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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – I– CONCRETE AND CONSTRUCTION TECHNOLOGY – SCIA1201

UNIT 1

INTRODUCTION 11 Hrs.

Mortar – Types – Sand – properties – uses Timber products: properties and uses of plywood, fibre board, particle board. Iron and Steel –Reinforcing steel – types – specifications. Structural steel – specifications miscellaneous materials (only properties, classifications and their use in construction industry): Glass, Plastics, A.C. Sheets, Bitumen, Adhesives, Aluminium. Cement – Different types – Chemical composition and Properties – Hydration of cement – Tests on cement – IS Specifications – Aggregates – Classification – Mechanical properties and tests as per BIS – Grading requirements – Water – Quality of water for use in concrete.

MORTAR

Mortar is a material used in masonry construction to fill the gaps between the bricks and blocks. **Mortar** is a mixture of sand, a binder such as cement or lime, and water and is applied as a paste which then sets hard. **Mortar** is a workable paste which hardens to bind building blocks such as stones, bricks, and concrete masonry units, to fill and seal the irregular gaps between them, spread the weight of them evenly, and sometimes to add decorative colors or patterns to masonry walls. In its broadest sense, mortar includes pitch, asphalt, and soft mud or clay, as used between mud bricks. The word "mortar" comes from Latin mortarium, meaning crushed.

Cement mortar becomes hard when it cures, resulting in a rigid aggregate structure; however, the mortar functions as a weaker component than the building blocks and serves as the sacrificial element in the masonry, because mortar is easier and less expensive to repair than the building blocks. Bricklayers typically make mortars using a mixture of sand, a binder, and water. The most common binder since the early 20th century is Portland cement, but the ancient binder lime mortar is still used in some specialty new construction. Lime, lime mortar and gypsum in the form of plaster of Paris are used particularly in the repair and repointing of historic buildings and structures so that the repair materials will be similar in performance and appearance to the original materials. Several types of cement mortars and additives exist.

What is the difference between cement and mortar?

Cement is a fine binding powder that is never used alone but is a component of both concrete and **mortar**, as well as stucco, tile grout, and thin-set adhesive. **Mortar** is composed of **cement**, fine sands and lime; it is used as a binding material when building with brick, block, and stone

What is mortar made of?

Masonry **mortar** is **composed of** one or more cementitious materials, fine mason sand and sufficient water to produce a workable mixture. The cementitious material may be a portland cement/lime mixture or masonry cement. A typical **mortar** consists of 1 part cementitious material to 2 ¼ - 3 ½ parts sand by volume

FIG. 1 MORTAR PLACED IN THE BRICK JOINT

TYPES OF MORTAR

Ancient mortar

Ordinary Portland cement mortar

Polymer cement mortar

Lime mortar

Pozzolanic mortar

Fire stop mortar

Radiocarbon dating

Ancient mortar

The first mortars were made of **mud and clay** as demonstrated in the 10th millennia BC buildings of Jericho, and the 8th millennia BCE of Ganj Dareh.

According to Roman Ghirshman, the first evidence of humans using a form of mortar was at the Mehrgarh of Baluchistan in the **Indus Valley, Pakistan, built of sun-dried bricks in 6500 BC**

Gypsum mortar, also called **plaster of Paris**, was used in the construction of many ancient structures. It is made from gypsum, which requires a lower firing temperature. It is therefore easier to make than lime mortar and sets up much faster, which may be a reason it was used as the typical mortar in ancient, brick arch and vault construction. Gypsum mortar is **not as durable as other mortars** in damp conditions.

In the Indian subcontinent, multiple cement types have been observed in the sites of the **Indus Valley Civilization**, with gypsum appearing at sites such as the Mohenjo-daro city-settlement that dates to **earlier than 2600 BC**.

Gypsum cement that was "**light grey** and contained sand, clay, traces of calcium carbonate, and a **high percentage of lime**" was used in the **construction of wells**, **drains**, and on the exteriors of "important looking buildings." **Bitumen mortar** was also used at a lower-frequency, including in the Great Bath **at Mohenjo-daro.**

In early **Egyptian pyramids**, which were constructed during the Old Kingdom (~2600–2500 BCE), the **limestone blocks** were bound by a **mortar of mud and clay,** or clay and sand. In later Egyptian pyramids, the mortar was made of gypsum, or lime. Gypsum mortar was essentially a mixture of plaster and sand and was quite soft.

2nd millennia BC **Babylonian** constructions used **lime or pitch** for **mortar**.

Historically, building with concrete and **mortar** next appeared **in Greece**. The excavation of the underground aqueduct of Megara revealed that a reservoir was coated with a **pozzolanic mortar** 12 mm thick. This aqueduct dates back to c. 500 BC Pozzolanic mortar **is a lime based mortar**, but is made with an additive of **volcanic ash** that allows it to be **hardened** underwater; thus it is known as **hydraulic cement**. The Greeks obtained the volcanic ash from the Greek islands Thira and Nisiros, or from the then Greek colony of Dicaearchia (Pozzuoli) near Naples, Italy. The Romans later improved the use and methods of making what became known as pozzolanic mortar and cement. Even later, the **Romans used a mortar** without pozzolana using **crushed terracotta**, introducing aluminum oxide and silicon dioxide into the mix. This mortar was not as strong as pozzolanic mortar, but, because it was denser, it better **resisted penetration by water.**

Hydraulic mortar was not available in ancient China, possibly due to a lack of volcanic ash. Around **500 AD**, sticky rice soup was mixed with slaked lime to make an inorganic and organic composite sticky **rice mortar** that had more strength and **water resistance** than lime mortar.

It is not understood how the art of making hydraulic mortar and cement, which was perfected and in such widespread use by both the Greeks and Romans, was then lost for almost two millennia. During the Middle Ages when the Gothic cathedrals were being built, the only active ingredient in the mortar was lime. Since cured lime mortar can be degraded by contact with water, many structures suffered over the centuries from wind-blown rain.

Ordinary Portland cement mortar

Ordinary Portland cement mortar, commonly known as **OPC mortar** or just cement mortar, is created by mixing powdered Ordinary Portland Cement, fine aggregate and water.

It was **invented in 1794** by Joseph Aspdin and patented on 18 December 1824, largely as a result of efforts to develop **stronger mortars**. It was made popular during the late nineteenth century, and had by 1930 became more popular than lime mortar as construction material. The advantages of Portland cement is that it **sets hard and quickly**, allowing a **faster pace of construction**. Furthermore, fewer skilled workers are required in building a structure with Portland cement.

As a general rule, however, Portland cement should not be used for the repair or pointing of older buildings built in lime mortar, which require the flexibility, softness and breathability of lime if they are to function correctly.

In the United States and other countries, **five standard types of mortar** (available as dry pre-mixed products) are generally used for both new construction and repair. Strengths of mortar change based on the mix ratio for each type of mortar, which are specified **under the ASTM standards**. These premixed mortar products are designated by one of the five letters, **M, S, N, O, and K. Type M mortar is the strongest, and Type K the weakest.**

Polymer cement mortar

Polymer cement mortars (PCM) are the materials which are made by **partially replacing the cement** hydrate binders of conventional cement mortar **with polymers**. The polymeric admixtures include latexes or emulsions, redispersible polymer powders, water-soluble polymers, liquid thermoset resins and monomers. Polymer mortar **has low permeability** that may be detrimental to moisture accumulation when used to repair a traditional brick, block or stone wall. It is mainly **designed for repairing concrete structures**.

Lime mortar

The setting speed can be increased by using impure limestone in the kiln, to form a **hydraulic lime** that will set on contact with water. Such a lime must be **stored as a dry powder**. Alternatively, a pozzolanic material such as calcined clay or brick dust may be added to the mortar mix. Addition of a pozzolanic material will make the mortar set reasonably quickly by reaction with the water.

It would be problematic to use Portland cement mortars to repair older buildings originally constructed using lime mortar. Lime mortar **is softer than cement mortar**, allowing brickwork a certain degree of flexibility to adapt to shifting ground or other changing conditions. Cement mortar is harder and allows little flexibility. The contrast can cause brickwork to crack where the two mortars are present in a single wall.

Lime mortar is considered breathable in that it will allow moisture to freely move through and evaporate from the surface. In old buildings with walls that shift over time, cracks can be found which allow rain water into the structure. The **lime mortar** allows this moisture to escape through evaporation and **keeps the wall dry**. Pointing or rendering an old wall with cement mortar stops the evaporation and can cause problems associated with moisture behind the cement.

Pozzolanic mortar

Pozzolana is a **fine**, sandy **volcanic ash**. It was originally discovered and dug at Pozzuoli, nearby Mount Vesuvius **in Italy**, and was subsequently mined at other sites, too. The **Romans** learned that pozzolana **added** to lime mortar allowed the lime to set relatively quickly and even **under water**. Vitruvius, the Roman architect, spoke of four types of pozzolana. It is found in all the volcanic areas of Italy in various **colours: black, white, grey and red**. Pozzolana has since become a generic term for any siliceous and/or aluminous additive to slaked lime to create hydraulic cement.

Finely grinned and mixed with lime it is hydraulic cement, like Portland cement, and makes a strong mortar that will also set under water.

Fire stop mortar

A firestop is a kind of passive fire protection measure. Firestop mortars are mortars most typically used to stop large openings in walls and floors required to have a fire-resistance rating. They differ in formula and properties from most other cementitious substances and cannot be substituted with generic mortars without violating the listing and approval use and compliance.

Firestop mortar is usually a **combination of chemical powder mixed with water**, forming a cementitious stone which dries hard. It is sometimes mixed with lightweight aggregates, such as perlite or vermiculite. It is sometimes pigmented to distinguish it from generic materials in an effort to prevent unlawful substitution and to enable verification of the certification listing.

Radiocarbon dating

As the mortar hardens, the current atmosphere is encased in the mortar and thus provides a sample for analysis. Various factors affect the sample and raise the margin of error for the analysis. The possibility to use **radiocarbon dating as a tool for mortar dating** was introduced as early as the 1960s, soon after the method was established (Delibrias and Labeyrie 1964; Stuiver and Smith 1965;

Folk and Valastro 1976). To evaluate the different anthropogenic carbon extraction methods for radiocarbon dating as well as to compare the different dating methods, i.e. radiocarbon and OSL, the first intercomparison study (MODIS) was set up and published in 2017.

TYPES OF MORTAR

Types of Mortars Used in Masonry Construction

Following are the types of mortars based on different factors:

- Based on **Applications**
- Based on **Binding Materials**
- Based on **Bulk Density**
- Based on **Strength** (ASTM C270)
- Based on **Special Purpose** of Mortars

BASED ON APPLICATION

Bricklaying or Stone Laying Mortar

This type of mortar used to bind bricks and stones in **masonry construction**. The proportions of ingredients for bricklaying or stone laying mortar is decided based on kind of binding material used.

FIG.2 STONE LAYING MORTAR

Finishing Mortar

Finishing mortar is used **for pointing** and **plastering works**. It is also used for architectural effects of building to give aesthetic appearances. The mortar used for ornamental finishing should have **great strength**, mobility and **resistance** against **atmospheric** action like rain, wind, etc.

FIG.3 FINISHING MORTAR

BASED ON BINDING MATERIAL

Cement Mortar

Cement is used as a binding material in this type of mortar and sand is employed as aggregate. The **proportion of cement and sand** is decided **based on** the specified **durability and working conditions**.

Cement mortar will give **high strength** and **resistance against water**. The proportion of cement to sand may varies from 1:2 to 1:6.

FIG.4 CEMENT MORTAR

Lime Mortar

In this case, lime is used as binding material. There are **two types** of limes namely **fat lime** and **hydraulic lime**. Fat lime in lime mortar requires 2 to 3 times of sand and it is used for dry work.

Hydraulic lime and sand in **1:2** ratios will give good results in damp conditions and also **suitable for water logged** areas.

Finally, the lime mortar has a **high plasticity** so it can be placed easily. The pyramids at Giza are plastered with lime mortar.

FIG.5 LIME MORTAR

Gypsum Mortar

Gypsum mortar **consists of plaster and soft sand** as binding material and fine aggregate. Commonly, it has **low durability** in damp conditions.

FIG.6 GYPSUM MORTAR

Gauged Mortar

In gauge mortar **combination of lime and cement** is employed as a binder material, and sand used as fine aggregate. Gauge mortar is, essentially, lime mortar which its strength increased by adding cement.

Consequently, the mortar will have high plasticity of the lime and high strength of the cement. The ratio of **cement to lime** ranges from **1:6 to 1:9,** and it is cost effective.

Surkhi Mortar

In surkhi mortar, **lime is used as binder** material and surkhi is employed as fine aggregate. The **surkhi is finely-powdered burnt clay** which provides more strength than sand and **cheap**ly available in the market.

FIG.7 SURKHI MORTAR

Aerated Cement Mortar

Basically, it is cement mortar to which air entraining agent is added to **increase plasticity and workability**. The resulted mortar is termed as aerated cement mortar.

Mud mortar

In this type of mortar, mud is used **as binding material and saw dust, rice husk or cow-dung is used as fine aggrega**te. Mud mortar is useful where lime or cement is not available. The use of mud mortars in the Middle-East and central Asia, and American cultures of the south-western USA is well documented.

FIG.8 MUD MORTAR

BASED ON BULK DENSITY

Heavy Mortar

If the mortar is having **bulk density of 15 KN/m^3 or more** then it is called as heavy mortar. Generally **heavy quartzes are used as fine aggregate** in this type of mortars.

Lightweight Mortar

If the mortar having bulk density of **lesser than 15 KN/m^3** then it is called as light mortar. Lightweight mortar is prepared by **mixing lime or cement as binder, sand, and saw dust, rice husk, jute fibers, coirs, or asbestos fibers**. Cinder mortar is a variety of light-weight mortars. Lightweight mortar is generally **used in the soundproof and heat proof constructions**.

BASED ON STRENGTH (ASTM C 270)

Type M Mortar

It is the highest strength mortar **minimum 17.2 MPa** (2500 psi). It is **used for exterior masonry work** and at or below grade application where substantial gravity or lateral loads are exerted. load bearing wall, footing, retaining wall are examples of below grade applications.

FIG.9 TYPE M MORTAR

Type S Mortar

It is a medium-strength mortar **minimum 12.4 MPa** (1800 psi) with high bonding ability. it is used for grade applications with normal to moderate loading.

Type S mortar has **great durability** that is why it is highly suitable for locations where the masonry is in contact with the ground, such as paving or shallow retaining walls.

FIG.10 TYPE S MORTAR

Type N Mortar

It is medium strength with **minimum 5.2 MPa** (750 psi) and most common type of mortar. Type N mortar used for reinforced interior and above-grade exterior load-bearing walls on which normal loads are imposed.

Type O Mortar

It is a low strength mortar with **minimum 2.5 MPa** (350 psi). Type O mortar employed **for interior non-load-bearing** applications with very limited exterior use. Added to that, it used for pointing where the structural integrity of the wall is intact.

BASED ON SPECIAL PURPOSE OF MORTARS

Fire Resistant Mortar

Fire resistant mortar is prepared by **mixing aluminous cement to the fine powder of fire bricks.** If there are any fire warnings to the structures in a particular zone, then fire resistant mortar will be used which acts as fireproof shield.

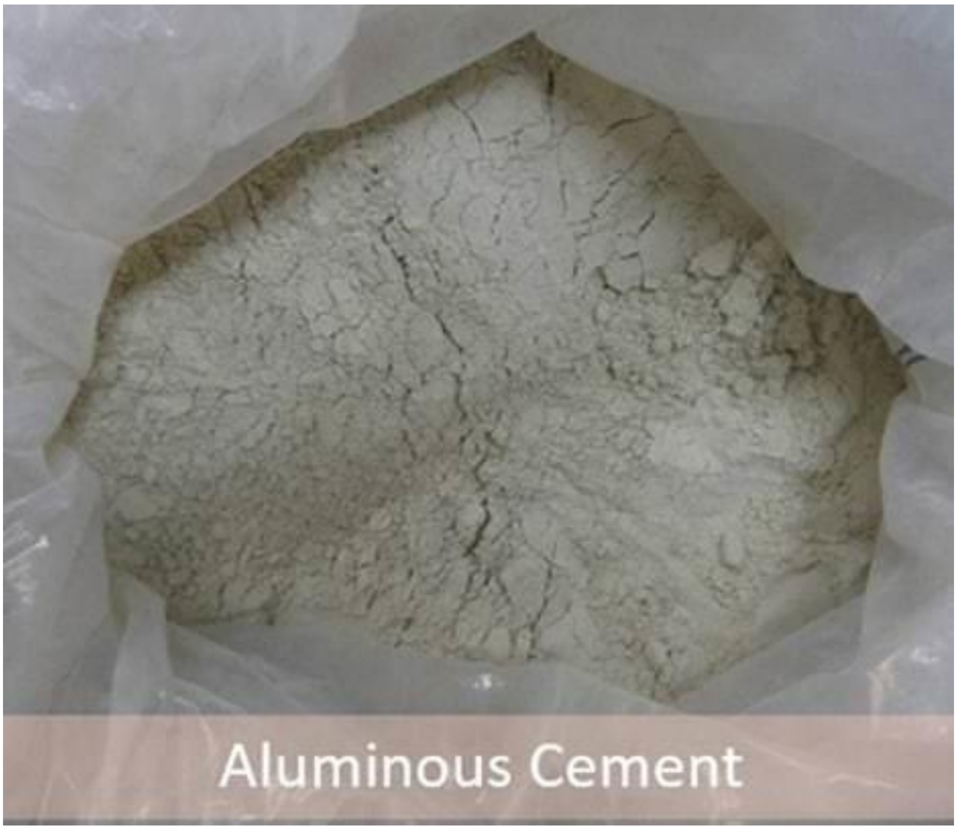

FIG.11 FIRE RESISTANT MORTAR

Packing Mortar

The constituents of packing mortars are generally **cement-sand, cement-loam** or sometimes cement-sand-loam. This type of mortar is **used to pack the oil wells**. Packing mortar should be of high homogeneity, **water resistance and high strength.**

FIG.12 PACKING MORTAR

Sound Absorbing Mortar

In sound absorbing mortar, **cement, lime, gypsum, or slag used as binding materials and pumice, cinders as fine aggregate**. It is used to reduce the noise level and acts as sound proof layer.

X-ray Shielding Mortar

To provide protection against ill effects of X-rays, the X-ray room walls and ceilings are plastered by X-ray shielding mortar. This is **heavy type mortar** with bulk **density** around **22KN/m^3**. Fine aggregates from heavy rock and suitable admixtures are used to prepare this type of mortar.

Chemical Resistant Mortar

It is generally used where there is a chance of chemical attack on the structures. There are so **many types of chemical resistant mortars** can be prepared but the selection of mortar is dependent on expected damage by particular chemical or group of chemicals. The additives added may not resist all the chemical attacks. For example, silicate type chemical mortar resists nitric, chromic, Sulphuric or any acidic damages but it cannot prevent the structure against damage by alkalies of any concentration

SAND

River sand

River sand is a product of **natural weathering of rocks** over a period of millions of years. Kaveri (anglicized as Cauvery), also referred as Ponni, is an Indian **river** flowing through the states of Karnataka and Tamil Nadu. It is the third largest after Godavari and Krishna in south India and the largest in Tamil Nadu.

What is river sand good for?

River Sand comes from the **beds** and banks **of rivers**. It has rounded particles and do **not contain impurities and clay**. This product has lower bleeding of water in concrete as well as **reduced honey combing and high resistivity** to aggressive environment. Requires less water and has smoother texture along with **better** shape.

What is the difference between river sand and M Sand?

Moisture is trapped in **between** the particles which are good for concrete purposes. Higher concrete strength compared to **river sand** used for concreting. Though **M Sand** uses natural coarse aggregates to form, it causes less damage to the environment as compared to **river sand**.

Why river sand is used for construction?

River **sand** or Natural **sand**

they are mainly **used** in concrete and masonry work. They can also be **used for RCC, plastering**, and much other brick or block works. This sand consists of a smoother texture and a **better shape** of grains. The river or natural sand demands very less water.

Is desert sand and beach sand the same?

Beach sand has been broken down predominantly by the action of water whereas **desert sand** has been broken down by wind. In each case the main contributing factor to the composition of the **sand** is the source rock which is being broken down.

Which sand is best for plaster?

Basically river sand are used for any plastering work. Generally, in any plastering work plasterers are used **natural sand**, **crushed** stone sand or **crushed** gravel sand

Why is desert sand not good for construction?

However, **desert sand** has little use; the **grains are too smooth** and **fine** to bind together, so it is **not suitable** for the making of for instance concrete. This **sand is not** used in **construction**, as its grains are too smooth and **fine** to bind together for building materials.

PROPERTIES OF SAND

As sand is an important construction material, it is always desirable to use the good quality sand. To judge the quality of the available sand, one must know the properties of good sand. Before using sand in a project, these desirable properties must be ensured.

Sand is a mixture of small grains of rock and granular materials which is mainly **defined by size**, being finer than gravel and coarser than silt and ranging in **size from 0.06 mm to 2 mm.** Particles which are larger than 0.0078125 mm but **smaller than 0.0625 mm are termed silt**.

Followings are the desirable **properties of sand**:

- Should be completely **inert**. (i.e., should not have any chemical activity).
- Grains should be **sharp, strong & angular**.
- Should **not contain** any hygroscopic **salts** (i.e., $CaCl_2$, $MgCl_2$, etc.).
- Should **not contain clay & silt**; usually 3-4% clay & silt is ordinarily permitted for practical reasons.

- There should be **no organic matter**.

Properties of Moulding Sand

- Porosity: Porosity also known as permeability is the most important property of the moulding sand.
- Cohesiveness: Cohesiveness is the property of sand to hold its particles together.
- Adhesiveness:
- Plasticity:
- Flow-Ability:
- Collapsibility:
- Refractoriness:

USES OF SAND

Sand is used to **provide bulk, strength**, and other properties to construction materials like asphalt and concrete. It is also used as a decorative material in landscaping. Specific types of sand are **used in the manufacture of glass** and as a molding material for metal casting.

Sand is a multi-purpose topographical material. It is known as one of the three fundamental **ingredients in concrete**. The composition of sand is diverse. Mostly sand is **made of silica** which is a common element. It can also come from another source of minerals like **quartz, limestone, or gypsum**.

FIG.13 RIVER SAND

In the real world, there are a lot of situations where we can find uses of sand. Followings are the common sand uses.

- We can use **sand to filter water**; it works like an **abrasive**.
- We can use sand to give a **grip to our painting** or wall art by combining 2 cups of paint with a ¾ cup of sand.
- People make **sandpaper** by gluing sand to a paper.
- While bunging metal, we can mix sand with clay binder for frameworks used in the **foundries**.
- Sand can be used for **cleaning up oil leak** or any spill by dredging sand on that spill. The material will form clumps by soaking up, and we can quickly clean the mess.
- Sand can be used **as a road base** which is a protective layer underneath all roads
- Industrial sand is used **to make glass**, as foundry sand and as abrasive sand.
- One creative usage of sand is serving as a candle holder. We can try putting some sand before pouring tea light or any candle in a glass. It holds the candle still and refrain the candle from rolling by giving it an excellent decoration.
- **Adds texture and aesthetic** appeal to space
- Sand is mostly pure to handle, promptly available and economically wise.
- We can make children's sandpit to keep the play areas safer. It is quite inexpensive as well.

- We use sand **in aquariums**, fabricating artificial fringing reefs, and in **human-made beaches**
- Sandy soils are ideal for **growing crops**, fruits and vegetables like watermelon, peaches, peanuts, etc.
- Sand can light a path by filling mason jars with sand and tea light which is another inexpensive way to make a walkway glow.
- We can keep a small scuttle of sand near a charcoal grill for inundating flare-ups.
- Sand can be used for cleaning narrow neck receptacle by putting a little sand and warm soapy water in the container.
- We can keep an item steady which needs repairing by using sand. Burying the broken pieces under sand grains helps to hold the elements together while gluing.
- Sand helps to **improve resistance** (and thus traffic safety) in icy or snowy conditions.
- We need sand in the beaches where tides, storms or any form of preconceived changes to the shoreline crumble the first sand.
- Sand containing silica is used for **making glass** in the automobile and food industry- even household products for the kitchen.
- Sand is a strong strand which is **used for plaster, mortar, concrete**, and asphalt.
- The usual bricks formulated of clay only is way weaker and lesser in weight than blocks made of clay mixed with sand

TIMBER

TIMBER

↓

(Denotes wood which is suitable for building or carpentry or various other engineering purposes and it is applied to the trees measuring

not less than 600mm in girth or circumference of the trunk)

Converted timber	**rough timber**	**standing timber**
(Timber which is sawn and cut into Suitable commercial sizes)	(timber which is obtained after felling a tree)	(timber contained in a living tree)

FIG.14 CLASSIFICATION OF TIMBER

The conversion of timber is a phrase usually used in reference to turning a **log into** a pile of boards/**planks**. This is done using a saw mill of some kind. There are several things that need to be taken into account when sawing up a log. Standing timber means the current value of trees that have been planted which will yield saleable timber when felled at maturity, usually forestry trees. The Inland Revenue accepts that fruit trees do not generate saleable timber.

FIG.15 CONVERTED TIMBER

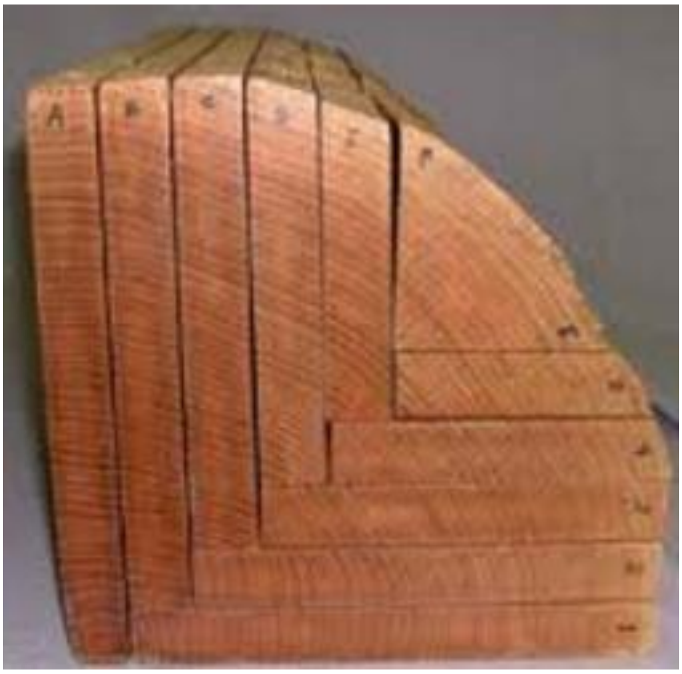

FIG.16 CONVERTED TIMBER (2)

FIG.17 ROUGH TIMBER

FIG.18 STANDING TIMBER

Processing of timber

- **Felling of trees**
  - Age of trees for felling
  - Method of felling
  - Season for felling
- **Seasoning of timber**
  - Meaning of seasoning
    (The water is to be removed before the timber can be used for any engineering purpose.)
  - Free moisture and bound moisture
    (Moisture in the timber can be either in the cell cavities or in the cell walls. The former is known as the free moisture or free water and major part of moisture in timber is present as free water. The latter is known as the bound moisture and it is closely associated with the body of timber.)
  - Determination of moisture content
    $P = ((W_1 - W_2) / W_2)) \times 100$ where P – percentage of moisture, W_1 – original weight of timber, W_2 oven – dry weight of timber.(drived in an oven at a temperature of 103 °C ± 2 °C)

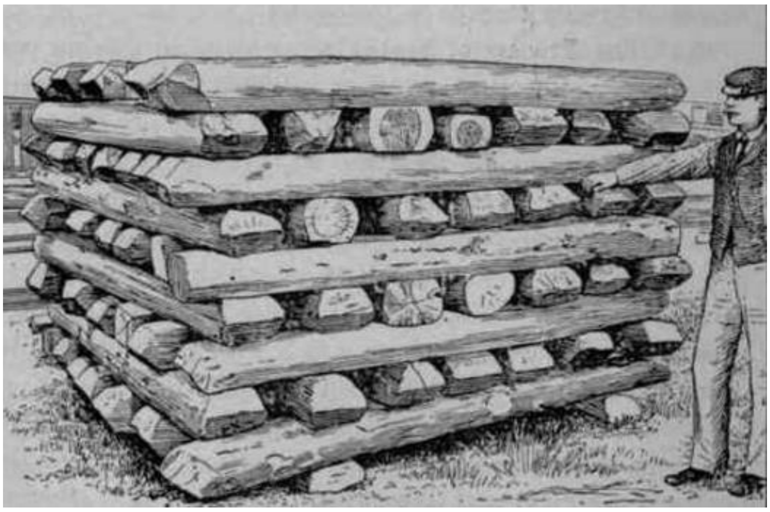

FIG.19 SEASONING OF TIMBER

FIG.20 SEASONING OF TIMBER

Objects of seasoning

To allow timber to burn readily, if used as fuel

- To impart **hardness, stiffness, strength** and better **electrical resistance** to timber.
- To **increase resisting** power of the timber
- To **maintain shape and size** of the components of timber To make timber easily workable
- To make **fit for** receiving treatment of **paints, preservatives, varnishes**, etc. To make timber safe form of fungi and insects.

Method of seasoning

Natural seasoning and **artificial** seasoning(various methods- boiling , chemical seasoning, kiln seasoning, electrical seasoning, and water seasoning.

- Comparison between natural seasoning and artificial seasoning

- Conversion of timber
    - Process by which timber is cut and sawn into suitable sections is known as the conversion. (power machines may be employed at different stages of process.)

FIG. 21CONVERSION OF TIMBER

Preservation of timber

Object of preservation of timber

To **increase the life** of timber structures

To make the timber structures **durable**

To protect the timber structures **form the attack of destroying** agencies such as **fungi, insects** , etc.

Requirements of a good preservative

- Should be capable of **covering a large area** with small quantity
- Should be **cheap and easily available**
- Should be **durable**
- Should be **non-inflammable**
- Should be quite efficient in **killing fungi, insects**, etc.
- Should be safe and **harmless** for persons and animals
- Should offer high **resistance** to the **moisture** and dampness.

