

## UNIT – I CONCRETE TECHNOLOGY

A **cement** is a binder, a substance that sets and hardens and can bind other materials together. The word "cement" traces to the Romans, who used the term *opus caementicium* to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick supplements that were added to the burnt lime, to obtain a hydraulic binder, were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*.

Cements used in construction can be characterized as being either **hydraulic** (pozzolan) or **non-hydraulic**, depending upon the ability of the cement to be used in the presence of water (see hydraulic and non-hydraulic lime plaster).

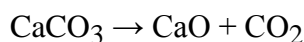
**Non-hydraulic cement** will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting.

**Hydraulic cement** is made by replacing some of the cement in a mix with activated aluminium silicates, or pozzolans, such as fly ash. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack (e.g., 1824 Portland cement).

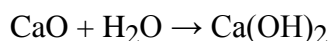
The chemical process for hydraulic cement found by ancient Romans used volcanic ash (activated aluminium silicates). Presently cheaper than volcanic ash, fly ash from power stations, recovered as a pollution control measure, or other waste or by products are used as pozzolanas with plain cement to produce hydraulic cement. Pozzolanas can constitute up to 40% of Portland cement.

The most important uses of cement are as a component in the production of mortar in masonry, and of concrete, a combination of cement and an aggregate to form a strong building material.

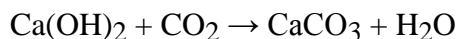
**Non-hydraulic cement**, such as slaked lime (calcium hydroxide mixed with water), hardens by carbonation in the presence of carbon dioxide which is naturally present in the air. First calcium oxide is produced by lime calcination at temperatures above 825 °C (1,517 °F) for about 10 hours at atmospheric pressure:



The calcium oxide is then *spent* (slaked) mixing it with water to make slaked lime:



Once the water in excess from the slaked lime is completely evaporated (this process is technically called *setting*), the carbonation starts:



This reaction takes a significant amount of time because the partial pressure of carbon dioxide in the air is low. The carbonation reaction requires the dry cement to be exposed to air, for this reason the slaked lime is a non-hydraulic cement and cannot be used under water. This whole process is called the *lime cycle*.

Conversely, the chemistry ruling the action of the **hydraulic cement** is hydration. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main components being:

Belite ( $2\text{CaO} \cdot \text{SiO}_2$ );

Alite ( $3\text{CaO} \cdot \text{SiO}_2$ );

Tricalcium aluminate ( $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ ) (historically, and still occasionally, called 'celite'); Brownmillerite ( $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ ).

The silicates are responsible of the mechanical properties of the cement, the tricalcium aluminate and the brownmillerite are essential to allow the formation of the liquid phase during the kiln sintering (firing). The chemistry of the above listed reactions is not completely clear and is still the object of research.

### What are Different Grades of Cement?

The grade 43 and 53 in cement mainly corresponds to the average compressive strength attained after 28 days ( 6724 hours) in mega pascals (Mpa) of at least three mortar cubes ( area of face 50 cm squared) composed of one part cement, 3 parts of standard s and ( conforming to IS 650:1966) by mass and P/4 ( P is the percentage of water required to produce a paste of standard consistency as per IS standard) + 3 percentage ( of combined mass of cement plus sand) of water , prepared, stored and tested in the manner described in methods of physical test for hydraulic cement. 721 hr not less than 23 MPa for 43 grade, 27 MPa for 53 grade 1682 hrs not less than 33MPa for 43 grade, 37MPa for 53 grade 6724 hrs not less than 43MPa for 43 grade, 53 MPa for 53grade

### Physical properties of Ordinary Portland Cement

**Cement should be tested for its following properties:**

#### 1. Fineness

Fineness, or particle size of portland cement affects rate of hydration, which is responsible for the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, which means more area available for water-cement reaction per unit volume. Approximately 95% of cement particles are smaller than 45 micron with the average particle size about 15 micron. Fineness is measured in terms of surface area per unit mass. Fineness can be tested by /Wagner turbidimeter/ test, /Blaine Air-permeability /test, 45-micrometer sieve

and electronic particle size analyzer.

## **2. Soundness**

Soundness refers to the ability of a hardened cement paste to retain its volume after setting. Lack of soundness is observed in the cement samples containing excessive amounts of hardburnt free lime or magnesia. /Autoclave expansion test/ is used to determine soundness of cement.

## **3. Consistency**

Consistency of a cement paste refers to its ability to flow. Normal consistency pastes are required to be prepared for testing cement specimens. A paste is said to have a normal consistency when the plunger of /Vicat apparatus/ penetrates it by  $10 \pm 1$  mm. the corresponding water-cement ratio is reported.

## **4. Setting Time**

Initial setting time is the time that elapsed from the instance of adding water untill the pastes ceases to behave as fluid or plastic. Whereas final setting time referred to the time required for the cement paste to reach certain state of hardness to sustain some load. Setting time is tested by /Vicat apparatus/ or /Gillmore needle/.

## **5. Compressive Strength**

Compressive strength of cement is tested by 50 mm mortar cubes made by using standard sand and cured in a prescribed way. the cubes are tested under a /compression testing machine/. The strength of cement varies with time, therefore in general it is reported as 3 day, 7 day or 28 day strength.

## **6. Heat of hydration**

The heat generated during the reaction of cement and water is known as heat of hydration. The factors affecting heat of hydration are C3A, C2S, water-cement ration, fineness of cement and curing temperature. /Conduction calorimeter /is used to test heat of hydration.

## **7. Loss on Ignition**

A cement sample of known weight is heated between  $900 - 1000^{\circ}\text{C}$  ( $1650 - 1830^{\circ}\text{F}$ ) until a constant weight is obtained. The weight loss of the sample due to heating is then determined. A high loss on ignition (more than 3%) indicates prehydration and carbonation, which may be due to

inappropriate storage or adulteration.

### 8. Specific gravity (relative density)

Specific gravity is generally required in mix proportioning for concrete. The particle density (measured by excluding the air between particles) of OPC is found to be in the range of 3.1 to 3.25 Megagram per cubic meter. The relative density of OPC is assumed as 3.15. The density of cement is determined by Le Chatelier apparatus.

### 9. Bulk Density

The bulk density can be determined by dividing the mass of cement particles and air between particles by the volume of cement sample. Bulk density of OPC ranges from 830 kg/cu.m to 1650 kg/cu.m. This test can be done with the help of two beakers having same amount of cement. The cement in one beaker is slightly vibrated which shows a decrease in the volume.

## Types of Cement in India

There are some varieties in cement that always find good demand in the market. To know their characteristics and in which area they are most required, it will be better to take a look at some of the details given below.

- TM **Portland Blast Furnace slag cement (PBFSC):** The rate of hydration heat is found lower in this cement type in comparison to PPC. It is most useful in massive construction projects, for example - dams.
- TM **Sulphate Resisting Portland Cement:** This cement is beneficial in the areas where concrete has an exposure to seacoast or sea water or soil or ground water. Under any such instances, the concrete is vulnerable to sulphates attack in large amounts and can cause damage to the structure. Hence, by using this cement one can reduce the impact of damage to the structure. This cement has high demand in India.
- TM **Rapid Hardening Portland Cement:** The texture of this cement type is quite similar to that of OPC. But, it is bit more fine than OPC and possesses immense compressible strength, which makes casting work easy.
- TM **Ordinary Portland Cement (OPC):** Also referred to as grey cement or OPC, it is of much use in ordinary concrete construction. In the production of this type of cement in India, Iron ( $\text{Fe}_2\text{O}_3$ ), Magnesium ( $\text{MgO}$ ), Silica ( $\text{SiO}_2$ ), Alumina ( $\text{Al}_2\text{O}_3$ ), and Sulphur trioxide ( $\text{SO}_3$ ) components are used.

- ™ **Portland Pozzolona Cement (PPC):** As it prevents cracks, it is useful in the casting work of huge volumes of concrete. The rate of hydration heat is lower in this cement type. Fly ash, coal waste or burnt clay is used in the production of this category of cement. It can be availed at low cost in comparison to OPC.
- ™ **Oil Well Cement:** Made of iron, coke, limestone and iron scrap, Oil Well Cement is used in constructing or fixing oil wells. This is applied on both the off-shore and on-shore of the wells.
- ™ **Clinker Cement:** Produced at the temperature of about 1400 to 1450 degree Celsius, clinker cement is needed in the construction work of complexes, houses and bridges. The ingredients for this cement comprise iron, quartz, clay, limestone and bauxite.
- ™ **White cement:** It is a kind of Ordinary Portland Cement. The ingredients of this cement are inclusive of clinker, fuel oil and iron oxide. The content of iron oxide is maintained below 0.4% to secure whiteness. White cement is largely used to increase the aesthetic value of a construction. It is preferred for tiles and flooring works. This cement costs more than grey cement.

SINo	Types Of Cement	Reference Indian Standard
1	Ordinary Portland Cement 33 Grade	IS:269
2	Ordinary Portland Cement 43 Grade	IS:8112
3	Ordinary Portland Cement 53 Grade	IS:12269
4	Rapid Hardening Cement	IS:8041
5	Extra Rapid Hardening Cement	—
6	Sulphate Resisting Cement	IS:12330
7	Portland Slag Cement	IS:455
8	Quick Setting Cement	—
9	Super Sulphated Cement	IS:6909
10	Low Heat Cement	IS:12600
11	Portland Pozzolana Cement (Fly ash based)	IS:1489 P-1
12	Portland Pozzolana Cement (Calcined IS:1489 P-2 based)	IS:1489 P-2
13	Air Entraining Cement	—
14	Coloured Cement: White Cement	IS:8042
15	Hydrophobic Cement	IS:8043
16	Masonry Cement	IS:3466
17	Expansive Cement	—
18	Oil Well Cement	IS:8229

19	Rediset Cement	—
20	Concrete Sleeper Grade Cement	IRS-R 40
21	High Alumina Cement	IS:6452
22	Very High Strength Cement	—

Types of Cement		Composition	Purpose
Rapid Cement	Hardening	Increased Lime content	Attains high strength in early days it is used in concrete where form work are removed at an early stage.
Quick setting cement		Small percentage of aluminium sulphate as an accelerator and reducing percentage of Gypsum with fine grinding	Used in works is to be completed in very short period and concreting in static and running water
Low Heat Cement		Manufactured by reducing tri-calcium aluminate	It is used in massive concrete construction like gravity dams
Sulphates resisting Cement		It is prepared by maintaining the percentage of tricalcium aluminate below 6% which increases power against sulphates	It is used in construction exposed to severe sulphate action by water and soil in places like canals linings, culverts, retaining walls, siphons etc.,
Blast Furnace Slag Cement		It is obtained by grinding the clinkers with about 60% slag and resembles more or less in properties of Portland cement	It can used for works economic considerations is predominant.
High Alumina Cement		It is obtained by melting mixture of bauxite and lime and grinding with the clinker it is rapid hardening cement with initial and final setting time of about 3.5 and 5 hours respectively	It is used in works where concrete is subjected to high temperatures, frost, and acidic action.
White Cement		It is prepared from raw materials free from Iron oxide.	It is more costly and is used for architectural purposes such as pre-cast curtain wall and facing panels, terrazzo surface etc.,
Coloured cement		It is produced by mixing mineral pigments with ordinary cement.	They are widely used for decorative works in floors
Pozzolanic Cement		It is prepared by grindin pozzolanic clinker with Portland cement	It is used in marine structures, sewage works, sewage works and for laying concrete under water such as bridges, piers, dams etc.,



Air Entraining Cement	It is produced by adding indigenous air entraining agents such as resins, glues, sodium salts of Sulphates etc during the grinding of clinker.	This type of cement is specially suited to improve the workability with smaller water cement ratio and to improve frost resistance of concrete.
Hydrographic cement	It is prepared by mixing water repelling chemicals	This cement has high workability and strength



## CONCRETE CHEMICALS AND APPLICATIONS

### Concrete Chemicals (Admixtures) and Applications

#### Concrete-Admixtures

Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color. Some admixtures have been in use for a very long time in concrete construction, such as calcium chloride to provide a cold-weather setting concrete.

