CONCRETE TECHNOLOGY

6TH SEMESTER

STRICTLY ACCORDING TO SCTE&VT SYLLABUS

DEPARTMENT OF CIVIL ENGINEERING

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Chapter	Name of topics
1	Concrete as a construction material
2	Cement
3	Aggregate, Water and Admixtures
4	Properties of fresh concrete
5	Properties of hardened concrete
6	Concrete mix Design
7	Production of concrete
8	Inspection and Quality Control of Concrete
9	Special Concrete
10	Deterioration of concrete and its prevention
11	Repair technology for concrete structures

<u>Concrete as a construction material</u>

Grade of Concrete

Grade of concrete is defined as the minimum strength the concrete must posses after 28 days of construction with proper quality control. Grade of concrete is denoted by prefixing M to the desired strength in MPa. For example, for a grade of concrete with 20 MPa strength, it will be denoted by M20, where M stands for Mix. These grade of concrete is converted into various mix proportions. For example, for M20 concrete, mix proportion will be 1:1.5:3 for cement:sand:coarse aggregates.

The strength is measured with concrete cube or cylinders by civil engineers at construction site. Cube or cylinders are made during casting of structural member and after hardening it is cured

for 28 days. Then compressive strength test is conducted to find the strength.

Regular grades of concrete are M15, M20, M25 etc. For plain cement concrete works, generally M15 is used. For reinforced concrete construction minimum M20 grade of concrete are used.

Advantages of Concrete

The following are the advantages of concrete :

Availability of concrete ingredients easily.

Easy handling and moulding of concrete into any shape.

Easy transportation from the place of mixing to place of casting before initial set takes place.

Ability to pump/spray to fill into cracks and lining of tunnels.

When reinforced, all types of the structures are made possible from an ordinary lintel to massive fly overs

Monolithic character gives better appearance and much i rigidity to the structure.

The property of concrete to possess high compressive strength, makes a concrete structure more economical than that of steel structure.

Disadvantages of Concrete

The following are the disadvantages of concrete :

Due to low tensile strength, concrete is required to be reinforced to avoid cracks.

In long structures expansion joints are required to be provided if there is large temperature variance in the area.

Construction joints are provided to avoid cracks due to drying shrinkage and moisture-expansion.

Soluble salts in concrete cause efflorescence if moisture reacts with them.

Concrete made with ordinary Portland cement, gets integrated in the presence of alkalies, sulfates etc.

Sustained loads develop creep in structures.

Cement

Composition of cement

Introduction

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

Manufacture of cement

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

Lime or calcium oxide, CaO: from limestone, chalk, shells, shale or calcareous rock

Silica, SiO_2: from sand, old bottles, clay or argillaceous rock

Alumina, Al_2O_3: from bauxite, recycled aluminum, clay

Iron, Fe_2O_3: from from clay, iron ore, scrap iron and fly ash

Gypsum, $CaSO_4.2H_20$: found together with limestone

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

hydration of cement

The Chemical reaction that takes place between cement and water is called as hydration of cement. This reacion is exothermic in nature, due to which considerable amount of heat is released during hydration of cement. This is called as 'heat of hydration'.

5 Phases of the hydration process

1. Phase: Initial mixing reaction

2. Phase: Dormancy

3. Phase: Strength acceleration

4. Phase: Speed reduction

5. Phase: Steady development

Water Cement Ratio

Water Cement Ratio means the ratio between the weight of water to the weight of cement used in concrete mix.

Normally water cement ratio falls under 0.4 to 0.6 as per IS Code 10262 (2009) for nominal mix (M10, M15 .... M25)

We all know that water cement ratio will directly affect the strength of concrete. Either it increases the strength if used in correct proportion or decrease it.

Effects of too much water in concrete

As stated above we need 23% of water to initiate the chemical process on cement.

Adding more water than this allowable Water cement limit will actually affect the strength.

If we keep on adding water to increase the workability then the concrete has lots of fluid materials where the aggregates will settle down. Once the water evaporated it leaves lots of voids in concrete which affects the concrete strength.

What is compressive strength of cement?

Compressive strength of the cement is the property of cement which specifies how much load it can withstand when cement is made into a hardened mass mixing with standard sand and water.

The process of testing compressive strength of concrete and and cement may be somewhat same but the materials required for preparing cubes are different. Please read carefully without skipping to get full concept.

factors affect the compressive strength of cement

1) Water-cement ratio
2) Cement-sand ratio
3) Type and grade of sand
4) Manner of mixing
5) Shape and size of the specimen
6) Curing condition
7) Age of specimen
8) Rate of loading

Compressive strength test of cement

Apparatus required

1) Cube mould of dimension 70.6mm * 70.6mm * 70.6mm.
2) Weighing machine (with the accuracy of ±1 gm in every 1000gm)
3) Trowel
4) Metal tray
5) Vibrating Machine
6) Stopwatch
7) Compression testing machine (With the accuracy of ± 1%)

Materials required

Cement (say OPC)

Sand (standard grade)

Water (for having a standard consistency)

Fineness of Cement

The **fineness of cement** is a measure of **cement particle size** and is denoted **as terms of** the specific surface area of **cement**. The **Fineness Test of Cement** is done by sieving cement sample through **standard IS sieve.** The weight of cement particle **whose size is greater** than **90 microns** is determined and the **percentage of retained cement** particle are calculated. This is **known** as the **Fineness of cement.**

Why Fineness of Cement Test Required?

We know that cement hydrates when cement is mixed with the water and a thin layer are formed around the particle.

This thin layer grows bigger and makes cement particles separate. Because of this, the cement hydration process slows down.

On other hand, cement smaller particles react much quicker than the larger particle.

A cement particle with a diameter of 1µm will react entirely in 1 day, whereas the particle with a diameter of 10µm takes about 1 month.

But, there is a side effect of having too much smaller particles in cement results in a quick setting, leaving no time for mixing, handling, and placing.

Therefore to increase the setting time of cement, cement is must be manufactured in a different range of particle sizes. The fineness of the cement test measures this parameter of cement.

Initial and Final Setting time of Cement

Initial and Final Setting time of Cement

Setting time of cement:

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

Initial Setting time of Cement:-

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

Or

The time at which cement starts hardens and completely loses its plasticity is called Initial setting time of cement.

Or

The time available for mixing the cement and placing it in position is an Initial setting time of cement. If delayed further, cement loses its strength.

For Ordinary Portland Cement, The initial Setting Time is 30 minutes.

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Final setting time of Cement:-

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

Or

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

Soundness of Cement

The **soundness of cement** indicates the **stability of any cement** during the **volume change** in the process of **setting and hardening**. In case the volume change in cement is **unstable after setting** and hardening, the concrete element will crack, which can **affect the quality of the structure** or even cause serious accidents, known as **poor dimensional stability.**

The soundness test of cement determines the expansion of cement after it starts setting. Certain cement has been found to undergo a large **expansion after setting** causing disruption of the set and hardened mass. This expansion of cement can cause serious problems for the durability of structures when such cement is used.

The **soundness of cement** is mainly measured by two methods: **EN-196 (1995),** which is based on the **Le Châtelier test method,** and the **autoclave test (ASTM-C151, 2015),** in which pressure is also **applied to the sample.**

Different Types Of Cement

1) Ordinary Portland Cement (OPC) ...
2) Portland Pozzolana Cement (PPC) ...
3) Rapid Hardening Cement. ...
4) Extra Rapid Hardening Cement. ...
5) Low Heat Cement. ...
6) Sulfates Resisting Cement. ...
7) Quick Setting Cement. ...
8) Blast Furnace Slag Cement.

Classification of Aggregates

Aggregates form an essential part of many construction projects, from large-scale commercial to smaller domestic works. Whether you need aggregates to form a sub-base for foundations or paving, decorative aggregates for driveways and footpaths – or simply need something to fill in unsightly holes – you should know which kind of aggregates will work best.

In this article, we'll run through the different classifications of aggregates, based on their varying properties.

Characteristics of Aggregates

Resistance to Freeze Thaw:

(Important in structures subjected to weathering) – The freeze thaw resistance of an aggregate is related to its porosity absorption, and pore structure. Specifications require that resistance to weathering be demonstrated by the magnesium sulfate test.

Abrasion Resistance:

(Important in pavements, loading plat-forms, floors, etc.) Abrasion resistance is the ability to withstand loads without excessive wear or deterioration of the aggregate.

Chemical Stability:

(Important to strength and durability of all types of structures) Aggregates must not be reactive with cement alkalies. This reaction may cause abnormal expansion and mąp-cracking of concrete.

Particle Shape and Surface Texture:

(Important to the workability of fresh concrete) Rough textured or flat and elongated particles, due to their high surface area, require more water to produce workable concrete than do rounded or cubical aggregates.

Grading:

(Important to the workability of fresh concrete) The grading or particle size distribution of an aggregate is determined by sieve analysis.

Specific Gravity (Density):

The specific gravity of an aggregate is the ratio of its weight to the weight of an equal volume of water at a given temperature. Most normal weight aggregates have a specific gravity ranging from 2.4 to 2.9. It is not a measure of aggregate quality. It is used for certain computations in a mix design.

Absorption and Surface Moisture:

The moisture conditions of aggregates are designated as:

Oven-Dry: Fully absorbent.

Air-Dry: Dry at the surface but containing some interior moisture, thus somewhat absorbent.

Saturated Surface-Dry: Neither absorbing water from, nor contributing water to the concrete mix.

Wet with free moisture: Containing an excess of moisture on the surface.

Batch weights of materials must be adjusted for moisture conditions of the aggregates.

Dry-rodded unit weight:

Dry-rodded unit weight is the mass (weight) of one cubic meter (foot) of dry coarse aggregate that is compacted, by rodding in three equal layers, in a standard container. For any one aggregate the dry-rodded unit weight varies with the size and gradation.

Grading of Aggregates.

Grading of aggregates is determining the average grain size of the aggregates before they are used in construction.

This is applied to both coarse and fine aggregates. The aggregate sample is sieved through a set of sieves and weights retained on each sieve in percentage terms are summed up.

On dividing this sum by 100, The Fineness Modulus of that aggregate is determined. This helps in deciding about the quantity of aggregates of known fineness moduli to be mixed for obtaining a concrete of desired density.

Quality of water

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. The water shall be clean and shall not contain sugar, molasses or gur or their derivatives, or sewage, oils, organic substances. If the quality of water to be used for mixing is in doubt, cubes of 75 mm in cement mortar 1:3 mix with distilled water and with the water in question shall be made separately. The latter type of cubes should attain 90% of the 7 days' strength obtained in cubes with same quantity of distilled water. Alternatively, the water shall be tested in an approved Laboratory for its use in preparing concrete / mortar

Functions of Admixtures to Modify Hardened Concrete Properties

1) Retard or reduce heat generation during early hardening.
2) Accelerate the rate of strength development.
3) Increase the strength of concrete or mortar (Compressive, tensile, or flexural). ...
4) Reduce scaling caused by deicing salts.
5) Concrete admixtures are of different types and they are as follows:
6) Water Reducing Admixtures.
7) Retarding Admixtures.
8) Accelerating Admixtures.
9) Air entraining concrete admixture.
10) Pozzolanic Admixtures.
11) Damp-proofing Admixtures.
12) Gas forming Admixtures.
13) Air detraining Admixtures.

