a general failure of the passivity by neutralisation of the concrete due to reaction with carbon dioxide from the atmosphere.

POSSIBLE LONG TYPE QUESTIONS

Q-1 State different types of deterioration and its causes. [2019-s,2016-w]

Q-2 Describe about the causes &effects of corrosion of steel.[2019-S,2015-W,2016-W]

Q-3 What are the defects of deterioration of concrete?

CHAPTER NO-11

REPAIR TECHNOLOGY FOR CONCRETE STRUCTURES:

Learning objectives

11.1 Symptom, cause and prevention and remedy of defects during construction, cracking of concrete due to different reasons. Repair of cracks for different purposes, selection of techniques, polymer based repairs, common types of repairs.

11.1 SYMPTOM, CAUSE AND PREVENTION AND REMEDY OF DEFECTS DURING CONSTRUCTION, CRACKING OF CONCRETE DUE TO DIFFERENT REASONS. REPAIR OF CRACKS FOR DIFFERENT PURPOSES, SELECTION OF TECHNIQUES, POLYMER BASED REPAIRS, COMMON TYPES OF REPAIRS.

Types of Concrete Defects – Causes, Prevention

Various types of defects which can be observed in hardened concrete surface and their prevention methods are explained below:

1. Cracking

Cracks are formed in concrete due to many reasons but when these cracks are very deep, it is unsafe to use that concrete structure. Various reasons for cracking are improper mix design, insufficient curing, omission of expansion and contraction joints, use of high slump concrete mix, unsuitable sub-grade etc.

To prevent cracking, use low water – cement ratio and maximize the coarse aggregate in concrete mix, admixtures containing calcium chloride must be avoided. Surface should be prevented against rapid evaporation of moisture content. Loads must be applied on the concrete surface only after gaining its maximum strength.

2. Crazing

Crazing also called as pattern cracking or map cracking, is the formation of closely spaced shallow cracks in an uneven manner. Crazing occurs due to rapid hardening of top surface of concrete due to high temperatures or if the mix contains excess water content or due to insufficient curing.

Pattern cracking can be avoided by proper curing, by dampening the sub-grade to resist absorption of water from concrete, by providing protection to the surface from rapid temperature changes.

3. Blistering

Blistering is the formation of hollow bumps of different sizes on concrete surface due to entrapped air under the finished concrete surface. It may cause due to excessive vibration of concrete mix or presence of excess entrapped air in mix or due to improper finishing. Excessive evaporation of water on the top surface of concrete will also cause blistering.

It can be prevented by using good proportion of ingredients in concrete mix, by covering the top surface which reduces evaporation and using appropriate techniques for placing and finishing.

4. Delamination

Delamination is also similar to blistering. In this case also, top surface of concrete gets separated from underlying concrete. Hardening of top layer of concrete before the hardening of underlying concrete will lead to delamination. It is because the water and air bleeding from underlying concrete are struck between these two surfaces, hence space will be formed.

Like blistering, delamination can also be prevented by using proper finishing techniques. It is better to start the finishing after bleeding process has run its course.

5. Dusting

Dusting, also called as chalking is the formation of fine and loose powdered concrete on the hardened concrete by disintegration. This happens due to the presence of excess amount of water in concrete. It causes bleeding of water from concrete, with this fine particles like cement or sand will rise to the top and consequent wear causes dust at the top surface.

To avoid dusting, use low slump concrete mix to obtain hard concrete surface with good wear resistance. Use water reducing admixtures to obtain adequate slump. It is also recommended to use better finishing techniques and finishing should be started after removing the bleed water from concrete surface.

6. Curling

When a concrete slab is distorted into curved shape by upward or downward movement of edges or corners, it is called curling. It occurs mainly due to the differences in moisture content or temperature between slab surface (top) and slab base (bottom).

Curling of concrete slab may be upward curling or downward curling. When the top surface is dried and cooled before bottom surface, it begins to shrink and upward curling takes place. When bottom surface is dried and cooled due to high temperature and high moisture content, it will shrink before top surface and downward curling occurs.