Based on their functions, admixtures can be classified into the following five major categories:

- Retarding admixtures
- Accelerating admixtures
- Super plasticizers
- Water reducing admixtures
- Air-entraining admixtures

Among other important admixtures that do not fit into these categories are admixtures whose functions include bonding, shrinkage reduction, damp proofing and coloring. The following paragraphs provides details on the above-mentioned categories of concrete admixtures. Retarding Admixtures

**Retarding admixtures** slow down the hydration of cement, lengthening set time. Retarders are beneficially used in hot weather conditions in order to overcome accelerating effects of higher temperatures and large masses of concrete on concrete setting time. Because most retarders also act as water reducers, they are frequently called water-reducing retarders. As per chemical admixture classification by ASTM-ASTM C 494, type B is simply a retarding admixture, while type D is both retarding and water reducing, resulting in concrete with greater compressive strength because of the lower water-cement ratio.

Retarding admixtures consists of both organic and inorganic agents. Organic retardants include unrefined calcium, sodium,  $\text{NH}_4$ , salts of lignosulfonic acids, hydrocarboxylic acids, and carbohydrates. Inorganic retardants include oxides of lead and zinc, phosphates, magnesium salts, fluorates and borates. As an example of a retardant's effects on concrete properties, lignosulfate acids and hydroxylated carboxylic acids slow the initial setting time by at least an hour and no more than three hours when used at 65 to 100 degrees Fahrenheit. The concrete contractor, however, need not memorize these chemical-specific results. Given the specific job requirements and goals, the concrete supplier should offer appropriate admixtures and concrete mixes from which to choose.

Accelerating admixtures

**Accelerators** shorten the set time of concrete, allowing a cold-weather pour, early removal of forms, early surface finishing, and in some cases, early load application. Proper care must be taken while choosing the type and proportion of accelerators, as under most conditions, commonly used accelerators cause an increase in the drying shrinkage of concrete.

Calcium chloride is a common accelerator, used to accelerate the time of set and the rate of strength gain. It should meet the requirements of ASTM D 98. Excessive amounts of calcium chloride in concrete mix may result in rapid stiffening, increase in drying shrinkage and corrosion of reinforcement. In colder climates, calcium chloride should not be used as an anti-freeze. Large amount of calcium chloride is required to lower the freezing point of the concrete, which may ruin the concrete. Super plasticizers

**Super plasticizers**, also known as plasticizers, include water-reducing admixtures. Compared to what is commonly referred to as a —water reducer or —mid-range water reducer, super plasticizers are —high-range water reducers. High range water reducers are admixtures that allow large water reduction or greater flowability (as defined by the manufacturers, concrete suppliers and industry standards) without substantially slowing set time or increasing air entrainment.

Each type of super plasticizer has defined ranges for the required quantities of concrete mix ingredients, along with the corresponding effects. They can maintain a specific consistency and workability at a greatly reduced amount of water. Dosages needed vary by the particular concrete mix and type of super plasticizer used. They can also produce a high strength concrete. As with most types of admixtures, super plasticizers can affect other concrete properties as well. The specific effects, however, should be found from the manufacturer or concrete supplier.

Water reducing admixtures

**Water reducing admixtures** require less water to make a concrete of equal slump, or increase the slump of concrete at the same water content. They can have the side effect of changing initial set time. Water reducers are mostly used for hot weather concrete placing and to aid pumping. A water-reducer plasticizer, however, is a hygroscopic powder, which can entrain air into the concrete mix via its effect on water's surface tension, thereby also, obtaining some of the benefits of air-entrainment (see below).

### **Air-entraining admixtures**

Air-entraining agents entrain small air bubbles in the concrete. The major benefit of this is enhanced durability in freeze-thaw cycles, especially relevant in cold climates. While some strength loss typically accompanies increased air in concrete, it generally can be overcome by reducing the water-cement ratio via improved workability (due to the air-entraining agent itself) or through the use of other appropriate admixtures. As always, admixtures should only be combined in a concrete mix by a competent professional because some of them can interact in undesirable ways. Bonding admixtures

**Bonding admixtures** including addition of compounds and materials such as polyvinyl chlorides and acetates, acrylics and butadiene-styrene co-polymers, can be used to assist in bonding new / fresh concrete with old / set concrete.

**Coloring agents** have become more commonly used, especially for patios and walkways. Most are surface applied and often have the additional effect of surface hardening. Such surface applied coloring admixtures generally should not be used on air-entrained concrete. Integrally colored concrete is also available.

### **Waterproofing and damp proofing admixtures**

Water proofing and damp proofing admixtures including soaps, butyl stearate, mineral oil and asphalt emulsions, are used to decrease the amount of water penetration into the larger pores of concrete. —Antifreeze admixtures typically are accelerators used in very high doses, with a corresponding high price, to achieve a very fast set-time, though they do not have properties to protect against freezing on their own. However, in general, these are not used for residential work. How we make cement (wet process technology)

The manufacture of cement is a very carefully regulated process comprising the following stages:

1. **Quarrying** - a mixture of limestone and clay.
2. **Grinding** - the limestone and clay with water to form a slurry.
3. **Burning** - the slurry to a very high temperature in a kiln, to produce clinker.
4. **Grinding** - the clinker with about 5% gypsum to make cement.

### **Raw Materials Extraction**

The limestone and clay occur together in our quarries at Cape Foulwind. It is necessary to drill and blast these materials before they are loaded in 70t capacity trucks.

The quarry trucks deliver the raw materials to the crusher where the rock is crushed to smaller than 100mm (4 inches). The raw materials are then stored ready for use.

### **Raw Materials Preparation**

About 80% limestone and 20% clay are ground in ball mills with water, producing very fine, thin, paste called slurry. The chemical composition of the slurry is very carefully controlled by adjusting the relative amount of limestone and clay being used.

The slurry is stored in large basins ready for use.

### **Clinker**

### **Burning**

The slurry is fed into the upper end of a rotary kiln, while at the lower end of the kiln, a very intense flame is maintained by blowing in finely ground coal.

The slurry slowly moves down the kiln and is dried and heated until it reaches a temperature of almost 1500 degrees Celsius producing "clinker". This temperature completely changes the limestone and clay to produce new minerals which have the property of reacting with water to form a cementitious binder. The hot clinker is used to preheat the air for burning the coal, and the cooled clinker is stored ready for use.

## Cement Milling

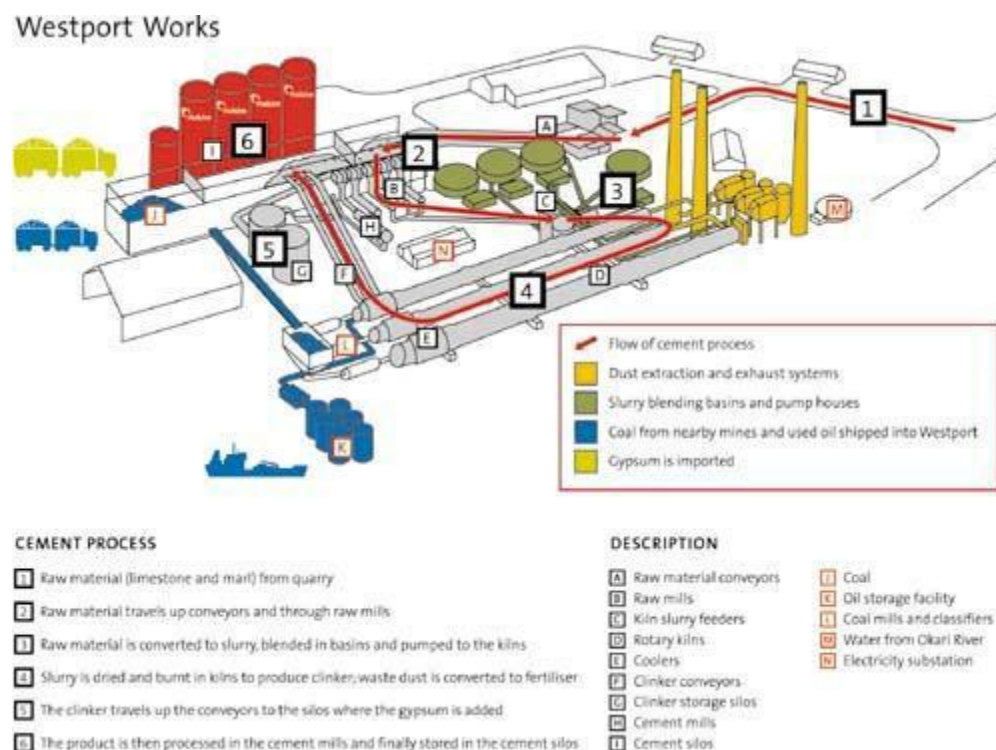
The clinker is finely ground with about 5% gypsum in another ball mill, producing cement. (The gypsum regulates the early setting characteristic of cement). The finished cement is stored in silos then carted to our wharf or packing plant facilities.

## Some Facts and Figures

The mills for grinding the raw materials are 2.4m in diameter and 11.0m long and are driven by 720kw (1000HP) electric motors producing 45t/h of slurry. The cement is ground in two mills: one 2.4m x 11.0m long producing 18t/h of cement; the other 3.8m x 11.4m, powered by 2300kw (3000 HP) electric motor and producing 60 t/h of cement. The kilns are either 98m or 110m long, and produce up to 25 t/h of clinker.

Two ships, the mv "Westport" and mv "Milburn Carrier II" carry cement to depots at Onehunga, Wellington, Napier, Gisborne, Nelson, Lyttelton and Dunedin for distribution to customers.