Accelerating Admixture

These admixtures are used to lower the **initial setting time** of the **fresh concrete mix.** They speed up the process of the initial stage of the **hardening of concrete** hence they are also called accelerators. These accelerators also increase the **strength of concrete** in its early stage by **increasing the rate of hydration.**

Speedy hardening of concrete is useful in many situations such as early **removal of formwork,** less period of curing, emergency repair works, for constructions in low-temperature regions, etc.

In these concrete admixtures, the only used accelerators are **silica fume, calcium chloride, finely divided silica gel, etc.** Calcium chloride is cost-effective and commonly used accelerating admixture.

Air Entraining Admixture

The primary function of **air-entraining admixture** is to **increase the durability of concrete** under **freezing and dewatering and thawing conditions**. When added to the concrete mix, these admixtures will form millions of air bubbles throughout the mix and **improves the properties of concrete**.

The properties of fresh concrete

Concrete is referred to as fresh when the setting and hardening process has not yet started. Fresh concrete can be deformed and poured which means it can be transported or pumped and used to fill moulds and formwork.

Fresh concrete has two fundamental poperties:

MOULDABILITY

Which means it can assume any shape.

WORKABILITY

The characteristics of the structure and the concrete placement techniques determine the composition of the concrete whose consistency is then adjusted on the basis of the Abrams cone slump test.

Workability is essential in order for the concrete to completely fill the moulds and formwork, whose shape may be complex, and in order to correctly cover the reinforcement.

Workability is influenced by many parameters: the nature and proportion of the cement, the shape of the aggregate particles, the proportion of water and the use of additives.

Workability of Concrete

Workability of concrete is the property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished' as defined by ACI Standard 116R-90 (ACI 1990b). ASTM defines it as "that property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity". The workability of concrete depends on many factors which are explained in factors affecting workability of concrete. Water cement ratio has much effect in the workability. Workability is directly proportional to water cement ratio. An increase in water-cement ratio increases the workability of concrete.

Compaction Factor Test for Concrete Workability

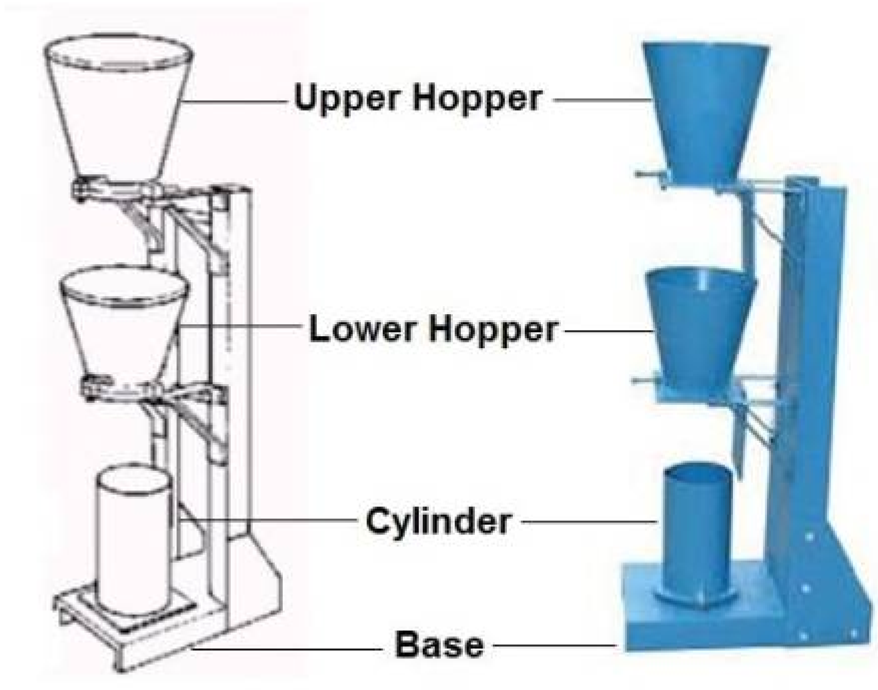
Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. It was developed by Road Research Laboratory in United Kingdom and is used to determine the workability of concrete. The 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

Place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it.

Cover the cylinder.

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.

Open the trapdoor of the lower hopper and allow the concrete to fall into the cylinder below.

Cut of the excess of concrete above the top level of cylinder using trowels and level it.

Clean the outside of the cylinder.

Weight the cylinder with concrete to the nearest 10 g. This weight is known as the weight of partially compacted concrete (**W1**).

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.

Level the top surface.

Weigh the cylinder with fully compacted. This weight is known as the weight of fully compacted concrete (**W2**).

Find the weight of empty cylinder (**W**).

Objective and Theory of Vee-Bee Test on Concrete

The main objective of Vee-Bee test is to determine the workability of the freshly mixed concrete. The Vee-Bee test gives an indication about the mobility and the compactibility aspect of the freshly mixed concrete. Vee-bee test carries out the relative effort measurement to change the mass of the concrete from a definite shape to the other. That is, as per the test, from the conical shape to the cylindrical shape by undergoing vibration process. The measurement of the effort is done by time measurement in seconds. The amount of work measured in seconds is called as the remolding effort. The time required for the complete remolding is a measure of the workability and is expressed in the Vee-Bee seconds. The experiment is named after the developer V Bahrmer of Sweden. The method can be also applied for dry concrete. For concrete that have slump value more than 50mm, the remolding activity will be so fast that the measurement of time is not possible.

Flow table test of concrete to test workability of concrete

Flow table test of concrete to test workability of concrete

Workability is a complex property of concrete which directly impacts on Concrete strength, quality and appearance and it also determines how easily freshly made concrete can be mixed, placed, compacted and finished with the minimum to no loss concerning homogeneity.

As mentioned, its a complex property which involves many factors concerning the good workable concrete. To test the freshly mixed concrete workability, the following tests are usually performed on field and lab.

Slump test
Kelly ball test
K slump test
Vee bee consistometer test
Flow table test.
Compaction factor test

Flow table test of concrete:

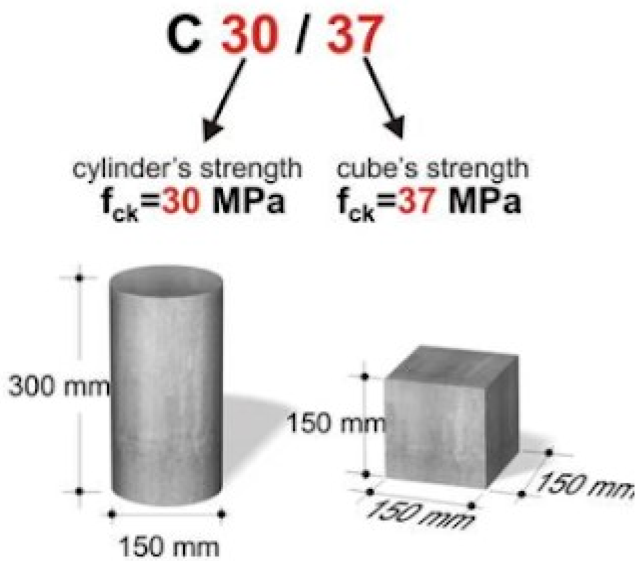
Flow table test of concrete also determines the Quality of Concrete concerning its consistency, cohesiveness and the proneness to segregation.
As there are two methods to find the flow value of concrete which one is outdated. Here we are explaining the new method of flow table test. This new flow table test is covered with **BS 1881 part 105 of 1984 and DIN 1048 part I.**

The workability requirements for a concrete construction depends on:

1) Water cement ratio.
2) Type of construction work.
3) Method of mixing concrete.
4) Thickness of concrete section.
5) Extent of reinforcement.
6) Method of compaction.
7) Distance of transporting.
8) Method of placement.

Difference between Concrete Cube and Cylinder Strength test

The Compressive strength test will result in a compressive load on the cube and the cylinder during the test procedure. This process will result in the Lateral Expansion of the sample which will result in the Poisson's ratio effect. The figure-1 below shows the compressive testing arrangement of a cube.



Flexural Strength

Flexural strength is an indirect measure of the tensile strength of concrete. It is a measure of the maximum stress on the tension face of an unreinforced concrete beam or slab at the point of failure in bending. It is measured by loading 150 x 150-mm (or (100 x 100-mm) concrete beams with a span length at least three times the depth.

The flexural strength is expressed as Modulus of Rupture (MR) in MPa and is determined by standard test methods ASTM C78 (third-point loading) or ASTM C293 (center-point loading). The specimen size and type of loading does
impact the measured flexural strength and comparisons or requirements should be based on the same beam size and loading configuration. The MR measured by third-point loading (ASTM C78) is lower than that determined by center-point loading (ASTM C293), sometimes by as much as 15 percent. It is also observed that a lower flexural strength will
be measured with larger beam specimen

In the theory of reinforced concrete, it is assumed that concrete is elastic, isotropic and homogeneous and obeys Hooke's law. Actually none of these assumptions is strictly true and concrete is not perfectly elastic material. By definition of elasticity, strain appears on the application of stress or force and disappears on removal of stress. If the stress-strain cure is straight as shown in Fig then the material is elastic.