Types of preservatives

- Ascu treatment
- Chemical salts
- Coal tar
- Creosote oil
- Oil paints
- Solignum paints

Methods of preservation of timber

- Brushing
- Charring
- Dipping and steeping
- Hot and cold open tank treatment
- Injecting under pressure
- Spraying

FIG.22 OIL PAINTS, BRUSHING

Qualities of good timber

In general, the quality of timber depends on the following factors:

- Environmental **conditions** of the locality
- **Maturity** of the tree
- Method of **seasoning**
- Nature of the soil
- Process of **preservation**
- Time of felling.

Following are the **characteristics** or quality of a good **timber**

- Appearance
- Colour
- Defects
- Durability
- Elasticity
- Fibres
- Fire- resistance

- Hardness
- Mechanical wear
- Shape
- Smell
- Sound
- Strength
- Structure
- Toughness
- Water permeability
- Weathering effects
- Weights
- Working conditions

Factors affecting the **strength of timber**

- Abnormalities of growth
- Faults in seasoning
- Invasion of insects
- Irregularities of grain
- Moisture content
- Presence of knots, shakes, etc.
- Way in which a timber piece is cut from the log, etc.

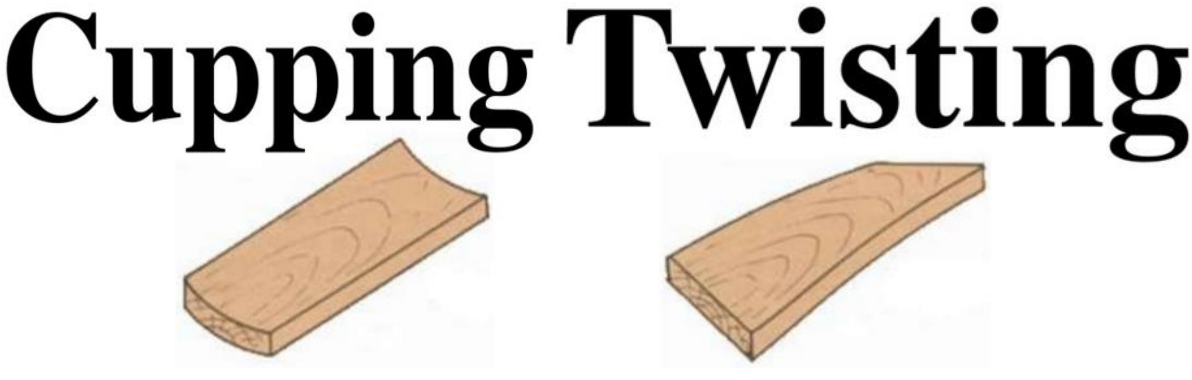

FIG.23 CUPPING AND TWISTING OF WOOD

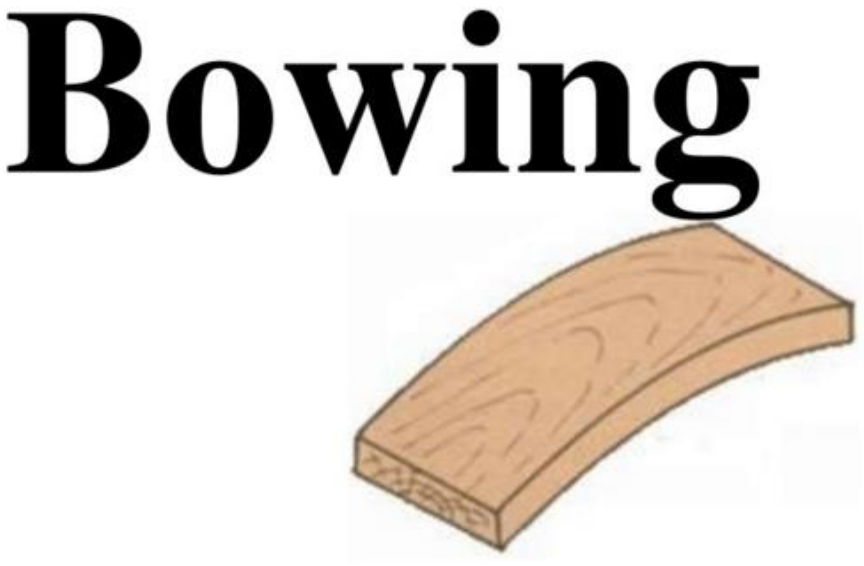

FIG.24 BOWING OF WOOD BY FAULT SEASONING

FIG.25 INVASION OF INSECTS

FIG.26 IRREGULARITIES OF GRAIN ON WOOD SURFACE

FIG.27 PRESENCE OF KNOTS

MARKET FORMS OF WOOD

Various types of market forms of timber

Batten - timber piece whose breadth and thickness do not exceed 50mm

Baulk - roughly squared timber piece and it is obtained by removing bark and sap wood. Cross-sectional dimension exceeds 50mm.

Board - timber piece with parallel sides and thickness is 50mm to 100mm

		and its width does not exceed 230mm
Deal	-	piece of soft wood with parallel sides and thickness varies from 50mm to 100mm and its width does not exceed 230mm.
End	-	short piece of batten, deal, scantling etc.,
Log	-	trunk of tree obtained after removal of branches
Plank	-	timber piece with parallel sides and thickness is less than 50mm and its width exceeds
Pole	-	it is a sound long log of wood and its diameter does not exceed 200mm and it is also known as a spar
Quartering	-	square piece of timber and the length of side being 50 mm to 150mm.
Scantling	-	timber piece whose breadth and thickness exceed 50mm but are less than 200mm in length (pieces of miscellaneous sizes of timber sawn out of a log.

USES OF TIMBER

Timber is widely **used** in work **wood** producing boxes, **furniture**, matches, and crates. Most of the **timber used** from the tropical forests is hardwood. Normally, **timber** finds **use** in the **construction industry** in **three** ways mainly as – **sawn wood, veneers and plywood, and fibreboards**.

What is Timber and What is it Used For?

Timber is a term that has several connotations and in many regions of the world is used synonymously with the term lumber. Most often, timber refers to either **standing trees** or trees that have been harvested which retain their bark or other characteristics for aesthetic purposes.

Timber as a Material

Timber is a versatile raw material that offers several advantages, enabling it to be used in a wide range of applications. Among these advantages are the following:

- Timber is a **renewable resource** and is grown in countries around the globe. This broad availability reduces the amount of transportation needed, allowing the material to be used closer to where it is produced.
- Timber has a fast growth rate with softwood varieties able to replenish at a faster rate than hardwoods.
- Timber does **not require a great** deal of **energy** for it **to** be **produced** into a **useable form**, relative to other material such as steel which requires furnaces operating at high temperature as part of the process.
- Timber stores the **excess carbon** that is removed from the atmosphere and continues to do so or the duration of its existence.
- Timber is a **natural material**, is **non-toxic**, is safe to handle, and does not produce hazardous vapours when cut or machined.
- Timber is easy to harvest and can be managed effectively to assure regrowth and replenishment.
- Timber is **easy to handle**, cut, and shape with readily available tools, lending to its ability to have widespread use.
- Its scrap or waste products can be repurposed so that there is little to no unused material from a given cut of timber.
- It has aesthetic appeal and can be stained, painted, or coated to produce a wide variety of finishes.
- **Softwood** timber is relatively **inexpensive**, making it suitable for wide use as a building and construction material.

- The material has relatively **high strength** and can be designed into configurations that function as load-bearing supports.
- Timber has good **thermal insulating** properties and can reduce the energy use of homes when the material is used in doors and windows.
- When properly dried as part of the processing of harvested wood, timber is not subject to fungal degradation, and the **removal of** excess **moisture reduces** the **weight** of the material, making it less expensive to transport and easier to handle.
- **Timber construction** is simpler and **faster** than with the use of stone or concrete.

Timber is durable, can last centuries, and is easier to maintain than other materials.

Common Uses of Timber

Timber is an important source of **fuel,** where its combustion can be used to heat homes, provide energy for cooking food, and heat water for domestic use. Wood pellets and other remnants of the **timber processing** such as **biomass** are shipped and may be used as a convenient form of wood-based fuel to be used in stoves or heaters. Some estimates suggest that up to 40% of all the timber harvested from forests worldwide is ultimately consumed as a fuel source. The use of **timber as fuel** will vary from region to region, depending on the availability of other fuel sources such as oil, natural gas, electricity, and renewables such as wind and solar power.

Timber can also be used as a fuel source to power boilers which heat water to produce steam and drive generators to create electrical power.

Construction Materials

Timber is transformed into a wide range of construction materials that are used in building and home construction. This includes dimensional lumber products that are built into walls, floors, and ceilings, such as:

- Studs
- Plates
- Joists

- Rafters
- Beams
- Firebreaks
- Supports

Timber also used along with adhesives to generate sheets of **plywood** to function as sheathing, or for the creation of Oriented Strand Boards (OSB), **veneer panels**, or Structural **Insulated Panel**s(SIPs). Timber also can be fabricated into structurally engineered wood products that are suitable for sustaining high loads, substituting for other materials such as steel I-beams. Timber is also fabricated into architectural or custom woodwork as well as other architectural mouldings.

Furniture

Many hardwoods are valued for their higher density and the beauty of their natural grain patterns, making them the primary choice of material for cabinet and furniture makers. These woods are heavier and more durable, but also slower growing, therefore tend to be more expensive than softwoods. Oak, maple, walnut, cherry, and poplar are common choices for higher-end furniture. **Less expensive softwoods used for furniture** include **pine, redwood**, spruce, and cedar.

Scrap and waste material from mills such as **wood shavings and sawdust** are combined with adhesives **to create chipboard, Light Density Fiberboard (LDF), Medium Density Fiberboard (MDF),** and other wood products that can be used to make inexpensive wooden furniture sold and shipped as ready-to-assemble items or furniture parts.

Timber Beams

Timber is used in applications requiring the **support of loads**, including on **docks, piers, jetties, railway** or railroad track ties, or telephone and utility **poles**, for example. There is also widespread use in timber home construction, where the characteristic of this style is the use of timber that is generally greater than 5 inches in size. In some applications, the timber may be left in its natural state including tree bark for design or aesthetic reasons.

Other uses of timber include landscape timbers for retaining walls or other decorative purposes, and boat timbers, for cases where wooden boat construction is still valued.

Paper and Pulp

A wide variety of paper products are created using **pulpwood** from timber. Paper for **books, magazines, newspapers**, and other printed items like brochures, flyers, and marketing materials, as well as copy paper, envelope paper, kraft paper, parchment paper, packaging paper, and photographic paper all are ultimately derived from timber.

Other Uses

Timber also finds use in the creation of **textile** products such as **rayon**. The oils and other extracts from timber are used in the creation of products including **paints, resins, and gum**. Timber of lower grades is also used for the creation of wooden boxes and crates for shipping and storage.

Summary

Timber is a **valued natural resource** that serves directly as a material for use in **construction, paper manufacturing**, specialty wood products such as furniture, and as a fuel source.

PROPERTIES OF PLYWOOD

- **High Strength** and **Dimensional Stability**. Plywood derives its structural **strength** from the timber from which it is manufactured.
- **High Impact Resistance**.
- Panel Shear or Braced Panels Shear.
- Water and **Chemical Resistance**.
- Flexibility or **Bendabil**ity.
- Fire Resistance.
- **Sound and Thermal Insulation**

Properties of Plywood as a Building Material

Every year the construction industry witnesses the demand for new building materials. Researchers and experts are relentlessly looking for new materials to overcome the problems faced due to traditional building materials. Among the building materials, **plywood** has become one of the most eye**-catching materials** that have brought a huge difference in the wood industry. Nowadays, due to the beneficial properties of plywood, it has become the most **demanding** building materials over traditional materials like natural wood, bricks, plastic, etc. Plywood is a wonderful combination of **lightness, strength and flexibility**. Therefore, the growth of the plywood market is increasing day by day across the world.

Plywood is an engineered wood which is made by stacking several **layers of wood veneers** (thin slice of natural wood).

In comparison to wood, the plywood is easily and readily available in all regions. Due to the cost factor of wood, plywood has made a way to the construction industry in the last couple of decades. The application of plywood in a building and construction industry along with interior design had made it a popular building material all over the world.

Since the benefits of plywood are immense, **many companies** over the world have started the **production of soft, hard, tropical and decorative plywood**. We use various types of plywood for **different uses**. Right from making **furniture** to constructing a house including **structural framework**, manufacturing of **doors, windows, drywall/partition wall, décor items**, etc. plywood is used. Many other **composite sheets** or panels are available in the market, but still, expert or woodworkers prefer plywood due to its inherent properties like strength and stability, ease of working, cost, etc

FIG.26 PROPERTIES OF PLYWOOD

Plywood derives its structural **strength** from the timber from which it is manufactured. This is in addition to the plywood properties obtained due to its laminated construction. **Cross-graining** (thin plies glued at the right angle with each other based on their pattern of grain) allows the plywood sheets to **resist splitting** and provides uniform strength with increased stability. Unlike natural wood, good quality plywood does **not suffer** from a **change in size** due to **change in moisture** content or humidity, i.e. it does not expand or contract. This is the biggest advantage of plywood.

USES OF PLYWOOD:

It is cost-effective when used in structural applications such as **flooring, walls, partitions, formwork, cupboard, shelves**, etc. because of its high strength and stability.

High Impact Resistance

Plywood has **high tensile strength** due to the cross lamination of panels which distributes the force over a large area and reduces tensile stress. Therefore, it can **withstand overloading** up to twice its designated load.

Uses:

- This is useful when we use it for flooring or **concrete formwork**.

- It is appropriate for the **floor** of various buildings, including industry with heavy wear.

Panel Shear or Braced Panels Shear

As stated by Bekhta, et al. in their research paper named "The effect of **chemical treatment** of wood veneer surfaces on their **bond ability**"; the plywood panels made by using treated veneers have higher shear strength than those made by using non-treated veneers.

Upon the **treatment of veneer**, plywood's shear **strength becomes** nearly **twice** that of the solid wood when used in the wooden structure as bracing for resisting the lateral load.

Uses:

This property makes it suitable for using as gussets in portal frames and as **bracing panels** and webs of **fabricated beams** of the wooden structure.

Water and Chemical Resistance

While manufacturing thin plies, **veneers** are treated with a substance that makes plywood highly resistant to water and chemicals. However, it has **low water and chemical resistance capacity as compared to natural wood.**

Uses:

- Since it is resistant to water and chemicals, it is therefore highly **preferred** in the **chemical industries**.
- To resist water and chemicals, the plywood is treated with waterproof glue along with the other chemical compounds. This is known as **Marine plywood.**
- This property makes it an ideal material mainly for **furniture**, concrete **formwork** and for outdoor projects garden furniture such as **tables, chairs**, and benches, **decking, porches, arbours, pergolas, planters**, etc. However, it may be noted that all plywood are not water resistant. One has to use an appropriate grade.

Flexibility or Bendability

Flexibility or the bending ability distinguishes plywood from the natural wood. Some special types of plywood can be easily bent without breaking or being damaged. As compared to wood; plywood can be manufactured to fit every requirement. Furthermore, the **plywood thickness** varies from a **few millimetres** to inches. The number of veneers used also ranges from three to several, thereby increasing the thickness of the plywood sheet. The extra layers of veneer add more strength to plywood. Lesser number of veneers or specially treated veneers makes plywood flexible or more bendable.

Uses:

- Flexibility in the shape and size of plywood makes it an appropriate material with respect to wood. Such flexible plywood is especially useful for creating **furniture** that is expected to have **curved surfaces**.
- Flexibility in thickness enables it for **ceilings and panelling work**, curved formwork, etc.
- It can also be used for manufacturing **furniture, decorative** items, etc.

Fire Resistance

Plywood can be **treated with a fire-resistant chemical** coating. It is combined with non-combustible materials such as fibrous cement or plasterboard. This chemical coating **resists the oxidation process**, thereby reducing the spread of fire.

Uses:

- This property makes it suitable for use in **fire-resistant structures**.

Sound and Thermal Insulation

As per research paper 'Wood Adhesives and Bonding Theory' published by Onur Ülker of Kirikkale University, the **use of** urea formaldehyde resin **adhesives** during the manufacturing of plywood **enhance the thermal properties** of plywood.

At the time of manufacturing of plywood, veneers or thin plies are glued together with resin adhesives, which make it a good thermal and noise insulator. The process of insulation of plywood significantly reduces heating and cooling costs.

Uses:

- In western countries, due to the need of high heat resistance, insulated plywood is highly preferable for **ceilings, flooring, roofing**, and wall cladding work.

Benefits of Using Plywood over Other Natural Woods

- When you work with natural wood, the **width** of the wooden member is the biggest challenge, as it cannot be **larger than the trunk of the tree**. Hence whenever you want a wooden member of a large width either for **door** or partition, you have to provide **joints**. The **joints need** very **skill**ed workmanship, so that thin lines are not visible and also, they perform well due to temperature and humidity change. Plywood, on the other hand is available in various standard shapes and sizes.
- Further, **wood** being **sensitive to moisture**, the joints may either expand or contract. These limitations of natural wood can be easily **overcome** while using **plywood**.
- Similarly, there is a limitation to the thickness of natural wood. Natural wood cannot be obtained beyond a certain thickness. Plywood has provided a solution to this problem and thus provides a **large surface area** which is **joint-less** and is not likely to get affected by moisture unlike natural wood.
- Plywood is available in **large size**, and hence one can **avoid joints** in furniture which is impossible in natural wood. Also, plywood is available upto **8ft length**. Therefore, it is economical as compared to natural wood.
- Due to the less number of joints, it obviously increases the speed of construction as compared to wood.
- It requires **less skilled labour** as compared to natural wood.
- Plywood can be **easily polished or painted**.
- According to the Plywood.com, plywood can last upto 10 years or even more. However, if it comes in contact with moisture or termite, its quality may get affected, and it may deteriorate. The **life of natural wood is more as compared to plywood.**

Experts use plywood due to its **unique properties** like;

- High **strength** and **stability**
- High **resistance** to **impact**
- Resistance to **water**, **chemicals, fire, and heat**
- Flexibility in **shape**, **size** and t**hickness** makes it fit for every requirement
- **No shrinking, swelling and wrapping**
- **Durable**
- **Cost-effect**iveness
- Environmentally friendly, **minimizes wastage of wood**

Thus, plywood is a versatile material. The cost of plywood varies depending upon the properties and purpose. In routine interior work, one can use ordinary plywood which is economical and that for specific purpose like resistance to water, use standard waterproof plywood which will have a higher cost as compared to the regular one.

Different grades of plywood are available in the market, and one has to choose the right grade depending as per one's requirement.

PROPERTIES AND USES OF FIBRE BOARD

Ref: PROPERTIES OF FIBER BUILDING BOARDS U, S. DEPARTMENT OF COMMERCE, R. P. LAMONT, Secretary, BUREAU OF STANDARDS

What is fiber board made of?

Fiberboard is a type of engineered wood product that is **made** out of wood **fibers**. Types of **fiberboard** (in order of increasing density) include **particle board** or **low-density** fiberboard (LDF), **medium-density** fiberboard (MDF), and **hardboard** (high-density fiberboard, HDF).

What are the properties of fiberboard?

In terms of its basic properties, wood fibre board is comparable to wood and possesses all of wood's best features: **strength**, **toughness** and warmth. It also has the following benefits, owing to its method of manufacture: homogeneous, no **grain direction**. **dense** but breathes.

What is fiber board used for?

Hard fiberboard can be used **as** wall slab, **door board, floor, furniture** and other decorations instead of wood. And the soft fiber board whose apparent density is low (< 400 kg/m^3) and porosity is high, often used **as heatproof or acoustical** materials.

PROPERTIES AND USES OF PARTICLE BOARD.

Particle board is gaining popularity as a building material due to its varieties of application and cheap rates. Particle board is an **eco-friendly material** as it **uses wood wastes** such as wood chips, **sawdust** and wood shavings mixed together **with a resin** to form boards. They are sometimes used as an **alternative to plywood** or medium density fiberboard to lower down the construction cost. Particle board has a wide range of applications, which a homeowner must know, before buying it. Here we brief about uses of particle board in building industry.

There are various uses of particle board in the construction industry which are as follows:

Uses of Particle Board in Flooring:

Particle board is used as a flooring material **in temporary structures** where there is **less application of loads**. Also it is widely used as covering for hardwood floors, as hardwood boards have low resistance to scratches to protect them. Wood veneer particle board or laminated particle board is used in flooring where finished **aesthetic look** is desired

Uses of Particle Board in Flooring Underlayment:

Particle board is extensively used as flooring underlayment or as a base for parquet flooring, **wood flooring**, or for **carpets**. For this purpose, the particle boards are treated with special chemicals and resins to make them **waterproof** or **termite proof**.

Uses of Particle Board in Partitioning or Wall Panelling:

Particle boards are used in wall partitions, as they are **non-load bearing members** in the structure. For **cost-effective** options, particle boards can be used as they have **thermal and sound insulation** properties. Laminated particle boards are extensively **used in wall panels** as they give finished walls. You can select from a **variety of** design in laminated **particle boards** for wall panels.

FIG.27 WALL PANEL WITH PARTICLE BOARD

FIG.28 WALL PANEL WITH PARTICLE BOARD (2)

Uses of Particle Board in False Ceilings:

Laminated particle boards and cement particle boards are widely used in false ceilings. Due to their **thermal insulation** properties they are extensively used in false ceilings for centrally **air-conditioned rooms**. Particle boards are extensively used as ceiling tiles **for auditoriums, computer centers, cinema** halls and **theaters** and in as display boards in **commercial establishments**. In building construction it is used in false ceiling and panelling due to its thermo-acoustic insulation properties

Uses of Particle Board in Core Material for Doors:

Particle boards are also used as a core material in **solid core doors** as well as in **flush doors**. Particle core is the most commonly used in manufacturing doors, as it provides flat and smooth surface for bonding with the door skin. It also has **good screw-holding capacity** for fixing hinges, unlike medium density fibreboard.

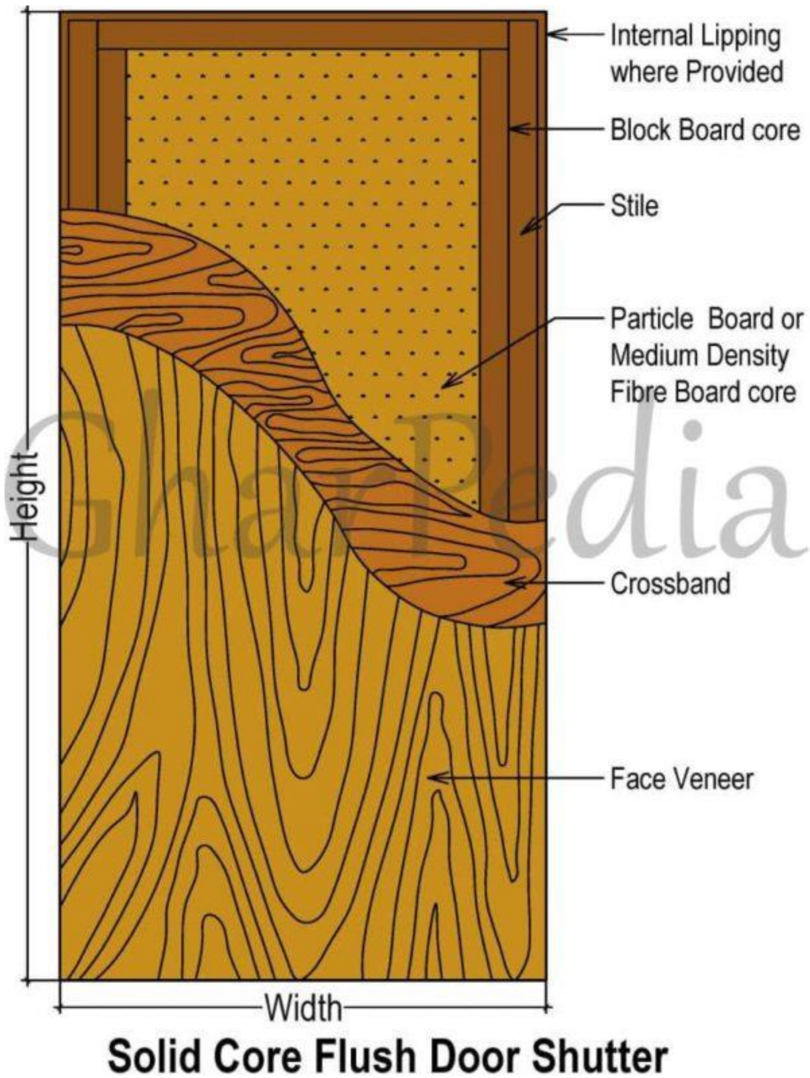

FIG.29 PARTICLE BOARD USED AS DOOR

Uses of Particle Board in Furniture:

There are numerous uses of particle board in furniture industry. Particle boards are extensively **used in residential** as well as **office furniture**. Wood veneer particle board are gaining popularity as they are durable and perform better in moist environment as compared to plain particle board. So they are **used in kitchen** areas and **bathroom**s in the form of **modular kitchen cabinets**, storage units, **countertops, table tops, wardrobes and dressing units**. Plain particle boards are useful in interior areas like bedrooms which have beds, wardrobes, storage units, etc. It is also used in making **shoe racks, computer tables, book shelves, television cabinets**, etc.

Nowadays office furniture is mass-produced by using particle boards. **Readymade units of office furniture** are directly supplied to the offices with decorative laminated particle board tops.

FIG.30 PARTICLE BOARD USED IN FURNITURE

Uses of Particle Board in Commercial Industry:

On commercial scale, particle boards are **used in television, speaker boxes, sewing machine tops, display boards, automobiles' parts** and in other products which requires furnished surfaces. Wood veneer particle boards are very extensively used in this industry.

IRON AND STEEL

The Four Main Types of Steel

- **Carbon** Steel. Carbon steel looks **dull**, matte-like, and is known to be vulnerable to corrosion.
- **Alloy** Steel. Next up is alloy steel, which is a mixture of several **d**ifferen**t** metals, like **nickel, copper,** and **aluminum**.
- **Tool** Steel.
- **Stainless** Steel.

How is steel different from iron?

The primary difference between **iron** and **steel** is that the former is a **metal**, whereas the latter is an **alloy**. Iron is simply a metal element that occurs naturally on Earth. In comparison, **steel** is a **man-made** alloy that's made by **mixing iron and carbon** together.

What is the best grade of steel?

Stainless steel

304 **stainless** steel is the most common form of **stainless** steel used around the world due to excellent **corrosion resistance** and value. 304 can withstand corrosion from most oxidizing acids. **Durability** makes 304 easy to sanitize, and therefore ideal for kitchen and food applications.

What is Grade 5 steel?

Grade 5 alloy steel is a **medium carbon zinc plated alloy steel** that is heat treated to **increase hardness**.

What are the 5 types of stainless steel?

There are five main families, which are primarily classified by their crystalline structure:

- **Austenitic stainless steel**.
- **Ferritic stainless** steels.
- **Martensitic stainless** steels.
- **Duplex stainless steel**.
- Precipitation **hardening stainless** steels.

Grades.

REINFORCING STEEL, TYPES, SPECIFICATIONS

Deformed and Plain Carbon Steel Bars

- 40 000 psi [280 MPa] or **Grade 40**
- 60 000 psi [420 MPa] or **Grade 60**
- 75 000 psi [520 MPa] or **Grade 75**
- 80 000 psi [550 MPa] or **Grade 80**
- 100 000 psi [690 MPa] or **Grade 100**

Steel Reinforcement Types and their Properties

Concrete is one of the most versatile construction materials throughout the world. However, since the early 1800s, it is known that c**oncrete** is **weak** in t**ension**. Weak tensile strength combined with the brittle behaviour of concrete results in the tensile failure without warning.

This is not desirable for any construction material. Thus, **concrete requires** some form of **tensile strength** to complement its brittle behaviour.

Historically, Steel has proved to be an ideal material as a **Steel** Reinforcement to complement **concrete** because the **thermal expansion** of both materials **is** the **same**. In other words, when cooled or heated both concrete and steel they expand or contract equally.

Steel also **bonds** well **with concrete**. In a composite material, the bond between two materials is necessary so that it functions as a single material. The bond between the two materials is due to the chemistry of the two materials, which produces a **chemical bond between them**. Besides, as the water from concrete evaporates, it shrinks and grips the steel bars also making a mechanical bond.

According to 'Madan Mehta', 'Walter Scarborough' and 'Diane Armpriest' (Authors of Building Construction), the mechanical bond is enhanced by using reinforcing bars or rebars that have surface deformations. Because a mechanical bond is a function of the area of contact between the two materials, the surface deformations increase such area over and above increasing friction between the two, thereby increasing the bond.

Steel Reinforcement

Steel Reinforcement is in the form of rebar or wire of steel, which is utilized **in concrete** members **to resist** primarily **tensile forces** caused by externally applied loads or volume changes.

In Concrete steel is embedded in such a manner that the two materials act together in **resisting forces**. The reinforcing steel-rods, bars, or mesh-**absorbs** the **tensile, shear**, and sometimes the compressive stresses in a concrete structure. **Plain concrete does not** easily **withstand tensile** and shear stresses caused **by wind, earthquakes, vibrations** and other forces and are therefore unsuitable in most structural applications.

The most common **types of Reinforcement** are **Plain & Deformed Reinforcing bars, Pre stressing Steel and wire reinforcement** made of steel.

FIG.31 TYPES OFSTEEL REINFORCEMENT

Steel Reinforcement Types & Classification

Rebar

Rebar is a round bar or a finished product rolled to close tolerances and called reinforcing bar.

The **types of steel** bars used in construction are

Plain & deformed reinforcement bars,

ribbed bars, HYSD Bars,

Carbon Steel Bars,

Low alloy steel bars,

Stainless steel bars,

Rail & Axle steel bars,

Galvanized steel bars,

Low-carbon chromium bars and

Epoxy coated bars etc.

Plain Reinforcement

Mild Steel Bars

FIG.32 MILD STEEL BARS

- The steel in use till these days for construction purposes was Plain mild steel bars. As per IS 432 (PART – I), It is designated as **Fe-250** (Where 250 = 0.2 % Proof Stress or Yield Stress in N/mm^2).
- Nowadays, it is **used only for small projects** in underdeveloped and developing countries.
- According to 'S. K. Duggal' (Author of Building Materials), mild steel reinforcement has proved to be a **better choice for impact** and suddenly applied **load**s.