The diagram below details the Westport Works production process.



## How cement is made (dry process technology)

A new plant at Weston near Oamaru would use dry process technology to produce cement.

Limestone and silica-rich sand or rock is quarried and crushed, and transported to storage stockpiles near the kiln where pre-blending takes place.

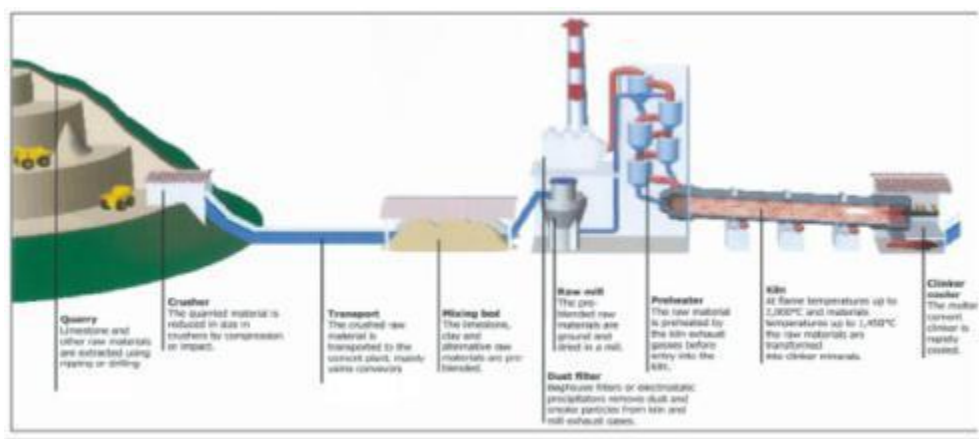
The raw materials are dried, ground and mixed to form a fine, homogenous powder, with moisture content of less than one percent.

This powder is fed into the kiln where the heat promotes the necessary chemical reactions. The kiln exhaust gases are the main source of heat used to dry the raw materials.

This is known as 'dry process' technology because no water is added to the ground raw materials. It is the process used by modern cement manufacturing plants.

Older cement kilns (including those at our current Westport plant) use a wet process, where the ground material is mixed with water to produce slurry, which is then fed to the kiln.

TM How we make cement



A modern 'dry process' plant uses approximately half the energy of a 'wet process' plant

## CEMENT MORTAR

### What is Mortar?

**Mortar is a mixture of sand and cements** that is most often used to build brick or block walls. In my July blog on cement and concrete I dealt exclusively with portland cement products and uses. I also promised that at a later date I would talk about the masonry world. For those of you on the edge of your seats since then, well today is your lucky day.

While Portland cement concrete is certainly one of the most widely used building product in the world, masonry mortar is close behind. It is doubtful that you live or work in a building that doesn't have mortar in it somewhere. The 3/8" gray line of material that separates the brick or block is mortar. Mortar is a very different animal than concrete. Concrete is designed to be used in thicker applications and to reach very high strengths. It achieves its durability through brute force. Mortar is also designed to be durable but achieves its goal through finesse. Its strengths are quite low compared with concrete and it is never used in thick applications. It is much creamier and more workable than concrete. If you play tennis, think of concrete as your most powerful serve when you are trying to smash the ball into or through your opponent so that they can't return the serve. Then think of mortar as a very gently placed lob close to the net that gets your opponent leaning the wrong way with no chance of returning the ball. Both achieve the desired result of earning you a point. The point of this long winded analogy is to let you know that using concrete and mortar interchangeably will lead to disaster.

### Types of Masonry Cement & Mortar

CEMEX's Masonry Cements are produced in Type N Masonry Cement, Type S Masonry Cement and Type M Masonry Cement strength levels for use in preparation of ASTM Specification C-270 Type N, M or Type S Masonry Mortar, respectively without any further additions.

Table 1 is a general guide for selection of mortar type. Other factors, such as type and absorption of masonry unit, climate and exposure, applicable building codes, and engineering requirements should also be considered.

TABLE 1 Recommended Guide for Selection of Mortar Type	
Building Segment	Mortar Type
Exterior, above grade, load-bearing non load-bearing parapet wall	N or S or M N N or S
Exterior, at or below grade	S or M
Interior load-bearing non load-bearing	N or S N

## Cement Concrete

**Concrete** is a composite material composed of aggregate bonded together with a fluid cement which hardens over time. Most use of the term "concrete" refers to Portland cement concrete or to concretes made with other hydraulic cements. However, technically road pavement is also a type of concrete, "asphaltic concrete", where the cement material is bitumen.

## Properties of Cement Concrete

The cement concrete possesses the following important properties:

1. It possesses a high compressive strength.
2. It is a corrosion resistance material and atmospheric agent has no appreciable effect on it.
3. It hardens with age the process of hardening continues for a long time after the concrete has attained sufficient strength. It is this property of cement concrete which gives it a distinct place among building materials.
4. It is more economical than steel.
5. It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as the reinforced cement concrete or simply as R.C.C.
6. Under the following two conditions, it has a tendency to shrink:
  1. There is initial shrinkage of cement concrete which is mainly due to the loss of water through forms, absorption by surfaces of forms etc.
  2. The shrinkage of cement concrete occurs as it hardens. This tendency of cement concrete can be minimized by proper curing of concrete.
7. It has a tendency to be porous. This is due to the presence of voids which are formed during and after its placing. The two precautions necessary to avoid this tendency are as follows:
  1. There should be proper grading and consolidating of the aggregates.
  2. The minimum water-cement ratio should be adopted.
8. It forms a hard surface, capable of resisting abrasion.
9. It should be remembered that apart from other materials, the concrete comes to the site in the form of raw materials only. Its final strength and quality depend entirely on local conditions and persons handling it. However the materials which concrete is composed may be subjected to rigid specifications

## Process of manufacture of concrete

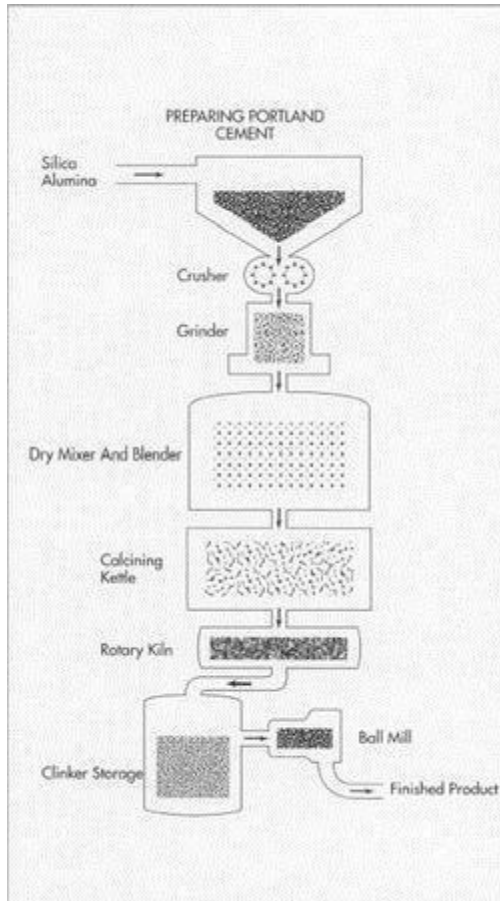
### *Mixing*

- <sup>TM</sup> 3 The cement is then mixed with the other ingredients: aggregates (sand, gravel, or crushed stone), admixtures, fibers, and water. Aggregates are pre-blended or added at the ready-mix concrete plant under normal operating conditions. The mixing operation uses rotation or stirring to coat the surface of the aggregate with cement paste and to blend the other ingredients uniformly. A variety of batch or continuous mixers are used.
- <sup>TM</sup> 4 Fibers, if desired, can be added by a variety of methods including direct spraying, premixing, impregnating, or hand laying-up. Silica fume is often used as a dispersing or densifying agent.



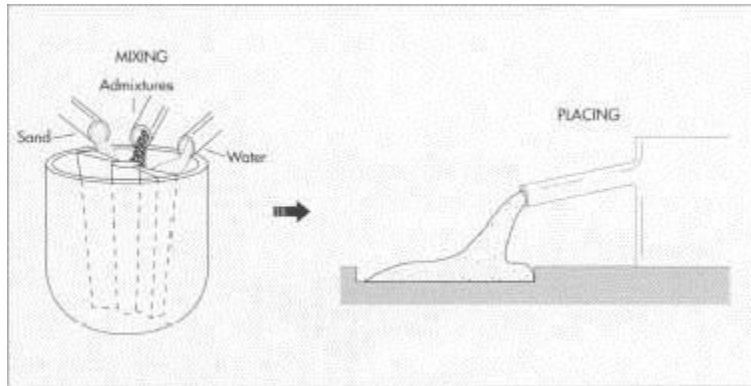
**Transport to work site**

- TM 5 Once the concrete mixture is ready, it is transported to the work site. There are many methods of transporting concrete, including wheelbarrows, buckets, belt conveyors,



The first step in making concrete is to prepare the cement. One type of cement, Portland cement, is considered superior to natural cement because it is stronger, more durable, and of a more consistent quality. To make it, the raw materials are crushed and ground into a fine powder and mixed together. Next, the material undergoes two heating steps—calcining and burning. In calcining, the materials are heated to a high temperature but do not fuse together. In burning, however, the materials partially fuse together, forming a substance known as "clinker." The clinker is then ground in a ball mill—a rotating steel drum filled with steel balls that pulverize the material.





After the Portland cement is prepared, it is mixed with aggregates such as sand or gravel, admixtures, fibers, and water. Next, it is transferred to the work site and placed. During placing, segregation of the various ingredients must be avoided so that full compaction—elimination of air bubbles—can be achieved.

special trucks, and pumping. Pumping transports large quantities of concrete over large distances through pipelines using a system consisting of a hopper, a pump, and the pipes. Pumps come in several types—the horizontal piston pump with semi-rotary valves and small portable pumps called squeeze pumps. A vacuum provides a continuous flow of concrete, with two rotating rollers squeezing a flexible pipe to move the concrete into the delivery pipe.

### ***Placing and compacting***

<sup>TM</sup> 6 Once at the site, the concrete must be placed and compacted. These two operations are performed almost simultaneously. Placing must be done so that segregation of the various ingredients is avoided and full compaction—with all air bubbles eliminated—can be achieved. Whether chutes or buggies are used, position is important in achieving these goals. The rates of placing and of compaction should be equal; the latter is usually accomplished using internal or external vibrators. An internal vibrator uses a poker housing a motor-driven shaft. When the poker is inserted into the concrete, controlled vibration occurs to compact the concrete. External vibrators are used for precast or thin in situ sections having a shape or thickness unsuitable for internal vibrators. These type of vibrators are rigidly clamped to the formwork, which rests on an elastic support. Both the form and the concrete are vibrated. Vibrating tables are also used, where a table produces vertical vibration by using two shafts rotating in opposite directions.