Creep

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

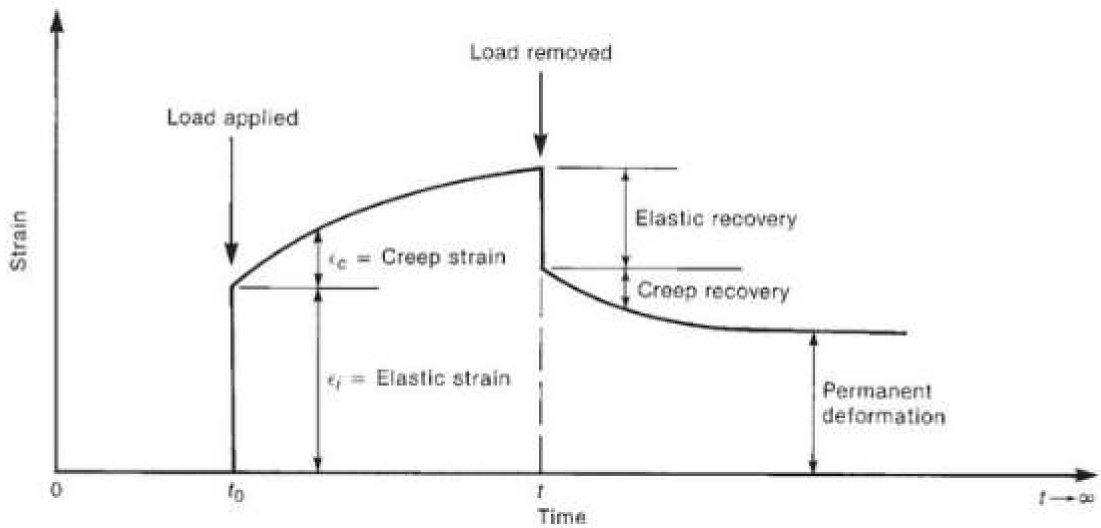
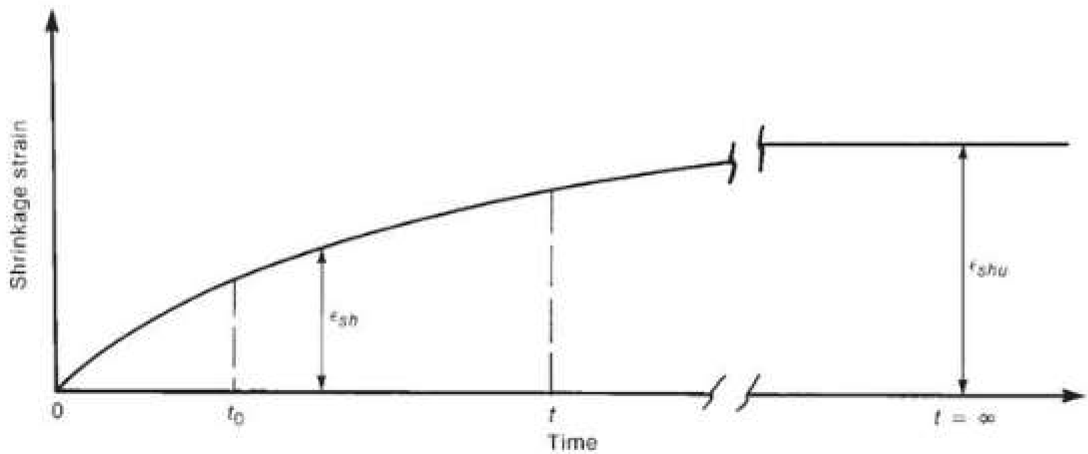


Figure A: Creep Strains due to Loading at time, t_0 and unloading at time t

The values from creep strain are used in the deflection calculation. According to BS8110: Part 2 section 7.3, the creep strain in concrete, ϵ_{cc} can be predicted from:

Shrinkage

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



Permeability 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.

Durability of concrete

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. ... For example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor

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Sulphate Attack on Concrete

Sulphate attack on concrete might show itself in different forms depending on:

The chemical form of the sulphate

The atmospheric environment which the concrete is exposed to.

What happens when sulphates get into concrete?

When sulphates enters into concrete:

It combines with the C-S-H, or concrete paste, and begins destroying the paste that holds the concrete together. As sulphate dries, new compounds are formed, often called ettringite.

These new crystals occupy empty space, and as they continue to form, they cause the paste to crack, further damaging the concrete.

Chloride attack on concrete

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

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

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

Acid attack on concrete

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

Efflorescence in Concrete

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

Presence of salts in one of the materials of concrete. Commonly salts are found in the fine aggregate or sand taken from the river beds.

If the concrete is not cured properly, the hydration process is incomplete on which the un-hydrated products near the surface form the efflorescence on the surface of concrete.

Type of Salts in Efflorescence

Calcium Sulphate
A common efflorescence salt source in brick

Sodium Sulphate
Often seen in cement-brick reactions

Potassium Sulphate
Noticeable in many cement-brick reactions

Calcium Carbonate

May be discovered in mortar or concrete backing

Sodium Carbonate

Frequently seen in mortar

Potassium Carbonate

Like sodium carbonate, commonly found in mortar

Vanadyl Sulphate
Usually found in brick

Manganese Oxide
Often present in brick.

Data Required for Mix Design of Concrete

1. Characteristic Compressive Strength at 28 Days:

2. Selection of Water-Cement Ratio:

3. Estimation of Entrapped Air:

4. Selection of Water Content and Fine to Total Aggregate Ratio:

5. Calculation of Cement Content:

6. Calculation for Aggregate Content:

7. Actual Quantities Required for the Mix:

8. The Calculated Mix Proportion should be Checked by Trial Batches:

What is the difference between nominal mix and design mix ?

NOMINAL MIX

It is used for relatively unimportant and simpler concrete works. In this type of mix, all the ingredients are prescribed and their proportions are specified.

Therefore there is no scope for any deviation by the designer. Nominal mix concrete may be used for concrete of M-20 or lower.

DESIGN MIX

It is a performance based mix where choice of ingredients and proportioning are left to the designer to be decided.

The user has to specify only the requirements of concrete in fresh as well as hardened state. The requirements in fresh concrete are workability and finishing characteristics, whereas in hardened concrete these are mainly the compressive strength and durability.

Nominal Mix

When the concrete is produced by taking standard arbitrary proportions of concrete ingredients, it is known as nominal mix concrete.

Nominal mix is a mix considering all ratio in volume where Strength and cost of concrete and strength of concrete varies.

It is Prescriptive type concrete.

It is used in ordinary concrete involving concrete grade not higher than **M20.**

There is no quality control.

Water cement ratio is based on durability criteria, experience & practical trials.

Water content can be modified by **slump value (field-based test)**

No entrapped air content is considered.

Trial mixes concept is mentioned.

Design Mix

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

Design mix is a mix considering all ratio of mix is by weight where strength of concrete is constant cost of concrete can be reduced.

Factors Affecting the design Mix of Concrete

1) Grade of Cement
2) Size and shape of aggregates
3) Grading Zone of Aggregate
4) Water absorption by the aggregate
5) The specific gravity of the materials
6) Type of Admixture added
7) Slump value of the concrete
8) W/C Ratio of concrete
9) Degree of supervision provided
10) Method of transportation of concrete

Concreting Methods(such as Tremie or underwater concreting).

Compressive Strength of Concrete. The grade designation gives characteristics compressive strength requirements of the concrete. ...

Workability of Concrete. ...

Durability of Concrete. ...

Water-Cement ratio. ...

Nominal Size of Aggregate. ...

grading of Combined Aggregate. ...

Quality Control At Site.

Concrete Mix Design as per IS Code

Concrete is a heterogeneous and hardened mass obtained from a mixture of cement, sand, coarse aggregate and water, in a certain proportion.

The grade of concrete varies greatly in accordance with the changing proportion of its constituent materials. The proportion and the ratio, in which the materials should be mixed together to obtain a certain grade of the concrete, has already been specified by IS 456:2000.

But the limitation of the code is, that it specifies the ratios of the materials, up to a certain grade, which is M25, beyond which, no certain proportion has been industrially approved.

batching of materials of concrete

Batching is the process in which the quantity or proportion of materials like cement, aggregates, water, etc. are measured on the basis of either weigh or volume to prepare the concrete mix. Proper Batching improves the workability of concrete by reducing the segregation or bleeding in concrete

mixing of concrete materials

Coarse aggregates are placed in the mixer first followed by sand and then cement. Mix the materials in the dry state in the mixing machine. Normally it should be 1.5 to 3 minutes. After proper mixing of dry materials, gradually add the correct quantity of water while the machine is in motion

transportation and placing of concrete

Discharge directly into forms through short chute.

By barrows: ...

Dumpers and trucks (agitating or non agitation)

Monorail system.

Elevating towers and hoists.

Skips operated by cranes or overhead cable ways.

compaction of concrete

Compaction is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of concrete. It increases significantly the ultimate strength of concrete and enhances the bond with reinforcement.

curing of concrete

Curing of Concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. ... A curing practice involves keeping the concrete damp or moist until the hydration of concrete is complete and strength is attained.

formwork requreteirement for concrete

Requirements of good formwork:-

It should be adequately strong to withstand an extensive variety of dead and live loads. ...

It should be inflexibly built and efficiently propped and supported to hold its shape without undue deflection.

The joints in the formwork should be tight enough to prevent leakage of cement grout.

quality control of concrete as per IS 456

CHECK LIST FOR QUALITY CONTROL OF RCC WORKS

Carry out slump test at regular intervals to ensure proper workability.

While concreting cubes must be taken to as per IS: 456 – 2000 to ensure the quality and strength of concrete by testing at 7, 21, and 28 days.

Make adequate number of cover blocks & chairs as per the required clear cover of various members. Cover Blocks must be placed at minimum of 1m c/c

Get reinforcement physical test certificate from supplier/manufacturer.

Ensure that binding wires are adequately used for tying up of reinforcements.

Check spacing/length of hooks and overlaps. Laps shall be staggered.

Check vertical & horizontal alignment & strength of centering and shuttering.

Ensure that thickness/width of section is adequate for inserting vibrator; else inform the design office for possible revision.

Ensure proper curing for required number of days. Use curing compound, if member is not easily accessible.

Check that expansion/construction joints are properly made & at correct location as per the drawings.

Make proper access/ walking arrangement over slab for proper inspection & to avoid any damage to reinforcements.

De-bonding compound to shuttering materials.

Depth and width of all beams must be checked.

Dimensions, diagonal, plumb and supporting of lift pit should be checked properly.

All beam sides should be absolutely in line and plumb.

Over all cleaning should be done before concreting.

Walk-way Planks to be used while casting the slab.

Slab concreting should be done in strips (Bays) to avoid cold joints. Concrete should be placed within 30 minutes for next strip otherwise keep the joint alive by putting one/two pans of concrete at joint and vibrate it.

Spare Vibrator and needless must be kept ready at the place of concreting.

Concrete should be poured from more than 1 m height to avoid segregation

Reinforcement should be placed as per specified spacing and diameter

Factors affecting Strength variation of concrete

1) Water Cement Ratio:
2) Moisture Content:
3) Quality of cement:
4) Storage of Cement:
5) Degree of Compaction:
6) Curing of Concrete:
7) Moulding Temperature:
8) Curing Temperature:

mixing of concrete as per IS 456

Standard mixes

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2.

Transportation of concrete and placing of concrete

Transportation of concrete and placing of concrete (IS 456:2000) Clause 13

Transportation of concrete

Transporting the concrete mix is defined as the transferring of concrete from the mixing plant to the construction site

As a general rule of thumb 30 to 60 minute of transportation are acceptable on a small job that is PCC work, filling of starter etc.

At Central or portable ready mix plant concrete should be discharge from the truck mixer within 2 hours

If non agitating transporting equipment is used then this time is reduced to 1 hour

After mixing concrete shall be transported to the formwork as rapidly as possible by methods which prevent the segregation or loss of the ingredients.