To prevent curling, use low shrink concrete mix, provide control joints, provide heavy reinforcement at edges or provide edges with great thickness.

7. Efflorescence

Efflorescence is the formation of deposits of salts on the concrete surface. Formed salts generally white in color. It is due to the presence of soluble salts in the water which is used in making concrete mix.

When concrete is hardening, these soluble salts gets lifted to the top surface by hydro static pressure and after complete drying salt deposits are formed on the surface.

It can be prevented by using clean and pure water for mixing, using chemically ineffective aggregates etc. And make sure that cement should not contain alkalis more than 1% of its weight.

8. Scaling and Spalling

Scaling and spalling, in both the cases concrete surface gets deteriorated and flaking of concrete occurs. The main cause for this type of cases is penetration of water through concrete surface. This makes steel gets corroded and spalling or scaling may occurs.

Some other causes are use of non-air entrained concrete mix, inadequate curing and use of lo strength concrete etc. This type of defects can be prevented by, using well designed concrete mixes, by adding air entrainment admixtures, proper finishing and curing, providing good slope to drain water coming on to the surface etc.

REASONS of CONCRETE CRACKS

We often get asked about the causes behind concrete cracks. Customers wonder why they can appear even in a newly poured foundation. A homeowner will question why it is cracking and wonder if they received substandard workmanship or products.

When installed properly, concrete is one of the most durable and long lasting products you can use around your home. But it is important that concrete contractors follow well-established guidelines with respect to concrete placement. Durable, high strength and crack resistant concrete does not happen by accident.

Often we see simple settlement cracks. As durable as concrete is once cured, it's hard to find a basement that doesn't have at least one crack in it.
Why Concrete Cracks

1. Excess water in the mix

Concrete does not require much water to achieve maximum strength, however, a much of concrete used in residential pours tends to have too much water added to the concrete on the job site. This water is added to make the concrete easier to install. This excess water will however, greatly reduce the strength of the concrete.
Shrinkage is another common reason for cracking. As concrete hardens and dries it shrinks. This is due to the evaporation of excess mixing water. The wetter or soupier the concrete mix, the greater the shrinkage will be.

2. Concrete drying too fast

Also, rapid drying of the slab will significantly increase the possibility of cracking. The chemical reaction, which causes concrete to go from the liquid or plastic state (or a solid state), requires water. This chemical reaction, or hydration, continues to occur for days and weeks after you pour the concrete.

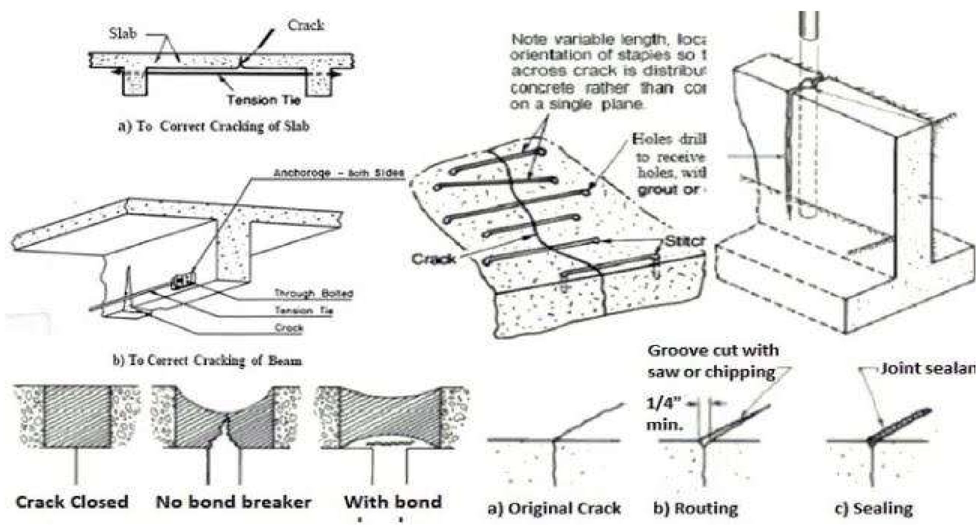
3. Improper strength concrete poured on the job

4. Lack of control joints (in concrete slab).

In a concrete slab, control joints help concrete crack where you want it to. The joints should be of the depth of the slab and no more than 2-3 times (in feet) of the thickness of the concrete (in inches). So 4″concrete should have joints 8-12′ apart.