### ***Curing***

<sup>TM</sup> 7 Once it is placed and compacted, the concrete must be cured before it is finished to make sure that it doesn't dry too quickly. Concrete's strength is influenced by its moisture level during the hardening process: as the cement solidifies, the concrete shrinks. If site constraints prevent the concrete from contracting, tensile stresses will develop, weakening the concrete. To minimize this problem, concrete must be kept damp during the several days it requires to set and harden.

## Concrete Mix Design As Per Indian Standard Code

# Concrete Mix Design

### Introduction

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

### Requirements of concrete mix design

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

- a ) The minimum compressive strength required from structural consideration
- b) The adequate workability necessary for full compaction with the compacting equipment available.
- c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions
- d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

## Types of Mixes

### 1. Nominal Mixes

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

### 2. Standard mixes

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed 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  $\text{N/mm}^2$ . The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

### 3. Designed Mixes

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed  $30 \text{ N/mm}^2$ . No control testing is necessary reliance being placed on the masses of the ingredients.

#### Factors affecting the choice of mix proportions

The various factors affecting the mix design are:

#### 1. Compressive strength

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete

at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

## **2. Workability**

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

## **3. Durability**

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

## **4. Maximum nominal size of aggregate**

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate.

IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

## **5. Grading and type of aggregate**

The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.

The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

## **6. Quality Control**

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and

minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

## Mix Proportion designations

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass

### Factors to be considered for mix design

- ☐ The grade designation giving the characteristic strength requirement of concrete.
- ☐ The type of cement influences the rate of development of compressive strength of concrete.
- ☐ Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
- ☐ The cement content is to be limited from shrinkage, cracking and creep.
- ☐ The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

## Procedure

1. Determine the mean target strength  $f_t$  from the specified characteristic compressive strength at 28-day  $f_{ck}$  and the level of quality control.

$$f_t = f_{ck} + 1.65 S$$

where S is the standard deviation obtained from the Table of approximate contents given after the design mix.

2. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.
3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.
5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.
7. Calculate the cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[ W + \frac{C}{S_c} + \frac{1}{p} \frac{f_a}{S_{fa}} \right] \times \frac{1}{1000}$$

$$V = \left[ W + \frac{C}{S_c} + \frac{1}{1-p} \frac{C_a}{S_{ca}} \right] \times \frac{1}{1000}$$

where V = absolute volume of concrete

= gross volume ( $1\text{m}^3$ ) minus the volume of entrapped

air  $S_c$  = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

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

$f_a$ ,  $C_a$  = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and

$S_{fa}$ ,  $S_{ca}$  = specific gravities of saturated surface dry fine and coarse aggregates, respectively

9. Determine the concrete mix proportions for the first trial mix.

10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.
11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

### ***Mixing Ratio for Concrete in:***

#### **M5**

- \* Mix ratio for M5 concrete is 1:5:10
- \* compressive strength is 5N/mm<sup>2</sup> @ 28 days.
- \* 1 part of cement, 5 parts of sand, 4 parts of coarse aggregate.

M-7.5 -1:4:8

M-10 - 1:3:6

M-15 - 1:2:4

M-20 - 1:1.5:3

M-25 -1:1:2

M-30 - M-40

**M- 40** is strongest It depends upon the design mix, . M-40 means its strength is 40N/mm<sup>2</sup>

Water: cement: F.A.: C.A. = 0.4: 1: 1.65: 2.92

## **TYPES OF CONCRETE WITH APPLICATIONS**

Types of concrete with applications for different structural components like beams, columns, slabs, foundations are explained here. Special concrete with uses.

### **Light weight concrete**

One of the main advantages of conventional concrete is the self weight of concrete. Density of normal concrete is of the order of 2200 to 2600. This self weight will make it to some extent an uneconomical structural material.

Self weight of light weight concrete varies from 300 to 1850 kg/m<sup>3</sup>.

It helps reduce the dead load, increase the progress of building and lowers the hauling and handling cost.

The weight of building on foundation is an important factor in the design , particularly in case of weak soil and tall structures. In framed structure , the beam and column have to carry load of wall and floor. If these wall and floor are made of light weight concrete it will result in considerable economy.

Light weight concrete have low thermal conductivity.( In extreme climatic condition where air condition is to installed the use of light weight concrete with low thermal conductivity is advantageous from the point of thermal comfort and low power consumption.

Only method for making concrete light by inclusion of air. This is achieved by a) replacing original mineral aggregate by light weight aggregate, b) By introducing gas or air bubble in mortar c) By omitting sand fraction from concrete. This is called no – fine concrete.

Light weight aggregate include pumice, saw dust rice husk, thermocole beads, formed slag.

Etc Light weight concrete aggregate exhibit high fire resistance.

Structural lightweight aggregate's cellular structure provides internal curing through water entrainment which is especially beneficial for high-performance concrete

Lightweight aggregate has better thermal properties, better fire ratings, reduced shrinkage, excellent freezing and thawing durability, improved contact between aggregate and cement matrix, less micro-cracking as a result of better elastic compatibility, more blast resistant, and has better shock and sound absorption, High-Performance lightweight aggregate concrete also has less cracking, improved skid resistance and is readily placed by the concrete pumping method

Aerated concrete is made by introducing air or gas into a slurry composed of Portland cement.

No fine concrete is made up of only coarse aggregate , cement and water. These type of concrete is used for load bearing cast in situ external walls for building. They are also used for temporary structures because of low initial cost and can be reused as aggregate.

### **High density concrete**

The density of high density concrete varies from 3360 kg/m<sup>3</sup> to 3840 kg/m<sup>3</sup>. They can however be produced with density upto 5820 kg/m<sup>3</sup> using iron as both fine and coarse aggregate.

Heavyweight concrete uses heavy natural aggregates such as barites or magnetite or manufactured aggregates such as iron or lead shot. The density achieved will depend on the type of aggregate used. Typically using barites the density will be in the region of 3,500kg/m<sup>3</sup>, which is 45% greater than that of normal concrete, while with magnetite the density will be 3,900kg/m<sup>3</sup>, or 60% greater than normal concrete. Very heavy concretes can be achieved with iron or lead shot as aggregate, is 5,900kg/m<sup>3</sup> and 8,900kg/m<sup>3</sup> respectively.

They are mainly used in the construction of radiation shields (medical or nuclear). Offshore, heavyweight concrete is used for ballasting for pipelines and similar structures

The ideal property of normal and high density concrete are high modulus of elasticity , low thermal expansion , and creep deformation

Because of high density of concrete there will be tendency for segregation. To avoid this pre placed aggregate method of concreting is adopted.

High Modulus of Elasticity, Low thermal Expansion ,Low elasticity and creep deformation are ideal properties.

The high density. Concrete is used in construction of radiation shields. They are effective and economic construction material for permanent shielding purpose.

Most of the aggregate specific gravity is more than 3.5

### **Mass concrete**

Mass concrete is defined in ACI as —any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking. The design of mass concrete structures is generally based on durability, economy, and thermal action, with strength often being a secondary, rather than a primary, concern. The one characteristic that distinguishes mass concrete from other concrete work is thermal behavior. Because the cement-water reaction is exothermic by nature, the temperature rise within a large concrete mass,



where the heat is not quickly dissipated, can be quite high. Significant tensile stresses and strains may result from the restrained volume change associated with a decline in temperature as heat of hydration is dissipated. Measures should be taken where cracking due to thermal behavior may cause a loss of structural integrity and monolithic action, excessive seepage and shortening of the service life of the structure, or be aesthetically objectionable. Many of the principles in mass concrete practice can also be applied to general concrete work, whereby economic and other benefits may be realized. Mass concreting practices were developed largely from concrete dam construction, where temperature-related cracking was first identified. Temperature-related cracking has also been experienced in other thick-section concrete structures, including mat foundations, pile caps, bridge piers, thick walls, and tunnel linings

### **Ready-mix Concrete**

Ready-mix concrete has cement, aggregates, water and other ingredients, which are weigh-batched at a centrally located plant. This is then delivered to the construction site in truck mounted transit mixers and can be used straight away without any further treatment. This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites. Ready-mix concrete is sometimes preferred over on-site concrete mixing because of the precision of the mixture and reduced worksite confusion. However, using a pre-determined concrete mixture reduces flexibility, both in the supply chain and in the actual components of the concrete. Ready Mixed Concrete, or RMC as it is popularly called, refers to concrete that is specifically manufactured for delivery to the customer's construction site in a freshly mixed and plastic or unhardened state. Concrete itself is a mixture of Portland cement, water and aggregates comprising sand and gravel or crushed stone. In traditional work sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete. Ready Mixed Concrete is bought and sold by volume – usually expressed in cubic meters. Ready Mixed Concrete is manufactured under computer-controlled operations and transported and placed at site using sophisticated equipment and methods. RMC assures its customers numerous benefits.

### **Advantages of Ready mix Concrete over Site mix Concrete**

- A centralised concrete batching plant can serve a wide area.

- The plants are located in areas zoned for industrial use, and yet the delivery trucks can service residential districts or inner cities.

- Better quality concrete is produced.

- Elimination of storage space for basic materials at site.

- Elimination of procurement / hiring of plant and machinery

- Wastage of basic materials is avoided.

- Labor associated with production of concrete is eliminated.

- Time required is greatly reduced.

- Noise and dust pollution at site is reduced.

### **Disadvantages of Ready-Mix Concrete**

The materials are batched at a central plant, and the mixing begins at that plant, so the traveling time from the plant to the site is critical over longer distances. Some sites are just too far away, though this is usually a commercial rather than technical issue.

Access roads and site access have to be able to carry the weight of the truck and load. Concrete is approx. 2.5tonne per m<sup>2</sup>. This problem can be overcome by utilizing so-called 'minimix' companies, using smaller 4m<sup>3</sup> capacity mixers able to access more restricted sites.

Concrete's limited time span between mixing and going-off means that ready-mix should be placed within 2 hours of batching at the plant. Concrete is still usable after this point but may not conform to relevant specifications.

**Polymer concrete**

Concrete is porous. The porosity is due to air voids , water voids or due to inherent property of gel structures. On account of porosity strength of concrete is reduced , reduction of porosity result in increase in strength of concrete. The impregnation of monomer and subsequent polymerization is the latest technique adopted to reduce inherent porosity of concrete and increase strength and other properties of concrete

There are mainly 4 types of polymer concrete

1. Polymer impregnated concrete
2. Polymer cement concrete
3. Polymer concrete
4. Partially impregnated and surface coated polymer concrete.

**Polymer impregnated concrete**

It is a precast conventional concrete cured and dried in oven or by dielectric heating from which the air in the open cell is removed by vacuum. Then a low viscosity monomer is diffused through the open cell and polymerized by using radiation, application of heat or by chemical initiation.