Main objective in transporting concrete is to ensure that the water cement ratio, slump or consistency, air content and home virginity are not modified from there intended states.

During hot and cold weather, concrete shall be transported in deep containers, other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted.

Placing of concrete

The concrete shall be deposited as nearly as practicable in its final position to avoid rehandling.

The concrete shall be placed and compacted before initial setting of concrete is start and should not be subsequently distributed.

Method of placing should be such as preclude segregation.

It Should be taken to avoid displacement of reinforcement or moment of formwork.

As a general rule of guidance the permissible free fall of concrete may be taken as 1.5 m. (it should not be more than 1.5)

curing requirements of Concrete as per I.S.456.

Curing of Concrete | Curing time & Duration | Curing methods

Concrete is a composite material consisting of cement, sand, and water in suitable proportions. The chemical interaction between cement and water binds the aggregate. Fresh concrete will be plastic so that it can be molded to any desired shape and compacted to form a dense mass.

Concrete should be placed in a position before it starts losing its plasticity. The time at which concrete completely lost its plasticity and became hard is called the final setting time of concrete.

Want to learn about the Initial and final setting of cement check out here:

Initial and final setting time of cement

Curing of concrete:

Curing plays a vital role in concrete strength development and durability. After adding water to the concrete mix (Cement, Sand & Aggregate), the exothermic reaction (hydration) takes place, which helps the concrete to harden. Hardening of concrete is not instant and continues for a longer period, which requires more amount of water for processing hydration. So, the concrete kept moist until the hydration reaction in concrete completes. This process called the curing of concrete.

or

Curing is the process in which the concrete kept moist to protect it from loss of moisture due to atmospheric temperature and hydration reaction.

or

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration.

Purpose of Curing of Concrete:-

The reaction between cement and water is called hydration. It is an exothermic reaction (the reaction which releases heat).

After adding water to the concrete mix, hydration starts, which makes the concrete to dry out quickly due to an exothermic reaction which releases heat. To complete the hydration process, concrete is kept moist to attain the maximum strength of concrete as soon as possible.

As there are many frequently asked questions about the curing of concrete. Below are some of them

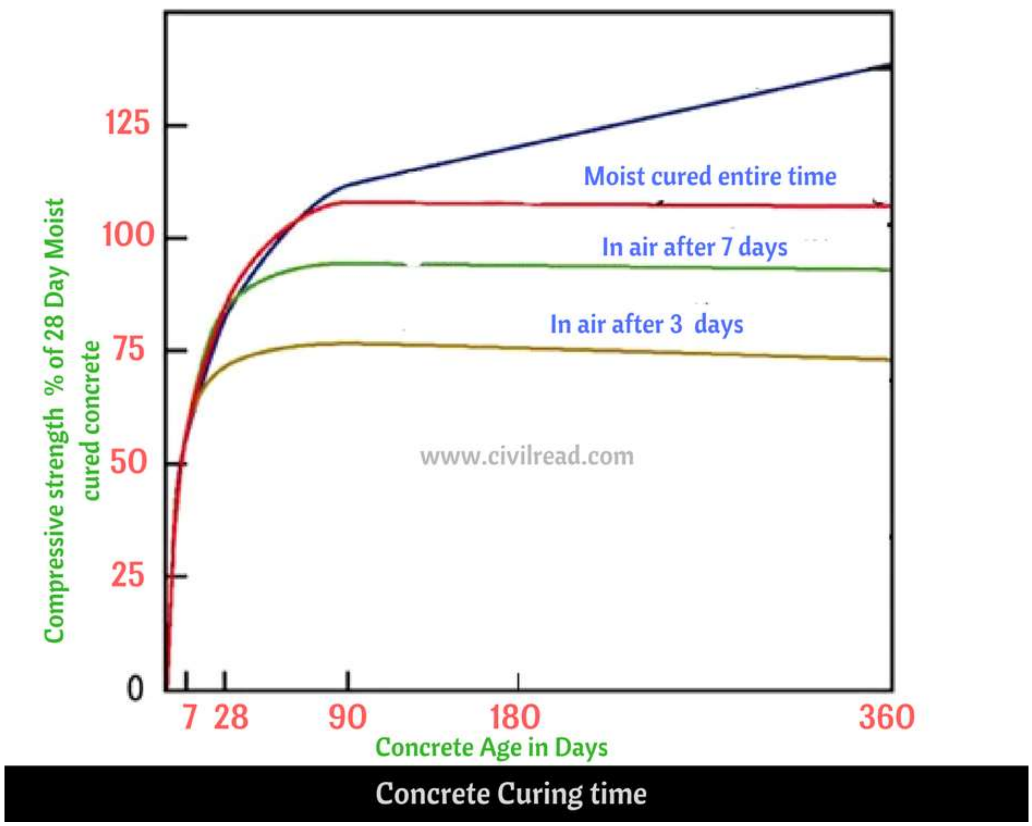
Procedure for curing of concrete :

Draining water on the concrete surface cures the concrete. Water cooler than 5^{0}C is not suitable for curing concrete. As the hydration reaction in concrete expels heat and keep concrete warm, Using cold water less than 5^{0}C on concrete may lead to cracking and failing. Alternate drying and wetting on the concrete surface causes volumetric changes in concrete and ultimately leads to cracking.

What is the curing period of concrete?

The minimum period for curing concrete to attain maximum strength is 28 Days.

For a clear understanding, check the below graph.



From the above graph, it is clear that concrete attained 50% of its design strength when it cured for 3-7 Days. 75% of Compressive strength achieved in 14 days. 90% of Concrete design strength achieved in 28 days. So it is clear as time increases on the concrete strength increased.

Minimum curing time for cement concrete:-

The early strength of concrete is most important, and it is responsible for the ultimate strength of concrete. We should do proper curing by considering the environmental conditions, type of structural members, atmospheric temperature. Maintaining the proper temperature also plays a vital role in concrete as mentioned, it should not be colder than 5^0C. Concrete is kept moist for at least 28 days. Nowadays, due to lack of time, the curing can be achieved by following modern techniques in 14-20 Days. Nevertheless, it is always advisable to keep concrete moist for at least 14 days.

As per IS 456 – 2000, concrete should not be cured less than 7 days for ordinary Portland Cement, & it must be at least 10 days for concrete with mineral admixtures or blended cement. In case of hot weather and arid temperature conditions, the curing should not be less than 10 Days for OPC and 14 days for concrete with blended cement & mineral admixtures.

The curing time or period of concrete is dependent on the following factors:

Specified Strength of Concrete

Grades of concrete

Atmospheric temperature:
Due to the chemical reaction between cement and water in concrete releases heat which requires water to complete hydration. In summer 50% of water is evaporated. So, More amount of water needed during sunny days.

Size and Shape of the Concrete member

Concrete Curing Methods:-

Below are the most important techniques which are prominently used all over the world.

1. Ponding:

This method adopted for floor slabs. The concrete surface divided into small ponds, and these ponds are filled with water continuously for 14 days.

2. Wet coverings:

This type of method performed for columns, footings, and the bottom surface of slabs, where ponding is not possible. Impermeable coverings like gunny bags or hessian are required to cover the concrete; these membranes sprayed with water to keep the concrete moist.

3. Membrane Curing of Concrete:

Ponding is not suitable at the places where the atmospheric temperatures are high. Water gets evaporated due to the excessive heat. Membrane curing is adopted to prevent the loss of water content due to atmospheric temperature from concrete.

Membrane curing helps seal off by forming an impermeable layer on the concrete surface, which eventually resists evaporation. This procedure is generally performed by brushing or spraying the curing compound on the concrete surface.

Membrane Curing

Different curing compounds are available to achieve the Membrane curing out of them, below four methods are essential and widely used.

Synthetic resin curing compound

Synthetic resin is a compound that forms as an impermeable membrane on a concrete surface to resist the water evaporation from concrete.

To proceed with further plastering, the synthetic resin membrane can be easily removed by spraying the hot water on the concrete surface. Hence it is suitable at areas where subsequent treatment applied to the concrete.

Acrylic curing compound:

Acrylic Curing compound is a polymer-based curing compound obtained from the polymers of Acrylic acid.

The best part of Acrylic based curing compound is there is no need to remove this compound for plastering. Acrylic helps to achieve excellent adhesion to plastering.

Wax Curing compound:

Wax curing has similar properties of synthetic resin. The usage of wax on the surfaces to be painted or tiled is not recommended because wax hampers the adhesion between surface and plastering or tiling.

Chlorinated rubber curing compound:

Chlorinated rubber forms a thick membrane on the concrete surface when laid. Using of chlorinated rubber-based curing compound seals the concrete effectively with no minute pores left. But the age of chlorinated rubber is very less, and it cannot stay for longer times.

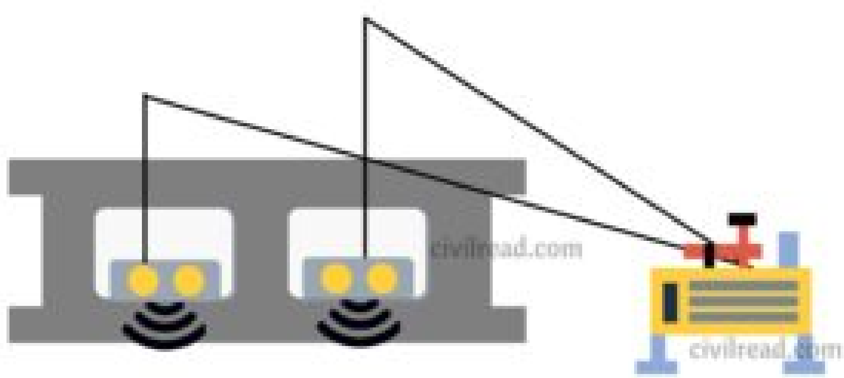
4. Steam curing of concrete:

This procedure is adopted at a Precast concrete plant where the concrete members are mass-produced. Steam has heat moisture in it, and it is sprayed on the concrete surface to keep concrete moisture and also increases the concrete temperature, which eventually quickens the pace of hardening concrete.