TABLE 1 MECHCANICAL PROPERTIES OF STEEL

Mechanical Properties		
Type & Nominal Size of Bars	**Ultimate Tensile Stress (N/mm^2)**	**Yield Stress (N/mm^2)**
Mild Steel bars: Grade I		
Dia. Up to and including 20 mm	410	250
Dia. Over 20 mm, up to and including 50 mm	410	240
Mild Steel bars: Grade II		
Dia. Up to and including 20 mm	370	225
Dia. Over 20 mm, up to and including 50 mm	370	215

A few other types of plain Rebars are Carbon steel plain bars and Low-Alloy steel plain bars conforms to the ASTMA615/A615M and ASTM A706/A706M respectively.

Deformed Reinforcement

Deformed reinforcements are steel rebar or **steel wire** having deformation on the surface. The purpose of the deformations commonly referred to as ribs are to **enhance** the **bond** and **friction between** the **concrete and** the **bar** or wire.

The **types** of deformed steel bars used as reinforcement are **Mild Steel** Ribbed bars, **HYSD** bars, **Carbon Steel** bars, Low-**Alloy Steel** bars, **Stainless Steel** bars, **Rail** & **Axle** Steel bars, **Galvanized** steel bars, Low carbon **chromium bars**, **Epoxy coated** bars etc.

Mild Steel Ribbed Bars

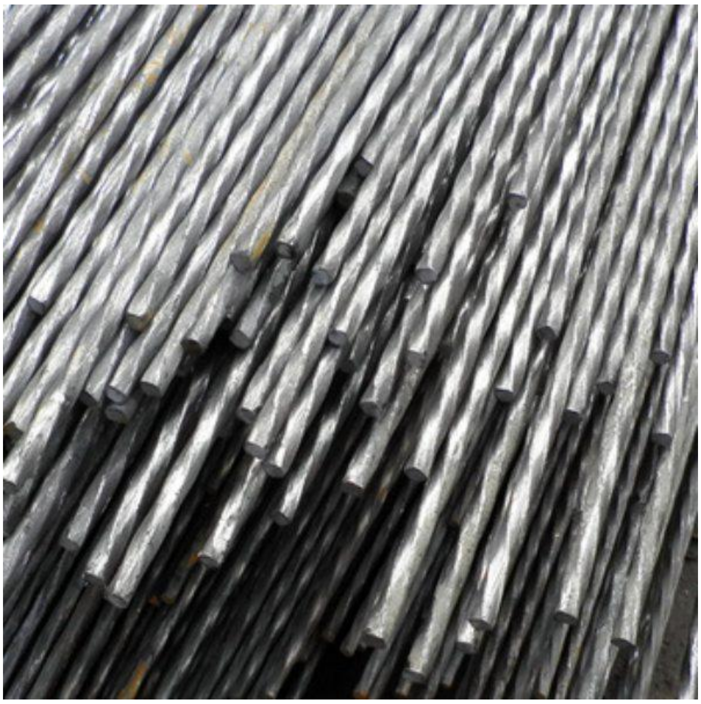

FIG.33 MILD STEEL RIBBED BARS

- For **preventing 'slip'** and **improv**ing the **mechanical bonding** between steel rebar and cement concrete, mild steel ribbed bars were developed and introduced around 1960.
- These are the **hot rolled mild steel** bars, but during rolling steel rods, ribs are produced on them. These ribs increase the bonding strength of the bars.
- **Mild steel** ribbed bars **are not recommended by** the **Indian Standard Code** or even American Society of Testing & Materials (ASTM).
- At the time of the introduction of mild steel ribbed bars, there was no specific patterns of ribs described. Rolling mills in different countries followed different patterns of rib.

High Yield Strength Deformed Bars (HYSD Bars) Conforming to IS 1786: 2008

- **H**igh **Y**ield **S**trength **D**eformed Steel **B**ars were **introduced in** India in **1967**. They completely **replaced mild steel** bars except in a few situations.

- As per IS 1786 High Yield Strength **Deformed Steel Bars are used as** reinforcement in concrete in the following rebar steel grades:

FIG.34 HYSD BARS

- Fe 415
- Fe 500
- Fe 550
- Fe 600

- High Yield Strength Deformed Rebar **has** lugs, **rib**s or deformation **on** the **surface** which inhibit longitudinal movement of the bars relative to the surrounding concrete. Thus, the deformed surface **ensures a better bond between reinforcement and concrete.**
- These bars results in a considerable **increase in yield, tensile and bond strength** when twisted hot or cold.
- Generally, the **higher strength** in steel can be **obtained by** increasing **carbon content**, Micro alloying, Cold twisting or **thermo mechanical Treatment**. In India, the TMT Process and Cold Twisting are used in the production of High Yield Strength Deformed Steel Bars.

TABLE 2 MECHCANICAL PROPERTIES OF HYSD BARS

Mechanical Properties							
Steel Grades	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600
Ultimate Tensile Stress (N/mm²)	10 % more than yield stress but less than 485 N/mm²	12 % more than yield stress but less than 500 N/mm²	8 % more than yield stress but less than 545 N/mm²	10 % more than yield stress but less than 565 N/mm²	6 % more than yield stress but less than 585 N/mm²	8 % more than yield stress but less than 600 N/mm²	6 % more than yield stress but less than 660 N/mm²
Yield Stress (N/mm²)	415	415	500	500	550	550	600
Elongation (%)	14.5	18	12	16	10	14.5	10

Ductile bars are usually used when buildings are constructed for better **seismic** performance and Earthquake **resistant**.

They are generally preferred and **used in Zone IV & V**, i.e. zone likely to have an earthquake. Higher the ductility, deformations withstand collapse.

Cold Twisted Deformed Bars (CTD Bars)

FIG.35 COLD TWISTED DEFORMED BARS

- The **process of cold working** involves stretching and **twisting of mild steel beyond yield** plateau to obtain cold twisted deformed bars.
- **Drawbacks** of Cold Twisted Deformed Bars are that there are **surface stress and visible cracks** due to cold twisting which leads to **higher corrosion**

rate and durability problems. Therefore, most of the European countries gave up the use of Cold Twisted Deformed Bars within a few years of its making.

- However, in India CTD Bars were commonly used since 1992. Cold Twisted Deformed Bars (CTD Bars) were sold in India under the brand name "**TOR STEEL**".

Thermo Mechanically Twisted Bars (TMT Bars)

FIG.35 THERMO MECHANICALLY TWISTED BARS

- The other method uses is a thermo – mechanical Treatment (TMT) Process in which red hot **rebars are quenched** through a series of **water jets causing a hardened outer** layer surrounding a **softer core**.
- Thus Resulting rebars have **higher yield strength** than mild steel and is characterized with definite Yield Point, Superior **ductility**, **Weldabil**ity and bendability.
- Thermo – Mechanically Treated Bars (TMT Bars) are produced in **various grades by** Steel Authority of India Ltd. (**SAIL**) and **TATA Steel**. The trade names of these bars are known as SAIL – TMT and TISCON – TMT respectively.
- **TMT** Bars are nowadays a fundamental **requirement for construction** in India.
- TMT Bars have improved properties such as **yield strength, ductility, toughness** and **corrosion resistance**.

- TMT Bars have **high resistance to seismic** loads due to its **higher ductility**. These make them as most suitable for use in earthquake- prone areas.
- With the improved properties, **TMT** Bars are **economical** and **safe** for use. Hence it is widely **used as** reinforcement for the construction of **roads**, **Buildings, Bridges** etc. TMT Bars are recommended for use in high – rise buildings because of saving in steel due to higher Strength.

Corrosion Resistant Rebar:

- The **latest** development of reinforcing bar are the thermo – mechanically treated high – strength corrosion resistant (**TMT – HCR**) rebars.
- The TMT – HCR rebars have superior **resistance to** aggressive **weather** conditions. The chemistry of TMT – HCR rebar is appropriately designed for substantially **reduci**ng atmospheric and **marine corrosion**.
- TMT – HCR Rebar finds wide **application**s in different spheres including **coastal** and marine **environment**s which are susceptible to corrosion, bridges, dams, industrial structures and high-rise buildings.

Deformed and Plain Carbon Steel Bars

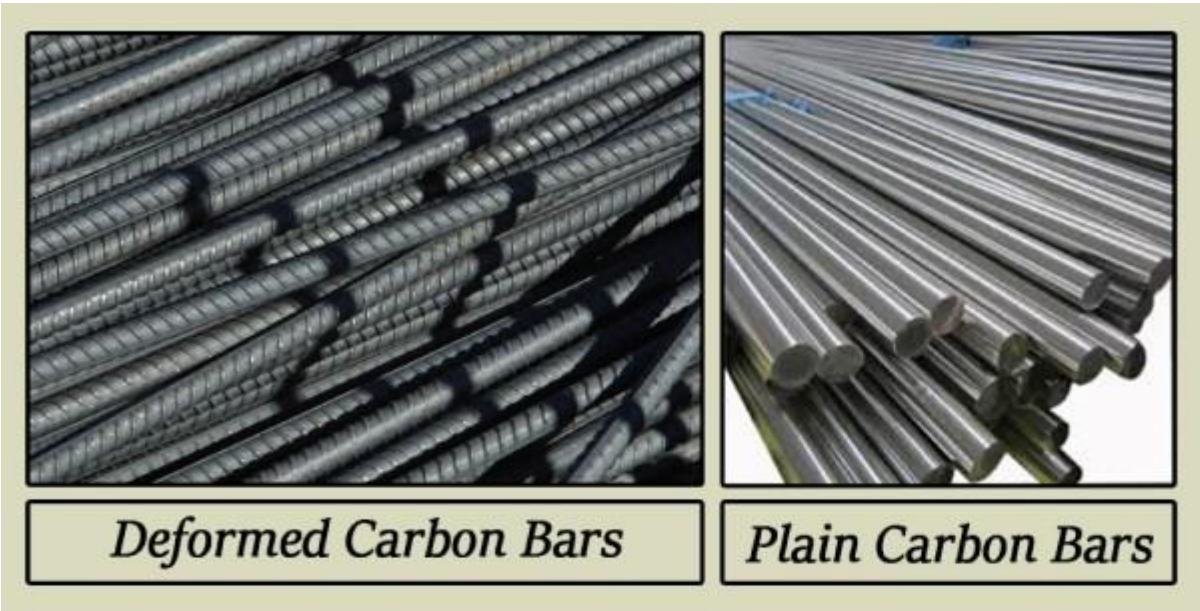

FIG.36 DEFORMED AND PLAIN CARBON STEEL BARS

- Carbon Steel Reinforcing bars conforming to the requirements of ASTM A615/A615M.

- Carbon Steel bars are the most commonly specified type of reinforcing bar and can be **used in** a wide variety of applications where there are **no special** performance **requirement**s.

Bars are designed as per following rebar steel grades,

- 280 MPa or Grade 40
- 420 MPa or Grade 60
- 520 MPa] or Grade 75
- 550 MPa] or Grade 80
- 690 MPa] or Grade 100

TABLE 3 MECHCANICAL PROPERTIES OF DEFORMED BARS

Mechanical Properties		
Steel Grade	Tensile Strength Psi [MPa]	Yield Strength Psi [MPa]
Grade 40 [280]	60 000 [420]	40 000 [280]
Grade 60 [420]	90 000 [620]	60 000 [420]
Grade 75 [520]	100 000 [690]	75 000 [520]
Grade 80 [550]	105 000 [725]	80 000 [550]
Grade 100 [690]	115 000 [790]	100 000 [690]

- It is rebar that is without anti- rust coating and has the **lowest price** compared to zinc coating and epoxy coating.
- Due to its price advantage, it is **useful for building**.

Low Alloy Steel Bars

- Low Alloy Steel Reinforcing bars conform to the requirements of ASTM A706/A706M.

- These Bars are usually designated as **Grade 60** [420] and **Grade 80** [550] respectively.
- The bars shall be processed from properly identified heats of mold – Cast or Strand – Cast Steel.
- The Steel used in the production of these bars shall be made by the **process** of the **electric – furnace**, basic – oxygen or **open – hearth**.
- The low – alloy steel bars are specified in situations where **enhance**d **weld**ability and **ductility** are needed.

TABLE 4 MECHCANICAL PROPERTIES OF LOW ALLOY STEEL BARS

Mechanical Properties		
Steel Grade	**Tensile Strength Psi [MPa]**	**Yield Strength Psi [MPa]**
Grade 60 [420]	80 000 [550]	60 000 [420]
Grade 80 [550]	100 000 [690]	80 000 [550]

Stainless Steel Bars

FIG.37 STAINLESS STEEL BARS

- Stainless Steel Bars have features of **long – life** cycles and long-term **corrosion resistance** property. Although it is the **most expansive** rebar, it has superior effectiveness of cost.

- The physical and mechanical properties of stainless-steel bars conform to ASTM A955/A955M-16 and are the same as those for carbon-steel bars conforming to ASTM A615.

Rail & Axle Steel Bars

According to A996/A996M – Standard Specification for Rail – Steel and Axle – Steel Deformed Bars for concrete reinforcement, these types of bars are designated with "R" for rail – steel and "A" for axle – steel.

Rail – Steel Bars are designated as the following rebar steel grades,

- 350 MPa or Grade 50
- 420 MPa or Grade 60

Axle – Steel Bars are designated as the following rebar steel grades,

- 280 MPa or Grade 40
- 420 MPa or Grade 60

TABLE 5 MECHCANICAL PROPERTIES OF RAIL BAR

Mechanical Properties		
Steel Grade	Tensile Strength Psi [MPa]	Yield Strength Psi [MPa]
Grade 40 [280]	70 000 [500]	40 000 [280]
Grade 50 [350]	80 000 [550]	50 000 [350]
Grade 60 [420]	90 000 [620]	60 000 [420]

Galvanized Steel Bars

FIG.38 GALVANIZED STEEL BARS

- Galvanized (Zinc – Coated) bars are obtained by **dipping** ASTM A615, ASTM A706 and ASTM 996 Bars **in a molten** bath of **zinc** in accordance with ASTM A767/A767M.
- It is normal black rebar with a layer of zinc coating, which can prevent the rebar from rusting and corrosion.
- According to the 'Fahim Al – Neshawy' (Scientist of Department of civil engineering in Aalto University, Finland), Owing to the property of zinc coating, it can be **used in bridges**.

Low – Carbon Chromium Bars

- Low-carbon chromium bars conforming to ASTM A1035/A1035M are permitted to be used only as **spiral reinforcement** or transverse reinforcement in columns.
- These limitations are imposed because the chromium steel used to manufacture reinforcing bars has **low ductility** and a relatively large **minimum yield strength** of 80,000 psi.

Epoxy Coated Bars

FIG.39 EPOXY COATED BARS

Deformed and Plain Epoxy-Coated Bars

- **Epoxy-coated bars** are **manufacture**d in the following **two ways**.
- The first method, a protective epoxy coating is applied **by** the **electrostatic spray** method to ASTM A615, ASTM A706 and ASTM A996 in accordance with ASTM A775/A775M-07a. The bars are usually fabricated after the application of the epoxy coating.
- In the second method, ASTM A615, ASTM A706 and ASTM A996 bars are prefabricated and then **coated with a protective fusion**-bonded epoxy coating by electrostatic spray or other suitable methods in accordance with ASTM A934/A934M-07.

- According to the 'DAVID P. GUSTAFSON' (Technical Director of Concrete Reinforcing Steel Institute), Epoxy – Coated rebars are considered by many engineers to be one of the most **effective** and **corrosion protection** systems.
- Epoxy Coated bars were first **used in bridge decks** as early 1973 in Pennsylvania. Since then, the uses of Epoxy-coated bars have continually expanded.
- More states and government agencies are specifying coated bars in bridge decks and in other transportation structures.
- Epoxy – Coated bars are now **used in parking garages, marine structures, water and wastewater treatment plants** and other **hydraulic structures**.

Wire Reinforcement

- The various deformed wires that can be used as a steel reinforcement are hard-drawn steel wire fabrics, welded deformed wire fabrics, Epoxy coated steel wire and welded wire, Stainless steel wire and welded wire.
    - **Hard – Drawn Steel Wire Fabrics Conforming to IS 1566: 1982**

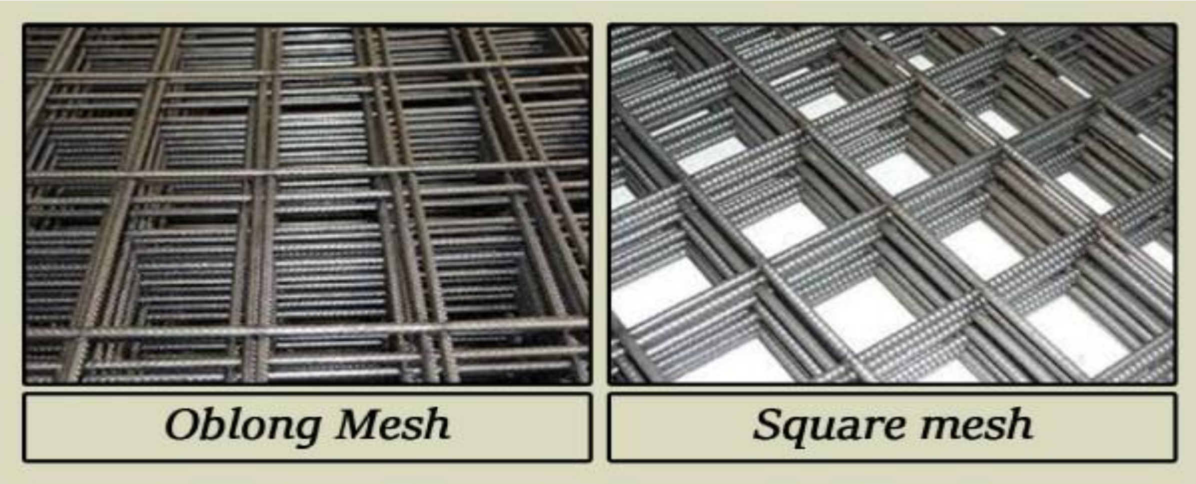

FIG.40 WIRE REINFORCEMENT

Hard-drawn Steel Wire Fabrics are made by a series of **wires arranged at right angles to each other**. According to IS 1566, There are two types of Hard-drawn Steel Wire Fabrics,

- Oblong Mesh
- Square Mesh

- The wire shall be cold-drawn from mild steel made by a various process such as open hearth, electric duplex, acid Bessemer, basic oxygen or combination of them.
- According to IS 432 (PART II): 1982, the **diameter of** hard-drawn **wire** is 3 mm, 4 mm, 5 mm, **6 mm, 8 mm** and **10 mm**.
- Mesh sizes, Weight and size of wires for square and oblong welded wire fabric shall be as agreed to between the purchaser and manufacturer.
- The Specification of Steel Wire also available in ASTM A496/A496M-07.

Welded Deformed Wire Fabrics

- Welded Deformed wire is fabricated from a series of wires arranged at right angles to each other and welded at all intersection. It is much stronger than mild steel and available in different width rolls under ASTM A497/A497M-07.
- Also, Plain Welded wire fabrics are available which conforms to ASTM A496/A496M-07.
- Welded Wire fabrics are used for floor slabs on well-compacted ground, road and runway pavements, culverts and small canal linings.
- **Other types of wire which used as reinforcement are**,
- **Epoxy Coated** Steel Wire and Welded Wires, which conforms to the ASTM A884/ A884M-06.
- Stainless-Steel Wire and Welded Wires, which conforms to the ASTM A1022/ A1022M-07.

Prestressing Steel

- Prestressing Steel generally consists of wires, bars, strands or bundles of such elements.
- The Steel is stressed under high-tensile forces either before the concrete is cast (Pretensioned) or after the concrete is cast and has hardened (Posttensioned).

Medium Tensile Steel Bars

- The steel reinforcement having an ultimate tensile strength **more than 540 N/mm^2** is categorized as Medium tensile steel Bars.
- These types of rebars are used when concrete reinforcement requires strength more than that of Mild steel Bars.

High Tensile Steel Bars

- The steel reinforcement having an ultimate tensile strength in a higher range (**1000 – 2200 N/mm^2**) is categorized as High Tensile Steel Bars.
- These types of rebars are generally used in prestressed concrete construction.
- Structural Steel shapes are made out of the kind of steel, which is found out a precise cross-section, at the same time it follows definite standards for mechanical properties. It comes in various shapes like I-beam, Z

shape, HSS shape, L shape structural channel, T shaped, Rail profile, Bar, Rod, Plate, Open joist of web steel etc.

STRUCTURAL STEEL AND SPECIFICATIONS

Steel is well known for providing structure and strength unlike any other when it comes to construction. The **durability** and **potency** that steel provides is not matched by the likes of wood or concrete. More often than not, it's the case that steel is the material of choice for construction, and people prefer steel due to its various **advantage**s.

Steel buildings tend to be built using various frames too, for example clearspan, modular and single slope. Due to the fact that steel is much easier and less time-consuming when it comes to building, along with its numerous other factors that have proved advantageous, steel, these days, has become the most sought after way of constructing buildings.

With steel, we can create structures like no other material when it comes to construction. No other material has the potency and durability that steel does. Structural steel has undoubtedly become the preferred choice for construction due to the various benefits it has. The buildings that are made from steel require various **structural frames**. Also, constructing with steel entails much less time which makes it the most sought after way of constructing structures.

With this in mind, in this blog, we outline some of the various types of steel and the benefits it can offer you.

Structural Steel

Firstly it’s beneficial to know what structural steel actually is and how it is formed. Structural steel shapes are made out of this kind of steel, which is formated from a **precise cross section**. Yet, at the same time it follows **definite standard**s for mechanical properties and chemical composition.

Structural steel comes in **various shapes like L-beam, Z shape**, HSS shape, **L shape (angle), structural channel (C-beam, cross section), T shaped, rail profile, bar, rod, plate** and an **open joist** of web steel.

Standard structural steel varies in different countries with various specifications. For example, European I-beam is Euronorm 19-57, whereas structural steel in the USA comes in carbon, **low alloy, corrosion resistant high strength** low alloy, quenched and tempered alloy steel etc.

Structural steel is versatile, **strong and durable**, so it's hardly surprising that it can be morphed into almost any shape based on the construction project at hand; it can be constructed almost immediately the moment it is received on the building site. Structural steel is **fire-resistant** in itself but fire protection methods should be put in place in case there is a possibility of it getting heated up to a point where it starts to lose its **durability and strength**. Corrosion has to be prevented when it comes to structural steel, but **tall buildings** are known to have withstood various kinds of adversities when built using structural steel.

Steel construction is increasing in popularity all over the world, with every region benefitting from steel throughout the years. Many of the best **architectural wonders** have been **constructed** through the **use of steel**, be it structural, carbon or rebar, including The Empire State Building and the Sydney Harbour Bridge. More importantly, the usage of **steel** is beneficial in terms of **eco friendliness** than other modes of construction, and due to this factor alone, it is given more preference.

Taking into consideration the rate of marvelous constructions, steel has proved favorable. With the usage of steel increasing within the construction industry, there is no doubt that it will take over the entire construction field soon in the future.

Here we take a look at the **various types of structural steel** and its uses in construction.

Parallel Flange Channels

These **channelled beams** are **U-shaped** with right angled corners, similar to the shape of a staple. They come in various **different sizes**, however, the two sides are always the same length and are parallel to one another. They also offer a **high strength** to weight ratio and have similar uses to angled sections.

Tapered Flange Beams

Taper flange beams come in an **I-shaped** and are also available in a vast **variety of sizes**. In construction, these are often **used as** cross-sections for **girder**s. Though they have a particularly resistance ratio, it is not usually recommended when pressure is present along the length as they are not **torsion** (twisting) **resistant**.

Universal Beam

Universal beams, also known ad **I-beams or H-beams**, come in the shape of their namesake: an 'I' when standing upright, and a 'H' on their side. Universal beams are usually made of structural steel and are used in construction and civil engineering, among other industries.

Universal Column

Universal beams are also widely used for structural purposes. They are similar to beams and are often referred to as **I-beams or H-beams**, however, all three sections are the same in length. As their name suggests, they are mainly used for columns, and **have** a brilliant **load-bearing capabilities**.

Angled Sections

Angled structural steel sections can come as either equal or unequal. Both will be right angled, however, unequal sections have different sized axis' making them **L-shaped**. This kind of section is much stronger (up to 20%) with a much **higher strength** to weight ratios. Angled sections are used in residential **construction, infrastructure, mining** and **transport**. Also, they are available in a wide range of lengths and sizes.

Circular Hollow Sections

Circular Hollow Sections come as hollow **tubular cross sections** and have a much higher **resistance to torsion** that tapered flange beams. The density of the walls is uniform within the entire circle which makes these beams great for use with multi-axis loading processes.

Rectangular Hollow Sections

These types of structural steel are much like the circular hollow sections, however they have **rectangular cross sections**. They are very popular in many **mechanical and construction steel applications**. Their flat surfaces make them prime for use in joining and metal fabrication.

Square Hollow Sections

Like their hollow section counterparts (except with square cross sections), these are used within smaller applications such as **columns or posts**. However, they are **unsuitable for beams** as their shapes are inherently difficult to bolt into other types of shape. They are also known as '**box sections**'.

Flat Sections

Arguably the most versatile type of steel section as they require to be attached to another section. In some cases, they can be attached to another section as a strengthening tool. They are also often referred to as '**plates**' (for example, checker plates).

Underwood Steel

Common structural shapes

The shapes available are described in many published standards worldwide, and a number of specialist and proprietary cross sections are also available.

A steel **I-beam**, in this case used to support timber joists in a house.

- **I**-beam (**I**-shaped cross-section - in Britain these include Universal Beams (UB) and Universal Columns (UC); in Europe it includes the IPE, HE, HL, HD and other sections; in the US it includes Wide Flange (WF or W-Shape) and **H sections**)

- **Z-Shape** (half a flange in opposite directions)
- HSS-Shape (**Hollow structural section** also known as SHS (structural hollow section) and including square, rectangular, circular (**pipe**) and **elliptical cross sections**)
- Angle (**L-shaped** cross-section)
- Structural channel, or **C-beam**, or **C** cross-section
- Tee (**T-shaped** cross-section)
- Rail profile (asymmetrical **I**-beam)
  - **Railway rail**
  - Vignoles rail
  - Flanged **T** rail
  - Grooved rail
- Bar, a long piece with a **rectangular cross section**, but not so wide so as to be called a sheet.
- Rod, a round or **square section** long compared to its width; see also rebar and dowel.
- **Plate**, metal sheets thicker than 6 mm or ¼ in.
- Open web steel **joist**

While many sections are made by hot or cold rolling, others are made by welding together flat or bent plates (for example, the largest circular hollow sections are made from flat plate bent into a circle and seam-welded).

The terms angle iron, channel iron, and sheet iron have been in common use since before **wrought iron was replaced by steel** for commercial purposes. They have lived on after the era of commercial wrought iron and are still sometimes heard today, informally, in reference to steel angle stock, channel stock, and sheet, despite that they are misnomers (compare "tin foil", still sometimes used informally for aluminium foil). In formal writing for metalworking contexts, accurate terms like angle stock, channel stock, and sheet are used

GLASS PROPERTIES

1. MECHANICAL PROPERTIES

Density : 2500 kg/m^3
A 4mm thick pane of glass weighs 10kg/m^2

Hardness : 470 HK

The hardness of float glass is established according to Knoop. The basis is the test method given in DIN 52333 (ISO 9385).

Compression resistance: 800 - 1000 MPa

The compression strength defines the ability of a material to resist a load applied vertically to its surface

Modulus of elasticity : 70 000 MPa

The modulus of elasticity is either determined from the elastic elongation of a thin bar, or from bending a bar with a round or rectangular cross section.

Bending strength : 45 MPa

The bending strength of a material is a measure of its resistance during deflection. It is determined by bending tests on glass plate using the double ring method according to DIN EN 1288-5.

The main characteristics of glass are **transparency, heat resistance, pressure** and **breakage resistance** and **chemical resistance**.

2. THERMAL PROPERTIES

- **Transformation range : 520 - 550°C**
- **Temp & Softening temperature : approx. 600°C**

Contrary to solid bodies of crystalline structure, glass has **no defined melting point**. It continuously **transforms from** the **solid** state **to** the **viscous plastic** state. The transition range is called the transformation range and according to DIN 52324 (ISO 7884), it **lies between 520°C and 550**°C. **Tempering** and **bending** require a temperature of a further 100°C.

Specific Heat : 0.8 J/g/K

The specific heat (in joules) defines the amount of heat required to raise the temperature of 1g of float glass by 1K. The specific heat of glass increases slightly the temperature is increased up to the transformation range.

Thermal conductivity : 0.8W/mK

Thermal conductivity determines the amount of heat required to flow through the cross sectional area of the float glass sample in unit time at a temperature gradient.

Thermal expansion: 9.10-6 K-1

There is a difference in the expansion behaviour of a body under the effect of heat between linear expansion and volumetric expansion. With solid bodies, the volumetric expansion is three times that of linear expansion. The temperature coefficient of expansion for float glass is given according to DIN 52328 and ISO 7991.

3. OPTICAL PROPERTIES

Glass has several **strong** points concerning optical properties: It can be **produced** in **large** and **homogeneous pane**s. Its optical properties are **not affected by ageing.** It is produced with perfectly flat and parallel surfaces.

Refractive index n = 1.52

If light from an optically less dense medium (air) meets an optically denser medium (glass), then the light ray is split at the surface interfaces. The measure of deflection determines the refractive index. For float glass, this refractive index is n=1.52.

4. TECHNICAL PROPERTIES

Chemical resistance against

- Water = class 3 (DIN 52296)
- Acid = class 1 (DIN 12116)
- Alkaline = class 2 (DIN 52322 and ISO 695)

The surface of **glass is affected** if it is exposed **for a long time to alkalis** (and ammonia gases in damp air) in conjunction with high temperatures. Float glass will also react to compounds that contain hydrofluoric acid under normal conditions. These are used for treating glass surfaces.

Wear tests

- **Abrasion tests** (DIN 52347 and ISO 3537) the scattering of light the transmission of directed light striking the surface is evaluated.
- **Light scatter** increase for float glass is approx. 1% (after 1000 abrasion cycles). The permitted light scatter increase for vehicle safety glass (windshield) is 2% in Europe (ECE R43) and the USA (ANSI Z 26.1).
- **Sand trickling process** (DIN 52348 et ISO 7991). For this diagonal impact abrasion test, 3kg of sand with a 0.5/0.71mm particle size are trickled onto the surface to be tested, which is inclined at 45 y from a height of 1600mm. Measurement of wear is the reduced luminous density (according to DIN 4646 part 2).
- **Reduced luminous density** for float glass is approx. 4cd/m2lux.
- **Micro scratch hardness** for float glass is approx. 0.12N (Mar resistance-test).