Mainly the following type of monomers are used

Methyl methacrylate(MMA)

1. Acrylonitrile
2. t- butyl styrene
3. Other thermoplastic monomer
4. The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that has occupied the total void space.
5. PIC require cast in situ structures

Polymer cement concrete

Polymer cement concrete is made by mixing cement, aggregate, water and monomer. Such plastic mixture is cast in moulds , cured dried and polymerized. The monomer that are used in PCC are

1. Polyester- styrene
2. Epoxy-styrene
3. Furans
4. Vinylidene chloride

PCC produced in this way have been disappointing. In many cases material poorer than ordinary concrete is obtained. This is because organic material are incompatible with aqueous systems and some times interfere with the alkaline cement hydration process. Russians developed a superior polymer by incorporation of furfuryl alcohol and aniline hydrochloride in the wet mix. This material is dense and non shrinking and to have high corrosion resistance, low permeability and high resistance to vibration and axial extension. PCC can be cast in situ for field application.

### **Polymer concrete**

Polymer concrete is an aggregate bound with a polymer binder instead of Portland cement as in conventional concrete. The main technique in producing PC is to minimize void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregate. This is achieved by properly grading and mixing the aggregate to attain maximum density and minimum voids

### **Shotcrete**

It is defined as a mortar conveyed through a hose and pneumatically projected at high velocity on to a surface. There are mainly two different methods namely wet mix and dry mix process. In wet mix process the material is conveyed after mixing with water.

### **Pre packed concrete**

In constructions where the reinforcement is very complicated or where certain arrangements like pipe, opening or other arrangements are incorporated this type of concreting is adopted. One of the methods is concrete process in which mortar is made in a high speed double drum and grouting is done by pouring on prepacked aggregate. This is mainly adopted for pavement slabs Vacuum concrete

Concrete poured into a framework that is fitted with a vacuum mat to remove water not required for setting of the cement; in this framework, concrete attains its 28-day strength in 10 days and has a 25% higher crushing strength. The elastic and shrinkage deformations are considerably greater than for normal-weight concrete.

### **Pumped concrete**

Pumped concrete must be designed to that it can be easily conveyed by pressure through a rigid pipe of flexible hose for discharge directly into the desired area. Pozzocrete use can greatly improve concrete flow characteristics making it much easier to pump, while enhancing the quality of the concrete and controlling costs.

### **Mix Homogeneity**

The designer must be aware of the need to improve the grade and maintain uniformity of the various materials used in the pumped mix in order to achieve greater homogeneity of the total mix. Three mix proportioning methods frequently used to produce pump able concrete are :

Maximum Density of Combined Materials

Maximum Density – Least Voids

Minimum Voids – Minimum Area

Mixes must be designed with several factors in mind:

1. Pumped concrete must be more fluid with enough fine material and water to fill internal voids.
2. Since the surface area and void content of fine material below 300 microns control the liquid under pressure, there must be a high quantity of fine material in a normal mix. Generally speaking, the finer the material, the greater the control.
3. Coarse aggregate grading should be continuous, and often the sand content must be increased by up to five percent at the expense of the coarser aggregate so as to balance the 500 micron fraction against the finer solids.

### **Pozzocrete Effective**

Unfortunately, adding extra water and fine aggregate leads to a weaker concrete. The usual remedies for this are either to increase the cement content, which is costly, or to use chemical admixtures, which can also be costly and may lead to segregation in marginal mixes. There is another and far more effective alternative:

### **POZZOCRETE**

There are many advantages to including POZZOCRETE in concrete mixes to be pumped. Among them are :

1. Particle Size. Pozzocrete meets IS 3812 Specification with 66% passing the 325 (45-micron) sieve and these fine particles are ideal for void filling. Just a small deficiency in the mix fines can often prevent successful pumping.
2. Particle Shape. Microscopic examination shows most Pozzocrete particles are spherical and act like miniature ball bearings aiding the movement of the concrete by reducing frictional losses in the pump and pinning. Studies have shown that Pozzocrete can be twice as effective as cement in improving workability and, therefore, improve pumping characteristics.

### **Pozzolanic Activity:**

his chemical reaction combines the Pozzocrete particles with the calcium hydroxide liberated through the hydration of cement to form additional cementitious compounds which increase concrete strength.

### **Water Requirement:**

Excess water in pumped mixes resulting in over six inch slumps will often cause material segregation and result in line blockage. As in conventionally placed mixes, pumped concrete mixes with excessive water also contribute to lower strength, increased bleeding and shrinkage. The use of Pozzocrete in pumped or conventionally placed mixes can reduce the water requirement by 2% to 10% for any given slump.

### **Sand/Coarse Aggregate Ratio:**

In pumped mixes, the inclusion of liberal quantities of coarse aggregate can be very beneficial because it reduces the total aggregate surface area, thereby increasing the effectiveness of the available cementitious paste. This approach is in keeping with the —minimum voids, minimum areal proportioning method. As aggregate size increases, so does the optimum quantity of coarse aggregate. Unfortunately, this process is

frequently reversed in pump mixes, and sand would be substituted for coarse aggregate to make pumping easier. When that happens, there is a need to increase costly cementitious material to compensate for strength loss. However, if Pozzocrete is utilized, its unique workability and pump ability properties permit a better balance of sand to coarse aggregate resulting in a more economical, pump able concrete.

## **SHOTCRETE**

Shotcrete is a process where concrete is projected or "shot" under pressure using a feeder or "gun" onto a surface to form structural shapes including walls, floors, and roofs. The surface can be wood, steel, polystyrene, or any other surface that concrete can be projected onto. The surface can be trowelled smooth while the concrete is still wet.

### **Benefits**

Shotcrete has high strength, durability, low permeability, excellent bond and limitless shape possibilities. These properties allow shotcrete to be used in most cases as a structural material. Although the hardened properties of shotcrete are similar to conventional cast-in-place concrete, the nature of the placement process provides additional benefits, such as excellent bond with most substrates and instant or rapid capabilities, particularly on complex forms or shapes. In addition to building homes, shotcrete can also be used to build pools

### **Methods of Application**

**Wet Mix** – All ingredients, including water, are thoroughly mixed and introduced into the delivery equipment. Wet material is pumped to the nozzle where compressed air is added to provide high velocity for placement and consolidation of the material onto the receiving surface.

**Dry Mix** – Pre-blended dry or damp materials are placed into the delivery equipment. Compressed air conveys material through a hose at high velocity to the nozzle, where water is added. Material is consolidated on the receiving surface by the high-impact velocity.

### **Features**

The properties of both wet and dry process shotcrete can be further enhanced through the addition of many different additives or admixtures such as:

**Silica Fume** – Provides reduced permeability, increased compressive and flexural strength, increased resistance to alkali and chemical attack, improved resistance to water washout, reduced rebound levels and allows for thicker single pass applications.

**Air-Entraining Admixtures** – Improve pumpability and adhesion in wet-process shotcrete and freeze-thaw durability in both wet and dry processes.

**Fibers** – Control cracking, increase toughness values and improve impact resistance and energy absorption.

**Accelerators** – Improve placement characteristics in adverse conditions, allow for thicker single pass applications, increase production capabilities and reduce the occurrence of fallouts on structures subjected to vibratio

## EQUIPEMENTS USED FOR MANUFACTURING OF CONCRETE PRESENTATION BY: MANPREET SINGH AGAM TOMAR

### 1. VARIOUS STAGES OF MANUFACTURING OF CONCRETE

- $\frac{3}{4}$  BATCHING
- $\frac{3}{4}$  MIXING
- $\frac{3}{4}$  TRANSPORTING
- $\frac{3}{4}$  PLACING
- $\frac{3}{4}$  COMPACTING
- $\frac{3}{4}$  CURING
- $\frac{3}{4}$  FINISHING

2. **BATCHING** Batching is the process of measuring concrete mix ingredients by either mass or volume and introducing them into the mixer . To produce concrete of uniform quality, the ingredients must be measured accurately for each batch.

- $\frac{3}{4}$  Volume batching
- $\frac{3}{4}$  Weight batching

**Volume batching** • This method is generally adopted for small jobs . • Gauge boxes are used for measuring the fine and coarse aggregate. • The volume of gauge box is equal to the volume of one bag of cement. • Gauge boxes are also called as FARMAS • They can be made of timbers or steel. • They are made generally deep and narrow • Bottomless gauge boxes are generally avoided. • While filling the gauge boxes the material should be filled loosely, no compaction is allowed.

**Weight Batching** • Batching by weight is more preferable to volume batching ,as it is more accurate and leads to more uniform proportioning. • It does not have uncertainties associated with bulking. It's equipment falls into 3 general categories : I. Manual, II. Semi automatic, III. Fully automatic.

In case of manual batching all weighing and batching of concrete are done manually. It is used for small jobs.

**Semi automatic** In case of semi automatic batching the aggregate bin gates are opened by manually operated switches . And gates are closed automatically when the material has been delivered. This system also contains interlock which prevents charging and discharging. 3) **Fully automatic** In case of automatic batching the material are electrically activates by a single switch and complete autographic record are made of the weight of each material. The batching plant comprises 2,3,4 or 6 compartment bins of several capacities. Over the conveyor belt the weigh batchers discharging are provided below the bins

3. **Mixing** The mixing should be ensure that the mass becomes Homogeneous , uniform in colour and consistency . Methods of Mixing :
- 1. Hands(using hand shovels)
  - 2. Stationary Mixers
  - 3. Ready mix concrete

**Hand Mixing** Mixing ingredients of concrete by hands using ordinary tools like, hand shovels etc. This type of mixing is done for Less output of concrete.

**Stationary Mixers** • Concrete is sometime mixed at jobsite in a stationary mixer having a size of 9 cubic meter . • These mixers may be of : 1. Tilting type , 2. Non-Tilting type ,

**Tilting type mixer** • It consist a conical drum which rotates on an inclinable axis. • It has only one opening. • The drum charged directly and discharged by tilting and reversing the drum.

**Non tilting type mixer** • The mixing drum is cylindrical in shape and revolves two – horizontal axis. • It has opening on both sides. • The ingredients are charged in from one opening. • For discharging concrete chute is introducing to other opening by operating a lever.

**Ready Mixed Concrete** Ready mixed concrete is proportioned and mixed off at the project site and is delivered to the construction area in a freshly mixed and unhardened state. It can be manufactured by any of the following methods: ➔ 1. Central-mixed concrete ➔ 2. Truck-mixed concrete

**Central Mixed Concrete** • Central-mixed concrete ➔ mixed completely in a stationary mixer • delivered in Agitator Trucks A non-agitating truck

**Agitator Trucks** • A vehicle carrying a drum or agitator body, in which freshly mixed concrete can be conveyed from the point of mixing to that of placing, the drum being rotated continuously to agitate the contents. ⤵ Advantages: Operate usually from central mixing plants ⤵ Watch for: Timing of deliveries should suit job organization. Concrete crew and equipment must be ready onsite to handle concrete. ⤵ Used for: Transporting concrete for all uses. Haul distances must allow discharge of concrete within 1½ hours.