5. Foundations poured in the winter

Foundations poured during cold months, or poured foundations that are left unheated during the cold winter months will develop many more cracks. Foundations poured on a base (ground) that is improperly compacted will inevitably develop more cracks as well.



Repair of cracks for different purposes , selection of techniques

There are several methods of concrete crack repair such as epoxy injection, routing and sealing, grouting, stitching, drilling and plugging, gravity filling of cracks in concrete.

Details of these methods for the selection of suitable methods for different types of cracks in concrete are discussed.

How to Select Suitable Method of Concrete Crack Repair?
Suitable method for repair of cracks in concrete can be selected based on evaluation of the crack in structure for its causes. Once the cause is known and type of crack is established, then suitable method can be selected.

For example, if the cracking was primarily due to drying shrinkage, then it is likely that after a period of time the cracks will stabilize. On the other hand, if the cracks are due to a continuing foundation settlement, repair will be of no use until the settlement problem is corrected.

Methods of Concrete Crack Repair

Epoxy injection

Epoxy injection method is used for cracks as narrow as 0.002 inch (0.05 mm). The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure.

Epoxy injection has been successfully used in the repair of cracks in buildings, bridges, dams, and other types of concrete structures (ACI 503R). However, unless the cause of the cracking has been corrected, it will probably recur near the original crack. If the cause of the cracks cannot be removed, then two options are available.

Epoxy injection Procedure

Clean the cracks

The first step is to clean the cracks that have been contaminated; to the extent this is possible and practical. Contaminants such as oil, grease, dirt, or fine particles of concrete prevent epoxy penetration and bonding, and reduce the effectiveness of repairs.

Preferably, contamination should be removed by vacuuming or flushing with water or other specially effective cleaning solutions.

Seal the surfaces

Surface cracks should be sealed to keep the epoxy from leaking out before it has gelled. Where the crack face cannot be reached, but where there is backfill, or where a slab-on-grade is being repaired, the backfill material or sub base material is sometimes an adequate seal.

A surface can be sealed by applying an epoxy, polyester, or other appropriate sealing material to the surface of the crack and allowing it to harden. If a permanent glossy appearance along the crack is objectionable and if high injection pressure is not required, a strippable plastic surface sealer may be applied along the face of the crack.

Install the entry and venting ports:

Three methods are used:

1. **Fittings inserted into drilled holes:** This method was the first to be used, and is often used in conjunction with V-grooving of the cracks. The method entails drilling a hole into the crack, approximately 3/4 in. (20 mm) in diameter and 1/2 to 1 in. (13 to 25 mm) below the apex of the V grooved section.
2. **Bonded flush fitting:** When the cracks are not V grooved , a method frequently used to provide an entry port is to bond a fitting flush with the concrete face over

the crack. The flush fitting has an opening at the top for the adhesive to enter and a flange at the bottom that is bonded to the concrete.

3. **Interruption in seal:** Another system of providing entry is to omit the seal from a portion of the crack. This method can be used when special gasket devices are available that cover the unsealed portion of the crack and allow injection of the adhesive directly into the crack without leaking.

Mix the epoxy

This is done either by batch or continuous methods. In batch mixing, the adhesive components are premixed according to the manufacturer's instructions, usually with the use of a mechanical stirrer, like a paint mixing paddle.

Care must be taken to mix only the amount of adhesive that can be used prior to commencement of gelling of the material.

Inject the epoxy

Hydraulic pumps, paint pressure pots, or air-actuated caulking guns may be used. The pressure used for injection must be selected carefully. Increased pressure often does little to accelerate the rate of injection.