The test was designed to determine the scratch hardness of plastics. A diamond point with 50 y cone angle and 15 mm point radius is drawn over the glass surface by applying different loads. The **load at which a scratch is produced on the surface is a measurement of scratch hardness**. This is not an accurate method; the influence of the tester must not be neglected.

GLASS CLASSIFICATIONS

Glass Types

- **Float** Glass.
- **Toughened** Glass.
- **Tinted** Glass.
- **Obscured** Glass**.**
- **Laminated** Glass**.**
- **Mirrored** Glass.
- **Low E** Glass.
- **Coated** Glass.

USES OF GLASS

What are the uses of a glass?

Glass is used in the following non-exhaustive list of products:

- **Packaging** (**jars** for food, **bottle**s for drinks, flacon for **cosmetics** and **pharmaceutical**s)
- **Tableware** (drinking glasses, plate, cups, bowls)
- Housing and buildings (**windows, facades**, conservatory, insulation, reinforcement structures)

Glass has been a fascinating material to humankind since it was first made in about 500 BC. At first thought to possess magical properties, glass has come a long way. It is one of the most versatile and **oldest** materials in the building industry. From its humble beginnings as a **window pane in luxury houses** of Pompeii to sophisticated structural members in new age buildings, its role in architecture has evolved over the years.

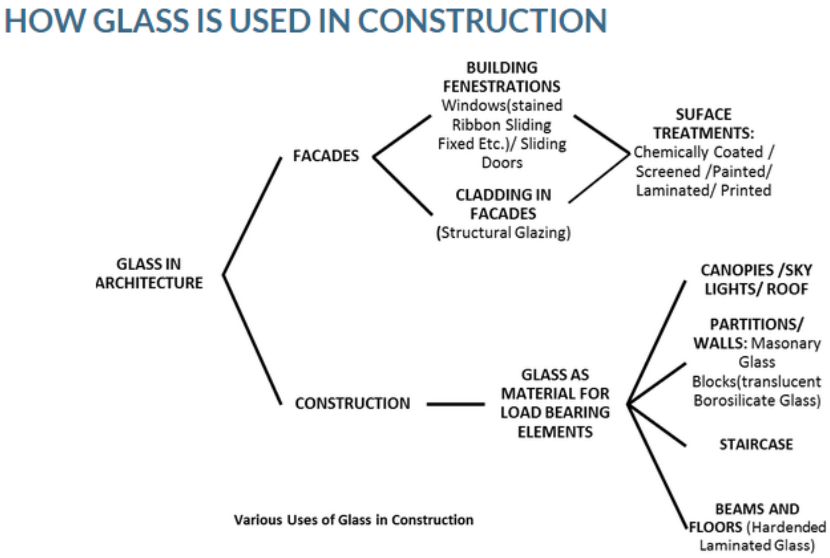

FIG.41 USES OF GLASS

TYPES OF GLASS

Float Glass: Float glass is also called **soda lime glass or clear glass**. This is produced by annealing the molten glass and is clear and flat. Its modulus of rupture is 5000-6000 psi. **Stronge**r than Rocky Balboa taking punches from 2000 psi punches man Ivan Drago. It is available in standard t**hickness** ranging from **2mm to 20mm**. and has **weight** range in **6-26kg/m2**. It has too much **transparency** and can cause glare. It is used in making canopies, shop fronts, glass blocks, railing **partition**s, etc.

Tinted Glass: Certain additions to the glass batch mix can add **color** to the clear glass without compromising its strength. **Iron oxide is added** to give glass a **green tint**; **sulphar** in different concentrations can make the glass **yellow**, **red** or **black**. **Copper sulphate** can turn it **blue**. Etc.

Toughened Glass This type of glass is tempered may have distortions and low visibility but it breaks into small dice-like pieces at modulus of rupture of 3600 psi. Hence it is used in making **fire resistant doors** etc. They are available in same weight and thickness range as float glass.

Laminated Glass: This type of glass is made by sandwiching glass panels within a protective layer. It is **heavier** than normal glass and may cause optical distortions as well. It is **tough and protects from UV radiation** (99%) and

insulates sound by 50%. Used in glass facades, aquariums, bridges, **staircases, floor slabs**, etc.

Shatterproof glass: By adding a polyvinyl butyral layer, shatter proof glass is made. This type of glass **does not from sharp edged pieces** even **when broken**. **Used in** skylight, **window, flooring**, etc

Extra clean glass: This type of glass is hydrophilic i.e. The **water moves over them without leaving any marks** and photocatylitic i.e. they are covered with Nanoparticles that attack and break dirt making it easier to clean and maintain.

Double Glazed Units: These are made by providing air **gap between two glass panes** in order **to reduce the heat loss and gain**. Normal glass can cause immense amount of heat gain and upto 30% of loss of heat of air conditioning energy. Green, energy efficient glass can reduce this impact.

Chromatic glass: This type of glass **can control daylight and transparency** effectively. These glasses are available in **three forms- photochromatic** (light sensitive lamination on glass), t**hermochromatic** (heat sensitive lamination on glass) and **electrochromatic** (light sensitive glass the transparency of which can be controlled by electricity switch.) It can be used in meeting rooms and ICUs

Glass wool: Glass wool is a **thermal insulation** that consists of intertwined and flexible glass fibers, which causes it to "package" air, and consequently make good insulating materials. Glass wool can be **used as** filler or **insulators** in buildings, also for soundproofing.

Glass blocks: Hollow glass wall blocks are manufactured as **two separate halves** and, while the glass is still molten, the two pieces are pressed together and annealed. The resulting glass blocks will **have a partial vacuum** at the hollow center. Glass bricks provide visual obscuration while admitting light

PLASTICS PROPERTIES

Plastics are a wide range of **synthetic or semi-synthetic material**s, that use **polymers as a main ingredient**. The plasticity during production makes it possible for plastic to be **moulded, extruded** or **pressed into solid objects** of various shapes, making it an adaptable material for many different uses. This adaptability, plus a wide range of beneficial properties, such as being light weight, durable and flexible, alongside cheap production processes has led to widespread adoption in contemporary society. Plastics typically are made through human industrial systems. Most modern **plastics are derived from fossil fuel based petrochemicals like natural gas** or **petroleum**; however, recent industrial methods use variants made from renewable materials such as derivatives of corn or cotton.

Plastics have many uses throughout society. In developed economies, about a third of plastic is **used in packaging** and roughly the same in buildings in applications such as **piping, plumbing** or vinyl siding. Other uses include **automobiles** (up to 20% plastic), **furniture**, and **toys**. In the developing world, the applications of plastic may differ; 42% of India's consumption is used in packaging. In the **medical field**, polymer implants and other medical devices are derived at least partially from plastic. **Worldwide**, about **50 kg of plastic is produced annually per person**, with production doubling every ten years.

The world's **first** fully synthetic **plastic** was Bakelite, invented in New York in **1907**, by Leo Baekeland, who coined the term "plastics". Dozens of different types of plastics are produced today, with many consumers interacting with common **plastics like polyethylene**, which is widely used in consumer packaging, and **polyvinyl chloride**, used in construction and pipes because of its **durability and strength**. Many chemists have contributed to the materials science of plastics, including Nobel laureate Hermann Staudinger, who has been called "the father of polymer chemistry" and Herman Mark, known as "the father of polymer physics".

The success and dominance of plastics starting in the early **20th century causes widespread environmental problems**, due to their **slow decomposition rate** in natural ecosystems. Toward the end of the 20th century, the plastics industry promoted **recycling** in order to assuage environmental concerns while continuing to produce virgin plastic. The main companies producing plastics doubted the economic viability of recycling at the time, and this is reflected in contemporary plastic collection. **Plastic collection and recycling is ineffective because of the complexity of cleaning and sorting post-consumer plastics**. Most plastic produced has not been reused, either being captured **in landfills** or persisting in the **environment** as plastic **pollution**. **Plastic pollution** can be found **in** all the world's major **water bodies**—for example, creating garbage patches in all of the world's **oceans and contaminating terrestrial ecosystems.**

What are physical properties of plastic?

Plastics can also be classified by: their various physical properties, such as: **hardness, density**, **tensile strength**, **resistance to heat and glass transition temperature**, and by their chemical properties, such as the organic chemistry of the polymer and its resistance and reaction to various chemical products

What are some chemical properties of plastic?

The term "plastics" includes materials composed of various elements such as **carbon, hydrogen, oxygen, nitrogen**, **chlorine**, and **sulfur**. Plastics typically have **high molecular weight**, meaning each molecule can have thousands of atoms bound together

TYPES OF PLASTIC

The seven types of plastic

- **Polyethylene Terephthalate** (**PETE**)
- **High-Density Polyethylene** (**HDPE**)
- **Polyvinyl Chloride (PVC - U**)
- **Polypropylene (PP**)
- **Polystyrene** or **Styrofoam** (**PS**)
- Others.

USES OF PLASTIC

Plastics Applications

What sectors use plastic?

Plastic is used across almost every sector, including producing **packaging**, in building and construction, in **textil**es, **consumer products**, transportation, **electrical and electronics** and industrial machinery.

Is plastic important for innovations?

In the UK, more patents are filed each year in plastics than for glass, metal and paper combined. There are constant innovations occurring with polymers that can help revolutionise industries. These include shape-memory polymers, light-responsive polymers and self-healing polymers.

What is plastic used for?

Aerospace

The **cost-effective** and safe transportation of people and goods is vital to our economy, cutting the weight of cars, aeroplanes, boats and trains can **cut fuel consumption** dramatically. The lightness of plastics therefore makes them invaluable to the transport industry.

Construction

Plastics are used in a growing range of applications in the construction industry. They have great versatility and combine excellent **strength to weight ratio, durability, cost effectiveness, low maintenance** and **corrosion resistance** which make plastics an **economical**ly attractive choice throughout the construction sector.

Electrical and Electronic Applications

Electricity powers almost every aspect of our lives, at home and in our jobs, at work and at play. And everywhere that we find electricity, we also find plastics.

Packaging

Plastics is the perfect material for use in packaging goods. Plastics is versatile, hygenic, **lightweight**, **flexible** and highly **durable**. It accounts for the largest usage of plastics world wide and is used in numerous packaging applications including **containers, bottles, drums, trays, boxes, cups** and vending packaging, baby products and protection packaging.

Automotive

Bumpers, dashboards, engine parts, seating and doors

Energy Generation

Wind turbines, solar panels and wave booms

Furniture

Bed and household furniture

Marine

Boat hulls and sails

Medical and Healthcare

Syringes, blood bags, dialysis machines, heart valves, artificial limbs and wound dressing.

Military

Helmets, body armour, tanks, warships, aircraft and communications equipment.

A.C. SHEETS PROPERTIES

Ref: Physical Properties of Asbestos-Cement Roof Sheeting after Long-term Exposure - S.K. Brown

TYPES OF AC SHEET

Asbestos cement sheet is **weatherproof, durable, corrosion-resist, heat insulating**. All these properties contribute it an ideal construction material. Three **types of asbestos cement** products at stock **-** **flat sheet**, **corrugated sheet** and **coated corrugated sheet**.

Impact strength: ≥ 2.0 kJ / m^2

Length: 1750 ±10mm

Density: ≥ 1.6 g / cm^3

Width: 1110 ±6mm

FIG.42 AC SHEETS

USES OF AC SHEET

Asbestos cement, generalized as **fibro** or **fibrolite** - short for "fibrous (or fibre) cement sheet" - and **AC sheet**, is a **building material** in which asbestos fibres are used to reinforce thin rigid cement sheets.

Although invented at the end of the 19th century, the material rose to **necessity during World War II** to make sturdy, inexpensive **military housing**, and continued to be used widely following the war as an **affordable external cladding** for buildings. Advertised as a **fireproof** alternative to other roofing materials such as asphalt, asbestos-cement roofs were popular not only for safety but also for affordability. Due to asbestos-cement's imitation of more expensive materials such as wood siding and shingles, brick, slate, and stone, the product was marketed as an affordable renovation material. Asbestos-cement faced competition with the aluminium alloy, available in large quantities after WWII, and the re-emergence of wood clapboard and vinyl siding in the mid to late twentieth century.

Asbestos-cement is usually formed into **flat** or **corrugated sheets** or **piping**, but can be **moulded** into any shape wet cement can fit. In Europe, many forms were historically used for cement sheets, while the US leaned more conservative in material shapes due to labour and production costs. Although fibro was used in a number of countries, it was in Australia and New Zealand where its use was the most widespread. Predominantly manufactured and sold by James Hardie & Co. until the mid-1980s, fibro in all its forms was a very popular building material, largely due to its **durabilit**y. The reinforcing fibres involved in construction were almost always asbestos.

The use of fibro that contains asbestos has been banned in several countries, including Australia. As recently as 2016, the material has been discovered in new components sold for construction projects.

Products used in the building industry

- **Roofs** - typically on industrial or farmyard buildings.
- **Flat sheets** for house walls and ceilings were usually **6** and 4.5 **mm** (0.24 and 0.18 in) **thick**, in 900 and **1200 widths** and from 1800 to **3000 long**.
- **Battens** 50 mm (2.0 in) wide × 8 mm (0.31 in) thick used to **cover** the **joints** in fibro sheets.
- "Super Six" corrugated roof sheeting and fencing.
- Internal wet area sheeting, "Tilux".
- Pipes of various sizes for water reticulation and drainage. **Drainage pipes** tend to be made of pitch fibre, with asbestos cement added to strengthen.

- Moulded products ranging from plant pots to outdoor telephone cabinet roofs and cable pits.

FIG.43 AC SHEETS ON ROOF

PROPERTIES OF BITUMEN

Following are the properties of Bitumen

- Adhesion.
- Resistance to Water.
- Hardness.
- Viscosity and Flow.
- Softening Point.
- Ductility.
- Specific Gravity.
- Durability.

TYPES OF BITUMEN

The bitumen can be classified into the following grade types:

- **Penetration Grade** Bitumen.
- **Oxidized** Bitumen Grades.
- **Cut Back** Bitumen.
- Bitumen **Emulsion**.

- **Polymer Modified** Bitumen.

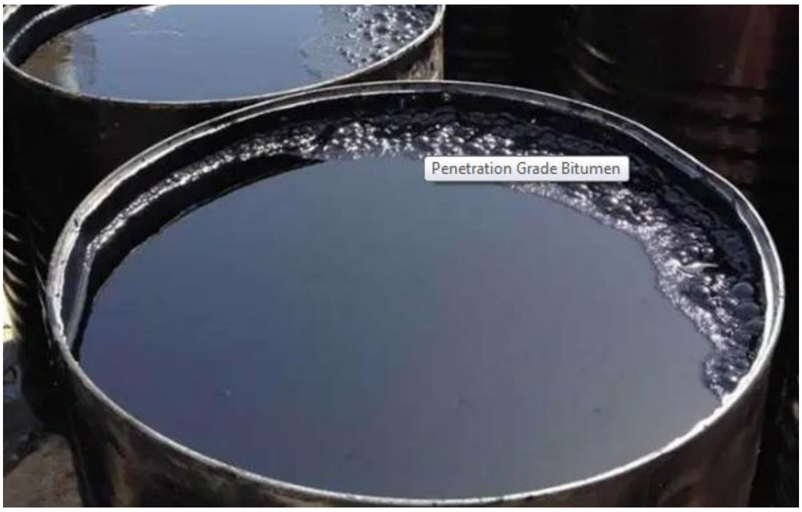

FIG.44 LIQUID BITUMEN

USES OF BITUMEN

What is the main use of bitumen?

Most refined bitumen is used in the **construction** industry. Mainly, it serves its use in **paving** and **roofing** applications. 85% of all bitumen is used as a binder in asphalt for **roads, runways, parking lots**, and **foot paths**.

What are the two uses of bitumen?

Bitumen is commonly used to build **highways, motorways** and rail networks. Bitumen has excellent **water-proofing** properties and is widely used for making **roofing** products along with a range of other household and industrial applications, from emulsion paints to sound-proofing.

What are the uses of bitumen in construction?

The vast majority of bitumen is used by the construction industry, as a constituent of products used in **paving and roofing**. Excellent **waterproofing** characteristics and thermoplastic behaviour make it ideal for a wide range of applications.

Why is bitumen used for roads?

Asphalt road surfaces are also considered a sustainable option for road paving material where bitumen is used as **binder** as this material can be **recycled**. The bitumen, produced by the refineries, plays an important role in **road durability** which is also important for sustainability.

PROPERTIES OF ADHESIVES

Master Bond's adhesive product line features important performance properties, such as:

- Abrasion Resistant.
- Creep and Fatigue Resistant.
- Dimensionally Stable.
- Flexibility and Toughened.
- Hardness.
- Low Shrinkage.
- Low Stress.
- Rigid Curing

ADHESIVE PROPERTIES

Selecting a structural strength adhesive for a specific application requires performance criteria of several characteristics. First are **bond-making** properties that determine ease of use and in-place manufacturing cost:

- Degree of surface preparation necessary
- Time to handling strength
- Cure conditions of heat or room temperature, the degree of pressure, and the fixturing to maintain that pressure.
- Viscosity for pumping and staying in place after application. Pseudoplastic and thixotropic qualities are desireable so that the adhesive thins during the shearing action of delivery and thickens in place without further shearing.

- Application with automated bulk systems or hand-held applicator to meet varying production requirements.

Then there are the following cured bond properties:

PHYSICAL PROPERTIES

- Adhesion to a variety of substrates allows bonding of dissimilar materials if necessary
- High **cohesive strength** is desirable
- Flexibility improves **peel strength** by flexing with peel stress
- High elastic modulus of substrate and adhesive **resists stress** at the bond line
- High damping capacity of the adhesive dissipates **dynamic stresses** of **vibration, motion**, & impact throughout the bond & peel stresses at the bond line
- Flexibility and **damping resistance** resists **thermal expansion stresses** when the coefficients of thermal expansion are different between adhesive and substrates

ENVIRONMENTAL RESISTANCE

- Resists end-use or post-processing temperatures to maintain adhesive chemistry and the physical bond.
- **Withstands physical shock** at a range of temperatures
- **Maintains adhesive** performance despite **exposure to UV light, rain, salt water**, and other **weathering conditions**

CHEMICAL RESISTANCE

Ability to withstand degradation from diesel fuel, solvents and other chemicals

TYPES OF ADHESIVES

How many types of adhesive are there?

There are **two types** of adhesives that harden by drying: **solvent-based** adhesives and **polymer dispersion** adhesives, also known as **emulsion**

adhesives. Solvent-based adhesives are a mixture of ingredients (typically polymers) dissolved in a solvent.

What are the 6 general types of adhesives?

Different Types of Glues:

- White Craft Glue: This is the most common craft glue for porous lightweight materials such as paper, cardboard, cloth, and kids' crafts. ...
- Yellow **Wood Glue**:
- **Super Glue** (also known as **cyanoacrylate adhesives**):
- **Hot glue**:
- **Spray adhesives**:
- Fabric adhesives:
- **Epoxy**:
- Polyurethane:

TYPES OF ADHESIVES

There are a large number of adhesive types for various applications. They may be classified in a variety of ways depending on their chemistries (e.g. **epoxie**s, **polyurethanes, polyimides**), their **form** (e.g. **paste, liquid, film, pellets, tape**), their **type** (e.g. **hot melt**, reactive hot melt, **thermosetting**, pressure **sensitive**, contact, etc.), or their load carrying capability (**structural, semi-structural, or non-structural).**

Structural adhesives refer to relatively **strong adhesives** that are normally used well below their glass transition temperature, an important property for polymeric materials, above which polymers are rubbery and below which they are glassy. Common examples of structural adhesives include epoxies, cyanoacrylates, and certain urethanes and acrylic adhesives. Such adhesives can carry significant stresses, and lend themselves to structural applications.

For many engineering applications, semi-structural (applications where failure would be less critical) and non-structural (applications of facades, etc. for aesthetic purposes) are also of significant interest to the design engineer, and provide **cost-effective** means required for assembly of finished products. These include contact adhesives where a solution or emulsion containing an elastomeric adhesive is coated onto both adherends, the solvent is allowed to evaporate, and then the two adherends are brought into contact. Examples include rubber cement and adhesives used to bond laminates to countertops.

Pressure sensitive adhesives are very **low modulus elastomers** which deform easily under small pressures, permitting them to wet surfaces. When the substrate and adhesive are brought into intimate contact, **Vander Waals forces** are sufficient to maintain the contact and can provide relatively durable bonds for lightly loaded applications. Pressure sensitive adhesives are normally purchased as tapes or labels for non-structural applications, although can also come as double-sided foam tapes which can be used in semi-structural applications. As the name implies, hot melts become liquid when heated, wetting the surfaces and then cooling into a solid polymer. These materials are increasing used in a wide array of engineering applications using more sophisticated versions of the glue guns widely used by consumers. Anaerobic adhesives cure within narrow spaces deprived of oxygen; such materials have been widely used in mechanical engineering applications to lock bolts or bearings in place. Cure in other adhesives may be induced by exposure to ultraviolet light or electron beams, or may be catalyzed by certain materials such as water which are ubiquitous on many surfaces.

Adhesives of various chemistries are available in many different forms as well. **For structural applications**, adhesives are **available as pastes, liquids, films**, and supported films. The latter are supported on loose knit or mat scrim cloth to improve the handling properties and also to offer some measure of thickness control. Many of these adhesives produce little or no out-gassing when cured, significantly reducing the likelihood of voids within the adhesive. It is important that these **adhesives be kept dry**, as absorbed moisture can create significant void problems. **Thermosetting structural adhesives** are normally **available in two-part forms** that are mixed through carefully controlled stoichiometry into a product that cures within the desired time window. One-part forms are also available in which the resin and hardener (cross-linking agent) are already mixed together. These one-part forms must be kept at sufficiently low temperature that the reaction does not occur prematurely, sometimes utilizing latent cross-linking agents that are not active at low temperatures. One-part thermosetting adhesives often have limited shelf life, and often must be stored at low temperatures, but do offer very high performance capabilities. Pot life refers to the time after a two-part adhesive is mixed during which it is workable and will still make a satisfactory bond. Materials with too short of a pot life will harden too fast, and do not give the workers sufficient time to assemble the product. An excessively long pot life may delay the cure time and slow the assembly process.

Adhesives may be applied in a variety of ways depending on the form it comes in. **Adhesives may be spread on a surface manually**, **or** may be dispensed using a variety of sophisticated **nozzles** and robotic equipment that is currently available. Maintaining adherend cleanliness, providing proper jigs and fixturing during cure, and providing adequate cure conditions may all be important considerations for certain types of adhesives.

The **glass transition temperature** (Tg) is one of the most important properties of any polymer, and refers to the temperature vicinity in which the amorphous portion of the polymer transitions from a hard, glassy material to soft, rubbery material. Although specific temperatures are often quoted for the glass transition temperature, it is important to remember that this transition temperature is a rate dependent process. **For thermosetting structural adhesives**, the glass transition **temperature should** normally **be 50°C higher** than the expected service temperature. Unless there are significant exotherms associated with the cure process, the glass transition temperature of an adhesive seldom exceeds the cure temperature. High performance structural bonds often require an elevated temperature cure to provide a sufficiently high Tg in a reasonable cure time. One concern with such conditions, however, is the residual stress which may develop with an assembled joint is cooled from the cure temperature to the service conditions.

For example, silly putty at room temperature will readily flow when pulled slowly, will bounce like a rubber ball when dropped on the floor, or can shatter in a brittle fashion when struck with a hammer. The glass transition temperature of epoxies and other adhesives can be significantly reduced by moisture absorption, a factor which should be considered when designing for humid applications.

USES OF ADHESIVES

Adhesives are designed for specific **applications**. Besides their role in the adhesion process, they can be used for other purposes, such **as sealing agents**, in order to eliminate the effect of self-loosening caused by dynamic loads, sealing of areas **to prevent oxidation and corrosion, waterproofing.**

Where are adhesives used in construction?

Adhesives are **used** as the **bonding layer** for floor fixing **between** the existing **floor and the substrate**. They are **mixed with** the **cement** used **for Joints**. They are very **useful in** Manufactured Housing or **pre-fabricated** housing. Fixing of Pre-finished Panels.

What are the uses of adhesives?

Adhesives are components that initiate the **adhesion of two compounds**. Earlier plant **resins** were **used as** common **adhesives** but **now** there are **synthetic products** which have **more** adhesion **power** than the natural ones. Besides the major function in any particular industry to bond substrates in order to structure the final product, adhesives are used for many functions in daily life. These are found every simple compound around us. It serves its purpose in each small product around us. It includes sealing the pipes or other items that require sealing.

The compounds used for preparation of adhesives should satisfy many criteria in order to serve its purpose of bonding two different substances together. It includes common household activity like screw fixation to avoid self-loosening and sticking out broken products.

The uses of synthetic adhesives are divided into 2 categories

Large scale use

Adhesive are in usage for all kinds of industries, small or heavy. In **small industries** like those of **food products**, **toys** or **stationary items**, adhesives play an important role in processing to packaging. In small industries it has roles like **connecting** the **parts of the toys**, the lipstick connected to its base. In **heavy industries** right from **assembling spare parts** of any machine or vehicle, car paint or branding them with labels. In furniture woods are bonded with strong adhesive and construction industry too for strength in the structures, Apart from these there are also many other uses for adhesives.

FIG.45 USES OF ADHESIVE

Daily uses

In day to day life there is variety of uses for adhesives which starts right from sticking envelopes to rejoining any broken materials.

FIG.46 USES OF ADHESIVE IN LARGE SCALE

Out of this glue is the most used form of **adhesive** in frequent basis. The form of glue **includes glue sticks**, cello tapes or **gums** etc for everyday to mend shoes, to glue postage stamps and pack gifts.

Adhesives are those

- Product that has to currently alter its design for being strong and adherent.
- Are those which **wet the particular surfaces** which are to be bonded displacing all air flow between the surfaces.

The **advantages** of adhesives over other binding methods include:

- **Easier binding** method compared to other traditional methods like welding
- **Faster method** of binding comparatively
- **Retain the flexibility** of the material compared to other methods
- **Doesn't affect the weight** of the material
- Depending on the material to be bound there are varied range of adhesives

PROPERTIES OF ALUMINIUM.

- **Light Weight**. Aluminium is a very light metal with a **specific weight** of 2.7 g/cm^3, about a third of that of steel.
- **Corrosion Resistance**.
- Electrical and **Thermal Conductivity**.
- Reflectivity.
- **Ductility**.
- Strength at Low Temperatures.
- Impermeable and Odorless.
- **Non-magnetic**.

What are the Physical Properties of Aluminium?

- **Color** : Silvery-white with a bluish tint.
- **Hardness** : The pure metal is soft, but it becomes strong and hard when alloyed.

- **Ductility** : It can be beaten into extremely thin sheets.
- **Malleability** : Capable of being shaped or bent.

What are the Properties of Aluminium? Definition of Aluminum

It is a silvery-white, **ductile metallic element**, the most abundant in the earth's crust but found only in combination, chiefly **in bauxite**. Having good conductive and **thermal properties**, it is used to form many **hard, light, corrosion-resistant alloys**. The Physical and Chemical Properties are the characteristics of a substance, like Aluminium, which distinguishes it from any other substance. Most common substances exist as States of Matter as solids, liquids, gases and plasma.

What are the Physical Properties of Aluminium?
The Physical properties of Aluminium are the characteristics that can be observed without changing the substance into another substance. Physical properties are usually those that can be observed using our senses such as **color, luster, freezing point, boiling point, melting point, density, hardness and odor**. The Physical Properties of Aluminium are as follows:

What are the Physical Properties of Aluminum?	
Color	Silvery-white with a bluish tint
Hardness	The pure metal is soft, but it becomes strong and hard when alloyed
Ductility	It can be beaten into extremely thin sheets
Malleability	Capable of being shaped or bent
Conductivity	Good electrical and heat conductors
Corrosion	Resists corrosion by the formation of a self-protecting oxide coating

TYPES OF ALUMINIUM

Aluminium alloys can be broadly separated into **two categories**: **cast aluminium alloys** and **wrought aluminium alloys**. Cast alloys of aluminium are those which contain **> 22%** alloying elements by composition, whereas **wrought** aluminium alloys contain **≤4%.** This may seem like a simple difference, but the percentage of alloying elements has a huge impact on material properties. **Aluminium loses its ductility as more alloying elements are added,** making most cast alloys susceptible to brittle fracture. Conversely, wrought alloys have allowed designers to increase aluminium's strength, **corrosion resistance, conductivity**, etc. while still retaining ductility and other beneficial qualities.

Cast aluminium alloys typically have low melting points and tensile strength when compared to wrought aluminium; the most commonly used aluminium alloy is aluminium-silicon, which features high levels of silicon that enable the alloy to be easily cast. Wrought aluminium accounts for the majority of aluminium products, such as those manufactured from extrusion or rolling. Elements such as copper, manganese, silicon, magnesium, magnesium silicon combinations, zinc, and lithium define the individual wrought aluminum alloy categories.

Cast Alloys

Cast alloys of aluminium are named using four numbers, with a decimal between the third and fourth digit. The first three numbers indicate the alloy, and the fourth number indicates the form the product is in. Below, in Table 6, is shown the different types of cast aluminium, their common alloying elements, and their basic material properties. Note that the properties (**cracking, corrosion, finishing, joining**) are given ratings of 1 to 5, 5 being the worst and 1 being the best, and are generalized quantifications of their capabilities:

.

Note: Cells with no number indicate that the value is not often specified, or is too difficult to generalize. A rating of 1 is considered exceptional, a rating of 5 is considered very poor, and 2-4 fall within this range.

Table 6 Different cast aluminum grades, with their general information shown

Aluminum grade	Alloying elements	Strengthening Process	Cracking	Corrosion Resistance	Finishing	Joining
1xx.x	unalloyed	Non-heat-treatable	-	1	1	1
2xx.x	Copper	Heat-treatable	4	4	1-3	2-4
3xx.x	Silicon, Magnesium, Copper	Heat-treatable	1-2	2-3	3-4	1-3
4xx.x	Silicon	Heat-treatable	1	2-3	4-5	1
5xx.x	Magnesium	Non-heat-treatable	4	2	1-2	3
6xx.x	NOT USED	NOT USED	-	-	-	-
7xx.x	Zinc	Heat-treatable	4	4	1-2	4
8xx.x	Tin, Copper, Nickel	Heat-treatable	5	5	3	5

USES OF ALUMINIUM

It is soft and malleable. Aluminium is used in a huge variety of products including **cans, foils, kitchen utensils, window frames**, beer kegs and **aeroplane parts**. This is because of its particular **properties**

MOST COMMON APPLICATIONS OF ALUMINIUM

In the past few weeks we've been championing aluminium and its evidential usefulness both in the past, present and (potentially) future. Differentiating between the various metals encountered in our day to day is not something the average person thinks much about, but once you're more 'metal-literate', the world can look very different indeed! Thus, in this blog we're going to show you 5 of the most common applications of aluminium; perhaps in places you never would have quite expected.