Agitator Trucks

**Non-agitating Trucks** ➔ Used for: Transport concrete on short hauls (small distance) over smooth roadways. ➔ Advantages: Cost of non-agitating equipment is lower than that of truck agitators or mixers. ➔ Watch for: Slump should be limited. Possibility of segregation. Height upon discharge is needed

**Truck-mixed concrete** ⤵ Used for: Intermittent (periodic) production of concrete at jobsite, or small quantities. ⤵ Advantages: Combined materials transporter and batching and mixing system. One-man operation.

#### 4. Transporting

1. Mortar Pan : Concrete is carried in small Quantities
  2. Wheelbarrows and Buggies : Short flat hauls on all types of onsite concrete construction
  3. Belt Conveyors : Conveying concrete horizontally or higher/lower level.
  4. Cranes and Buckets : Used for Work above ground level , Buckets use with Cranes, cableways, and helicopters.
  5. Pumps : Conveying concrete from central discharge point to formwork.
  6. Transit Mixer : used for transporting the concrete over long distance particularly in RMC plant .
5. **Compaction of concrete** • Compaction of concrete is process adopted for expelling the entrapped air from the concrete • In the process of mixing , transporting and placing of concrete air is likely



to get entrapped in the concrete . • It has been found from the experimental studies that 1% air in the concrete approximately reduces the strength by 6%. • If we don't expel this air, it will result into honeycombing and reduced strength

### Different Methods Of Concrete Compaction

1. Hand Compaction Rodding Ramming Tamping
2. Compaction by Vibration Internal vibrator Formwork Vibrator Table Vibrator Platform vibrator Surface vibrator .

**Hand Compaction** Hand compaction is used for ordinary and unimportant structures. Workability should be decided in such a way that the chances of honeycombing should be minimum. The various methods of hand compaction are as given below: **⚡ Rodding** It is a method of poking with 2m long, 16 mm dia. rod at sharp corners and edges. The thickness of layers for rodding should be 15 to 20 cm.

**Ramming** • It is generally used for compaction on ground in plain concrete. It is not used either in RCC or on upper floors. **⚡ Tamping** • It is a method in which the top surface is beaten by wooden cross beam of cross section 10 cm x 10 cm. both compaction and leveling are achieved simultaneously. It is mainly used for roof slabs and road pavements.

**Compaction by Vibration** • Vibration is imparted to the concrete by mechanical means. It causes temporary liquefaction so that air bubbles come on to the top and expelled ultimately. Mechanical vibration can be of various types as given under. **⚡ Internal Vibration** It is most commonly used technique of concrete vibration. Vibration is achieved due to eccentric weights attached to the shaft. The needle diameter varies from 20 mm to 75 mm and its length varies from 25 cm to 90 cm. the frequency range adopted is normally 3500 to 5000 rpm. The correct and incorrect methods of vibration using internal vibration needles are shown below.

**External Vibration** • This is adopted where internal vibration can't be used due to either thin sections or heavy reinforcement. External vibration is less effective and it consumes more power as compared to the internal vibration. The formwork also has to be made extra strong when external vibration is used

**Table Vibration** • It is mainly used for laboratories where concrete is put on the table

**Platform Vibration** • It is similar to table vibrators but these are generally used on a very large scale

**Surface Vibration** • These are also called screed board vibrators. The action is similar to that of tamping. The vibrator is placed on screed board and vibration is given on the surface. It is mainly used for roof slabs, road pavements etc., but it is not effective beyond 15 cm depth.

## 6. Curing Methods - Methods of Curing of

### Concrete Durability of Concrete

Curing can be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining a satisfactory moisture content and a favorable temperature in concrete during the period



immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.

If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a new born baby. Methods of Curing Concrete

## **METHODS FOR CURING OF CONCRETE**

There are various methods of curing. The adoption of a particular method will depend upon the nature of work and the climatic conditions. The following methods of curing of concrete are generally adopted.

Curing of Concrete

Curing of Concrete

1. Shading concrete work
2. Covering concrete surfaces with hessian or gunny bags
3. Sprinkling of water
4. Ponding method
5. Membrane curing
6. Steam curing

### **1. Shading Of Concrete Work**

The object of shading concrete work is to prevent the evaporation of water from the surface even before setting. This is adopted mainly in case of large concrete surfaces such as road slabs. This is essential in dry weather to protect the concrete from heat, direct sun rays and wind. It also protects the surface from rain. In cold weather shading helps in preserving the heat of hydration of cement thereby preventing freezing of concrete under mild frost conditions. Shading may be achieved by using canvas stretched on frames. This method has a limited application only.

### **2. Covering Concrete Surfaces With Hessian or Gunny Bags**

This is a widely used method of curing, particularly for structural concrete. Thus exposed surface of concrete is prevented from drying out by covering it with hessian, canvas or empty cement bags. The covering over vertical and sloping surfaces should be secured properly. These are periodically wetted. The interval of wetting will depend upon the rate of evaporation of water. It should be ensured that the surface of concrete is not allowed to dry even for a short time during the curing period. Special arrangements for keeping the surface wet must be made at nights and on holidays.

### **3. Sprinkling of Water**

Sprinkling of water continuously on the concrete surface provides an efficient curing. It is mostly used for curing floor slabs. The concrete should be allowed to set sufficiently before sprinkling is started. The spray can be obtained from a perforated plastic box. On small jobs sprinkling of water may be done by hand. Vertical and sloping surfaces can be kept continuously wet by sprinkling water on top surfaces and allowing it to run down between the forms and the concrete. For this method of curing the water requirement is higher.

#### 4. Ponding Method

This is the best method of curing. It is suitable for curing horizontal surfaces such as floors, roof slabs, road and air field pavements. The horizontal top surfaces of beams can also be ponded. After placing the concrete, its exposed surface is first covered with moist hessian or canvas. After 24 hours, these covers are removed and small ponds of clay or sand are built across and along the pavements. The area is thus divided into a number of rectangles. The water is filled between the ponds. The filling of water in these ponds is done twice or thrice a day, depending upon the atmospheric conditions. Though this method is very efficient, the water requirement is very heavy. Ponds easily break and water flows out. After curing it is difficult to clean the clay.

#### 5. Membrane Curing

The method of curing described above come under the category of moist curing. Another method of curing is to cover the wetted concrete surface by a layer of water proof material, which is kept in contact with the concrete surface of seven days. This method of curing is termed as membrane curing. A membrane will prevent the evaporation of water from the concrete. The membrane can be either in solid or liquid form. They are also known as sealing compounds. Bituminised water proof papers, wax emulsions, bitumen emulsions and plastic films are the common types of membrane used.

Whenever bitumen is applied over the surface for curing, it should be done only after 24 hours curing with gunny bags. The surface is allowed to dry out so that loose water is not visible and then the liquid asphalt sprayed throughout. The moisture in the concrete is thus preserved. It is quite enough for curing.

This method of curing does not need constant supervision. It is adopted with advantage at places where water is not available in sufficient quantity for wet curing. This method of curing is not efficient as compared with wet curing because rate of hydration is less. Moreover the strength of concrete cured by any membrane is less than the concrete which is moist cured. When membrane is damaged the curing is badly affected.

#### 6. Steam Curing

Steam curing and hot water curing is sometimes adopted. With these methods of curing, the strength development of concrete is very rapid.

These methods can best be used in pre cast concrete work. In steam curing the temperature of steam should be restricted to a maximum of 75°C as in the absence of proper humidity (about 90%) the concrete may dry too soon. In case of hot water curing, temperature may be raised to any limit, up to 100°C.

At this temperature, the development of strength is about 70% of 28 days strength after 4 to 5 hours. In both cases, the temperature should be fully controlled to avoid non-uniformity. The concrete should be prevented from rapid drying and cooling which would form cracks

#### Tests on Concrete

**SAMPLING** The first step is to take a test sample from the large batch of concrete. This should be done as soon as discharge of the concrete commences. The sample should be representative of

the concrete supplied. The sample is taken in one of two ways:

For purposes of accepting or rejecting the load: Sampling after  $0.2 \text{ m}^3$  of the load has been poured. For routine quality checks: Sampling from three places in the load.

### **a) Concrete Slump Test**

This test is performed to check the consistency of freshly made concrete. The slump test is done to make sure a concrete mix is workable. The measured slump must be within a set range, or tolerance, from the target slump.

Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It can also be defined as the relative plasticity of freshly mixed concrete as indicative of its workability.

#### **Tools and apparatus used for slump test (equipment):**

1. Standard slump cone (100 mm top diameter x 200 mm bottom diameter x 300 mm high)
2. **Small scoop**
  1. Bullet-nosed rod (600 mm long x 16 mm diameter)
3. **Rule**
  1. Slump plate (500 mm x 500 mm)

#### **Procedure of slump test for concrete:**

1. Clean the cone. Dampen with water and place on the slump plate. The slump plate should be clean, firm, level and non-absorbent. Collect a sample of concrete to perform the slump test.
2. Stand firmly on the footpieces and fill  $1/3$  the volume of the cone with the sample. Compact the concrete by 'rodding' 25 times. Rodding means to push a steel rod in and out of the concrete to compact it into the cylinder, or slump cone. Always rod in a definite pattern, working from outside into the middle.
3. Now fill to  $2/3$  and again rod 25 times, just into the top of the first layer.
4. Fill to overflowing, rodding again this time just into the top of the second layer. Top up the cone till it overflows.
5. Level off the surface with the steel rod using a rolling action. Clean any concrete from around the base and top of the cone, push down on the handles and step off the footpieces.
6. Carefully lift the cone straight up making sure not to move the sample.
7. Turn the cone upside down and place the rod across the up-turned cone.
8. Take several measurements and report the average distance to the top of the sample. If the sample fails by being outside the tolerance (ie the slump is too high or too low), another must be taken. If this also fails the remainder of the batch should be rejected.

**b) The Compression Test**

The compression test shows the compressive strength of hardened concrete. The compression test shows the best possible strength concrete can reach in perfect conditions. The compression test measures concrete strength in the hardened state. Testing should always be done carefully. Wrong test results can be costly.

The testing is done in a laboratory off -site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in Megapascals (MPa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it.

**Apparatus for compression test**

Cylinders (100 mm diameter x 200 mm high or 150 mm diameter x 300 mm high) (The small cylinders are normally used for most testing due to their lighter weight)

1. Small scoop
2. Bullet-nosed rod (600 mm x 16 mm)
3. Steel float
4. Steel plate

How to do a compression test?