Steam Curing of Concrete

5. Curing of Concrete by infrared radiation:

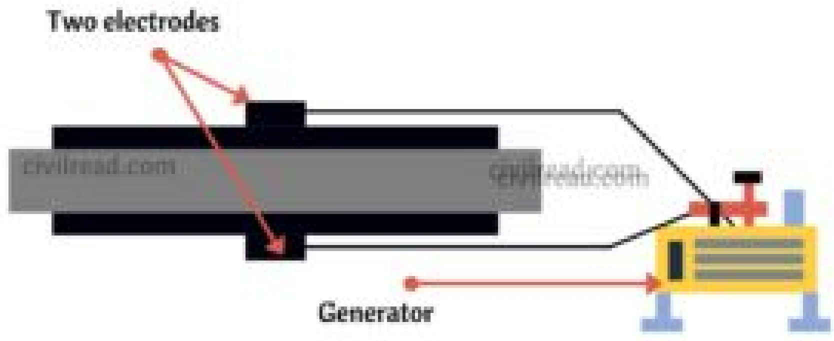
This method is adopted in cold climatic regions. In this procedure, the infrared radiation is applied to the concrete, increasing the initial temperature, which increases the strength of concrete. This is the most effective method than steam curing, as raising the initial temperature in concrete does not decrease the ultimate strength of concrete. This technique is adopted for the hollow concrete members where the heaters are placed in concrete members which emit the temperature of 90^0



Curing of Concrete by Infrared Radiation

6. Curing of concrete by an Electric Current:

In this method, the concrete is cured by passing an alternating current to it. Two plates, one at top and another at the bottom of the concrete surface, acts as an electrode, and then the alternating current is passed to them. 30V or 60V of potential difference maintained among these electrodes. The curing attained by concrete at 28 days can be achieved within three days by performing this method.



Curing of Concrete by Electric Current

Durability of Reinforced Concrete in Different Environmental Conditions

Some precautions to be taken care while constructions of reinforced concrete structure for durability are:

Proper amount of minimum cover specified by the code should be provided.

Minimum cement content in concrete mix and maximum water-cement ratio guidelines based on type of environment provided by the code should be followed.

Using good quality lab tested coarse and fine aggregates suitable for construction and free from (or within permissible limits) impurities such as dust, alkalies, chlorides, sulfates etc. should be used.

Based on environment attack on structure, suitable type of cement, concrete admixtures and water-cement ratio should be used.

Good placement and compaction of concrete.

Following formwork removal schedule as per type of construction as per guidelines given by standard codes.

Proper curing of concrete for the required period of time.

READY MIXED CONCRETE

Ready mixed concrete is an ideal concrete that is manufactured in a factory or in a batching plant based on standard required specifications; Ready-mixed concrete is a mixture of Portland or other cement, water, and aggregates: sand, gravel, or crushed stone.

The finished concrete mixture is then transported to the worksheet within the transit mixer above the truck.

Here we will learn about ready mixed concrete, types of ready mix concrete & much more.

INTRODUCTION TO READY MIX CONCRETE:

Ready mixed concrete (RMC) is a ready to use materials with a prearranged combination of cement, sand, aggregates and water.

The idea of Ready Mix Concrete (RMC) was first introduced by the architect Jurgen Heinrich Magens.

In 1907, he found that the time available for transport could be increased not only by cooling fresh concrete, but also by vibrating throughout transport.

Objective of ready mixed concrete:

Higher quality concrete is produced.

Elimination of space for storing for primary materials on site.

Dissipation of primary materials is prevented.

TYPES OF READY MIXED CONCRETE:

1.Transit Composite Concrete:

Transit composite concrete is also called dry-batch concrete because all the essential components are immediately charged in the truck mixer.

The mixer drum is quickly rotated at the charging speed during the loading and after it is rotated at conventional mixing speed.

In such ready-mix concrete, three types of adjustments are also possible.

2.Shrink Mixed Concrete:

In shrink-mixed concrete, the concrete is partially mixed in the plant mixer and partially mixed in a truck-mounted drum mixer during transit time.

The amount of mixture within the transit mixer depends on the amount of mixture carried out at the central mixing plant.

Tests need to be performed to establish the need for mixing of drum mixers.

3. Central Mixed Concrete:

Central mixed concrete is also known as a central batching plant, where the concrete is added accurately before loading into a truck mixer, they are also called wet-batch or pre-mixed plants.

Sometimes, non-agitating units or dump trucks will also be used, when reasonableness is required or leads are low.

MATERIAL USED IN READY MIXED CONCRETE:

Aggregates:

They are important materials in concrete, they occupy 70–80% of the volume of concrete, the aggregates are divided into two categories by consideration of size:

Coarse aggregate

Fine aggregate

Aggregates bigger than 4.75 mm are considered as coarse aggregate, with a dimension of 4.75 mm or less is considered a fine aggregate.

Cement:

Cement is composed of four main compounds: Dicalcium Silicate (2Ca0 Si.), Tricalcium silicate (3Ca0 Si02), Tricalcium aluminate (3Ca0 Al203), Tetra-Calcium aluminoferrite (4Ca0 Al203 Fe203).

These compounds are designated as C2S, C3S, C3A, and C4AF, where C stands for calcium oxide (lime), S for silica and A for alumina and iron oxide.

Small quantities of alcohol and magnesia are additionally present, as well as minor quantities of alkalis and other elements.

Fly ash:

The coal used in plants is mainly composed of combustible elements such as carbon, hydrogen and oxygen and non-combustible impurities (from 10 to 40%) commonly present as clay, shale, quartz, feldspar and limestone.

The size of fly ash ranges from 1.0 to 100 microns and the average size is about 20 microns.

The pH value of water should be between 6.0 and 8.0 according to IS 456-2000.

Advantages of ready mixed concrete:

Quality concrete is obtained from a ready-mixed concrete mix plant that uses advanced equipment and stationary methods.

There is strict control over material testing process constraints and continuous monitoring are the key practices throughout the construction.

In the case of site mix concrete, poor management over the enter materials, batching, and mixing methods are resolved within the ready mix concrete methodology.

In the construction works to be adopted within the ready mix concrete plant, the speed after the mechanical operation is fixed.

The output from the site combines the concrete plant using an 8/12 mixer which is 30–60 metric cubes per hour to 4-5 metric cubes per hour within the ready mix concrete plant.

Better handling and proper mixing will help in reducing cement consumption by 10 – 12%.

Also, the use of admixture and various materials will help to reduce the amount of cement.

Concrete mixes are used with high versatility, these are the best concrete methods.

Cement is shielded and dust is minimized because the finished concrete uses a bulk mixture of concrete instead of a bag of cement.

Conservation of cement will conserve energy and resources: due to low consumption, cement production is low hence environmental pollution is low.

Thus an extra durable structure is obtained, which will increase service life and saves costs.

In the manufacture of ready-mix concrete, there may be much less dependence on human laborers, so the probabilities of human errors are lowered, dependence on intensive laborers also decreases.

Small or massive quantities of concrete are delivered on time as per specification.

There has been no delay due to site-based batching plant erection or dismantling; no equipment rental; no depreciation of value.

Consumption of petrol and diesel is low, hence noise and air pollution are reduced.

Disadvantages of Ready Mixed Concrete:

Transit time might from the time of preparation of concrete on the distribution site, might affect the performance.

There is a need to add extra water or penetration to maintain functionality according to the specification.

On-site, quality assurance (QA) / quality control (QC) has to test functionality through fatigue testing before being used for manufacture.

Traffic during the transit of concrete might result in the setting of concrete so the addition of entrances is required to delay the setting period.

Formwork and placing arrangements should be prepared in a big area in advance as concrete might be bought in large portions.

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.

INTRODUCTION TO HIGH PERFORMANCE CONCRETE:

High-performance concrete (HPC) has been used in developed countries whereas in India until the last decade, HPC meant only high strength concrete.

Experience has shown that apart from strength, there are other equally important criteria such as durability, practicality, toughness.

The main objective of developing HPC is to extend the life of the structure.

Characteristics of High Performance Concrete:

Due to the tight and refined pore structure of the cement paste, it has very low porosity.

1) It has a very low permeability of concrete.
2) High resistance to chemical attack.
3) Low heat of hydration.
4) High early strength and continued strength development.
5) Low water binder ratio.
6) Low bleeding and plastic shrinkage.

TYPES OF HIGH PERFORMANCE CONCRETE:

High performance concrete: when the strength range is 50- 100Mpa.

Very high performance concrete: when the strength range is 100–150 MPa.

Hyper performance concrete: when the strength range is greater than 150Mpa.

PROPERTIES OF HIGH PERFORMANCE CONCRETE:

-The split tensile strength with metakaolin and steel fibres is 4.38 MPa and 3.87 MPa.

-The tensile strength is improved by 11.64%.

-For GGBS concrete mixture with fibre, the tensile strength is 4.12MPa and for concrete mixture without fibre is 3.94MPa.

Advantages of high performance concrete:

These HPC are easy for placement and consolidation without affecting strength.

It reduces the size of structural members and increasing the usable space.

Structural members are small in size because smaller sections are sufficient to hold higher loads.

Reduction in thickness of flooring slabs and supporting beam is a significant component of buildings.

The reduction of structural members such as beams, columns, and slabs leads to a reduction in self-weight and dead load leading to a substantial reduction in prices.

It had higher seismic resistance as compared to standard concrete.

Also, had high abrasion resistance.

The formwork area and its value are reduced.

Shoring and stripping time are reduced due to the high initial strength.

The construction of high-rise buildings in congested areas is cost savings.

Long spans and short beams for the same magnitude of loading used in bridge construction.

The ability of HPC for long distances reduces the number of supports and foundations.

It extends the life of construction in extreme environments.

They are high efficiency under static, dynamic, and fatigue loads.

It had less creep and shrinking.

They are greater stiffness resulting from a higher modulus.

It had high resistance to chemical attack, long-term durability, and significantly improve crack propagation.

This cement reduces maintenance and repair costs.

Disadvantages of high performance concrete:

These HPC have extended quality control.

This concrete has a high cost.

They are special constituents.

They are manufacture and placed carefully.

Application of high performance concrete:

Pavements:

HPC is used for highway efficiency due to potential economic benefits

Fast track concrete paving (FTCP) technology can be utilized for full pavement reconstruction.

Bridge:

HPC is being used extensively in the world to manufacture precast pylons, piers and girders of many long bridges.

Concrete structures are preferable for railway bridges that eliminate noise, vibration problems and maintenance costs.

Skyscrapers:

Reasons for using high strength concrete in the area of tall buildings are dead loads, deflection, vibration and reducing maintenance costs.

Miscellaneous applications:

These concrete with and without conventional reinforcement has been used in many field applications.

These include bridge deck overlays, floor slabs, hydraulic structures, thin spheres, rock slope stabilization, and many precast products.

CONCLUSION:

High-performance concrete becomes an important element of tall buildings as it enhances the visual impact and it can tolerate severe environments.

It reducing the size of the sections and they are high durability.

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.

Chemical Composition of Silica Fume Material

It contains more than 90 percent of silicon dioxide.

Other constituents are carbon, sulfur, oxides of aluminum, iron, calcium, magnesium, sodium, and potassium.

Physical Properties of Silica Fume Material

The diameter of the silica fume particle ranges from 0.1 micron to 0.2 micron.

The surface area is about 30,000 m^2/kg.

Density varies from 150 to 700 kg/m^3 but when it is about 550 kg/m^3, it is best suited as a concrete additive.

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

Properties of Hardened Silica Fume Concrete

The compressive strength of silica fume concrete is higher than ordinary concrete (62 – 80 MPa), Fig. 1. Similarly, the flexural strength is also higher, Fig. 2.