If the crack is vertical or inclined, the injection process should begin by pumping epoxy into the entry port at the lowest elevation until the epoxy level reaches the entry port above.

Remove the surface seal

After the injected epoxy has cured, the surface seal should be removed by grinding or other means as appropriate.

Alternative procedure

For massive structures, an alternate procedure consists of drilling a series of holes [usually 7/8 to 4-in. (20 to 100-mm) diameter] that intercepts the crack at a number of locations. Typically, holes are spaced at 5-ft (1.5-m) intervals. Another method recently being used is a vacuum or vacuum assist method.

There are two techniques: one is to entirely enclose the cracked member with a bag and introduce the liquid adhesive at the bottom and to apply a vacuum at the top. The other technique is to inject the cracks from one side and pull a vacuum from the other. Typically, epoxies are used; however, acrylics and polyesters have proven successful.

Routing and Sealing of Crack

Routing and sealing of cracks can be used in conditions requiring remedial repair and where structural repair is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant (Fig.1).

This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements.

The sealants may be any of several materials, including epoxies, urethanes, silicones, polysulfides, asphaltic materials, or polymer mortars. Cement grouts should be avoided due to the likelihood of cracking.

For floors, the sealant should be sufficiently rigid to support the anticipated traffic. Satisfactory sealants should be able to withstand cyclic deformations and should not be brittle.

The procedure consists of preparing a groove at the surface ranging in depth, typically, from 1/4 to 1 inch (6 to 25 mm). A concrete saw, hand tools or pneumatic tools may be used. The groove is then cleaned by air blasting, sandblasting, or waterblasting, and dried.

The bond breaker may be a polyethylene strip or tape which will not bond to the sealant. Careful attention should be applied when detailing the joint so that its width to depth aspect ratio will accommodate anticipated movement (ACI 504R).

Concrete Crack Repair by Stitching

Stitching involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs) that span the crack as shown in Fig.3. Stitching may be used when tensile strength must be reestablished across major cracks.

The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the staples in the holes, with either a non shrink grout or an epoxy resin-based bonding system.

Additional Reinforcement for Crack Repair

Conventional reinforcement

Cracked reinforced concrete bridge girders have been successfully repaired by inserting reinforcing bars and bonding them in place with epoxy.

This technique consists of sealing the crack, drilling holes that intersect the crack plane at approximately 90 deg (Fig.4), filling the hole and crack with injected epoxy and placing a reinforcing bar into the drilled hole.

Prestressing steel

Post-tensioning is often the desirable solution when a major portion of a member must be strengthened or when the cracks that have formed must be closed (Fig.5).

This technique uses pre stressing strands or bars to apply a compressive force. Adequate anchorage must be provided for the prestressing steel, and care is needed so that the problem will not merely migrate to another part of the structure.

Drilling and Plugging Method

Drilling and plugging a crack consists of drilling down the length of the crack and grouting it to form a key (Fig.6).

This technique is only applicable when cracks run in reasonable straight lines and are accessible at one end. This method is most often used to repair vertical cracks in retaining walls. A hole [typically 2 to 3 in. (50 to 75 mm) in diameter] should be drilled, centered on and following the crack.

Gravity Filling Method

Low viscosity monomers and resins can be used to seal cracks with surface widths of 0.001 to 0.08 in. (0.03 to 2 mm) by gravity filling. High-molecular- weight methacrylates, urethanes, and some low viscosity epoxies have been used successfully. The lower the viscosity, the finer the cracks that can be filled.

The typical procedure is to clean the surface by air blasting and/or water blasting. Wet surfaces should be permitted to dry several days to obtain the best crack filling.

Grouting Method of Crack Repair

Portland cement grouting

Wide cracks, particularly in gravity dams and thick concrete walls, may be repaired by filling with Portland cement grout. This method is effective in stopping water leaks, but it will not structurally bond cracked sections.

The procedure consists of cleaning the concrete along the crack; installing built-up seats (grout nipples) at intervals astride the crack (to provide a pressure tight connection with the injection apparatus); sealing the crack between the seats with a cement paint, sealant, or grout; flushing the crack to clean it and test the seal; and then grouting the whole area.