Procedure for compression test of concrete

1. Clean the cylinder mould and coat the inside lightly with form oil, then place on a clean, level and firm surface, ie the steel plate. Collect a sample.
2. Fill 1/2 the volume of the mould with concrete then compact by rodding 25 times. Cylinders may also be compacted by vibrating using a vibrating table.
3. Fill the cone to overflowing and rod 25 times into the top of the first layer, then top up the mould till overflowing.
4. Level off the top with the steel float and clean any concrete from around the mould.
5. Cap, clearly tag the cylinder and put it in a cool dry place to set for at least 24 hours.

After the mould is removed the cylinder is sent to the laboratory where it is cured and crushed to test compressive strength

## Flow table test



Equipment; flow table, Abrams cone, waterbucket and broom.



The cone filled with concrete, prior to lifting.



The diameter of the resulting flow is measured.

The **flow table test** or **flow test** is a method to determine the consistence of fresh concrete. There is also another **flow table test** used to determine the Transportable Moisture Limit of solid bulk cargoes which are considered to be potentially liquefiable.<sup>[1]</sup>

**Application** When fresh concrete is delivered to a site by a truck mixer it is sometimes necessary to check its consistence before pouring it into formwork.

If the consistence is not correct, the concrete will not have the desired qualities once it has set, particularly the desired strength. If the concrete is too pasty, it may result in cavities within the concrete which leads to corrosion of the rebar, eventually leading to the formation of cracks (as the rebar expands as it corrodes) which will accelerate the whole process, rather like insufficient concrete cover. Cavities will also lower the stress the concrete is able to support.

## Equipment

- TM Flow table with a grip and a hinge, 70 centimetres (28 in) square.
- TM Abrams cone, open at the top and at the bottom - 30 centimetres (12 in) high, 17 centimetres (6.7 in) top diameter, 25 centimetres (9.8 in) base diameter.
- TM Water bucket and broom for wetting the flow table.
- TM Tamping rod, 60 centimetres (24 in) long

## Conducting the test

- TM The flow table is wetted.
- TM The cone is placed in the center of the flow table and filled with fresh concrete in two equal layers. Each layer is tamped 10 times with a tamping rod.

Wait 30 seconds before lifting the cone

- TM The cone is lifted, allowing the concrete to flow.
- TM The flow table is then lifted up 40mm and then dropped 15 times, causing the concrete to flow
- TM After this the diameter of the concrete is measured
- TM [Home](#)
- TM Products
- TM [Concrete](#)
- TM Kelly ball

## Kelly ball



This method is used to determine the penetration of a hemispherical metal weight into freshly mixed concrete, which is related to the workability of the concrete.

The apparatus consists of a cylinder with one end having a hemispherical shape and the other end fit with a graduated handle. The weight assembly is lowered through a frame into the concrete and the penetration measured.

™ Weight approx.: 15 kg

## **WORKABILITY TEST OF CONCRETE BY VEE-BEE CONSISTOMETER METHOD (IS-1199-1956)**

### **Objective**

To determine the workability of freshly mixed concrete by using of Vee – Bee consistometer apparatus.

### **Scope and Significance**

The workability of fresh concrete is a composite property, which includes the diverse requirements of stability, mobility, compactability, placeability and finishability. There are different methods for measuring the workability. Each of them measures only a particular aspect of it and there is really no unique test, which measures workability of concrete in its totality. This test gives an indication of the mobility and to some extent of the compactibility of freshly mixed concrete. The test measures the relative effort required to change a mass of concrete from one definite shape to another (i.e., from conical to cylindrical) by means of vibration. The amount of effort (called remoulding effort) is taken as the time in seconds, required to complete the change. The results of this test are of value when studying the mobility of the masses of concrete made with varying amounts of water, cement and with various types of grading of aggregate. The time required for complete remoulding in seconds is considered as a measure of workability and is



expressed as the number of Vee-Bee seconds. The method is suitable for dry concrete. For concrete of slump in excess of 50mm, the remoulding is so quick that the time cannot be measured.



Vee-Bee Consistometer

## Apparatus

- TM Cylindrical container,
- TM Vee-Bee apparatus (consisting of vibrating table, slump cone)
- TM Standard tamping rod,
- TM Stop watch and
- TM Trowels.

## Procedure

(1) Place the slump cone in the cylindrical container of the consistometer. Fill the cone in four layers, each approximately one quarter of the height of the cone. Tamp each layer with twenty-five strokes of the rounded end of the tamping rod. The strokes are distributed in a uniform manner over the cross-section of the cone and for the second and subsequent layers the tamping bar should penetrate into the underlying layer. After the top layer has been tamped, struck off level the concrete with a trowel making the cone exactly filled.

(2) Move the glass disc attached to the swivel arm and place it just on the top of the slump cone in the cylindrical container. Adjust the glass disc so as to touch the top of the concrete cone, and note the initial reading on the graduated rod.



(3) Remove the cone from the concrete immediately by raising it slowly and carefully in the vertical direction. Lower the transparent disc on the top of concrete. Note down the reading on the graduated rod.

(4) Determine the slump by taking the difference between the readings on the graduated rod recorded in the steps (2) and (3) above.

(5) Switch on the electrical vibrations and start the stopwatch. Allow the concrete to remould by spreading out in the cylindrical container. The vibrations are continued until the concrete is completely remoulded, i.e, the surfaces becomes horizontal and the whole concrete surface adheres uniformly to the transparent disc.

(6) Record the time required for complete remoulding seconds which measures the workability expressed as number of Vee-Bee seconds.

## Observations and Calculation

Initial reading on the graduated rod, **a**

Final reading on the graduated rod, **b**

Slump = **(b) – (a)**, in cm

Time for complete remoulding, seconds

## Results

The consistency of the concrete is reported in seconds.

## Standard Values

Workability Description	Vee-Bee Time (in Second)
Extremely Dry	32-18
Very Stiff	18-10
Stiff	10-5
Stiff Plastic	5-3
Plastic	3-0
Flowing	—

## Popular NDT Tests for Concrete Used in field are:

1. Rebound Hammer Test- RH Test
2. Ultrasonic Pulse Velocity- UPV Test
3. Combined Method UPV & RH Test
4. Core Extraction for Compressive Strength Test
5. Ingredient Analysis of Concrete Core
6. Concrete Cover Measurement by Laser Based Instt.

This paper, describes in detail only Rebound Hammer (RH) test, Ultrasonic Pulse Velocity (UPV) test & Core Test which are widely used & accepted by engineers at site and also referred in IS: 456-2000, under Inspection & Testing of Structures. These are followed by a description of the combined methods approach in which more than one nondestructive method is used to estimate strength of concrete. The Ingredient Analysis, Cover Measurement, Permeability, and Density methods are of limited application and are briefly described the concluding part of the paper.

### 1. Rebound Hammer–RH (Schmidt) Test

In 1948, a Swiss Engineer, Ernst Schmidt from Zurich developed a test hammer for measuring the hardness of concrete by the rebound principle. Since then the Rebound Hammer (RH) test has gained recognition at construction site & precast Industry.

#### Principle

The Schmidt Rebound Hammer is principally a surface hardness tester with little apparent theoretical relationship between the strength of concrete and the Rebound number of the hammer. However, within limits, empirical correlations have been established between strength properties & rebound number. This correlation between the concrete strength and rebound number is required to be established at site/field laboratories before it is used for strength estimation of concrete. Sometimes it is referred as field calibration of rebound hammer. Lab calibration are based on Brinell Hardness & Rebound Nos. are checked on std. calibrated Anvil for the purpose. Proper site calibrations eliminate the lab calibration, which is for the checking of hammer performance.

### Rebound Number and Compressive Strength

There is a general correlation between compressive strength of concrete and the hammer rebound number. Coefficients of variation for compressive strength for a wide variety of specimens averaged 25%. The large deviations in strength can be narrowed down considerably by proper calibration of the hammer, which allows for various variables discussed earlier. By consensus, the accuracy of estimation of compressive strength of test specimens cast, cured, and tested under laboratory conditions by a properly calibrated hammer lies between  $\pm 15$  and  $\pm 20\%$ . However, the probable accuracy of prediction of concrete strength in a structure is  $\pm 25\%$ .

### Limitations and Usefulness

The limitations of the Schmidt hammer are many; these should be recognized and allowances be made when using the hammer. It cannot be overstressed that this instrument must not be regarded as a substitute for standard compression tests but as a method for determining the uniformity of concrete in the structures and comparing one concrete by the Schmidt hammer within an accuracy of  $\pm 15$  to  $\pm 20\%$  may be possible only for specimens cast, cured, and tested under identical conditions as those from which the calibration curves are established. The prediction of strength of structural concrete by using calibration charts based on the laboratory test is not recommended.

## 2. Ultrasonic Pulse Velocity-UPV Test

The test instrument consists of a means of producing and introducing a wave pulse into the concrete and a means of sensing the arrival of the pulse and accurately measuring the time taken by the pulse to travel through the concrete.

Portable ultrasonic testing equipment are available. The equipment is portable, simple to operate, and includes rechargeable battery and charging unit. Typically, pulse times of up to 6500  $\mu$ s can be measured with 0.1- $\mu$ s resolution. The measured travel time is prominently displayed. The instrument comes with a set of two transducers, one each for transmitting and receiving the ultrasonic pulse. Transducers with frequencies of 25 to 100 KHz are usually used for testing concrete. These transducers primarily generate compressional waves at predominantly one frequency, with most of the wave energy directed along the axis normal to the transducer face.

### Factors Affecting UPV Test

Although it is relatively easy to conduct a pulse velocity test, it is important that the test be conducted such that the pulse velocity readings are reproducible and that they are affected only by the properties of the concrete under test rather than by other factors. The factors affecting the pulse velocity can be divided into two categories: (1) factors resulting directly from concrete properties; and (2) other factors. These influencing factors are discussed below:

### Effects of Concrete Properties

1. Aggregate Size, Grading, Type, and Content
2. Cement Type
3. Water-Cement Ratio
4. Admixtures
5. Age of Concrete

### Other Effects

1. Transducer Contact
2. Temperature of Concrete
3. Moisture and Curing Condition of Concrete
4. Path Length
5. Size and Shape of a Specimen

6. Level of Stress
7. Presence of Reinforcing Steel

## Applications of UPV Tests



UPV Test being perform on Deck Slab of Flyover on NH-2 at Firozabad (U.P.), India

The pulse velocity method has been applied successfully in the laboratory as well as in the field. It can be used for quality control, as well as for the analysis of deterioration. The applications of the pulse velocity method on a concrete structure are:

1. Estimation of Strength of Concrete
2. Establishing Homogeneity of Concrete
3. Studies on the Hydration of Cement
4. Studies on Durability of Concrete
5. Measurement of Surface Crack Depth
6. Determination of Dynamic Modulus of Elasticity

## Combined Method–UPV & RH Test



UPV Test being perform on Minor Bridge Pier on NH-11 at Dausa (Raj.), India

Hardness scales are arbitrarily defined measures of the resistance of a material to indentation under static or dynamic load or resistance to scratch, abrasion, wear, cutting or drilling. Concrete test hammers

evaluate surface hardness as a function of resiliency, i.e the ability of hammer to rebound or spring back.