The modulus of elasticity is substantially higher than that of ordinary concrete.

Creep of silica fume concrete is lesser than conventional concrete

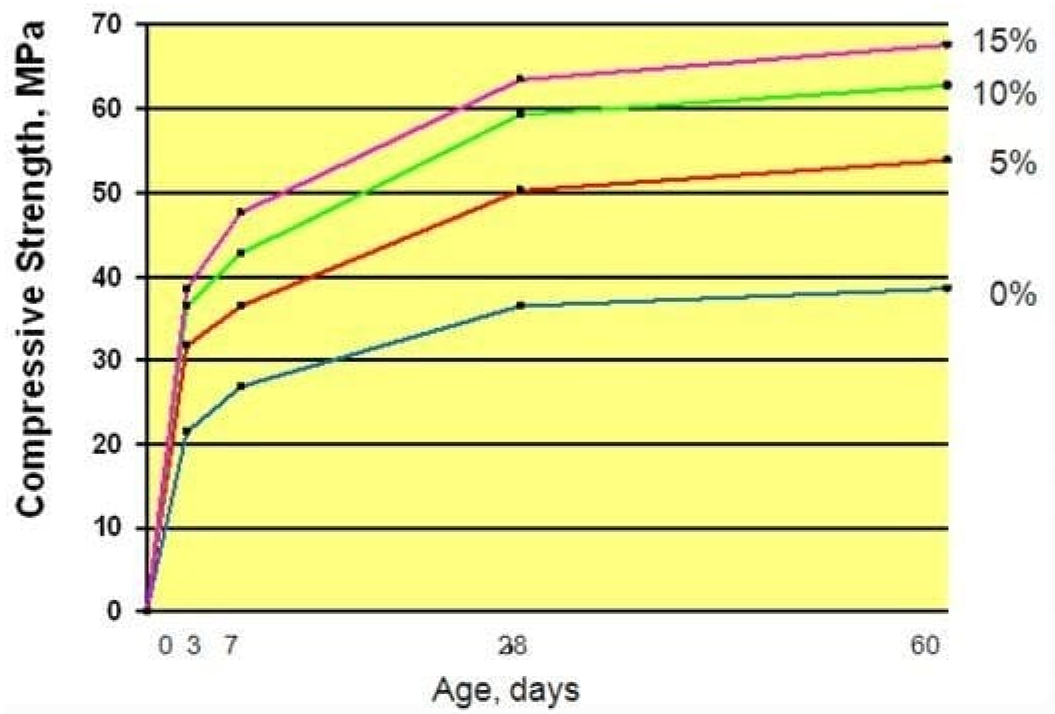


Fig. 1: Strength

Development of Silica Fume Concrete

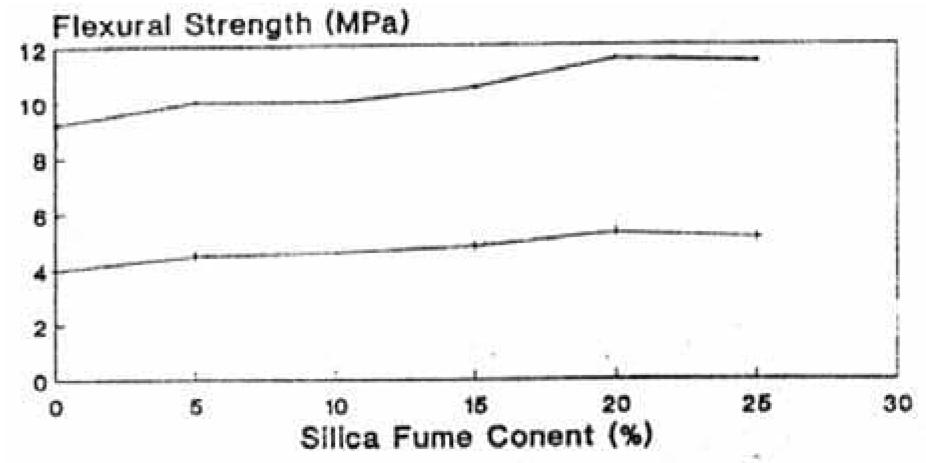


Fig. 2: Flexural Strength of Silica Fume Concrete

Durability

Permeability of silica fume concrete is low; hence, penetration of sulfate ions is low.

Abrasion resistance and corrosion resistance are high.

The reaction of silica fume with lime in the paste matrix improves durability. Lime material reacts with different chemicals and cause expansion.

Advantages

Silica fume enhances the properties of fresh and hardened concrete.

Silica fume reduces segregation and bleeding.

High durability

The finishing process is efficient due to low bleeding.

High early compressive strength

High flexural strength and modulus of elasticity

High bond strength

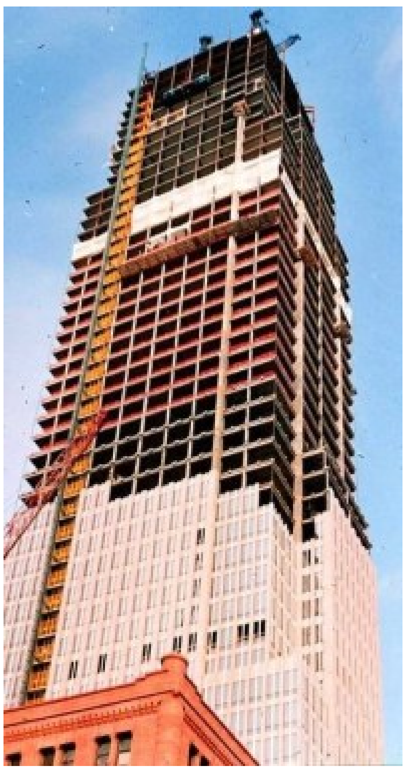
Suitable for mass concreting since it prevents thermally induced cracking.

Disadvantages

1) Availability issue
2) High cost

Applications

1) High rise buildings,
2) Parking structure,
3) Dam structure, .
4) Nuclear waste storage facility
5) Shotcrete rehabilitation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High rise Building

Parking Structure

Dam Structure

Silica Fume Concrete

What is silica fume concrete?

Concrete made from cement, silica fume, fine and coarse aggregate, and water.

What are the desirable properties of silica fume concrete?

Compressive strength, flexural strength, and bond strength of silica fume is better than normal strength concrete. In addition, the durability of this type of concrete fend off most aggressive chemical attacks.

What are the properties of fresh silica fume concrete?

Low workability, considerably cohesive, low bleeding and segregation, and low slump value.

What are the advantages of silica fume concrete?

High durability, segregation and bleeding, efficient finishing process, high early compressive strength., high flexural strength and modulus of elasticity, high bond strength., and suitable for mass concreting since it prevents thermally induced cracking.

What are the applications of silica fume concrete is civil engineering?

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

Guniting

Guniting is a process used in construction for the application of slope stabilization and certain rehabilitation purpose mainly in the construction of retaining walls, swimming pool construction, tunnel construction, in fluid tank construction and some of the concrete repair works.

theconstructor.org - compressive strength concrete cube test

Clear definition of guniting is understood properly by knowing what is shotcrete.

Guniting was a method of early origin in the US, where the method is defined as the process of spraying a mix or mortar or concrete to a surface of application with the help of a spray gun. This method makes use of a spray gun and hence the process was named as Guniting.

Later, in the time of 1930s a method of spraying concrete or mortar mix with the help of a nozzle spray under compressed pressure and high velocity was followed by the American Railway Engineers Association(AREA).

The American concrete Institute too adopted this method in the 1950s and was named as shotcrete. These institutes never used the word 'Gunite' or 'guniting'. The shotcrete can be carried out with a dry mix or a wet mix.

Advantages of Guniting or Dry Shotcreting Process

The dry- mix shotcrete process is a method that is used widely and have the following advantages:

1. The process of guniting is highly versatile in nature. This method can be applied for structures to occupy any shape say undulating, spherical or curves. This versatility is the major reason why it is used in swimming pools, artificial caves and waterfall etc. so that special shapes and features can be provided. This feature made it employ in application of tunnel lining, slope protection, refractory works and many of the repair works. These also have a diverse use in the construction of dams, reservoirs, bridges, pipelines, and canals.

2. As the water added to the mix is carried out at the nozzle, the control of water is possible. This adjustment can be controlled instantly by the crew while carrying out the spraying procedure. This will hence make it possible to give a mix either wet or dry based on the demand. This is controlled by the addition of water at the nozzle.

3. When compared with the wet shotcrete process, the dry-mix shotcrete or the guniting mix can be prepared quickly. This is more useful in overhead application because if it is wet mix heights would bring problems like sagging or sticking or segregation.

4. For small works like filling the cracks for a smaller region or for very thin lining or coatings or for very fine treatments, it is recommended to opt dry-mix shotcrete process (guniting) when compared with the wet-mix shotcrete process.

5. Guniting is a best choice in those work types were unexpected stoppage of work is possible. The use of wet-mix shotcrete process will be not useful in such situations, resulting in wastage of mix.

Disadvantages of Guniting or Dry Shotcrete Process

1. The process of guniting will require highly skilled and experienced labor so that there is proper check on the pressure, the amount of water added at the nozzle and finally apply a good quality mix on the surface of application. Here the majority of quality is concerned with the operator who performs the guniting operation.

2. The guniting process will face the issue of rebound of the mix. As the mix is sprayed on the surface of the material there is chances that the ingredients get bounce off and then fall on the ground. This

occurrence is called as rebound. This phenomenon is more common in the case of guniting of dry-mix process when compared with the wet-mix shotcrete process.

Different types of defects in concrete structures can be cracking, crazing, blistering, delamination, dusting, curling, efflorescence, scaling and spalling. These defects can be due to various reasons or causes.

Causes for Defects in Concrete Structures

Causes of defects in concrete structures can be broadly categorized as:

1) Structural deficiency resulting from errors in design, loading criteria, unexpected overloading, etc.
2) Structural deficiency due to construction defects.
3) Damage due to fire, floods, earthquakes, cyclones etc.
4) Damage due to chemical attack.
5) Damage due to marine environments.
6) Damage due to abrasion of granular materials.
7) Movement of concrete due to physical characteristics.
8) Structural Defects due to Design and Detailing

In such case, the design is required to be reviewed in detail and remedial measures worked out by the design team. Once this is done the methods of carrying out the remedial measures will be similar those arising out of other defects.

Structural Deficiency due to Construction Defects

Defective construction methods form the largest segment of source of distress to the beams. Such defects can be broadly subdivided as follows:

Defects due to the quality of raw materials.

Non adoption of designed concrete mix.

Use of defective construction plant for producing, transporting, and placing the concrete.

Defective workmanship.

Inadequate quality detailing.