Precision Tubing in **motor vehicles**, **refrigerators, air conditioning, solar panels** etc.

As we've explained elsewhere on the blog before, the use of pure aluminium is very rare in the commercial world. Usually the non-ferrous metal is mixed with other metals to create an alloy depending on the desired use. When this comes to precision tubing, the strong heat transfer applications allow it to be used extensively for the automotive, AC and solar market industries, as well as for carrying liquids or gases. It's been noted as being very similar to plastic in how it can be worked upon without breaking, and for being very widely recycled.

Power Lines

Aluminium's **light weight and durability** would make it an ideal candidate for transporting energy across long distances, but as a pretty poor conductor it needs to be mixed with the properties of copper (which is normally too heavy and expensive to do the job on its own), or better yet, boron. The ability to withstand corrosion and general lack of a need for a costly support structure is a plus, and the aluminium alloys themselves are often reinforced with steel - a true match made in metal heaven!

Rolled Aluminium products

One of the few explicit uses of aluminium in more common everyday use, by its more informal title tin foil is produced through the metalworking process of 'rolling', whereby sheet ingots are cast from molten billet aluminium, then re-rolled on sheet and foil rolling mills to the desired thickness (or lack thereof), or by continuously casting and cold rolling. Impermeable to oxygen and water, it can be used to not only cook food but also to keep it fresh as well, thus it's a very rare day indeed in which you don't spot a bit of tin foil somewhere.

Heat sinks for cooling CPU's and graphics processors

The heavy thermal, corrosion and biofouling resistance of aluminium alloys, plus its thermal conductivity, have made them the key material of choice for most commercial heat sinks. These are passive heat exchangers that cool a device (typically a microprocessor or graphics card) by dissipating heat from the device to the environment. Heat sinks come in the form of the copper foil of a circuit board or a separate device, and is attached through a variety of methods including thermally conductive tape or epoxy.

Construction

A no-brainer really; aluminium is pretty much necessary in construction work! From skylights to **bridges** and **ladders t**o **railings**, whether implemented as rods, **doors** or **wiring**, the **low maintenance** and **ability to paint**, mould and join with other materials leaves little reason to not consider it for your chosen project. We see aluminium daily without even thinking about it, and undoubtedly the use of **aluminium angles**, tubes and boxes in construction are just a few of its biggest starring roles.

FIG.47 USES OF ALUMINIUM

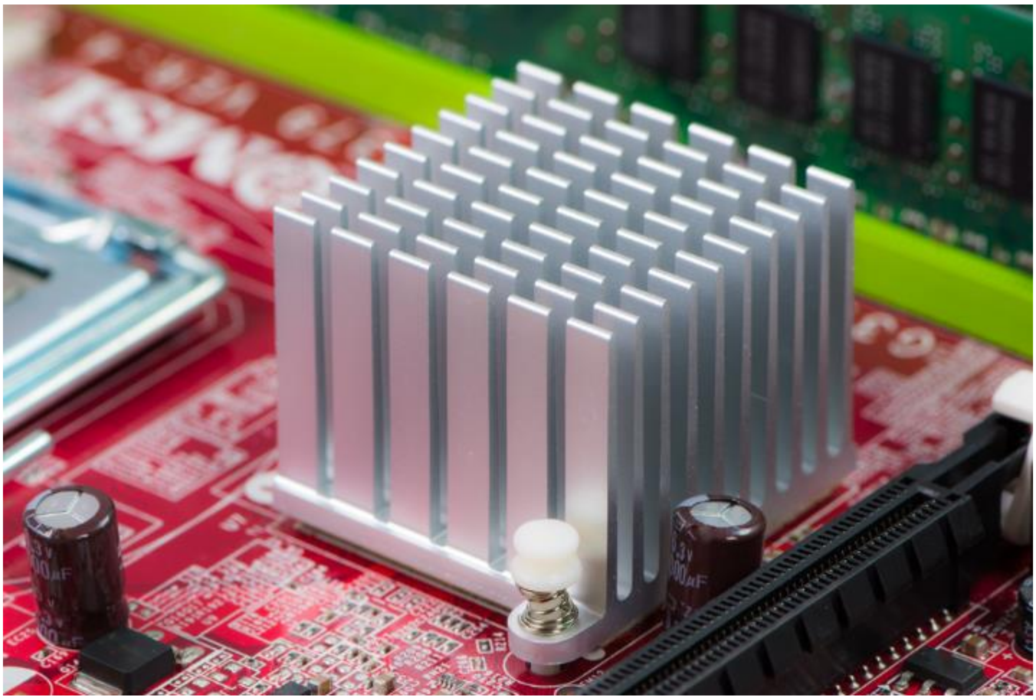

FIG.48 USES OF ALUMINIUM IN CIRCUITS

CEMENT

Cement is a **binder**, a substance used for construction that **sets**, **hardens**, and adheres to other materials to bind them together. **Cement** is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

What is cement made of?

It is manufactured through the **chemical combination of** 8 main **ingredients** during the **cement** production process. These ingredients are generally extracted from **limestone, clay, marl, shale, chalk, sand, bauxite**, and **iron ore**.

TYPES OF CEMENT

Different Types of Cement

- **Ordinary Portland** Cement (OPC)
- Portland **Pozzolana** Cement (PPC)
- **Rapid Hardening** Cement.
- Extra Rapid Hardening Cement
- **Low Heat** Cement.
- **Sulfates Resisting** Cement.
- **Quick Setting** Cement.
- **Blast Furnace Slag** Cement.
- **White cement**

Types of Cement Used In the Construction Industry

In the construction industry, there are different types of cement. The differences between each type of cement are its properties, uses and composition materials used during the manufacturing process.

Cement is a **cover material** which makes a bond **between aggregates** and **reinforcing** materials.

There are different types of cement for different construction works. Keep reading to learn more about the most common ones.

Different Types of Cement

1. Ordinary Portland Cement (OPC)

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

- **Concrete**: When OPC is mixed with aggregates and water, it makes concrete, which is widely used in the construction of buildings
- **Morta**r: For joining masonry
- **Plaster**: To give a perfect finish to the walls

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

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

2. Portland Pozzolana Cement (PPC)

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

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

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

3. **Rapid Hardening Cement**

Cement suppliers in Malaysia also offer rapid Hardening cement. Rapid Hardening Cement is made when **finely grinded C3S** is displayed in OPC with higher concrete. It is commonly used in rapid constructions like the construction pavement.

4. Extra Rapid Hardening Cement

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

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

5. Low Heat Cement

Cement manufacturers in Malaysia offers low heat cement that is prepared by keeping the percentage of **tricalcium aluminate below 6%** and by increasing the proportion of C2S.

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

6. Sulphates Resisting Cement

This type of cement is manufactured **to resist sulphate attack in concrete**. It has a lower percentage of Tri calcium aluminates.

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

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

7. Quick Setting Cement

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

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

8. **Blast Furnace Slag Cement**

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

9. High Alumina Cement

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

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

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

10. White Cement

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

CHEMICAL COMPOSITION OF CEMENT

The cement contains 35 to **40 percent lime**, 40 to **50 percent alumina**, up to **15 percent iron oxides**, and preferably not more than about **6 percent silica**. The principal cementing compound is **calcium aluminates** ($CaO \cdot Al_2O_3$).

Introduction

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

Manufacture of cement

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

- Lime or calcium oxide, CaO: from limestone, chalk, shells, shale or calcareous rock
- Silica, SiO_2: from sand, old bottles, clay or argillaceous rock
- Alumina, Al_2O_3: from bauxite, recycled aluminum, clay
- Iron, Fe_2O_3: from from clay, iron ore, scrap iron and fly ash
- Gypsum, $CaSO_4.2H_20$: found together with limestone

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

Chemical shorthand

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

Compound	**Formula**	**Shorthand form**
Calcium oxide (lime)	Ca0	C
Silicon dioxide (silica)	SiO_2	S
Aluminum oxide (alumina)	Al_2O_3	A
Iron oxide	Fe_2O_3	F
Water	H_2O	H
Sulfate	SO_3	S

PROPERTIES OF CEMENT

Physical Properties of Cement

- **Fineness** of cement.
- **Soundness**.
- **Consistency**.
- **Strength**.
- **Setting time**.
- **Heat** of hydration.
- Loss of ignition.
- **Bulk density**.

Physical Properties of Cement

Different blends of cement used in construction are characterized by their **physical properties**. Some **key** parameters control the **quality of cement**. The physical properties of good cement are based on:

- **Fineness** of cement
- **Soundness**
- **Consistency**
- **Strength**
- **Setting time**
- Heat of **hydration**
- Loss of ignition
- **Bulk density**
- **Specific gravity** (Relative density)

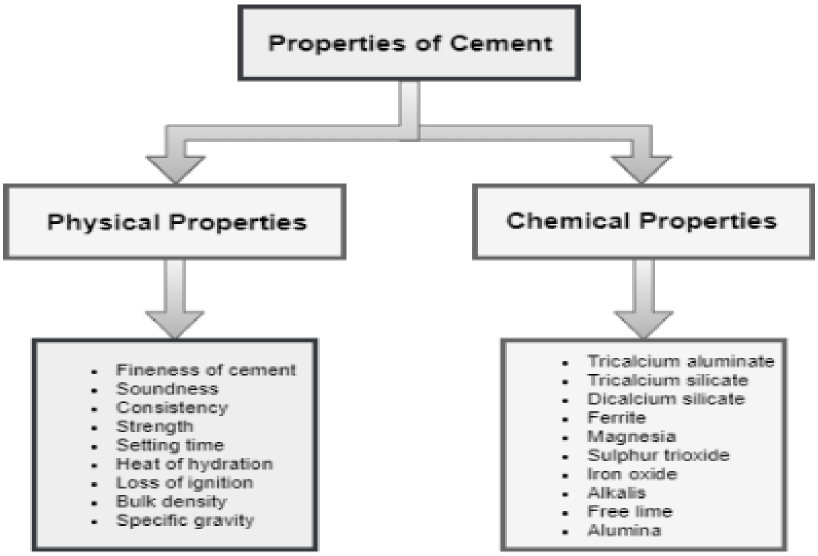

FIG.49 PROPERTIES OF CEMENT

1) Fineness of Cement

The size of the particles of the cement is its fineness. The required fineness of good cement is achieved **through grinding** the clinker in the last step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

2) Soundness of Cement

Soundness refers to the ability of cement to **not shrink upon hardening**. Good quality cement retains its volume after setting without delayed expansion, which is caused by **excessive free lime** and magnesia.

3) Consistency of Cement

The **ability of cement paste to flow** is consistency.

It is measured by Vicat Test.

In Vicat Test Cement paste of normal consistency is taken in the Vicat Apparatus. The plunger of the apparatus is brought down to touch the top surface of the cement. The plunger will penetrate the cement up to a certain depth depending on the consistency. A cement is said to have a normal consistency when the **plunger penetrates 10 mm**.

4) Strength of Cement

Three types of strength of cement are measured **compressive, tensile** and **flexural**. Various **factors** affect the strength such as **water-cement ratio**, cement-**fine aggregate ratio**, **curing** conditions, size and shape of a specimen, the manner of moulding and mixing, loading conditions and age.

Compressive Strength: It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

Tensile strength: Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

Flexural strength: This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its centre point until failure.

5) Setting Time of Cement

Cement sets and **hardens when water is added**. This setting time can vary depending on multiple **factor**s, such as **fineness of cement, cement-water ratio**, **chemical content**, and **admixture**s. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

Initial set: When the paste begins to stiffen noticeably (typically occurs within 20**-25 minutes**)

Final set: When the cement hardens, being able to sustain some load (occurs below **10 hours**)

6) Heat of Hydration

When **water is added to cement**, the **reaction** that takes place is called **hydration**. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather.

On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress.

The heat of hydration is affected most by C3S and C3A present in cement, and also by water-cement ratio, fineness and curing temperature.

The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7th and 28th days).

7) Bulk density

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from **62 to 78 pounds per cubic foot.**

8) Specific Gravity (Relative Density)

Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of **3.15**, but other types of cement (for example, Portland-blast-furnace-slag and portland-pozzolan cement) may have specific gravities of about **2.90**.

HYDRATION OF CEMENT

When **cement, water, aggregate, and additives are mixed together**, a significant heat increase occurs. This is due to the exothermic process in the **reaction between cement and water** (called **hydration**).

Introduction

Portland cement is hydraulic cement hence it derives its strength from chemical reactions between the cement and water. The process is known as hydration.

Cement consists of the following major **compounds**

Tricalcium silicate, C_3S

Dicalcium silicate, C_2S

Tricalcium aluminate, C_3A

Tetracalcium aluminoferrite, C_4AF

Gypsum, CSH_2

Chemical reactions during hydration

When water is added to cement, the following series of reactions occur:

- The tricalcium aluminate reacts with the gypsum in the presence of water to produce ettringite and heat:

  Tricalcium aluminate + gypsum + water ettringite + heat
  $C_3A + 3CSH_2 + 26H\ C_6AS_3H_{32}$, H = 207 cal/g

  Ettringite consists of long crystals that are only stable in a solution with gypsum. The compound does not contribute to the strength of the cement glue.

- The tricalcium silicate (alite) is hydrated to produce calcium silicate hydrates, lime and heat:

  Tricalcium silicate + water calcium silicate hydrate + lime + heat
  $2C_3S + 6H\ \ C_3S_2H_3 + 3CH$, H = 120 cal/g

  The CSH has a short-networked fiber structure which contributes greatly to the initial strength of the cement glue.

- Once all the gypsum is used up as per reaction (i), the ettringite becomes unstable and reacts with any remaining tricalcium aluminate to form monosulfate aluminate hydrate crystals:

  Tricalcium aluminate + ettringite + water monosulfate aluminate hydrate
  $2C_3A + 3\ C_6AS_3H_{32} + 22H\ \ 3C_4ASH_{18}$,

  The mono sulphate crystals are only stable in a sulphate deficient solution. In the presence of sulphates, the crystals resort back into ettringite, whose crystals are two-and-a-half times the size of the mono sulphate. It is this increase in size that causes cracking when cement is subjected to sulphate attack.

- The belite (dicalcium silicate) also hydrates to form calcium silicate hydrates and heat:

  Dicalcium silicates + water calcium silicate hydrate + lime
  $C_2S + 4H \ C_3S_2H_3 + CH, \ H = 62$ cal/g

  Like in reaction (ii), the calcium silicate hydrates contribute to the strength of the cement paste. This reaction generates less heat and proceeds at a slower rate, meaning that the contribution of C_2S to the strength of the cement paste will be slow initially. This compound is however responsible for the long-term strength of Portland cement concrete.

- The ferrite undergoes two progressive reactions with the gypsum:
  - in the first of the reactions, the ettringite reacts with the gypsum and water to form ettringite, lime and alumina hydroxides, i.e.
    - Ferrite + gypsum + water ettringite + ferric aluminium hydroxide + lime
    - $C_4AF + 3CSH_2 + 3H \ C_6(A,F)S_3H_{32} + (A,F)H_3 + CH$
  - the ferrite further reacts with the ettringite formed above to produce garnets, i.e.
    - Ferrite + ettringite + lime + water garnets
    - $C_4AF + C_6(A,F)S_3H_{32} + 2CH + 23H \ 3C_4(A,F)SH_{18} + (A,F)H_3$

The garnets only take up space and do not in any way contribute to the strength of the cement paste.

The hardened cement paste
Hardened paste consists of the following:

Ettringite - 15 to 20%
Calcium silicate hydrates, CSH - 50 to 60%
Calcium hydroxide (lime) - 20 to 25%
Voids - 5 to 6% (in the form of capillary voids and entrapped and entrained air)

Conclusion

Each of the compounds in cement has a role to play in the hydration process. By changing the proportion of each of the constituent compounds in the cement (and other factors such as grain size), it is possible to make different types of cement to suit several construction needs and environment.

TESTS ON CEMENT

Quality Tests on cement are carried out to check the strength and quality of the cement used in construction. It helps to identify the usage of cement for different purposes based on its durability and performance.

The following tests are conducted on cement in the laboratory are as follows:

1. **Fineness** Test
2. **Consistency** Test
3. **Setting Time** Test
4. **Strength** Test
5. **Soundness** Test
6. Heat of **Hydration** Test
7. **Tensile Strength** Test
8. Chemical **Composition** Test

Fineness test on cement

The fineness of cement is responsible for the rate of hydration, rate of evolution of heat and the rate of gain of strength. Finer the grains more is the surface area and faster the development of strength.

The fineness of cement can be determined by Sieve Test or Air Permeability test.

Sieve Test: Air-set lumps are broken, and the cement is sieved continuously in a circular and vertical motion for a period of 15 minutes. The residue left on the sieve is weighed, and it should **not exceed 10%** for ordinary cement. This test is rarely used for fineness.

FIG.50 FINENESS TEST ON CEMENT APPARATUS

Air Permeability Test: Blaine's Air Permeability Test is used to find the specific surface, which is expressed as the total surface area in sq.cm/g. of cement. The surface area is more for finer particles.

Consistency test on cement

This test is conducted to find the setting times of cement using a standard consistency test apparatus, **Vicat's apparatus**

.

Standard consistency of cement paste is defined as that water content which will permit a Vicat **plunger of 10 mm diameter** and 50 mm length to penetrate depths of 33-35 mm within 3-5 minutes of mixing.

FIG.51 CONSISTENCY TEST ON CEMENT APPARATUS

The test has to undergo three times, each time the cement is mixed with water varying from 24 to 27% of the weight of cement.

This test should be conducted at a constant temperature of 25°C or 29°C and at a constant humidity of 20%.

Setting Time of cement

Vicat's apparatus is used to find the setting times of cement i.e., initial setting time and final setting time.

Initial Setting Time: For this test, a needle of **1 mm square** size is used. The **needle** is allowed to penetrate into the paste (a mixture of water and cement as per the consistency test). The time taken to penetrate 33-35 mm depth is recorded as the initial setting time.

FIG.52 SETTING TIME TEST ON CEMENT APPARATUS

Final Setting Time: After the paste has attained hardness, the needle does not penetrate the paste more than 0.5 mm. The time at which the needle does not penetrate more than 0.5 mm is taken as the final setting time.

Strength test of cement

The strength of cement cannot be defined directly on the cement. Instead the strength of cement is indirectly defined on **cement-mortar of 1:3**. The compressive strength of this mortar is the strength of cement at a specific period.

Soundness test of cement

This test is conducted in **Le Chatelier's apparatus** to detect the **presence** of **un combined lime** and magnesia in cement.

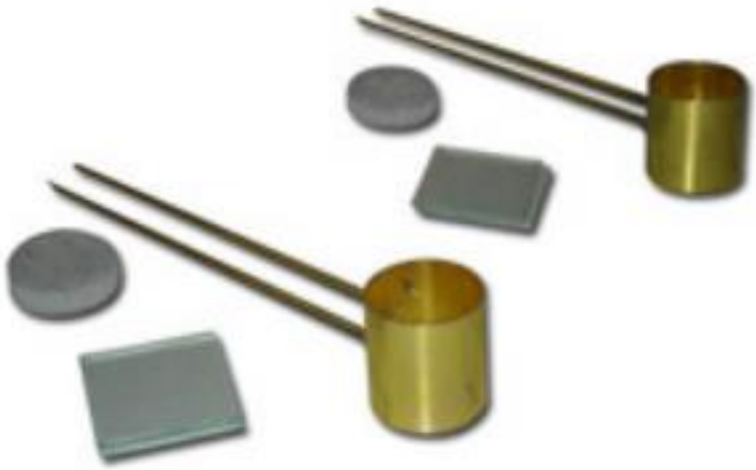

FIG.53 SOUNDNESS TEST ON CEMENT APPARATUS

Heat of Hydration Test

During the hydration of cement, heat is produced due to chemical reactions. This heat may raise the temperature of concrete to a high temperature of 50°C. To avoid these, in large scale constructions low-heat cement has to be used.

FIG.54 HEAT OF HYDRATION TEST ON CEMENT APPARATUS

This test is carried out using a calorimeter adopting the principle of determining heat gain. It is concluded that Low-heat cement should not generate 65 calories per gram of cement in 7 days and 75 calories per gram of cement in 28 days.

Tensile Strength of Cement

This test is carried out using a cement-mortar briquette in a tensile testing machine. A 1:3 cement-sand mortar with the water content of 8% is mixed and moulded into a briquette in the mould.

FIG.55 TENSILE STRENGTH TEST ON CEMENT APPARATUS

This mixture is cured for 24 hours at a temperature of 25°C or 29°C and in an atmosphere at 90% relative humidity.

The average strength for six briquettes tested after 3 and 7 days is recorded.

Chemical Composition Test

Different tests are conducted to determine the amount of various constituents of cement. The requirements are based on IS: 269-1998, is as follows:

- The ratio of the percentage of alumina to that of iron oxide should not be less than 0.66.
- Lime Saturation Factor (LSF), i.e., the ratio of the percentage to that of alumina, iron oxide and silica should not be less than 0.66 and not be greater than 1.02.
- Total loss on ignition should not be greater than 4%.
- Total sulphur content should not be greater than 2.75%.
- Weight of insoluble residue should not be greater than 1.50%.
- Weight of magnesia should not be greater than 5%.

Field Tests of Cement

The following tests should undergo before mixing the cement at construction sites:

Colour Test of Cement

The colour of the cement should not be uneven. It should be a uniform grey colour with a light greenish shade.

Presence of Lumps

The cement should not contain any hard lumps. These lumps are formed by the absorption of moisture content from the atmosphere. The cement bags with lumps should be avoided in construction.

FIG.56 PRESENCE OF LUMPS IN CEMENT

Cement Adulteration Test

The cement should be smooth if you rubbed it **between fingers**. If not, then it is because of adulteration with sand.

FIG.57 ADULTERATION TEST ON CEMENT

Float Test

The particles of cement should flow freely in water for sometime before it sinks.

Date of Manufacturing

It is very important to check the manufacturing date because the strength of cement decreases with time. It's better to use cement **before 3 months** from the date of manufacturing.

IS SPECIFICATIONS OF CEMENT

Cement is one of the most important **constituent of concrete** used all over the world. **Specifications** for these different grades of **cement** shall conform to IS 269:2013, IS 8112:2013, IS 12269:2013 respectively.

IS: 6452 – **specifications for** HAC for structural use (high alumina **cement**). S: 3466 – **specifications for** masonry **cement**. IS: 4031 – chemical analysis and tests on **cement**. **IS: 456**; 10262; SP 23 – **codes** for designing concrete mixes.

AGGREGATES

Aggregate' is a term for any particulate material. It includes **gravel, crushed stone, sand, slag, recycled concrete** and **geo synthetic aggregates**. Aggregates make up some **60 - 80% of** the **concrete** mix. They **provide compressive strength** and bulk to concrete

Why do we use aggregates in concrete?

Aggregates make up 60-80% of the volume of concrete and **70-85% of the mass of concrete**. Aggregate is also very important for **strength, thermal** and **elastic properties of concrete**, dimensional stability and volume stability. Cement is more likely to be affected by shrinkage.

Which type of aggregate is good for concrete?

Both **gravel and crushed stone** are generally acceptable for making quality concrete, although gravel is usually preferred for exposed aggregate. The use of **recycled concrete**, crushed to proper-size concrete aggregate, has also demonstrated successful performance.

AGGREGATES CLASSIFICATION

What is an Aggregate?

Aggregates are the important constituents of the concrete which give body to the concrete and also reduce shrinkage. Aggregates occupy 70 to 80 % of total volume of concrete. So, we can say that one should know definitely about the aggregates in depth to study more about concrete.

Classification of Aggregates as per Size and Shape

Aggregates are classified based on so many considerations.

We know that aggregate is derived from naturally occurring rocks by blasting or crushing etc., so, it is difficult to attain **required shape** of aggregate. But, the **shape** of aggregate will **affect the workability of concrete**. So, we should take care about the shape of aggregate. This care is not only applicable to parent rock but also to the crushing machine used.

Aggregates are classified according to shape into the following types

- **Rounded** aggregates
- **Irregular** or partly rounded aggregates
- **Angular** aggregates
- **Flaky** aggregates
- **Elongated** aggregates
- Flaky and elongated aggregates

Rounded Aggregate

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

FIG.58 ROUNDED AGGREGATE

Irregular Aggregates

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

Angular Aggregates

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

FIG.59 ANGULAR AGGREGATES

Flaky Aggregates

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

FIG. 60 FLAKY AGGREGATES

Elongated Aggregates

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

FIG. 61 ELONGATED AGGREGATES

Flaky and Elongated Aggregates

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

FIG.62 FLAKY AND ELONGATED AGGREGATES

Classification of Aggregates Based on Size

Aggregates are available in nature in different sizes. The size of aggregate used may be related to the mix proportions, type of work etc. the size distribution of aggregates is called grading of aggregates.

Following are the classification of aggregates based on size:

Aggregates are classified into 2 types according to size

- **Fine** aggregate
- **Coarse** aggregate

Fine Aggregate

When the aggregate is sieved through **4.75mm** sieve, the aggregate passed through it called as fine aggregate. Natural sand is generally used as fine aggregate, silt and clay are also come under this category. The soft deposit consisting of sand, silt and clay is termed as loam. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

TABLE 6 SIZE OF AGGREGATES

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

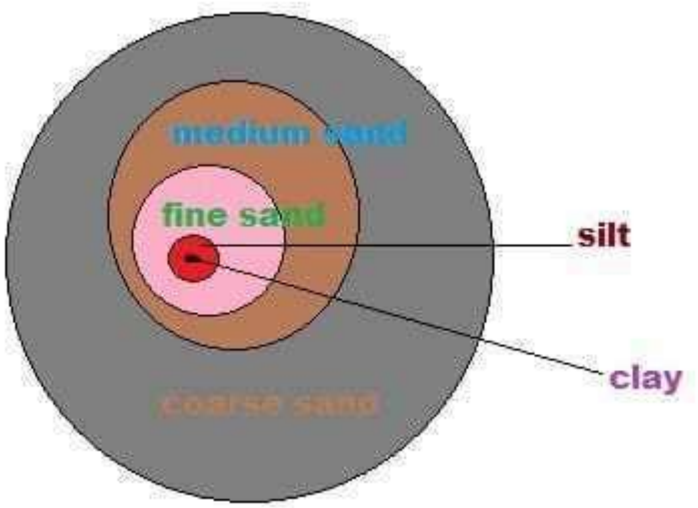

FIG.63 SIZE OF AGGREGATES

Coarse Aggregate

When the aggregate is sieved through **4.75mm sieve**, the aggregate **retained** is called coarse aggregate. Gravel, cobble and boulders come under this category. The maximum size aggregate used may be dependent upon some conditions. In general, **40mm** size aggregate used for normal strengths and **20mm** size is used for high strength concrete. the size range of various coarse aggregates given below.

TABLE 7 SIZE OF COARSE AGGREGATE

Coarse aggregate	**Size**
Fine gravel	4.75mm – 8mm
Medium gravel	8mm – 16mm
Coarse gravel	16mm – 64mm
Cobbles	64mm – 256mm
Boulders	>256mm

MECHANICAL PROPERTIES OF AGGREGATES

TOUGHNESS:

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

The aggregate shall be taken as in the case of crushing strength value test i.e., the aggregate should pass through 12.5 mm I.S. sieve and retained on 10 mm I.S. sieve. It should be oven dried at 100°C to 110°C for four hours and then air cooled before test.

Now the prepared aggregate is **filled upto 1/3rd height of the cylindrical cup** of the equipment. The diameter and depth of the cup are 102 mm and 50 mm respectively. After filling the cup upto **1/3rd** of its height, the aggregate is **tamped with 25 strokes** of the rounded end of the tamping rod.

After this operation the cup shall be further filled upto **2/3rd** of its height and a further tamping of **25 strokes** given. The cup finally shall be filled to over flowing and tamped with 25 strokes and surplus aggregate removed and the weight of aggregate noted. The value of weight will be useful to repeat the experiment.

Now the **hammer** of the equipment weighting **14.0 kg** or 13.5 kg is raised till its lower face is **380 mm** above the upper surface of the aggregate and., allowed to **fall freely** on the aggregate and the process is repeated for **15 times**

The **crushed aggregate** is now removed from the cup and **sieved through 2.36 mm** I.S. sieve. The fraction passing through the sieve is weighed accurately.

Let the weight of oven dry sample in the cup = W kg.

Weight of aggregate passing 2.36 mm sieve = W_1 kg.
Then impact value = $[(W_1/W) \times 100]$
This value should **not** be more **30%** for aggregate to be **used in concrete** for wearing surfaces as **road** and **45%** for other type of concrete.

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

For testing hardness of aggregate following three methods can be used:
(a) **Deval** Attrition test
(b) **Dorry** abrasion test.
(c) **Los Angeles** test.

(a) Deval Attrition Test:
This test has been covered by IS 2386 Part (IV)-1963. In this test particles of known weight are subjected to wear in an iron cylinder rotated **10,000** (ten thousand) times at the rate of **30 to 33** revolutions per minute (**rpm**). After the specified revolution of the cylinder the material is taken out and sieved on 1.7 mm sieve and the percentage of material **finer than 1.7mm** is determined. This percentage is taken as the attrition value of the aggregate. The attrition value of about 7 to 8 usually is considered as permissible

Dorry Abrasion Test:
This test has not been covered by Indian standard specifications. In this test a cylindrical specimen having its diameter and height of 25 cm is subjected to abrasion against a rotating metal disk sprinkled with quartz sand. The loss in weight of the cylinder after **1000** (one thousand) **revolution**s is determined.

Then the hardness of rock sample is expressed by an empirical relation as follows:
Hardness or sample = 20 – Loss in weight in grams/3

For good rock this value should not be less the 17. The rock having this value of 14 is considered poor.

(c) Los-Angeles Test:
This test has been covered by IS 2386 (Part-IV) 1963. In this test aggregate of the specified grading is placed in a **cylindrical drum** of inside length and diameter of 500 mm and 700 mm respectively. This cylinder is mounted horizontally on stub shafts. For abrasive charge, steel balls or **cast iron balls** of approximately 48 mm diameter and each weighting 390 grams to **445 gram** are used. The numbers of balls used vary from 6 to **12** depending upon the grading of the aggregate. For 10 mm size aggregate 6 balls are used and for aggregates bigger than 20 mm size usually 12 balls are used.