The interpretation of the pulse velocity measurements in concrete is complicated by the heterogeneous nature of this material. The wave velocity is not determined directly, but is calculated from the time taken by a pulse to travel a measured distance. A piezoelectric transducer emitting vibration at its fundamental frequency is placed in contact with the concrete surface so that the vibrations travel through the concrete and are received by another transducer, which is in contact with the opposite face of the test object.

## Conclusion



Combined nondestructive methods refer to techniques in which one test is used to improve the reliability of the in site concrete strength estimated by means of another test alone.

The validity of a combined technique can be evaluated from the degree of improvement this additional test provides to the accuracy and reproducibility of predictions, vs. the additional cost and complexity of the combined method and the extent to which it is practicable to perform the additional test in site.

Of the various combinations proposed by different researchers and from the reported data it seems that only the combined techniques based on the Ultrasonic Pulse Velocity and surface hardness measurement have been adopted for practical evaluation of the in site compressive strength of concrete.



#### Diamond Bit Core Drilling

The limitations of a combined method are usually those pertinent to the limitations of each component test, except when a variation in the properties of concrete affects the component test, except when a variation in the properties of concrete affects the component test results in opposite directions. In this case, the errors can be self-correcting. Development of a prior correlation relationship is essential if the estimated from the combined test are to be meaningful. The more information that can be obtained about the concrete ingredients, proportions, age, curing conditions, etc. the more reliable the estimate is likely to be.

When testing suspect quality concrete of unknown composition, it is highly desirable to develop a prior correlation relationship in which factor such as aggregate type and approximate age of concrete are introduced as constants. For most in site concrete an approximate age and petrological type of aggregate can be determined, thus reducing the number of uncontrollable variables.



Core Drilling in Progress on the Inside Wall (After Epoxy Grouting) of Box Culvert on NH-26 at Sagar, (M.P.)

The most important influences on the accuracy and reliability of strength estimates seem to be the coarse aggregate type in the concrete.

When a reliable prior correlation relationship exists for a particular concrete type, the use of combined nondestructive techniques provides a realistic alternative to destructive testing. It often possible to perform a large and thus a representative number of tests at a reduced cost compared with coring, and without an adverse effects on the integrity of structural element.

## Core Extraction for Compressive Strength Test

### Test Specimens



Core Dressing-Cutting in Lab using Diamond Wheel Cutter in the Lab before Capping and Curing for Compressive Strength Test on CTM

**Core Specimens-** A core specimen for the determination of compressive strength shall have a diameter at least three times the maximum nominal size of the coarse aggregate used in the concrete, and in no case shall the diameter of the specimen be less than twice the maximum nominal size of the coarse aggregate. The length of the specimen, when capped, shall be as nearly as practicable twice its diameter.

### Procedure

**Core Drilling-** A core specimen taken perpendicular to a horizontal surface shall be located, when possible, with its axis perpendicular to the bed of the concrete as originally placed.

### Measurement of Drilled Core Specimens

**Mean Diameter-** The mean diameter shall be determined to the nearest millimeter from three pairs of measurements. The two measurements in each pair shall be taken at right angles to each other, one pair being taken at the middle of the core and the other pairs at the quarter points of the depth. The mean of the six readings shall be taken as the diameter.

**Position of Reinforcement-** The positions of any reinforcement shall be determined by measuring to the nearest millimetre from the centre of the exposed bars to the top of the core. The diameter and, if possible, the spacing of the bars shall be recorded, and also the minimum top and bottom cover.





Extracted Three Numbers of Cores (Making One Sample)  
from RCC Structure-Box Culvert on NH-26 at Sagar  
(M.P.)

**Capping-** The ends of the specimen shall be capped before testing. The material used for the capping shall be such that its compressive strength is greater than that of the concrete in the core. Caps shall be made as thin as practicable and shall not flow or fracture before the concrete fails when the specimen is tested. The capped surfaces shall be at right angles to the axis of the specimen and shall not depart from a plane by more than 0.05 mm.

## Apparatus

**Number of Specimens-** At least three specimens, preferably from different batches, shall be made for testing at each selected age.

**Procedure-** Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2 mm and their weight shall be noted before testing.



Capped and Cured Concrete Core Specimen under  
Compressive Strength Test in CTM

Calculation- The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than  $\pm 15\%$  of the average. Otherwise repeat tests shall be made.

A correction factor according to the height/diameter ratio of specimen after capping shall be obtained from the hardened curve. The product of this correction factor and the measured compressive strength shall be known as the corrected compressive strength, this being the equivalent strength of a cylinder having a height/diameter ratio of two. The equivalent cube strength of the concrete shall be determined by multiplying the corrected cylinder strength by 5/4..

## **EXTREME WEATHER CONCRETING**

In countries which experience extreme weather conditions special problems are encountered in preparation, placement and curing of concrete. India has regions of extreme hot weather (hot-humid and hot-arid) as well as cold weather. The Indian Standards dealing with extreme weather concreting are: IS: 7861 (Part 1-1975 Reaff. 2007)-Hot weather concreting and IS: 7861 (Part 2-1981 Reaff. 2007) -Cold weather concreting.

### **HOT WEATHER CONCRETING:**

Special problems are encountered in the preparation, placement and curing of concrete in hot weather. High temperature result in :

- $\frac{3}{4}$  Rapid hydration of cement
- $\frac{3}{4}$  Increased evaporation of mixing water
- $\frac{3}{4}$  Greater mixing water demand
- $\frac{3}{4}$  Large volume changes in concrete resulting in cracks.
- $\frac{3}{4}$  Reduction in strength.
  - The climatic factors affecting concrete in hot weather are:
- $\frac{3}{4}$  High ambient temperature
- $\frac{3}{4}$  Reduced relative humidity
- $\frac{3}{4}$  Increased wind velocity

Problems associated with hot weather concreting shall be addressed as follows:

- $\frac{3}{4}$  Controlling the temperature of concrete ingredients
- $\frac{3}{4}$  Suitable proportioning of concrete mixes.
- $\frac{3}{4}$  Controlling the temperature of concrete as placed.
- $\frac{3}{4}$  Controlling the processes such as concrete production and delivery
- $\frac{3}{4}$  Carrying out effective protection and curing of placed concrete.

## Controlling the temperature of concrete ingredients:

The most direct approach to keep concrete temperature down is by controlling the temperature of its ingredients. The contribution of each ingredient to the temperature of concrete is a function of the temperature, specific heat and quantity used of that ingredient. The aggregates and mixing water exert the most pronounced effect on temperature of concrete. Thus, in hot weather all available means shall be used for maintaining these materials at as low temperatures as practicable.

### Aggregates

Any one of the procedures or a combination of the procedures given below may be used for lowering the temperature or at least for preventing excessive heating of aggregates.

Shading stockpiles from direct rays of the sun.

Sprinkling the stockpiles of coarse aggregate with water and keeping them moist.

This results in cooling by evaporation, and this procedure is specially effective when relative humidity is low. Such sprinkling should not be done haphazardly because it leads to excessive variation in surface moisture and thereby impairs uniformity of workability. When coarse aggregates are stockpiled during hot weather, successive layers should be sprinkled as the stockpile is-built up. If cold water is available, heavy spraying of coarse aggregate immediately before use may also be done to have a direct cooling action. Coarse aggregates may also be cooled by methods, such as inundating them in cold water or by circulating refrigerated air through pipes or by other suitable methods.

### Water

The mixing water has the greatest effect on temperature of concrete, since it has a specific heat of about 4.5 to 5 times that of cement or aggregate. The temperature of water is easier to control than that of other ingredients and, even though water is used in smaller quantities than the other ingredients, the use of cold mixing water will effect a moderate reduction in concrete placing temperatures. For a nominal concrete mixture containing 336 kg of cement, 170 kg water, 1850 kg of aggregate per ma, a change in 2°C water temperature will effect a 0.5 ° C change in the concrete temperature.

Efforts shall be made to obtain cold water, and to keep it cold by protecting pipes, water storage tanks, etc. Tanks or trucks used for transporting water shall be insulated and/or coloured and maintained white or yellow. Under certain circumstances, reduction in water temperature may be most economically accomplished by mechanical refrigerator or mixing with crushed ice. Use of ice as a part of the mixing water is highly effective in reducing concrete temperature since, on melting alone, it takes up heat at the rate of 80 kcal/kg. To take advantage of heat of fusion, the ice shall be incorporated directly into the concrete as part of the mixing water. Conditions shall be such that the ice is completely melted by the time mixing is completed.

NOTE :- If the ice is not melted completely by the time mixing is completed, there can be a possibility of Ice melting after consolidation of concrete and thus leaving hollow pockets in concrete, with detrimental effects.

Recommended procedure for concreting during hot weather conditions is given below:

Ambient temperature shall be below 40°C at the time of placement of concrete. Concreting may be planned during morning and evening hours.

The period between mixing and delivery (placing) shall be kept an absolute minimum.

Keep aggregates under shade and cool aggregates by sprinkling water.

Formwork, reinforcement shall be sprinkled with cool water just prior to placement of concrete.

### **Case study of Extreme weather concreting**

#### **COLD WEATHER CONCRETING:**

The production of concrete in cold weather introduces special and peculiar problems which do not arise while concreting at normal temperatures. Quite apart from the problems associated with setting and hardening of cement concrete, severe damage may occur if concrete which is still in the plastic state is exposed to low temperature, thus causing ice lenses to form and expansion to occur within the pore structure. Hence it is essential to keep the temperature of the concrete above a minimum value before it is placed in the formwork. After placing, concrete may be kept above a certain temperature with the help of proper insulating methods before the protection is removed. During periods of low ambient temperature, special techniques are to be adopted to cure the concrete while it is in the formwork or after its removal.

The Precautions to be taken and methods adopted for concreting in sub-zero temperature is listed below.

- a. Utilization of the heat developed by the hydration of cement and practical methods of insulation.
- b. Selection of suitable type of cement
- c. Economical heating of materials of concrete

(Heating of water is the easiest to be adopted)

- d. Admixtures of anti-freezing materials
- e. Electrical heating of concrete mass
- f. Use of air-entraining agents

#### **READY MIX CONCRETE:**

Concrete is basically a mixture of Portland Cement, water and aggregates comprising sand and gravel or crushed stone. In traditional construction sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete. Ready Mix

Concrete, or RMX as it is popularly called, refers to concrete that is specifically manufactured elsewhere and transported in a Transit Mixer for delivery to the customer's construction site in a ready-to-use freshly mixed state. RMX can be custom-made to suit different applications. Ready Mix Concrete is bought and sold by volume - usually expressed in cubic meters.