It is very necessary to choose the right type of cement for the concrete going into the structure under consideration. Ordinary Portland cement is the most common of all cements. Provided the quality of cement conforms to the relevant standard specifications, at the time of use, normally no problem is encountered in respect of ordinary Portland cement. Where the concrete is exposed to aggressive environment, it may be necessary to use special cements, such as, sulphate resisting Portland cement, blast furnace slag cement, low C_3A cement. The quality of aggregates, particularly in respect of alkali-aggregate reaction, needs to be taken into account, fortunately cases of defects / failures attributed to alkali aggregate reaction in India are very rare. The use of water containing salt for making concrete can also contribute to deterioration of the concrete. The design of concrete mix can be satisfactorily carried out using a wide variety of aggregates. A reasonable continuity of grading of aggregates should be ensured. Excessive use of water in the concrete mix is the largest single source of weakness. The accuracy of weighing the various components is very much dependent on the quality of the weigh batching system, available. Spring loaded dials of the weigh batchers contribute toward$ excessive variability in the quality of weigh-batched concrete in India. Other contributory factors that add to bad workmanship include segregation, improper placement, inadequate or excessive vibration leakage of mortar through shuttering joints, inadequate concrete cover, in sufficient curing etc. Proper detailing of reinforcement, including adequate cover is essential to ensure successful placement of concrete. Bad detailing results in congestion of reinforcement to such an extent that concrete just cannot be placed and compacted properly, even if the concrete is workable. Detailing of reinforcement should be based on a proper appreciation of how the concrete placement and compaction is going to be carried out.

Other factors leading to poor design detailings

Re-entrant corners.

Abrupt changes in section.

Inadequate joint detailing.

Deflection limits.

Poorly detailed drips and scuppers.

Inadequate or improper drainage.

Poor detailing of expansion joints.

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.

Fig-Cracking

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.

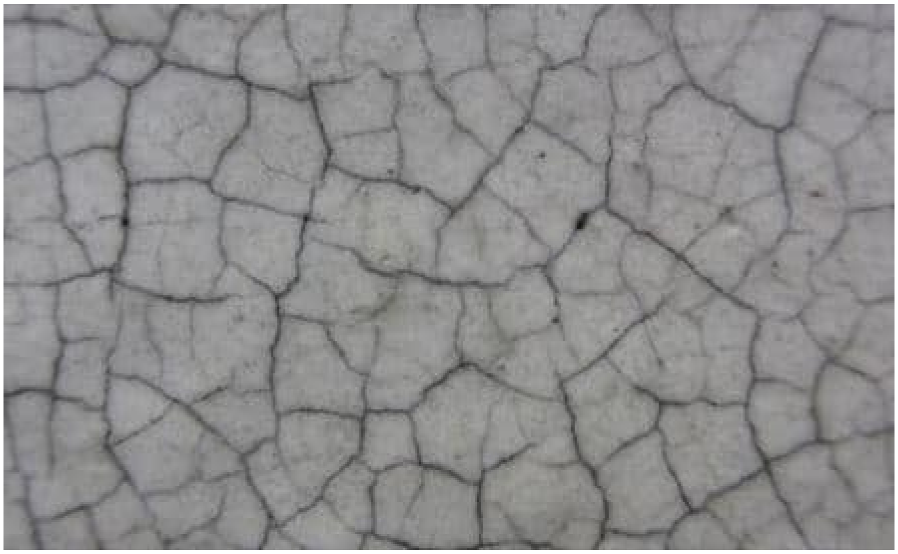


Fig -Crazing or Pattern Cracking

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.

Fig : Concrete Blisters

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.

Fig : Delamination

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.

Fig : Dusting

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.

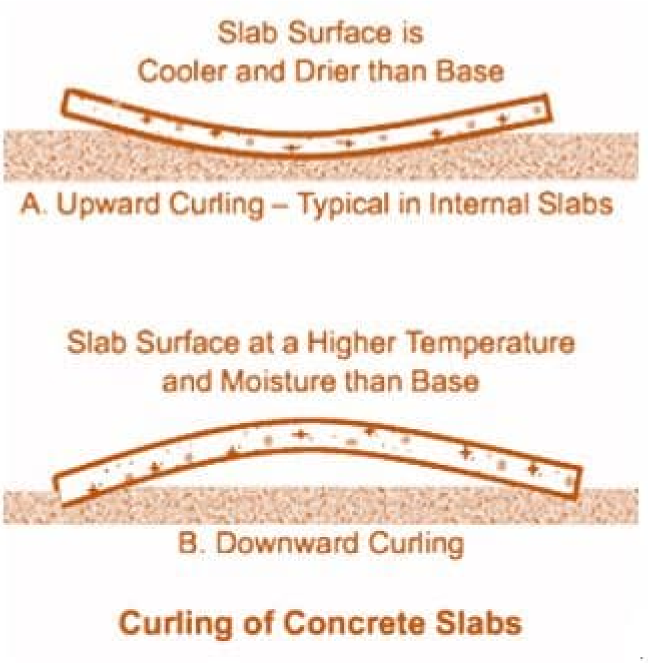


Fig : Curling of Concrete Slab

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.

Fig : Efflorescence

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.

Fig : Scaling

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.

Fig : Spalling

There are various techniques available for repair and rehabilitation of concrete structure for failure and defects in concrete. These techniques and materials for repair of concrete is described. Concrete is the most widely used and versatile construction material possessing several advantages over steel and other construction materials. However very often one come across with some defects in concrete. The defects may manifest themselves in the form of cracks, spalling of concrete, exposure of reinforcement, excessive deflections or other signs of distress. On many occasions, corrosion of reinforcement may trigger off cracking and spalling of concrete, coupled with deterioration in the strength of the structure. Such situations call for repairs of affected zones and sometimes for the replacement of the entire structure.

Causes for Failures or Defects in Concrete Structures

The following are the major causes for failures of concrete structures:

Structural deficiency arising out of faulty design and detailing as well as wrong assumptions in the loading criteria.

Structural deficiency due to defects in construction, use of inferior and substandard materials, poor workmanship, and negligence in quality control and supervision.

Damages caused due to fire, floods, earthquakes, etc.

Chemical deterioration and marine environments.

Damages caused due to abrasion, wear and tear, impact, dampness etc.

Movement of concrete caused due to settlement of foundation, thermal expansion etc.

Identification of Failures and Defects in Concrete Structures

A correct diagnosis establishing the cause, nature and extent of damage, and the weakness or deterioration caused in the structure is very essential, since a faulty diagnosis may lead to improper selection of materials and repair techniques leading to the failure of the repaired zone again. It may also be necessary that the serviceability of the structure is checked after carrying out the necessary repairs.

Need for Repair and Rehabilitation of Concrete Structure

The need of structural repairs can arise from any of the following:

Faulty design of the structure

Improper execution and bad workmanship

Extreme weathering and environmental conditions

High degree of chemical attack

Ageing of the structure

Techniques for Repairs and Rehabilitation of Concrete Structure

The technique to be adopted for repair or restoration of the structure depends on the cause, extent and nature of damage, the function and importance of the structure, availability of suitable materials and facilities for carrying out repair, and a thorough knowledge of the long-term behavior of the materials used for the repair work. Depending upon the requirement, the repairing technique may be of a superficial (cosmetic) nature or, in some cases, may involve the replacement of part or whole of the structure.

The repairing techniques can be classified into three major groups:

Injection into cracks, voids or honey-combed areas.

Surface treatment

Removal and replacing of defective or damaged material / area.

A variety of new materials have been developed for the repair and restoration of damaged structures by following any one of the above methods. These are briefly described below.

Materials for Repairs and Rehabilitation of Concrete Structure

Cement, Cement Grouts, etc.

In most cases, the repair material may be cement-based, since cement is the only active ingredient in concrete. Dry pack consisting of rich cement concrete or cement grouting may be suitable for sealing damaged areas and cracked portions. Spraying of concrete or cement sand grout by means of high pressure nozzles, usually termed as 'shotcrete' or 'guiniting', respectively, may prove effective in many cases where a large surface area is to be repaired. The guiniting or shotcrete may be carried out with or without the use of steel reinforcing mesh or steel fibers.

Resin based Repairs of Concrete

The resins normally used are from epoxide, polyester, acrylic or polythene families. The application of resins for repair work requires a thorough understanding of their chemical and physical properties and their performance in the structure, particularly with the passage of time and under unfriendly environs. Epoxy resin systems find application in civil engineering works such as grouting of cracks, repairs of eroded concrete structures, emergency repairs of bridges, aqueducts, chemically corroded columns and beams. Generally, resin materials are used in repair and restoration work where properties such as, high strength (hence thin sections), excellent adhesion (hence small patches), quicker curing (hence saving in time), and high chemical resistance are required. One of the most commonly adopted resins is from epoxide. A brief description of the properties and applications of epoxy based resins is given below.

Epoxy Resins for Concrete Repair

The resin mortar may be obtained by adding fillers such as coarse sand or calcined bauxite grit. The chemical reaction begins as soon as the resin and hardener are combined. Most combinations have a pot-life between 30 and 60 minutes. They develop excellent strength and adhesive properties and are resistant to many chemicals besides possessing good water proofing. Epoxy resin when cured with different hardeners offer wide range of properties. Once cured, they form irreversible system (thermosetting). The characteristic properties of cured epoxy resin systems repair and rehabilitation of concrete structure are

High adhesive strength to almost all materials

Low shrinkage during curing

Exceptional dimensional stability

Natural gap filling properties

Thermosetting (does not melt)

Resistance to most chemicals and environments

Ability to cure in wet conditions and underwater (for selected grades)

Ease of application

Procedure of epoxy resin grouting

Locating the cracks

Cleaning of the cracked surface

Drilling and fixing of nozzles for grouting at suitable intervals with epoxy putty

Grouting of epoxy mixture with the help of the grout pump

Sealing of nozzles through which grouting is done

A grout vessel essentially consists of a pressure vessel (to withstand 10 – 15 kg/cm^2 pressure) with inlet and outlet for resin mixture, pressure gauge, connection for compressed air with regulator for pressure grouting. A pre-mixed resin + hardener is filled in the grouting vessel and through the nozzle the activated resin is pumped in the cracks. When cracks get filled in, the grouting is carried in the next nozzle and so on till all the cracks are filled in. When cured, the epoxy resin improves the load carrying capacity of the cracked structure.