Procedure:
For the conduct of test, the sample and the abrasive charge are placed in the Los-Angeles testing machine and it is rotated at a speed of 20 to **33** revolutions per minute. For aggregates upto 40 mm size the machine is rotated for 500 revolutions and for bigger size aggregate **1000** revolutions. The charge is taken out from the machine and sieved on **1.7 mm sieve**.

Let the weight of oven dry sample put in the drum = W Kg.

Weight of aggregate passing through 1.7 sieve = W_1 Kg.
Then abrasion value = $[(W_1/W) \times 100]$
The abrasion value should not be more than 30% for wearing surfaces and not more than 50% for concrete used for other than wearing surface. The results of Los Angeles test show good correlation not only the actual wear of aggregate when used in concrete, but also with the compression and flexural strength of concrete made with the given aggregate.

Table 8 gives an idea of toughness, hardness, crushing strength etc. of different rocks.

TABLE 8 TEST VALUES OF DIFFERENT ROCKS

S. No.	Rock Group	Crushing strength MPa		Abrasion value	Impact value	Attrition value		Specific gravity
		Rock	Aggregate			Dry	Wet	
1.	Basalt	207	12	17.6	16	3.3	5.5	2.85
2.	Flint	214	17	19.2	17	3.1	2.5	2.55
3.	Granite	193	20	18.7	13	2.9	3.2	2.69
4.	Gristone	229	12	18.1	15	3.0	5.3	2.67
5.	Lime stone	171	24	16.5	9	4.3	7.8	2.69
6.	Quartizite	339	16	18.9	16	2.5	3.0	2.62
7.	Schist	254	—	18.7	13	3.7	4.3	2.76
8.	Gabbro	204	—	18.7	19	2.5	3.2	2.95
9.	Homfels	354	11	18.8	17	2.7	3.8	2.88
10.	Porphyry	239	12	19.0	20	2.6	2.6	2.66

SPECIFIC GRAVITY*:*

The specific gravity of a substance is the ratio of the weight of unit volume of the substance to the unit volume of water at the stated temp. In concrete making, aggregates generally contain pores both permeable and impermeable hence the term specific gravity has to be defined carefully. Actually there are several types of specific gravity. In concrete technology specific gravity is used for the calculation of quantities of ingredients. Usually the specific gravity of most aggregates varies between **2.6 and 2.8**.

Specific gravity of certain materials as per concrete hand book CA-1 Bombay may be assumed as shown in Table 4.9.

TABLE 9 SPECIFIC GRAVITY OF CEMENT AND AGGREGATES

Material	Specific gravity
Cement	3.15
Average sand	2.00
Granite	2.80
Gravel	2.66
Sand	2.65

Method of Determination of Specific Gravity of Aggregate:

IS-2386-Part-III-1963 describes various procedures to find out the specific gravity of aggregates of different sizes. Here the method applicable to aggregates larger than 10 mm in size has been described as follows

A sample of aggregate not less than 2 kg in weight is taken and washed thoroughly to remove dust, and silt particles etc. The washed sample is placed in a wire basket and immersed in distilled water at a temperature of 27 ± 5°C.

Immediately after immersion, the entrapped air is removed from the sample by lifting the basket containing sample 25 mm above the bottom of the jar or tank and allow it drop 25 times at the rate of 1 mm per sec. During this operation, care should be taken that basket and aggregate remain fully immersed in water. After this, the sample is kept in water for about 24 ± ½ hour.

After this period the basket and aggregate is given a jerk to remove the air etc. and weighed in water at the temperature of 27 ± 5°C. Let the weight of basket and aggregate be A_1. The basket and sample of aggregate is removed from the water and allowed to drain for a few minutes. Then the aggregate is taken out from the basket and placed on a dry cloth and dried further. The empty basket is again immersed in water and weighed in water after giving 25 jolts. Let this weight be A_2.

The aggregate is surface dried in shade for not more than 10 minutes and the aggregate are weighed in air. Let this weight be B. Now the aggregate is oven dried for 24 ± ½ hour at a temperature of 100 to 110°C. It is then cooled in air tight container and weighed. Let this weight be C.

Thus,

Weight of sample in water = $(A_1 – A_2) = A$
Weight of saturated surface dry in air sample = B

Weight of oven dry sample = C

(a) Then specific gravity = $[C/(B – A)]$

(b) Apparent specific gravity = $[C/(C – A)]$

(c) Water absorption = $100 (B – C)$

(d) Bulk density = Net weight of the aggregate in kg./capacity or the container in litres

Example:

Find the value of- (i) Specific gravity, (ii) Apparent specific gravity, (iii) Apparent particle density, (iv) Bulk particle density.

(i) Mass of oven dry sample C = 480 gram

(ii) Mass of saturated surface dried sample in air B = 490 gram

(iii) Weight of vessel with water = 1400 gram

(iv) Weight of vessel + water + sample = 1695 gram.

Solution:

(i) Specific gravity = [mass of oven dry sample/(mass or saturated surface sample – sample weight in water)]
= [C/(B – A)] = [480/(490-295)]
= 480/195 = 2.50
(ii) Apparent specific gravity = [C/(C – A)] = [480/(480 – 295)]
= 480/185 = 2.59
(iii) Apparent particle density = 1000 x Apparent specific gravity = 2.59 x 1000 = 2590 kg/m^3
(iv) Bulk Particle density = Bulk specific gravity x 1000
= 2.59 x 1000 = 2500 kg/m

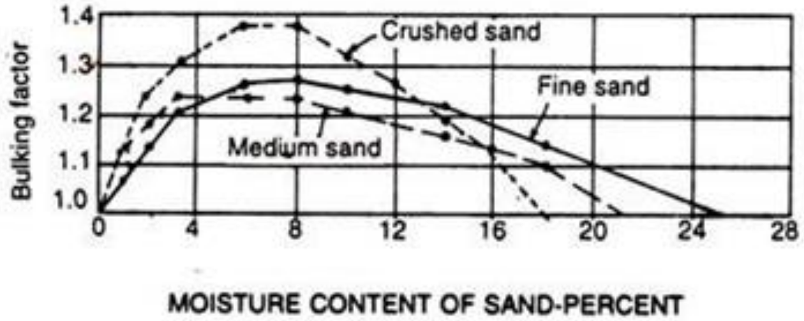

FIG. 64 BULK FACTOR OF SAND WITH VARYING MOISTURE CONTENT

AGGREGATES TESTS AS PER BIS

REF: IS : 2386 (Part I) - 1963 Indian Standard METHODS OF TEST FOR AGGREGATES FOR CONCRETE

GRADING REQUIREMENTS OF AGGREGATE

Grading of aggregates is determining the **average grain size** of the aggregates before they are used in construction. This is applied to both coarse and fine aggregates. The aggregate sample is sieved **through a set of sieves** and weights retained on each sieve in percentage terms are summed up.

Grading

Beginning with the material grading, particle distribution curves for MIBA samples subjected to standard screening are presented in Figure 65, along with the overall grading envelopes for capping material, class 6f in Specification for Highway Works (SHW) Series 600 (Highways England, 2016a) and types 1 and 2 unbound mixtures, SHW Series 800 (Highways England, 2016b). It is found that the bottom ash meets the grading requirements for these unbound applications and indeed, the samples shown in red colour in Figure 6.1 were subsequently used in unbound granular form as sub base or fill material.

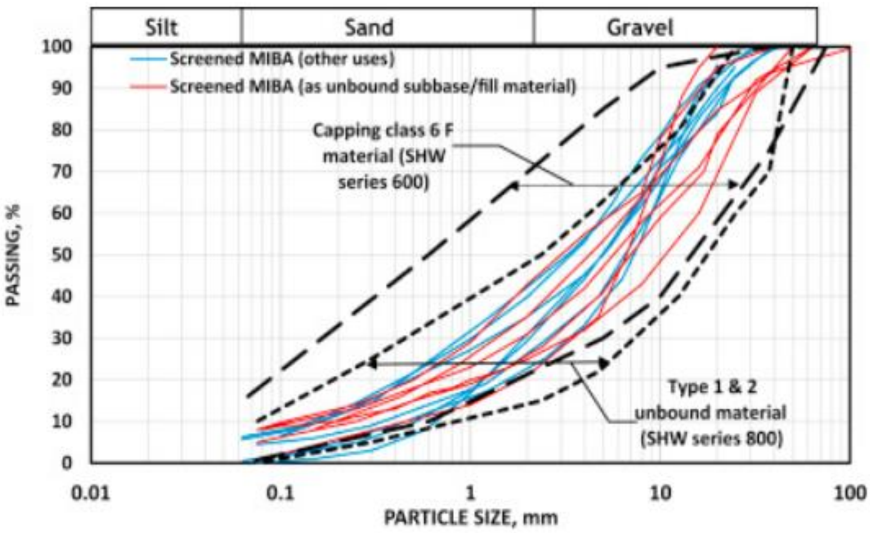

FIG. 65 GRADING OF PARTICLES

It is also evident that MIBA consists of predominantly gravel and sand size fractions, with a low silt content. The grading curves for the MIBA samples in Figure 6.1 are quite consistent, though there is a degree of variation in the cut-off fraction removed during the screening stage. This oversized fraction screened off can be selected to best fit the grading requirements for a future use as an unbound road pavement material. On the fine end, the MIBA samples are projected to satisfy the maximum fines (0.063 mm) content of 9% specified for types 1 and 2 unbound mixtures in SHW Series 800 (Highways England, 2016b), whilst the effective size (D_{10}) of the material ranged from 0.1 to 0.65 mm.

QUALITY OF WATER IN CONCRETE.

Quality of water for construction works are same as drinking **water**.

Quality of Water for **Concrete** Construction and its Specification.

Type of Solid in water	**Permissible Limits for Construction**
Inorganic matter	3000 mg/l
Sulphates (SO4)	500 mg/l
Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l

Concrete is a chemically combined mass which is manufactured from binding materials and inert materials with water. It is most popular construction material due to its unique durability and reasonable strength; more interestingly can be modified and designed for wide range of strength requirements and set under variable environmental conditions. **Cement is** the most **important material** of **concrete** which is produced at the cost of environmental emission of CO_2; **to produce 1 tonne cement nearly 900 kg CO_2 is released in the environment**. So such an energy intensive materials constitutes concrete which may be seriously affected by (both strength and durability point of view) by relatively available and cheap but essential element water; more precisely impurities in water. Quality of mixing water are mainly considered for performance of concrete in both fresh and harden state.

Impurities in mixing water intervene the setting time of the paste and may produce detrimental effect on strength and durability of concrete also. When impurities are chemically active, they may take part in the **chemical** reaction contributing significant **change in setting, hardening and development of strength of concrete.** More over **health hazard** during handling these water should carefully considered. In this regard past performance of a particular source of water can be used to evaluate suitability of water; if not available, some testing inevitable to evaluate water for setting time, compressive strength and durability.

Function of Water in Concrete

Three water serves the following purpose:

To wet the surface of aggregates to develop adhesion because the cement pastes adheres quickly and satisfactory to the wet surface of the aggregates than to a dry surface.

To prepare a plastic mixture of the various ingredients and to impart workability to concrete to facilitate placing in the desired position and

Water is also needed **for the hydration of the cementing materials** to set and harden during the period of curing.

The quantity of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete. Sometimes may not be harmless or even beneficial during mixing. So clear distinction should be made between the effect on hardened concrete and the quality of mixing water.

Potable water as mixing water

The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have **inorganic solid less than 1000 ppm**. This content lead to a solid quantity 0.05% of mass of cement when w/c ratio is provided 0.5 resulting small effect on strength.

But some water which are not potable may be used in making concrete with any significant effect. Dark color or bad smell water may be used if they do not posses deleterious substances. **P^H of water to even 9 is allowed** if it not tastes brackish. In **coastal areas** where local water is saline and have no alternate sources, the **chloride concentration up to 1000 ppm is** even **allowed** for drinking. But this excessive amount of alkali carbonates and bicarbonates, in some natural mineral water, may **cause alkali-silica reaction**.

Acceptable source of water

Besides **potable water**, various new and existing sources are available for mixing water which can be used for complete and partial replacement of valuable potable water. This includes

Ground water

Reclaimed water

Treated water from municipal sewer

Waste water of ready-mix concrete plant etc.

In many regions of the world there have **scarcity of water** like **Dubai** and **Qatar** and the local authorities are looking for new sources and **reused water**. There treated water are used for agricultural requirements and daily needs for construction industry. like washing aggregates, as concrete mixing water and curing of the same. Water from river and sometimes even sea are considered suitable if it is free from brackish matter. In arid regions, brackish **groundwater is mixed with desalinated water and considered suitable for concrete** production and for concrete slurry too.

Sampling guideline for mixing water

In addition to testing on constituent of concrete like aggregate cementitious materials and admixtures etc., **testing of water** is an important **part of quality control** of concrete. A systematic testing schedule for water testing yields higher efficiency of concrete and assure good performance in regard of strength and durability.

Important thing to remember is that water can be changed by chemical, physical or biological reactions; such modification may occur during sampling and at the time of analyzing. So it should be **tested before using in concrete**.

Collection of sample

The location of sampling should be at mid-stream and **extracted from mid depth**, as far as possible. When there have obstructions or major discharges are fall into river, the **sample** should be taken **in downstream** of **discharge**s by a distance more than 100m in case of small stream; in a word, the site should be such that no change in water in the stream are seen with naked eyes. In case of **wide river at least three samples** should be taken along the cross section.

Sampling of waste water

When water from narrow effluent channels of **treated sewers** are to be tested, the **sample** should be taken **from one third depth of water** neither skimming the top surface nor scrapping the bottom. It is important to locate site having sufficient flow so that no nearby deposition is occurred. Caution should be taken during sampling to keep in-situ condition of dissolved gas i.e. must not be agitated to liberate dissolved gasses or to cause some degree if aeration.

It was observed that sewage flows are often intermittent which requires to collect samples an hour interval throughout 24 hours. At room temperature **waste water** generally decompose rapidly, so test set-up for certain **parameter** should be available at site. These are as follows:

- **Dissolved oxygen**
- **Residual chlorine**
- **Sulphides**
- **P^H**
- **Nitrites** etc.

For some tests addition of preservatives just after collection of water will be enough.

Can ready-mix concrete washout water be used in concrete?

It is recommended in AS 1379 and ASTM C94, that water used in washout operation in ready-mix concrete plant **can be used in concrete** as mixing water. Only requirement is to store it in such a way that contamination from deleterious matters is prevented and water is collected from storage outlet. Water **should conform ASTM** C 1602; the sources and testing frequencies and other requirements of testing to qualify water sources. According to ASTM C94 water may be water itself or may be ice or any forms of moisture on the aggregate surface and wash water remains in the drum of truck mixer can be used for concreting next batch.

Plant washout water often called **recycled ready-mix water**. In 2007 experiment results were published by GL Low et al. about the requirements of recycling of cement-slurry water found from ready-mix concrete batching plant. He also examined the performance of concrete casted from reused water without any treatment. This study revealed the effects of application of such water in concrete mix on both fresh and hardened concrete based on the requirements of ASTM C94 and BS4550. The interesting thing was that they used **two criteria** namely **specific gravity** and **PH**; slurry water from such source can meet acceptance criteria based on concrete performance in setting time, compressive strength and drying shrinkage, when specific gravity of recycles water not exceed 1.03 and PH value of water lies between 12.3 to 13.3.

Determination of Suitability of Mixing Water

A simple way of determining the suitability of such water is to compare the setting time of cement and the strength of mortar cubes using the water in question with the corresponding results obtained using known suitable or distilled water. About **10% tolerance** is generally allowed. Such tests are recommended when water for which no service record is available containing dissolved solids in excess of 2000 ppm or, in excess of 1000 ppm. When unusual solids are present a test is also advisable.

TABLE 10 WATER QUALITIES IN CONCRETE

Quality Parameters	Maximum Limit (ppm)
Chlorides	500
SO_3	1000
Alkali Carbonates and Bicarbonates	1000
Turbidity	2000

The effect on concreting for different types of contamination or impurities are described below:

Suspended Solids

Mixing water which high content of suspended solids should be allowed to stand in a setting basing before use as it is **undesirable** to introduce large quantities of **clay and slit in**to
.

Acidity and Alkalinity

Natural water that are slightly acidic are harmless, but presence of humic or other **organic acids** may result adverse **affect** over the **hardening of concrete**. Water which are highly alkaline should also be tested.

Algae

The presence of **algae in** mixing **water causes air entrainments** with a consequent **loss of strength**. The green or brown slime forming algae should be regarded with suspicion and such water should be tested carefully.

Sea Water

Sea water contains a total **salinity** of about **3.5%** (78% of the dissolved solids being NaCl and 15% $MgCl_2$ and $MgSO_4$), which **produce**s a slightly **higher early strength** but a **lower long-term strength**. The **loss of strength** is usually limited to **15%** and can therefore be tolerated. **Sea water reduces the initial setting time of cement** but do not effect final setting time.

Chloride

Water containing large amount of chlorides tends to **cause** persistent dampness and **surface efflorescence**. The presence of chlorides in concrete containing embedded **steel** can **lead to** its **corrosion**.

Moisture Content of Aggregate

Aggregate usually contains some surface moisture. **Coarse aggregate** rearly **contains** more than **1%** of surface moisture but **fine aggregate** can contain in excess of **10%**. This water can represent a substantial proportion of the total mixing water indicating a significant importance in the quality of the water that contributes surface moisture in aggregate.

Effect of lead exist in mixing water

An investigation was conducted on behavior of concrete under existence of heavy metal in mixing water by Madhusudana Reddy, B and et al (2011). They examined the effect of presence of lead (Pb+) in mixing water on setting times, compressive strength, soundness and attack of sodium-sulfate on high strength cement mortar. Two types of specimens of cement mortar were used, one was casted with deionised water and others were casted with deionised water with different concentrations of lead. The lead concentration used were 10, 50, 100, 500, 1000, 2000, 3000, 4000 and 5000 mg/liter.

The results were interesting, as compared to reference specimens, it was figured out from results that specimens having **high concentration of lead lost significant strength** with a significant **increase in setting time** of cement in mortar. However, a marginal increase in setting time and compressive strength was found at a concentration of 2000 mg/liter.

Impurities influencing setting time of concrete

H. Y. Ghorab and et al (1990) have studied the effect of water (from natural sources) on the setting time of cement and reported that **setting time** of ordinary portland cement mainly **dependent on quality of water**. As compared to setting time of concrete cast of tap water, a reduction of 4% was observed when used water from the Nile river and approximately 25% reduction was found in concrete cast with groundwater; same result also found for sea water.

V. V. Red and et al. studied on the setting time and development of strength in fly ash concrete under alkaline water in laboratory condition. It was found that initial and final setting time of concrete either accelerated or retarded depending on type of alkalinity rendered by sodium carbonate or sodium bi-carbonate. When sodium carbonate exists in mixing water, both initial and final setting times are accelerated when the concentration is 6 gm/liter and 4 gm/liter respectively. In case of sodium bi-carbonate, both initial and final setting time are retarded when its concentration in mixing water is equal to 4 gm/liter and 6 gm/liter respectively. **Compressive strength and tensile strength were found reduced with increase in sodium carbonate** and sodium bi-carbonate content in mixing water in excess of 6 gm/liter and 10 gm/liter respectively.

TEXT / REFERENCE BOOKS

1. Arora and Bindra, Building construction, Dhanpath Rai and Sons.
2. Punmia B.C., Building construction. Laxmi Publications.
3. Rangwala S.C., Engineering Materials, Charotar Publishers.
4. Shetty M.S., Concrete Technology, S. Chand & Company.
5. Sahu G.C. & Joygopal Jena., Building Materials and Construction, McGraw Hill Education.
6. Gambhir M.L., Concrete Technology, Tata McGraw Hill.
7. Krishna Raju N, Design of Concrete Mixes, CBS Publishers.
8. National Building Code.
9. Neville A.M. and Brooks.J.J, Concrete Technology, Pearson Education

QUESTION BANK

Part A

1. List the types of mortar.
2. What are the properties of sand?
3. List the uses of plywood.
4. What are the classifications of structural steel?
5. Compile the mechanical properties of aggregate.

Part B

1. Bring out the Quality of water in concrete.
2. Explain the properties, classifications of structural steel and their use in construction.
3. Narrate the Chemical composition and Properties of Cement.
4. Bring out the Grading requirements of Aggregates
5. Narrate the uses of Glass, Plastics, A.C. Sheets and Bitumen.

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DEPARTMENT OF CIVIL ENGINEERING

UNIT – II – CONCRETE AND CONSTRUCTION TECHNOLOGY - SCIA1201

UNIT 2 CONCRETE AND ADMIXTURES 9 Hrs.

Concrete – Aggregates – Mechanical & Physical properties and tests – Grading requirements –Water quality for concrete – Admixtures – types and uses – plasticizers – accelerators – retarders–water reducing agents- Making of concrete – batching – mixing – types of mixers –transportation – placing – compacting – curing. Properties of concrete – fresh concrete – workability – segregation and bleeding **-** factors affecting workability & strength – tests on workability – tests for strength of concrete in compression, tension & flexure Concrete quality control – statistical analysis of results – standard deviation – acceptance criteria – mix proportioning (B.I.S method) – nominal mixes.

CONCRETE

Definition of concrete

A mass formed by concretion or coalescence of separate particles of matter in one body. **Artificial rock**.

A hard strong building material made by **mixing** a cementing material (such as Portland **cement**) and a mineral **aggregate** (such as sand and gravel) with sufficient **water** to cause the cement to set and bind the entire mass.

What is another word for concrete?
Related **words for concrete**: pavement, solid, actual, cement, compact, coalesce, consolidated, raft, indurate, precast and particular.

AGGREGATES

'**Aggregate**' is a term for any particulate material. It includes **gravel, crushed stone, sand, slag, recycled** aggregate and **geo synthetic aggregates**. Aggregates make up some **60 - 80%** of the **concrete** mix. They provide **compressive strength** and bulk to concrete.

Aggregates are generally thought of as **inert** filler within a concrete mix. But a closer look reveals the major role and influence aggregate plays in the properties of both fresh and hardened concrete. Changes in **gradation**, maximum size, **unit weight**, and **moisture content** can all **alter** the character and **performance of** your concrete **mix**.

Economy is another reason for thoughtful aggregate selection. You can often save money by selecting the maximum allowable aggregate size. Using **larger coarse aggregate** typically **lowers the cost** of a concrete mix by reducing cement requirements, the most costly ingredient. Less cement (within reasonable limits for durability) will mean less water if the water-cement (w/c) ratio is kept constant. Lower water content will **reduce** the potential for **shrinkage** and for cracking associated with restrained volume change.

Typical Aggregate Proportions

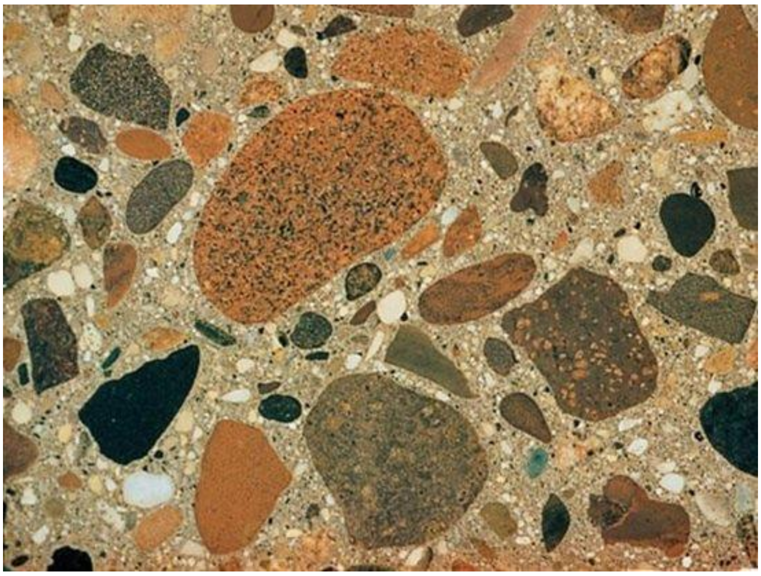

FIG.1 WELL GRADED PARTICLE OF AGGREGATE IN CONCRETE

Aggregates comprise as much as 60% to 80% of a typical concrete mix, so they must be properly selected **to be durable**, blended for optimum **efficiency**, and properly controlled to produce consistent concrete **strength**, **workability**, finishability, and durability. The ingredients in conventional concrete mixes usually fall within these proportional ranges.

MECHANICAL & PHYSICAL PROPERTIES OF AGGREGATES

REF: PHYSICAL PROPERTIES OF AGGREGATES (IN SEPARATE PDF FILE)

REF: Mechanical Properties of Coarse Aggregate : Ten Percent Fine Value (TPFV) - Bing video

Basic **properties** of aggregates include mineralogical **composition, surface texture** and **grain shape**, dustiness, **porosity**, frost resistance, **resistance** to **abrasion** and polishing, and **asphalt absorption** capacity.

Physical Properties Absorption, **Porosity**, and **Permeability** Surface **Texture** Strength and Elasticity **Density** and **Specific Gravity** Aggregate Voids Hardness Particle Shape Coatings Undesirable Physical Components.

PHYSICAL PROPERTIES

The physical properties of aggregates are those that refer to the physical structure of the particles that make up the aggregate.

ABSORPTION, POROSITY, AND PERMEABILITY

The internal **pore** characteristics are very important properties of aggregates. The **size,** the **number,** and the **continuity of** the **pore**s through an aggregate particle may **affect the strength** of the aggregate, **abrasion resistance**, surface **texture**, **specific gravity**, **bonding** capabilities, and resistance to freezing and thawing action. Absorption relates to the particle's ability to take in a liquid. Porosity is a ratio of the volume of the pores to the total volume of the particle. **Permeability** refers to the **particle's ability to allow liquids to pass through**. If the rock pores are not connected, a rock may have high porosity and low permeability.

SURFACE TEXTURE

Surface texture is the **pattern** and the relative **roughness** or smoothness of the aggregate particle. Surface texture **plays** a big role in developing the **bond between an aggregate** particle **and** a c**ement**ing material. A rough surface texture gives the cementing material something to **grip**, producing a stronger **bond**, and thus creating a stronger hot mix asphalt or Portland cement concrete. Surface texture also **affects the workability** of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the **water requirements** of Portland cement concrete. Some aggregates may initially have good surface texture, but may polish smooth later under traffic. These aggregates are unacceptable for final wearing surfaces. Limestone usually falls into this category. Dolomite does not, in general, when the magnesium content exceeds a minimum quantity of the material.

STRENGTH AND ELASTICITY

Strength is a measure of the **ability** of an aggregate particle to stand up to pulling or **crushing forces**. Elasticity measures the "stretch" in a particle. High strength and elasticity are desirable in aggregate base and surface courses. These qualities minimize the rate of disintegration and maximize the stability of the compacted material. The best results for Portland cement concrete may be obtained by compromising between high and low strength, and elasticity. This permits volumetric changes to take place more uniformly throughout the concrete.

DENSITY AND SPECIFIC GRAVITY

Density is the **weight per unit of volume** of a substance. Specific gravity is the **ratio of the density of the substance to the density of water**.

The following chart illustrates these relationships for some common substances.

TABLE 1 SPECIFIC GRAVITY OF SUBSTANCES

Typical Values		
Substance	**Specific Gravity**	**Density (lb/ft^3)**
Water	1.0 (73.4 °F)	62.4 lb/ft^3 (73.4 °F)
Limestone	2.6	165 to 170 lb/ft^3
Lead	11.0	680 to 690 lb/ft^3

The **density and** the **specific gravity** of an aggregate particle are **dependent** up**on** the density and specific gravity of the **minerals** making up the particle and upon the porosity of the particle. These may be defined as follows:

1) All of the **pore space** (bulk density or specific gravity)

2) Some of the pore space (effective density or specific gravity)

3) None of the pore space (apparent density or specific gravity)

Determining the porosity of aggregate is often necessary; however, measuring the volume of pore space is difficult. Correlations may be made between porosity and the bulk, apparent and effective specific gravities of the aggregate.

As an example, **specific gravity** information about a particular aggregate helps in **determining the amount of asphalt needed** in the hot mix asphalt. If an aggregate is highly absorptive, the aggregate continues to absorb asphalt, after initial mixing at the plant, until the mix cools down completely. This process leaves less asphalt for bonding purposes; therefore, a more porous aggregate requires more asphalt than a less porous aggregate. The porosity of the aggregate may be taken into consideration in determining the amount of asphalt required by applying the three types of specific gravity measurements.

In the example in **Figure 2**, the bulk **specific gravity includes all the voids**, the apparent specific gravity does not include any of the pores that would fill with water during a soaking, and the effective specific gravity excludes only those pores that would absorb asphalt. Correlation charts and tables provide guidance to asphalt quantities or acceptability of the aggregate.

AGGREGATE VOIDS

There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of the aggregate materials.

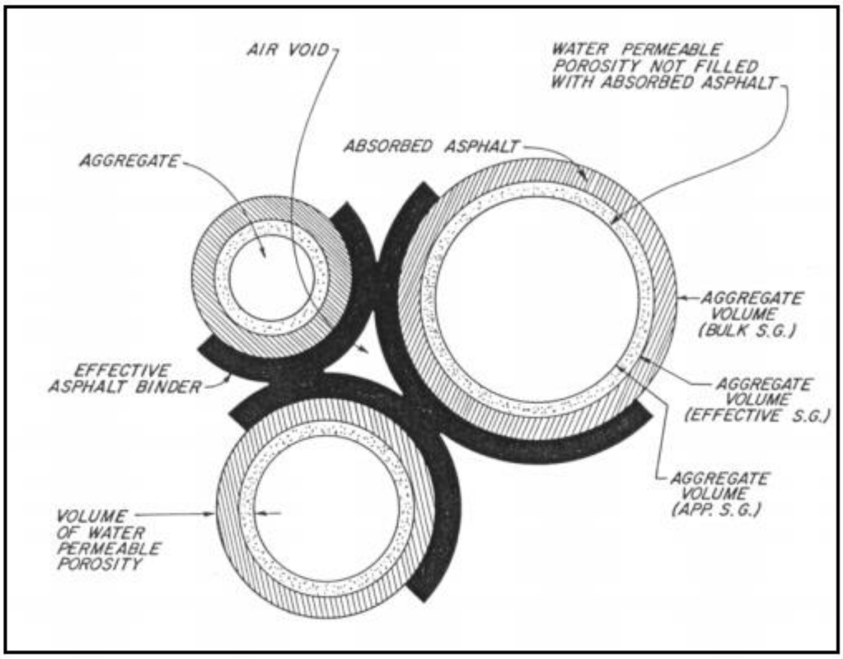

FIG.2 AGGREGATE SPECIFIC GRAVITIES

The **voids within an aggregate** particle should not be confused with the void system which makes up the space between particles in an aggregate mass. The **voids between the particles** influence the design of hot mix asphalt or Portland cement concrete.