Dry packing

Dry packing is the hand placement of a low water content mortar followed by tamping or ramming of the mortar into place, producing intimate contact between the mortar and the existing concrete.

Because of the low water-cement ratio of the material, there is little shrinkage, and the patch remains tight and can have good quality with respect to durability, strength, and water tightness.

Dry pack can be used for filling narrow slots cut for the repair of dormant cracks. The use of dry pack is not advisable for filling or repairing active cracks.

Before a crack is repaired by dry packing, the portion adjacent to the surface should be widened to a slot about 1 in. (25 mm) wide and 1 in. (25 mm) deep. The slot should be undercut so that the base width is slightly greater than the surface width.

Overlay and Surface Treatments of Cracks

Fine surface cracks in structural slabs and pavements may be repaired using either a bonded overlay or surface treatment if there will not be further significant movement across the cracks.

Unbonded overlays may be used to cover, but not necessarily repair a slab. Overlays and surface treatments can be appropriate for cracks caused by one-time occurrences and which do not completely penetrate the slab.

Surface treatments

Low solids and low-viscosity resin-based systems have been used to seal the concrete surfaces, including treatment of very fine cracks. They are most suited for surfaces not subject to significant wear.

Bridge decks and parking structure slabs, as well as other interior slabs may be coated effectively after cracks are treated by injecting with epoxy or by routing and sealing.

Materials such as urethanes, epoxies, polyesters, and acrylics have been applied in thickness of 0.04 to 2.0 in. (1 to 50 mm), depending on the material and purpose of the treatment. Skid-resistant aggregates are often mixed into the material or broadcast onto the surface to improve traction.

Overlays

Slabs containing find dormant cracks can be repaired by applying an overlay, such as polymer modified Portland cement mortar or concrete, or by silica fume concrete. Slabs with working cracks can be overlaid if joints are placed in the overlay directly over the working cracks.

In highway bridge applications, an overlay thickness as low as 1-1/4 in. (30 mm) has been used successfully. Suitable polymers include styrene butadiene or acrylic latexes. The resin solids should be at least 15 percent by weight of the Portland cement, with 20 percent usually being optimum.

Polymer based repairs

Concrete is the most common and versatile building material in the world. With the growth of operational life, the construction damage caused by improper design, management and poor durability of material, and so forth, often occurs. It not only affected the normal usage of construction but also caused huge economic losses. Therefore, the repair and reinforcement of the damaged structures are the important issues for the construction industry today.

Polymer-modified cement mortar has been widely used as repair mortar due to its high strength, good durability, and good bonding properties to old concrete constructions. Researchers had studied the mechanical properties of polymer-modified mortar used for repairing and the results showed that polymer could greatly improve the mortar repair performance [1–3]. Additionally, the polymer was reported to be able to improve the durability of repair mortar which was an important aspect to be considered in construction

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Define efflorescence.

Ans: Efflorescence is the formation of deposits of salts on the concrete surface. Formed salts generally white in color. It is due to the presence of soluble salts in the water which is used in making concrete mix.

Q-2 Define scaling and spalling.

Ans: Scaling and spalling, in both the cases concrete surface gets deteriorated and flaking of concrete occurs. The main cause for this type of cases is penetration of water through concrete surface. This makes steel gets corroded and spalling or scaling may occurs.

Q-3 Define epoxy injection.

Ans: Epoxy injection method is used for cracks as narrow as 0.002 inch (0.05 mm). The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure.

Q-4 Define curling.

Ans: When a concrete slab is distorted into curved shape by upward or downward movement of edges or corners, it is called curling. It occurs mainly due to the differences in moisture content or temperature between slab surface (top) and slab base (bottom).

POSSIBLE LONG TYPE QUESTIONS

Q-1 What are the method are adopted for repair of cracks? [2009-S,2009-W,2011-S,2015-S,2017-W]

Q-2 what are the common defects of concrete cracks?[2019-S]