Bonding Old to New Concrete

Epoxy resin with a special polyamide hardener combination is successfully used for bonding old to new concrete. **The process consists of —**

Removal of all loose and damaged concrete using mechanical means or water jet

Surface to be dried

A suitable epoxy resin [unmodified solvent less epoxy resin + polyamide hardener (special grade)] is applied with stiff nylon brush

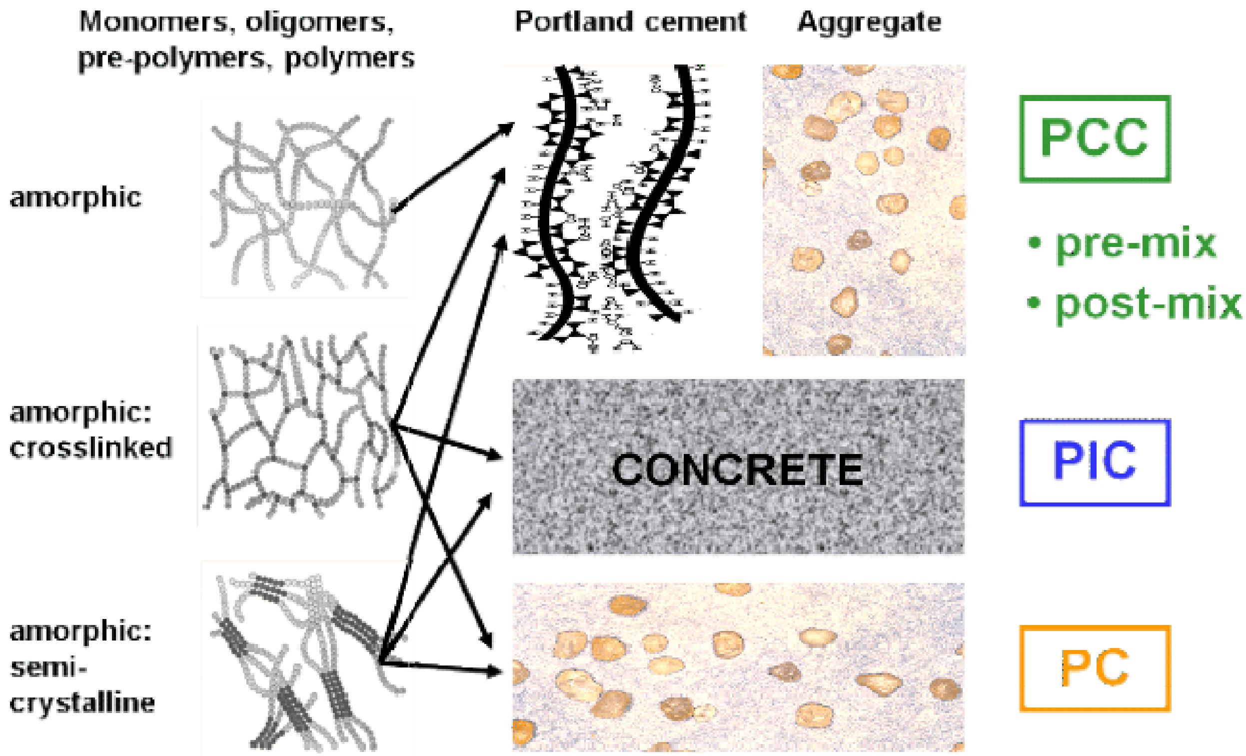
The fresh concrete should be poured when epoxy coating has become just tack free

Care should be taken not to completely dry the coating.

Epoxy resins are a not primary construction material. A judicious use of these resins is required in view of the high cost of these resins. The resins should be used in emergencies. Properties of epoxy resin systems can be advantageously exploited, when other materials cannot be used due to strength or other considerations. Epoxy resins are finding many new applications in pressing conditions such as underwater repairs of dams, ships, etc. Many new applications will be found using epoxy and other synthetic resins in future.

Polymer Concrete Composites

Most of the deficiencies found in ordinary structural concrete are removed using polymer concrete composites either in the form of a surface coating over the structure or by impregnating it into the structure. Polymer concrete composites are relatively new developments and have been used in structural applications since 1950. They possess very high strengths and are more durable and resistant to most chemicals and acids. There are three types of polymer concrete composites, namely polymer impregnated concretes (PIC), polymer concretes (PC), and polymer cement concretes or polymer modified concretes (PCC or PMC). In PICs the monomers (usually styrene, methyl-methacrylate (MMA), polymethyl methacrylate (PMMA), etc.) are impregnated into the pore system of the hardened concrete, thereby filling up the pores and making them impermeable and resistant to chemical attack; In PCs the polymer is the sole binder in lieu of cement and water. In PCCs and PMC s, a polymeric additive (latex or pre-polymer) is added to the normal cement composite during the mixing stage itself.



All the three types of polymer concrete composites are useful for carrying out repairs and restoration work in damaged structures. The use of these composites for post-distress and post-failure applications is steadily increasing because of their superior durability, excellent bond to parent concrete structure, superior abrasion and wear-resistant properties, a high degree of resistance to chemicals like chlorides and acids, and their very low water absorption. Repairs of cracks can be easily carried out by injecting the polymer concrete damaged by corrosion of reinforcement can be chipped off and replaced by polymer concrete.

Sealants

Many commercial sealants are available for sealing of cracks in concrete structures. Joint sealants should ensure structural integrity and serviceability. They should also serve as protection against the passage of harmful liquids, gases, and other undesirable substance which would impair the quality of concrete. In the case of repair of a cracked surface, the cracks are first enlarged along their exposed face and are pointed up with the sealants.

Surface Treatment to Concrete

The durability of the concrete can also be increased particularly on the surface by applications of different materials which make it waterproof, hardened and resistant to chemical attack.

Some of the commonly used surface treatments are:

Sodium silicate, magnesium or zinc fluoride

Drying oils like Tung or Linseed oil

Chlorinated rubber paints and neoprene paints

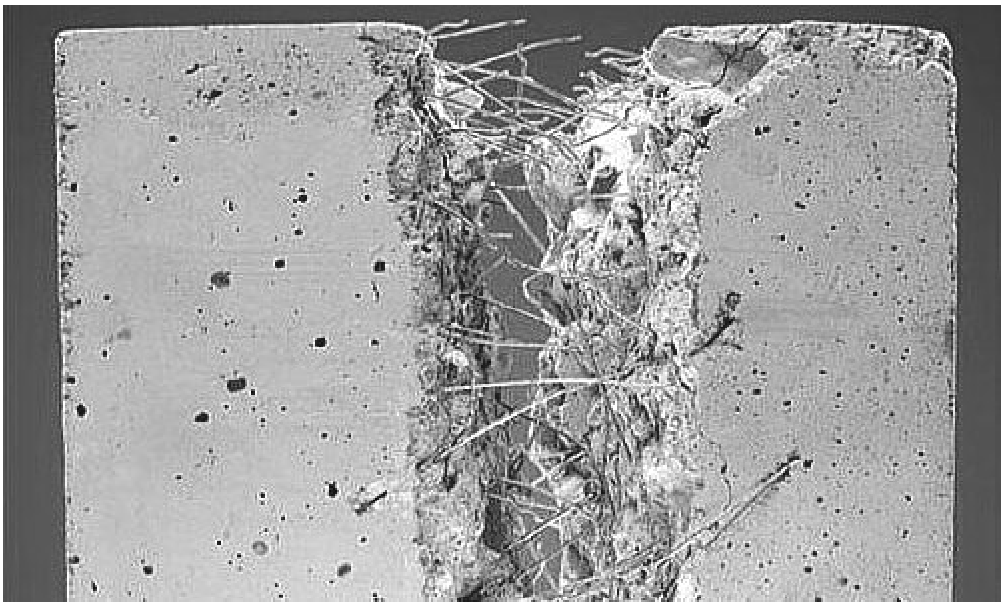
Epoxy paints

Silican Fluoride treatment

The surface of the hardened and dry concrete can be made abrasion resistant and less dust generating by application of solutions of sodium silicate, magnesium or zinc sulphates or silico fluorides. Drying oil like tung oil or linseed oil can be used. Alternatively, carborundum or fused alumina or finely divided iron aluminum chloride preparations may be added in the surface layer while placing the fresh concrete. Floor paints also provide reasonable durability if the traffic on floor is not heavy. Paints containing synthetic resins particularly polyurethanes or epoxies or chlorinated rubber provide greater resistance to wear. They also protect against solutions of salts and dilute acids. Sodium silicate and silico fluoride applications provide protection against mild conditions of attack by aqueous solutions or organic liquids. Bitumen and coal tar gives protection against insects and borers. Some plastic materials, rubber latex glass fiber coatings and PVC linings have also been successfully employed to improve durability of concrete.

Steel Fiber Reinforced Concrete

Use of small diameter steel fibers in concrete has been found to improve several properties of concrete and particularly its tensile strength and impact and wear resistance. One of the uses of steel fiber reinforced concrete (SFRC) is in the area of repairs and restoration of concretestructures



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The damaged portions of a concrete structure can be removed and can be made good by placing of SFRC to the sides and bottom of damaged structures by guiniting or shotcrete techniques. Because of its improved wear and tear and abrasion resistance, SFRC has been successfully employed for the repair of industrial floors and bridge decks with or without the use of polymer concrete.

Other Materials for Repair and Rehabilitation of Concrete

There are several other materials which can also be used for repairs of certain structures. For repairs to existing foundations, special chemical grouts have been developed which will ensure the compaction of the soil below and provides protection to the reinforcing steel in the foundations. Superplastized fiber reinforced concrete has been used in carrying out repairs to machine foundations and underground structures. Certain chemicals and surface coatings marketed under brand names are said to seal the cracks in structures like water tanks and afford sufficient protection to the steel from corrosion. Special paints (latex or bitumen based) have also been developed for applying to the concrete surface or to the bars for making them resistant to aggressive environs. With the increasing number of cases of damages being observed on structures built in the past, repairs and rehabilitation of such structures have assumed greater importance. Some of the techniques and materials found useful to reinstate some affected structures. Table below shows the materials generally recommended for repair of concrete structures. Epoxy resins and concrete composites show high potential as promising repair materials. Timely detection of deficiencies in concrete and steel of an existing structure and execution of immediate remedial measures will prevent further deterioration of the structure and will result in huge savings in the maintenance cost. The old dictum, ‘prevention is better than cure’ is applicable to concrete structures, both at the time of constructing the structures and at a time when the structure has shown signs of initial distress.

Materials for Repair of Concrete

Repair Operation	Material	Comments
Sealing of fine cracks	Epoxy resins	- Good bonding properties even in the presence of moisture
Sealing of large cracks and joints	Portland cement Mortar Polymer mortar Putties and caulks	- Well – compacted – Good bonding properties - Based on synthetic polymers and tars
General sealing of surface	Synthetic polymers and asphalt coatings	
Localized patching of surfaces	- Concrete or mortar using Portland cement - Rapid-setting cements - Polymer resins; epoxies; polyesters	- Calcium aluminate and regulated-set cements – Good bonding

Repair Operation	Material	Comments

Overlays and shotcrete	- Portland cement concrete - Steel fiber reinforced concrete - Latex modified concrete - Polymer concrete - Asphaltic concrete	- Quick-setting admixtures - Resistance to cracking - Good bonding