HARDNESS The hardness of the minerals that make up the aggregate particles and the firmness with which the individual grains are cemented or interlocked control the resistance of the aggregate to **abrasion and degradation**. **Soft aggregate** particles are composed of minerals with a **low** degree of **hardness**. Weak particles have poor cementation. Neither type is acceptable. The Mohs Hardness Scale is frequently used for determination of mineral hardness (Figure 3). Although there is no recognizable INDOT specification or requirement which pertains to Mohs Hardness Scale, the interpretation, concept, and use of this scale is useful for the field identification of potentially inferior aggregates.

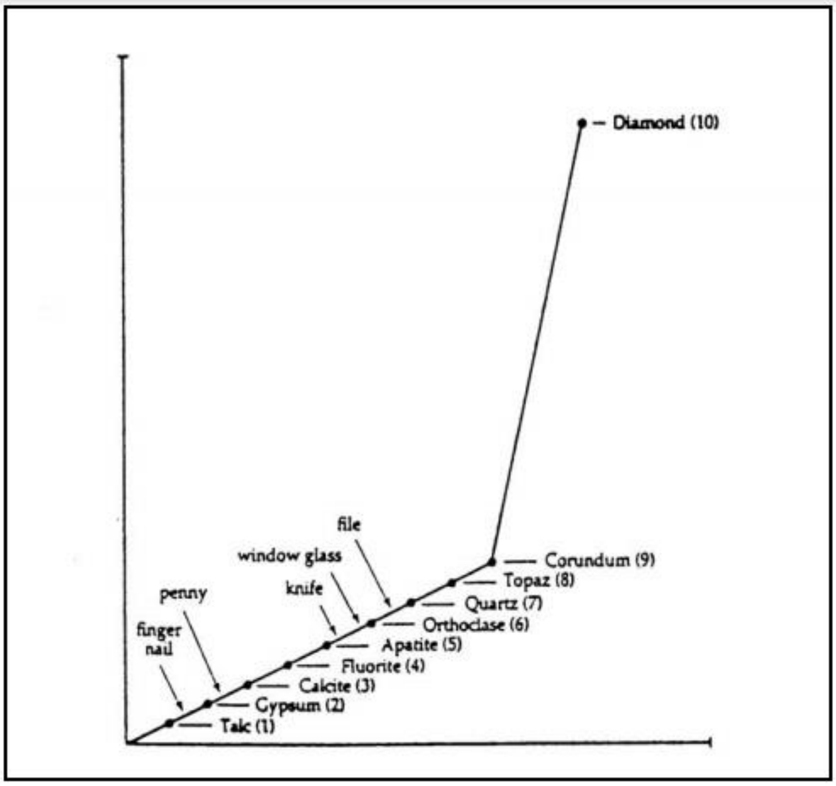

FIGURE 3 RELATIVE HARDNESS OF MINERALS IN MOH'S SCALE (NUMBERS IN PARENTHESES)

PARTICLE SHAPE

The shape of the aggregate particles affects such things as:

1) The asphalt demands of hot mix asphalt

2) The workability and the strength of both Portland cement concrete and asphalt pavements.

The **best aggregates** to use for strength are **crushed stone** or crushed gravel. Crushed aggregate have irregular, angular particles that tend to interlock when compacted or consolidated.

The crushed stone or crushed gravel aggregate make the asphalt or concrete mix somewhat difficult to place. To improve the workability, many mixes contain both angular and round particles. The **coarse aggregate** particles are usually **crushed stone** or crushed gravel, and the **fine aggregate** particles are usually **natural sand**. The Standard Specifications detail the requirements for crushed materials for various uses.

COATINGS

Coating is a layer of substance **covering a part or the entire surface of an aggregate** particle. The coating may be of natural origin, such as mineral deposits formed in sand and gravel by ground water, or may be artificial, such as **dust formed by crushing** and handling.

Generally when the aggregates are used in hot mix asphalt or Portland cement concrete mixes, the **aggregates** are required **to be washed** to remove the coating (contaminant) left on the particles. The coating may prevent a good bond from forming between the aggregate surfaces and the cementing agent. The **coating** could even **increase** the quantity of **bonding** agent required in the mixture. If the quantity of the coating varies from batch to batch, undesirable fluctuations in the consistency of the mix may result. Deposits containing aggregates which display a history of coating problems require decantation.

UNDESIRABLE PHYSICAL COMPONENTS

Particles with undesirable physical characteristics include but are not limited to the following:

1) Non-durable **soft** or structurally weak **particles**
2) **Clay lumps** or clay balls 3-7
3) Flat or **elongated particles**
4) **Organic matter** contaminants
5) **Lightweight** chert

MECHANICAL PROPERTIES OF AGGREGATES

What are the mechanical properties of aggregates?

Aggregate: Mechanical Properties of Aggregate | Concrete Technology

1. **Toughness**:
2. **Hardness**:
3. **Specific Gravity**:
4. Porosity and **Absorption of Water** by Aggregate:
5. Bulking of Sand:

Toughness:

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

The test procedure is as follows:

The aggregate shall be taken as in the case of crushing strength value test i.e., the aggregate should **pass through 12.5 mm** I.S. sieve and **retained on 10 mm** I.S. sieve. It should be **oven dried** at 100°C to 110°C for four hours and then air cooled before test.

Now the prepared aggregate is filled upto 1/3rd height of the cylindrical cup of the equipment. The diameter and depth of the cup are 102 mm and 50 mm respectively. After filling the cup upto 1/3rd of its height, the aggregate is tamped with 25 strokes of the rounded end of the tamping rod.

After this operation the cup shall be further filled upto 2/3rd of its height and a further tamping of 25 strokes given. The cup finally shall be filled to over flowing and tamped with 25 strokes and surplus aggregate removed and the weight of aggregate noted. The value of weight will be useful to repeat the experiment.

Now the **hammer of** the equipment weighting **14.0 kg** is raised till its lower face is **380 mm above** the upper surface of the aggregate and., allowed to fall freely on the aggregate and the process is repeated for **15 times**

The crushed aggregate is now removed from the cup and **sieved through 2.36 mm** I.S. sieve. The fraction passing through the sieve is weighed accurately.

Let the weight of oven dry sample in the cup = W kg.

Weight of aggregate passing 2.36 mm sieve = W_1 kg.
Then impact value = $[(W_1/W) \times 100]$

This value should not be more **30% for aggregate to be used in concrete** for wearing surfaces as road and 45% for other type of concrete.

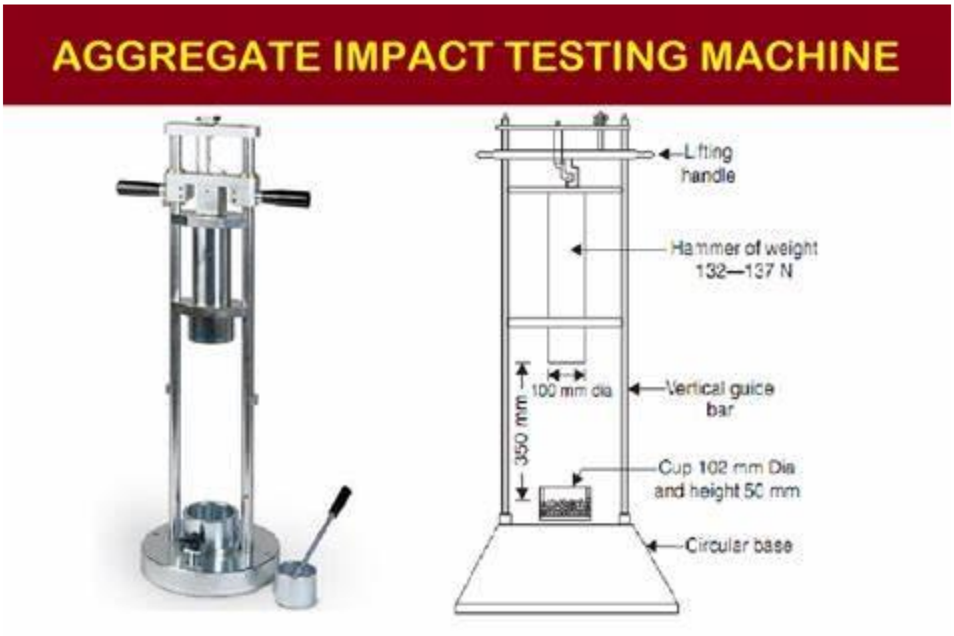

FIG. 4 IMPACT TESTING MACHINE

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

For testing hardness of aggregate following three methods can be used:
(a) Deval Attrition test.
(b) Dorry abrasion test.
(c) Los Angeles test.

(a) Deval Attrition Test:
This test has been covered by IS 2386 Part (IV)-1963. In this test particles of known weight are subjected to wear in an iron **cylinder rotated 10,000** (ten thousand) times at the rate of **30 to 33 revolutions per minute**. After the specified revolution of the cylinder the material is taken out and **sieved on 1.7 mm sieve** and the percentage of material finer than 1.7mm is determined. This percentage is taken as the attrition value of the aggregate. The attrition value of about 7 to 8 usually is considered as permissible.

FIG. 5 DEVAL ATTRITION TEST APPARATUS

Dorry Abrasion Test:
This test has not been covered by Indian standard specifications. In this test a cylindrical specimen having its diameter and height of 25 cm is subjected to

abrasion against a rotating metal disk sprinkled with quartz sand. The loss in weight of the cylinder after 1000 (one thousand) revolutions is determined.

Then the hardness of rock sample is expressed by an empirical relation as follows:
Hardness or sample = 20 – Loss in weight in grams/3

For good rock this value should not be less the 17. The rock having this value of 14 is considered poor.

(c) Los-Angeles Test:
This test has been covered by IS 2386 (Part-IV) 1963. In this test aggregate of the specified grading is placed in a cylindrical drum of inside **length and diameter of 500 mm and 700 mm** respectively. This cylinder is mounted horizontally on stub shafts. For abrasive charge, steel balls or **cast iron balls** of approximately **48 mm diameter** and each weighting **390 grams** to 445 gram are used. The numbers of balls used vary from 6 to 12 depending upon the grading of the aggregate. For 10 mm size aggregate 6 balls are used and for aggregates bigger than 20 mm size usually 12 balls are used.

Procedure:
For the conduct of test, the sample and the abrasive charge are placed in the Los-Angeles testing machine and it is rotated at a speed of 20 to 33 revolutions per minute. For aggregates upto 40 mm size the machine is rotated for 500 revolutions and for bigger size aggregate 1000 revolutions. The charge is taken out from the machine and **sieved on 1.7 mm sieve**.

FIG. 6 LOS ANGELES TEST APPARATUS

Let the weight of oven dry sample put in the drum = W Kg.

Weight of aggregate passing through 1.7 sieve = W_1 Kg.
Then abrasion value = $[(W_1/W) \times 100]$
The abrasion value should not be more than 30% for wearing surfaces and not more than **50% for concrete used** for other than wearing surface. The results of Los Angeles test show good correlation not only the actual wear of aggregate when used in concrete, but also with the compression and flexural strength of concrete made with the given aggregate.

Table 2 gives an idea of toughness, hardness, crushing strength etc. of different rocks.

TABLE 2 AVERAGE TEST VALUES OF AGGREGATE TESTS

S. No.	Rock Group	Crushing strength MPa		Abrasion value	Impact value	Attrition value		Specific gravity
		Rock	Aggregate			Dry	Wet	
1.	Basalt	207	12	17.6	16	3.3	5.5	2.85
2.	Flint	214	17	19.2	17	3.1	2.5	2.55
3.	Granite	193	20	18.7	13	2.9	3.2	2.69
4.	Gristone	229	12	18.1	15	3.0	5.3	2.67
5.	Lime stone	171	24	16.5	9	4.3	7.8	2.69
6.	Quartizite	339	16	18.9	16	2.5	3.0	2.62
7.	Schist	254	—	18.7	13	3.7	4.3	2.76
8.	Gabbro	204	—	18.7	19	2.5	3.2	2.95
9.	Homfels	354	11	18.8	17	2.7	3.8	2.88
10.	Porphyry	239	12	19.0	20	2.6	2.6	2.66

3. Specific Gravity:

The specific gravity of a substance is the **ratio of the weight of unit volume of the substance to the unit volume of water** at the stated temp. In concrete making, aggregates generally contain pores both permeable and impermeable hence the term specific gravity has to be defined carefully. Actually there are several types of specific gravity. In concrete technology specific gravity is used for the calculation of quantities of ingredients. Usually the specific gravity of most **aggregates varies between 2.6 and 2.8**.

Specific gravity of certain materials as per concrete hand book CA-1 Bombay may be assumed as shown in Table 3.

TABLE 3 SPECIFIC GRAVITY OF CEMENT AND AGGREGATE

Material	Specific gravity
Cement	3.15
Average sand	2.00
Granite	2.80
Gravel	2.66
Sand	2.65

Method of Determination of Specific Gravity of Aggregate:

IS-2386-Part-III-1963 describes various procedures to find out the specific gravity of aggregates of different sizes. Here the method applicable to aggregates larger than 10 mm in size has been described as follows —

A sample of aggregate not less than 2 kg in weight is taken and washed thoroughly to remove dust, and silt particles etc. The washed sample is placed in a wire basket and immersed in distilled water at a temperature of 27 ± 5°C.

Immediately after immersion, the entrapped air is removed from the sample by lifting the basket containing sample 25 mm above the bottom of the jar or tank and allow it drop 25 times at the rate of 1 mm per sec. During this operation, care should be taken that basket and aggregate remain fully immersed in water. After this, the sample is kept in water for about 24 ± ½ hour.

After this period the basket and aggregate is given a jerk to remove the air etc. and weighed in water at the temperature of 27 ± 5°C. Let the weight of basket and aggregate be A_1. The basket and sample of aggregate is removed from the water and allowed to drain for a few minutes. Then the aggregate is taken out from the basket and placed on a dry cloth and dried further. The empty basket is again immersed in water and weighed in water after giving 25 jolts. Let this weight be A_2.

The aggregate is surface dried in shade for not more than 10 minutes and the aggregate is weighed in air. Let this weight be B. Now the aggregate is oven dried for 24 ± ½ hour at a temperature of 100 to 110°C. It is then cooled in air tight container and weighed. Let this weight be C.

Thus,

Weight of sample in water = $(A_1 - A_2) = A$

Weight of saturated surface dry in air sample = B

Weight of oven dry sample = C

(a) Then specific gravity = [C/(B – A)]

(b) Apparent specific gravity = [C/(C – A)]

(c) Water absorption = 100 (B – C)

(d) Bulk density = Net weight of the aggregate in kg./capacity or the container in litres

Example:
Find the value of- (i) Specific gravity, (ii) Apparent specific gravity, (iii) Apparent particle density, (iv) Bulk particle density.

(i) Mass of oven dry sample C = 480 gram

(ii) Mass of saturated surface dried sample in air B = 490 gram

(iii) Weight of vessel with water = 1400 gram

(iv) Weight of vessel + water + sample = 1695 gram.

Solution:
(i) Specific gravity = [mass of oven dry sample/(mass or saturated surface sample – sample weight in water)]

= [C/(B – A)] = [480/(490-295)]

= 480/195 = 2.50

(ii) Apparent specific gravity = [C/(C – A)] = [480/(480 – 295)]

= 480/185 = 2.59

(iii) Apparent particle density = 1000 x Apparent specific gravity = 2.59 x 1000

= 2590 kg/m^3
(iv) Bulk Particle density = Bulk specific gravity x 1000

= 2.59 x 1000 = 2500 kg/m^3

Absolute Specific Gravity:
It can be defined as the ratio of the weight of the solid, referred to vacuum, to the weight of an equal volume of gas free distilled water both taken at the standard or a stated temperature, usually it is not required in concrete

technology. Actually the absolute specific gravity and particle density refer to the volume of solid material excluding all pores, while apparent specific gravity and apparent particle density refer to the value of solid material including impermeable pores, but not the capillary pores. In concrete technology apparent specific gravity is required.

Porosity and Absorption of Water by Aggregate:

All aggregates, particles have pores within their body. The characteristics of these pores are very important in the study of the properties of aggregate. The porosity, permeability, and absorption of aggregates influence the resistance of concrete to freezing and thawing, bond strength between aggregate and cement paste, resistance to abrasion of concrete etc.

The size of pores in the aggregate varies over a wide range, some being very large, which could be seen even with naked eye. The smallest pore of aggregate is generally larger than the gel pores in the cement paste, pores smaller than 4 microns are of special interest as they are believed to affect the durability of aggregates subjected to alternate freezing and thawing. Some of the pores are wholly within the body of the aggregate particles and some of them are open upto the surface of the particle.

The cement paste due to its viscosity cannot penetrate to a great depth into the pores except the largest of the aggregate pores. Therefore, for the purpose of calculating the aggregate content in concrete, the gross volume of the aggregate particles is considered solid. However water can enter these pores, the amount and rate of penetration depends upon the size, continuity and total volume of pores.

When all the pores in the aggregate are full with water, then the aggregate is said to be saturated and surface dry. If this aggregate is allowed to stand in the laboratory, some of the moisture will evaporate and the aggregate will be known as air dry aggregate. If aggregate is dried in oven and no moisture is left in it, then it is known as bone dry aggregate. Thus the ratio of the increase in weight to the dry weight of the sample, expressed as a percentage is known as absorption.

The knowledge of absorption of aggregate is important in adjusting water-cement ratio of the concrete. If water available in the aggregate is such that it contributes some water to the dilution of cement paste, in that case the water-cement ratio will be more than the required and the strength will go down.

On the other hand, if the aggregate is so dry that it will absorb some of the mixing water, in that case the mix will have lower water-cement ratio and the mix may become unworkable. Hence, while deciding the water-cement ratio, it is assumed that the aggregate is in saturated but surface dry condition, i.e. neither it will add water to cement paste, nor it will absorb water from the mix.

It has been observed that absorption of water by dry aggregate slows down due to the coating of particles with cement paste. The water absorption by aggregate should be determined for 10 to 30 minutes instead of total water absorption. The value of absorption of water may be taken as follows as recommended by concrete hand book CAI Bombay in Table 4.

TABLE 4 WATER ABSORPTION BY AGGREGATES

S. No.	Aggregate	Moisture absorbed by wt of aggregate
1.	Average sand	1.0 %
2.	Pebbles and crushed lime stone	1.0 %
3.	Granite and trap rock	0.5 %
4.	Porous sand stone	7.0 %
5.	Very light and porous aggregate	25.0 %

Surface Water:

While using aggregate in the concrete, water on the surface of the aggregate should be taken into account, as it will contribute to the water in the mix and will affect the water-cement ratio of the mix, causing lower strength of the concrete. It is difficult to measure surface water of the aggregate. Therefore its value may be assumed according to I.S. 456, 1964 given in Table 5

TABLE 5 SURFACE WATER CARRIED BY AGGREGATES

S. No.	Aggregote	App. quantity of surface water in lit/m^3
1.	Very wet sand	120.0
2.	Moderately wet sand	80.0
3.	Moist sand	40.0
4.	Moist gravel or crushed rock (as coarser the aggregate, lesser the surface water)	20 to 40

Bulking of Sand:

The moisture present in fine aggregate causes increase in its volume, known as bulking of sand. The moisture in the fine aggregate develops a film of moisture around the particles of sand and due to surface tension pushes apart the sand particles, occupying greater volume. The bulking of the sand affects the mix proportion, if mix is designed by volume batching. Bulking results in smaller weight of sand occupying the fixed volume of the measuring box, and the mix becomes deficient in sand and the resulting concrete becomes honeycombed and its yield is also reduced.

The extent of bulking depends upon the percentage of moisture present in sand and its fineness. The increase in volume relative to that occupied by a saturated and surface dry sand increases with an increase in the moisture content of the sand upto a value of 5 to 8%, causing bulking ranging from 20 to 40% as shown in Table 4.13. Fig. 4.8 and Table 6 shows bulking of sand with various moisture contents as suggested by concrete hand book CAI, Bombay.

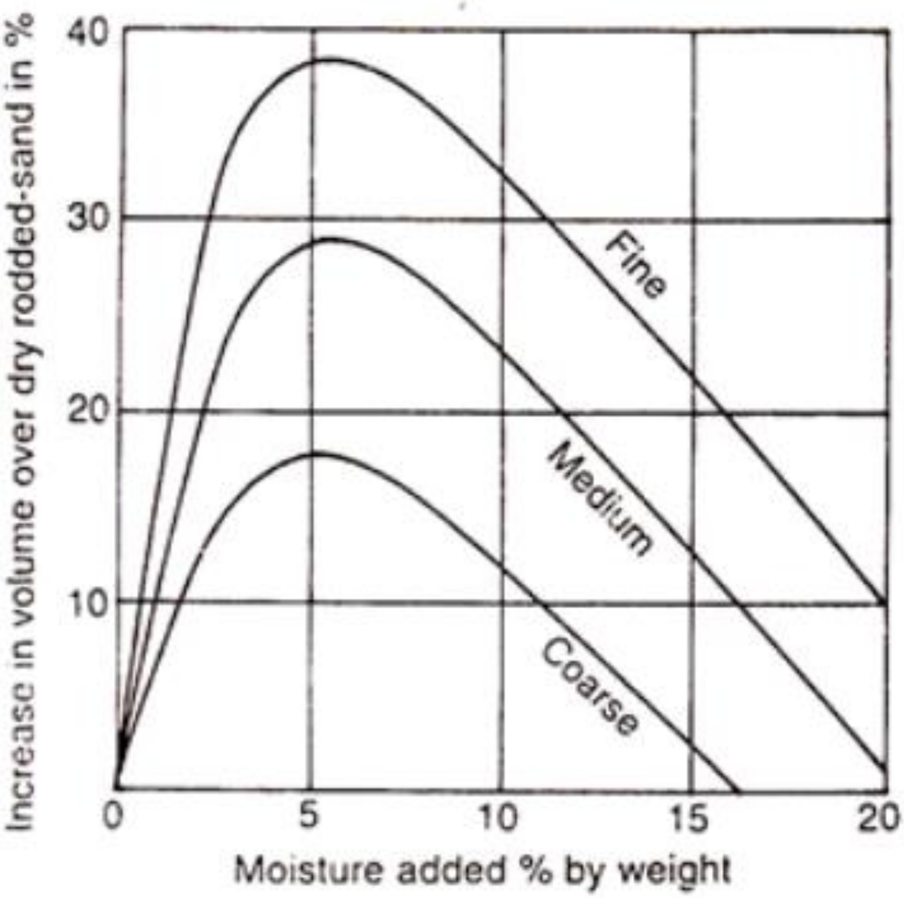

FIG.7 BULKING OF SAND

TABLE 6 BULKING OF SAND

S. No.	Moisture percent	Percentage bulking			Remark
		Fine sand	Medium sand	Coarse sand	
1.	1	16	8	6	Coarser the sand, lesser the bulking
2.	2	26	16	12	
3.	3	32	22	15	
4.	4	36	27	17	
5.	5	38.5	29	18	
6.	6	37	28	18	
7.	8	35	26	16	
8.	10	32	22	12	
9.	12	28	19		
10.	15	22	12	8	
11.	17	10	7	0	
12.	20	0	0	0	
13.	27	0	0	0	

the film of water formed around the sand particles merge and the water moves into the voids between the particles so that the total volume of sand decreases, till the sand is fully saturated. The volume of fully saturated sand is same as that of the dry sand for the same method of filling the container.

Determination of Bulking of Sand:
Since the volume of saturated sand is same as that of dry sand, the most convenient way of determining bulking of sand is by measuring the decrease in volume of the given sand on saturation. For the measurement of bulking of sand, usually a container of known volume, a 30 cm long steel rule, and a 6 mm iron rod is required.

Procedure:
Put sufficient quantity of sand loosely into the container, till it is about two-thirds full. Level off the top of the sand with steel rule, and push this rule at the middle of the surface to the bottom of the container and measure its height. Let the height be h cm.

Now empty this sand into another container. While emptying, care should be taken that no sand particles are lost. Take about 1/3rd to half-full the first container with water and add about half the sand to it and rod it with 6 mm diameter steel rod. The sand should be rodded till the air bubbles cease to come out. At this stage the volume of sand is minimum. At this stage add the remaining sand and rod it also till air bubbles cease to come out. Smooth and level the top surface of the saturated sand and measure its height by pushing the steel rule at the middle of the surface to the bottom of the container. Let this height be h_1 cm.
Then % bulking = $[(h_1/h2) \times 100]$

Effect of Bulking of Sand:

For volume batching, bulking has to be allowed for by increasing the total volume of sand used, otherwise the mix will be deficient in sand and segregation of the mix may take place. Also the resulting concrete will be honeycombed and its yield will be reduced, raising its cost of production. The volume to be increased can be calculated either by knowing this percentage of bulking as shown above or by bulking factor.

If,

V_m = vol. of moist sand
V_s = vol. of saturated sand
then bulking = $[(V_m - V_s)/V_s]$
and bulking factor = $1 + [(V_m - V_s)/V_s] = V_m/V_s$
Hence to know the total volume of sand to be used can be calculated by multiplying the vol. V_s by the bulking factor. The value of bulking factor can be determined by the curves of Fig. 7. Fig. 7 gives bulking factor against moisture content upto 20% for three types of sands.

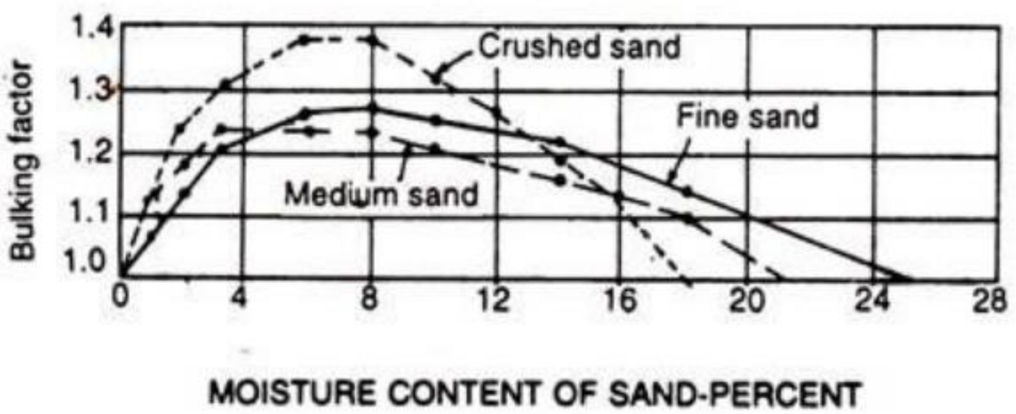

FIG.8 BULKING OF SAND WITH DIFFERENT MOISTURE CONTENT

GRADING REQUIREMENTS OF AGGREGATES

Grading of aggregates is determining the average **grain size** of the aggregates before they are used in construction. This is applied to both **coarse and fine** aggregates. The aggregate sample is sieved through a set of sieves and weights retained on each sieve in percentage terms are summed up.

What is grading of coarse aggregate?

Coarse aggregates used in concrete making contain aggregates of various sizes. This **particle size distribution** of the coarse aggregates is termed as "**Gradation**". The sieve analysis is conducted to determine this particle size distribution. It is this matrix that is vulnerable to all ills of concrete.

What is grading of aggregate?

The particle size distribution of aggregate, as determined by sieve by sieve analysis, is termed as the grading of aggregate. The **gradation** of aggregate plays a **vital role** in governing properties like **workability and finishing**. If all the particles of an aggregate are of **uniform size**, then compacted mass will have maximum **void**s, whereas particles of different sizes lead to dense mass. The particle size distribution of aggregate should be in such a manner that voids of larger particles are to be filled up with smaller particles.

Note

- **Proper grading** of aggregates **results** in dense concrete and requires **less** quantity of **fine aggregate and cement** paste.
- **Grading** of aggregate **affect**s the **workability** which, in turn, controls the water and cement requirements, segregation and plays an important role in placing and finishing operations of concrete.

Types of grading of aggregate

It is also mainly dependent upon the different sizes of particles available in the aggregate, the grading may be of the following four types are the given below.

1. Well graded aggregates

The aggregate is said to be **well graded** if the voids created by large-sized particles are filled almost by smaller size particles hence leaving minimum voids to be filled by cement paste. Well, graded aggregate contains **all sizes of particles**, thus leading to a compact and dense mass of **concrete** mix. This type of grading is considered the best because all sizes of particles are available, which leads to a **lesser** quantity of **cement** requirements.

2. Gap graded aggregates

When the particles of **certain sizes are missing** in aggregate then the grading is termed as gap graded. Most of the crushers in India are single size crushers thus creating single size aggregates. The **gap-graded aggregate does not affect** compressive or **tensile** **strengths**

3. Poorly graded aggregates

The grading in which the proportions of certain intermediate particles are deficient or in **excess** is termed as **poorly graded aggregate**.

4. Continuously graded aggregates

Aggregate is said to be **continuously graded** when it contains **all particle size** groups i.e., from the maximum particle size to the minimum size. Such grading is termed as coarser or finer depending upon the higher proportions of coarser or finer particles they contain in reference to specified grading with which they are being compared.

Factor affecting the effects of grading of aggregate

The grading of aggregate has the following effects on the properties of fresh and hardened concrete. It is mainly four types are the following given below.

1. Density of aggregates

The well-graded aggregate has a lesser number of voids as compared to particles of the same size. Thus proper grading of aggregate produces dense concrete and requires less quantity of cement to fill the voids. Therefore, the concrete produced is economical.

2. Segregation of aggregates

Segregation is an undesirable property in fresh concrete. Coarser grading tends to segregate if the required proportion of finer material is not available to maintain cohesiveness. Therefore, with the help of grading the deficient particles can be maintained.

3. Bleeding of aggregates

Bleeding is an undesirable property in fresh concrete. **Lack of finer grading leads to bleeding.** Bleeding is more in case of coarser grading of aggregate.

4. Strength of aggregates

Grading of aggregate has no direct effect on strength but indirectly influences the strength parameters. For concrete having a low water-cement ratio, **coarser**

grading is required because it provides less specific surface area. Whereas, for high water-cement ration finer grading is desirable.

QUALITY OF WATER IN CONCRETE.

Quality of water for construction works is same as **drinking water**.

Quality of Water for **Concrete** Construction and its Specification.

Type of Solid in water	**Permissible Limits for Construction**
Inorganic matter	3000 mg/l
Sulphates (SO4)	500 mg/l
Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l

Concrete is a chemically combined mass which is manufactured from binding materials and inert materials with water. It is most popular construction material due to its unique durability and reasonable strength; more interestingly can be modified and designed for wide range of strength requirements and set under variable environmental conditions. **Cement is** the most **important material** of **concrete** which is produced at the cost of environmental emission of CO_2; **to produce 1 tonne cement nearly 900 kg CO_2 is released in the environment**. So such an energy intensive materials constitutes concrete which may be seriously affected by (both strength and durability point of view) by relatively available and cheap but essential element water; more precisely impurities in water. Quality of mixing water are mainly considered for performance of concrete in both fresh and harden state.

Impurities in mixing water intervene the setting time of the paste and may produce detrimental effect on strength and durability of concrete also. When impurities are chemically active, they may take part in the **chemical** reaction contributing significant **change in setting, hardening and development of strength of concrete.** More over **health hazard** during handling these water should carefully considered. In this regard past performance of a particular source of water can be used to evaluate suitability of water; if not available, some testing inevitable to evaluate water for setting time, compressive strength and durability.

Function of Water in Concrete

Three water serves the following purpose:

- **To wet the surface of aggregates** to develop adhesion because the cement pastes adheres quickly and satisfactory to the wet surface of the aggregates than to a dry surface.
- **To prepare a plastic mixture** of the various ingredients and to impart workability to concrete to facilitate placing in the desired position and
- Water is also needed **for the hydration of the cementing materials** to set and harden during the period of curing.

The quantity of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete. Sometimes may not be harmless or even beneficial during mixing. So clear distinction should be made between the effect on hardened concrete and the quality of mixing water.

Potable water as mixing water

The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have **inorganic solid less than 1000 ppm**. This content lead to a solid quantity 0.05% of mass of cement when w/c ratio is provided 0.5 resulting small effect on strength.

But some water which are not potable may be used in making concrete with any significant effect. Dark color or bad smell water may be used if they do not posses deleterious substances. **P^H of water to even 9 is allowed** if it not tastes brackish. In **coastal areas** where local water is saline and have no alternate sources, the **chloride concentration up to 1000 ppm is** even **allowed** for drinking. But this excessive amount of alkali carbonates and bicarbonates, in some natural mineral water, may **cause alkali-silica reaction**.

Acceptable source of water

Besides **potable water**, various new and existing sources are available for mixing water which can be used for complete and partial replacement of valuable potable water. This includes

Ground water
Reclaimed water
Treated water from municipal sewer
Waste water of ready-mix concrete plant etc.

In many regions of the world there have **scarcity of water** like **Dubai** and **Qatar** and the local authorities are looking for new sources and **reused water**. There treated water are used for agricultural requirements and daily needs for construction industry. like washing aggregates, as concrete mixing water and curing of the same. Water from river and sometimes even sea are considered suitable if it is free from brackish matter. In arid regions, brackish **groundwater is mixed with desalinated water and considered suitable for concrete** production and for concrete slurry too.

Sampling guideline for mixing water

In addition to testing on constituent of concrete like aggregate cementitious materials and admixtures etc., **testing of water** is an important **part of quality control** of concrete. A systematic testing schedule for water testing yields higher efficiency of concrete and assure good performance in regard of strength and durability.

Important thing to remember is that water can be changed by chemical, physical or biological reactions; such modification may occur during sampling and at the time of analyzing. So it should be **tested before using in concrete**.

Collection of sample

The location of sampling should be at mid-stream and **extracted from mid depth**, as far as possible. When there have obstructions or major discharges are fall into river, the **sample** should be taken **in downstream** of **discharge**s by a distance more than 100m in case of small stream; in a word, the site should be such that no change in water in the stream are seen with naked eyes. In case of **wide river at least three samples** should be taken along the cross section.

Sampling of waste water

When water from narrow effluent channels of **treated sewers** are to be tested, the **sample** should be taken **from one third depth of water** neither skimming the top surface nor scrapping the bottom. It is important to locate site having sufficient flow so that no nearby deposition is occurred. Caution should be taken during sampling to keep in-situ condition of dissolved gas i.e. must not be agitated to liberate dissolved gasses or to cause some degree if aeration.

It was observed that sewage flows are often intermittent which requires to collect samples an hour interval throughout 24 hours. At room temperature **waste water** generally decompose rapidly, so test set-up for certain **parameter** should be available at site. These are as follows:

Dissolved oxygen
Residual chlorine
Sulfides
P^H
Nitrites etc.

For some tests addition of preservatives just after collection of water will be enough.

Can ready-mix concrete washout water be used in concrete?

It is recommended in AS 1379 and ASTM C94, that water used in washout operation in ready-mix concrete plant **can be used in concrete** as mixing water. Only requirement is to store it in such a way that contamination from deleterious matters is prevented and water is collected from storage outlet. Water **should conform ASTM** C 1602; the sources and testing frequencies and other requirements of testing to qualify water sources. According to ASTM C94 water may be water itself or may be ice or any forms of moisture on the aggregate surface and wash water remains in the drum of truck mixer can be used for concreting next batch.

Plant washout water often called **recycled ready-mix water**. In 2007 experiment results were published by GL Low et al. about the requirements of recycling of cement-slurry water found from ready-mix concrete batching plant. He also examined the performance of concrete casted from reused water without any treatment. This study revealed the effects of application of such water in concrete mix on both fresh and hardened concrete based on the requirements of ASTM C94 and BS4550. The interesting thing was that they used **two criteria** namely **specific gravity** and **PH**; slurry water from such source can meet acceptance criteria based on concrete performance in setting time, compressive strength and drying shrinkage, when specific gravity of recycles water not exceed 1.03 and PH value of water lies between 12.3 to 13.3.

Determination of Suitability of Mixing Water

A simple way of determining the suitability of such water is to compare the setting time of cement and the strength of mortar cubes using the water in question with the corresponding results obtained using known suitable or distilled water. About **10% tolerance** is generally allowed. Such tests are recommended when water for which no service record is available containing dissolved solids in excess of 2000 ppm or, in excess of 1000 ppm. When unusual solids are present a test is also advisable.

TABLE 7 WATER QUALITIES IN CONCRETE

Quality Parameters	Maimum Limit (ppm)
Chlorides	500
SO_3	1000
Alkali Carbonates and Bicarbonates	1000
Turbidity	2000

The effect on concreting for different types of contamination or impurities are described below:

Suspended Solids

Mixing water which high content of suspended solids should be allowed to stand in a setting basing before use as it is **undesirable** to introduce large quantities of **clay and slit into**
.

Acidity and Alkalinity

Natural water that are slightly acidic are harmless, but presence of humic or other **organic acids** may result adverse **affect** over the **hardening of concrete**. Water which are highly alkaline should also be tested.

Algae

The presence of **algae in** mixing **water causes air entrainments** with a consequent **loss of strength**. The green or brown slime forming algae should be regarded with suspicion and such water should be tested carefully.

Sea Water

Sea water contains a total **salinity** of about **3.5%** (78% of the dissolved solids being NaCl and 15% $MgCl_2$ and $MgSO_4$), which **produce**s a slightly **higher early strength** but a **lower long-term strength**. The **loss of strength** is usually limited to **15%** and can therefore be tolerated. **Sea water reduces the initial setting time of cement** but do not effect final setting time.

Chloride

Water containing large amount of chlorides tends to **cause** persistent dampness and **surface efflorescence**. The presence of chlorides in concrete containing embedded **steel** can **lead to** its **corrosion**.

Moisture Content of Aggregate

Aggregate usually contains some surface moisture. **Coarse aggregate** rearly **contains** more than **1%** of surface moisture but **fine aggregate** can contain in excess of **10%**. This water can represent a substantial proportion of the total mixing water indicating a significant importance in the quality of the water that contributes surface moisture in aggregate.

Effect of lead exist in mixing water

An investigation was conducted on behavior of concrete under existence of heavy metal in mixing water by Madhusudana Reddy, B and et al (2011). They examined the effect of presence of lead (Pb^{+}) in mixing water on setting times, compressive strength, soundness and attack of sodium-sulfate on high strength cement mortar. Two types of specimens of cement mortar were used, one was casted with deionised water and others were casted with deionised water with different concentrations of lead. The lead concentration used were 10, 50, 100, 500, 1000, 2000, 3000, 4000 and 5000 mg/liter.

The results were interesting, as compared to reference specimens, it was figured out from results that specimens having **high concentration of lead lost significant strength** with a significant **increase in setting time** of cement in mortar. However, a marginal increase in setting time and compressive strength was found at a concentration of 2000 mg/liter.

Impurities influencing setting time of concrete

H. Y. Ghorab and et al (1990) have studied the effect of water (from natural sources) on the setting time of cement and reported that **setting time** of ordinary portland cement mainly **dependent on quality of water**. As compared to setting time of concrete cast of tap water, a reduction of 4% was observed when used water from the Nile river and approximately 25% reduction was found in concrete cast with groundwater; same result also found for sea water.

V. V. Red and et al. studied on the setting time and development of strength in fly ash concrete under alkaline water in laboratory condition. It was found that initial and final setting time of concrete either accelerated or retarded depending on type of alkalinity rendered by sodium carbonate or sodium bi-carbonate.

When sodium carbonate exists in mixing water, both initial and final setting times are accelerated when the concentration is 6 gm/liter and 4 gm/liter respectively. In case of sodium bi-carbonate, both initial and final setting time are retarded when its concentration in mixing water is equal to 4 gm/liter and 6 gm/liter respectively. **Compressive strength and tensile strength were found reduced with increase in sodium carbonate** and sodium bi-carbonate content in mixing water in excess of 6 gm/liter and 10 gm/liter respectively.

ADMIXTURES

REF: Types of Admixtures in Concrete - Bing video 8.04min

https://youtu.be/OdgErcEF1z4

USED IN CONCRETE

Various types of admixtures are used in concrete **to enhance the performance** of concrete.
Concrete admixture is defined as the material other than the aggregate, water and cement added to the concrete.

Types of Concrete Admixtures
Concrete admixtures are of different types and they are as follows:

1. **Water Reducing Admixtures**
2. **Retarding Admixtures**
3. **Accelerating** Admixtures
4. Air entraining concrete admixture
5. Pozzolanic Admixtures
6. Damp-proofing Admixtures
7. Gas forming Admixtures
8. Air detraining Admixtures
9. Alkali Aggregate Expansion Inhibiting Admixtures
10. Anti-washout Admixtures
11. **Grouting** Admixtures
12. **Corrosion Inhibiting Admixtures**
13. **Bonding** Admixtures
14. Fungicidal, Germicidal, Insecticidal Admixtures
15. **Colouring** Admixtures

1. Water Reducing Admixtures

Water reducing admixtures, the name itself defining that they are used **to minimize the water demand** in a concrete mix. Workability is the important property of concrete which is improved with the addition of water but **if water is added more** than required the **strength and durability** properties **of concrete gets affected.**

In addition to **increase in workability** it also **improve**s the **strength** of concrete, good **bond** between concrete and steel, **prevent**s cracking, **segregation**, **honeycombing**, bleeding etc.

Water reducing admixtures are also **called as plasticizers** and these are classified into three types namely plasticizers, **mid-range plasticizers** and **super plasticizers**. Normal plasticizer reduces the water demand up to **10%**, mid-range plasticizers reduce the water demand up to **15%** while **super plasticizers reduce the water demand up to 30%.**

Calcium, sodium and **amonium** lignosulphonates **are** commonly used **plasticizer**s. Some of the new generation super plasticizers are **acrylic polymer** based, **poly carboxylate**, **multicarbovylatether**s etc.

FIG 9 WATER REDUCING ADMIXTURE ADDED CONCRETE

2. Retarding Admixtures

Retarding admixtures **slow down the rate of hydration of cement** in its initial stage and **increase the initial setting time** of concrete. These are also called as retarders and used especially in high temperature zones where concrete will set quickly.

The quick setting in some situations may lead to discontinuities in structure, poor bond between the surfaces, creates unnecessary voids in concrete etc. Retarders are useful to eliminate this type of problems.

Commonly used retarding admixture is **calcium sulphate** or **gypsum.** Starch, **cellulose products**, common **sugar, salts** of acids are some other retarders. Most of water reducing admixtures is also acts as retarding admixtures and they are called as retarding plasticizers.

FIG.10 RETARDING ADMIXTURE (GYPSUM)

3. Accelerating Admixtures

Accelerating admixtures are used **to reduce the initial setting time of concrete**. They speed up the process of initial stage of hardening of concrete hence they are also called as accelerators. These accelerators also **improves** the **strength** of concrete in it **early stage** by **increasing the rate of hydration**

Earlier hardening of concrete is useful in several situations such as **early removal of formwork**, lesser period of curing, **emergency repair works**, for constructions in low temperature regions etc.

Some of the accelerating admixtures are **triethenolamine**, **calcium formate**, **silica fume, calcium chloride**, finely divided **silica gel** etc. **Calcium chloride** is the cheap and commonly used accelerating admixture.

FIG.11 ACCELERATOR (SILICA FUME)

4. Air Entraining Concrete Admixture

Air entraining admixtures are one of the most important inventions in concrete technology. Their primary function is **to increase the durability of concrete** under freezing and thawing conditions. When added to concrete mix, these admixtures **will form millions of non-coalescing air bubbles throughout the mix and improves the properties of concrete.**

Air entrainment in concrete will also **improve** the **workability** of concrete, **prevents** segregation and **bleeding**, lower the unit weight and modulus of elasticity of concrete, **improve**s the **chemical resistance** of concrete and reduction of cement or sand or water content in concrete etc

Most used air entrainment admixtures are **vinsol resin, darex, Teepol, Cheecol** etc. These admixtures are actually made of **Natural wood resins, alkali salts**, **animal and vegetable fats** and oils etc.

FIG.12 FREEZING AND THAWING EFFECT ON CONCRETE

5. Pozzolanic Admixtures

Pozzolanic admixtures are used **to prepare dense concrete** mix which is bets suitable for water retaining structures **like dams, reservoirs** etc. They also **reduce the heat of hydration** and thermal shrinkage.

Best Pozzolanic materials in optimum quantity gives best results and prevents or **reduce**s many risks such as alkali aggregate reaction, leaching, **sulphate attack** etc.

Pozzolanic materials used as admixtures are either natural or artificial. **Natural**ly occurring **Pozzolanic** materials are **clay, shale, volcanic tuffs**, pumicite, etc. and **artificial pozzolans** available are **fly ash, silica fume, blast furnace slag, rice husk ash, surkhi** etc.

FIG.13 FLY ASH

6. Damp-proofing Admixtures

Damp proofing or water proofing admixtures are used **to make the concrete** structure **impermeable** against water and to prevent dampness on concrete surface. In addition to water proof property, they also acts like accelerators in early stage of concrete hardening.

Damp proofing admixtures are available in liquid form, powder form, paste form etc. The main constituents of these admixtures are **aluminium sulphate**, **zinc sulphate aluminium chloride, calcium chloride, silicate of soda** etc. which are chemically active pore fillers.

FIG.14 DAMPNESS ON CONCRETE SURFACE

7. Gas forming Admixtures

Aluminium powder, activated carbon, hydrogen peroxide are generally used gas forming chemical admixtures. When gas forming admixtures are added, it reacts with hydroxide obtained by the hydration of cement and **forms minute bubbles of hydrogen gas in the concrete**.

The range of formation of bubbles in concrete is depends upon many factors such as amount of admixture, chemical composition of cement, temperature, fineness etc. The formed bubbles help the concrete to **counteract the settlement and bleeding** problems.

FIG.15 ACTIVATED CARBON POWDER

Gas forming admixtures are also **used to prepare light weight concrete**. For settlement and bleeding resistance purpose, small quantity of gas forming admixtures which is generally 0.5 to 2% by weight of cement is used. But for making light weight concrete larger quantity generally 100 grams per bag of cement is recommended.

8. Air detraining Admixtures

Air-detraining Admixtures are **used to remove the excess air from the concrete** voids. Sometimes, the aggregates may release the gas into concrete and air entrained is more than required then this type of admixtures is useful.
Some of the mostly used air-detraining admixtures are **tribute phosphate, silicones, water insoluble alcohols** etc.

9. Alkali Aggregate Expansion Preventing Admixtures

Alkali aggregate expansion in concrete is happened by the reaction of **alkali** of cement with the silica present in the aggregates. It **forms a gel** like substance and **cause volumetric expansion of concrete** which may **lead to cracking** and disintegration.

Use of Pozzolanic admixtures will prevent the alkali-aggregate reaction and in some cases air-entraining admixtures are also useful. Generally used admixtures to reduce the risk of alkali aggregate reaction are **aluminium powder and lithium salts.**

FIG.16 EFFECT OF ALKALI AGGREGATE REACTION ON CONCRETE

10. Anti-washout Admixtures

Anti-washout admixtures are used in concrete especially for **under water concrete** structure. It protects the concrete mix from being washed out under water pressure. It **improves the cohesiveness** of concrete.

This type of admixtures are prepared from **natural or synthetic rubbers, cellulose based thickener**s etc.

FIG.17 UNDERWATER CONCRETING

11. Grouting Admixtures

Grouting admixtures are added to grout materials to improve the grout properties according to the requirement of grout. Sometimes, there is a need of **quick set** grout and sometimes there is a need of slow set grout to **spread into deep cracks or fissures.**

Hence, different admixtures are used as grout admixtures based on situation. Accelerators like **calcium chloride, tri ethanolamine** etc. are used as grout admixtures when the grout is to be set rapidly. Similarly retarders like **mucic acid, gypsum** etc. are **used to slow down the setting time** of grout.

Gas forming admixtures like aluminium powder is added to grout material to counteract the settle of foundations.

FIG.18 GROUTING ON CONCRETE

12. Corrosion Preventing Admixtures

Corrosion of steel in reinforced concrete structure is general and it is severe when the structure is exposed to saline water, industrial fumes, chlorides etc. To prevent or **to slow down the process of corrosion** preventing admixtures are used.

Some of the corrosion preventing admixtures used in reinforced concrete is **sodium benzoate, sodium nitrate, sodium nitrite** etc.

FIG.19 CORROSION OF STEEL IN CONCRETE

13. Bonding Admixtures

Bonding admixtures are used to create a **bond between old and fresh concrete** surfaces. In general, if fresh concrete is poured over a hardened concrete surface, there is a chance of failure of fresh concrete surface due to weak bond with old surface.

To make the bond stronger, bonding admixtures are added to cement or mortar grout which is applied on the concrete surface just before placing fresh concrete. This type of admixtures are used for pavement overlays, screed over roof provision, repair works etc.

Bonding admixtures are **water emulsions** and they are made from **natural rubber, synthetic rubbers, polymers like poly vinyl chloride, polyvinyl acetate** etc.

FIG.20 CONCRETE PAVEMENT OVERLAY

14. Fungicidal, Germicidal, Insecticidal Admixtures

To **prevent the growth of bacteria, germs, fungus on hardened concrete** structures, it is recommended that the mix should have fungicidal, germicidal and insecticidal properties. These properties can be developed by adding admixtures like **poly halogenated phenols, copper compounds and dieledren emulsions** etc.

FIG.21 CONCRETE AFFECTED BY FUNGI

16. Colouring Admixtures

Colouring admixtures are the **pigments** which produce colour in the finished concrete. The admixtures used to produce colour should not affect the concrete strength. Generally colouring admixtures are added to cement in a ball mill, then **coloured cement** can be obtained which can be used for making coloured concrete. Some of the colouring admixtures and their resultant colours are tabulated below.

Table 8 Colouring Admixtures and their Resultant Colours

Admixture	Colour obtained
Iron or Red oxide	Red
Hydroxides of iron	Yellow
Barium manganese and Ultramarine	Blue
Chromium oxide and chromium hydroxide	Green
Ferrous oxide	Purple
Carbon black	Black
Manganese black , Raw umber	Brown

FIG.22 COLORED CONCRETE

Plasticizers types and uses in concrete

Super plasticizers are used for producing **flowing concrete** to be used in inaccessible locations, floors or where very quick placing is required. A self levelling and **self-compacting** concrete is called flowing concrete. Super plasticizers are also used for the production of **high strength** and high performance concrete.

Sand, cement, filler and water are involved in the preparation of concrete. The amount of the last component should be minimal, since it is water that worsens the strength of the finished concrete base to frost, moisture, and reduces its strength. In order to increase the plasticity of concrete, make it easier to work and to improve its performance in it add plasticizers. About their features, advantages of application, types, we will consider further.

Plasticizer for concrete what is needed: the advantages of plasticizers
In relation to the principle of plasticizer, they are divided into **two types**:

- hydrophilic
- hydro phobizing

The **first** option is characterized by increased **wet ability**, the main function of which is to increase the plastic and flow characteristics of the concrete.

The **second** type of plasticizer saturates the concrete mixture with a large amount of air. Thus, it is possible to **reduce the tension** of moisture in the solution, while the plastic characteristics of the solution increase.

In modern construction, plasticizers are an indispensable element of almost every concrete solution. This is due to their **advantage**s:

1. The main advantage of using plasticizers is an **increase in the plasticity** of the ready-mixed concrete. Thus, with the composition is easy to work, it well falls into all hard-to-reach places and covers the smallest pores.

2. A second advantage of plasticizers is the possibility of considerable **savings in cement mortar**. Adding plasticizers to the concrete solution can save on the amount of cement mortar. If you compare a solution prepared without adding plasticizers and with them, the amount of cement used in the second case will be 14-17% less.

3. **Increase the strength** characteristics of the finished concrete foundation by twenty five percent.

4. Since the concrete solution is highly mobile and plastic, for the filling of large objects, special equipment is **used in the form of a concrete pump** or an automatic concrete pump. Particularly relevant for the erection of buildings monolithic type. At the same time, the strength remains at the proper level.

FIG.23 PLASTICIZERS USED IN CONCRETE

5. The laid concrete mortar **does not need additional compaction** with a vibrator for concrete, since the plasticizers make it quite ductile and durable. At the same time, it is possible to save time and effort without using vibrators.

6. Since the concrete solution has **high flow ability** and good adhesion to the surface, it is used in the process of pouring the element with reinforced sections.

7. By adding a plasticizer, it is possible to obtain a solution that has a **high** level of **density**. The structures constructed with the help of such a solution have high **water resistance**.

8. Since the amount of moisture that is present in the solution is minimal, the design eventually becomes **frost-resistant** and has an additional resistance before cracking.

9. The **high level of adhesion** of concrete solution to the surface into which it is poured is also explained by the use of plasticizers for concrete.

Note that the use of plasticizers for concrete adversely affects the setting time of the concrete mix. Therefore, in some cases, in addition to plasticizers, accelerators for its solidification are added to the concrete solution.

FIG.24 PLASTICIZERS ADDED IN CONCRETE

Types of plasticizers for concrete and their characteristics

If we consider the material on the basis of which the plasticizer was made, several **types of plasticizers** are distinguished:

- organic origin;
- organomineral substances;
- inorganic substances.

The **first** version of the plasticizer contains **waste from the oil industry**, timber processing or agrochemicals.

Additives of inorganic origin contain in their composition various kinds of chemical substances in the form of **formaldehyde** or **naphthasulfite** stratum.

Depending on the principle of operation, the **plasticizer**s for concrete are **divided into**:

1. **Modifying substances -** these compositions increase the strength characteristics of concrete in a very many times. In addition, the concrete has frost resistance, corrosion resistance, low vapor permeability and high mobility.

FIG.25 PLASTICIZERS ADDED CONCRETE

Substances that accelerate strength - with their help it is possible to improve the brand strength of a concrete solution.

2. When working in the winter season, plasticizers with a frost resistance effect should be used.

3. The **use of super plasticizers** is important if the concrete solution is subjected to **prolonged transport in hot weather**. With their help, it is possible to achieve high mobility of the concrete composition, while it becomes more water resistant, elastic and durable. With their help, it is possible to reduce the consumption of cement in the concrete, thus reducing the cost of preparing concrete mortar.

4. Additives that add air to the concrete composition. The principle of their action is comparable with porous chocolate, additives in the composition of concrete, make it microporous and very frost-resistant. During the freezing process, the water expands and it enters the pores, thereby not changing the composition and properties of the concrete structure.

5. Additives of a **self-compacting composition** - with their help it is possible to produce castings of a densely reinforced type.

FIG.26 TYPE OF PLASTICIZER

Area of use of plasticizers for concrete and mortar
With the use of plasticizers for concrete can significantly save time and money, making the concrete more plastic and more frost-resistant. Please note that there are a large number of plasticizers for concrete mortar, which increase its quality characteristics. Before combining the formulations of one type or another, you should make sure their compatibility.

Plasticizer for concrete is used both on large construction sites during the pouring of multi-story houses, and in private housing construction. Plasticizers are particularly relevant when pouring foundations. Since, the base with their help acquires additional strength, frost and moisture resistance.

Thus, the use of plasticizers can reduce the amount of water present in the solution. With the use of plasticizers it is possible to make monolithic concrete, a concrete composition of fine-grained and light composition, using it when pouring various kinds of structural elements.

By adding plasticizers to the concrete solution, it is possible to build high-quality floor screeds, concrete blocks, curbs, slabs, fountains, pillars and columns. Products, after pouring, do not crack; differ in a long service life

ACCELERATOR TYPES AND USES IN CONCRETE

Concrete is the most essential material in the construction. This is made from cement, sand, aggregates, water, and concrete admixtures. Concrete **admixtures** or concrete additives are the important materials which are used to modify the properties of fresh concrete as well as the hardened concrete such as an increase or **decrease in setting time, increase hardening, workability, strength, unit weight** etc. Concrete admixtures are added before mixing or during mixing of concrete. There are different types of concrete admixtures/concrete additives or construction chemicals available in the market. Some of them are concrete **accelerators, plasticizers, Superplasticizer, retarder, air entraining admixtures** etc.

FIG.27 ACCELERATOR USED IN CONCRETE

Accelerating Admixture:

An admixture that causes an **increase in the rate of hydration** of the cement and thus shortens the time of setting increases the rate of strength development, or both.

All the concrete admixtures give different effects and modification to properties of concrete. Different natural or manufactured chemicals are used as admixtures.

What are Concrete Accelerators?

According to ‘A. M. Neville’, honorary member of the American Concrete Institute, Concrete accelerators are the substance that **accelerates the early strength** development of concrete, i.e. hardening and it may also **accelerate the setting of concrete.**

In more simple words, accelerating admixtures are added in the concrete for minimizing the setting time and increasing the rate of early strength development in concrete. It **increases the rate of stiffening** and the rate of hardening. There is a difference in the stiffening and hardening. **Stiffening**

means the concrete starts to get set and **hardening means concrete starts to gain strength after setting**. Chemical compositions of accelerators include some of the inorganic compounds such as soluble chlorides, carbonates, silicates, fluosilicates, and some organic compounds such as triethanolamine.

Concrete Accelerators: How it Works?

FIG.28 CONCRETE ACCELERATOR

Concrete accelerators are used for **minimizing setting time**, the main action of the accelerator occurs in the plastic state of the cement paste. When it's used for hardening of concrete, the accelerator acts primarily in the hardened state. Some concrete accelerators affects either in setting or hardening, while several accelerators affects both in setting and hardening.

As it is seen, when water is mixed with the cement, chemical reactions (**hydration**) takes place, which is **responsible for the setting and hardening** of concrete. The rates of this chemical reaction (**rate of hydration**) can be **changed by adding** small amounts of **chemical** substances to the cement-water mix. Such chemical substances affect these rates to give an overall increase the hydration rate, i.e. an accelerating effect and therefore, they are termed as concrete accelerators or accelerating admixtures.

Accelerating admixtures can be used in powder form, slurry form or liquid form, during mixing of concrete or before mixing of concrete.

Concrete accelerators can be classified according to their difference between setting and hardening properties, type of concrete in which they are used and on their physical forms, in which they are used. As per the 'Myrdal, Roar. (2007)' R&D director construction chemical, Norway & senior scientist at SINTEF building and infrastructure, **classification of concrete accelerators** are as follows:

1. As per the **difference between setting and hardening properties:**

- **Set Accelerating** Admixture –

This decreases the time to commencement of transition of the mix from the plastic, to the rigid state.

- **Hardening Accelerating** Admixture –

This increases the rate of development of early strength in the concrete, with or without affecting the setting time.

2. As per the **type of concrete:**

- Accelerators for **Normal** Concrete –

In this, accelerators are added during mixing at a concrete plant.

- **Shotcrete** Accelerator for Sprayed Concrete –

3. As per **their physical form:**

- **Powder** Form –

In these accelerators are Insoluble inorganic salts and compounds.

- **Liquid** Form –

In these accelerators are water-soluble inorganic and organic salts and compounds.

- Slurry Form –

In these accelerators are insoluble, inorganic salts and compounds dispersed in water.

Application of Concrete Accelerators

- Accelerators are used in the construction when the **structure** is to be **placed shortly** in the service.
- Accelerating admixtures are used in the **emergency repair** work in road pavements, repairs of existing buildings etc.
- Concrete accelerators are used for the **underwater concreting** and for the repair work of the waterfront structures in the tidal variation's region. Know the

different types of concreting methods that helps to place the concrete in underwater.

- These are also used for the basement **waterproofing o**perations.
- Concrete accelerators are used **in cold weather concreting** because; it partially compensates the retarding effect of low temperature during cold weather concreting.

Advantages of Concrete Accelerators

- Some of the concrete accelerators produced now a days are so powerful that, it is possible to make the cement set into a stone **hard in less than five minutes.**
- Concrete accelerators permits **earlier removal of formwork** because, it increases the rate of early strength development in concrete;
- They provide **earlier finishing** of surfaces.
- Accelerating admixtures are also more beneficial in the field of **pre-fabrication.**
- Accelerating admixtures **reduces** the required period of concrete **curing**.
- Accelerating admixtures r**educe** the early heat of hydration and overcome **thermal cracking** problem in concrete.
- Concrete admixtures can accelerate the setting time as well as there are admixtures that decelerate concrete setting time.

Disadvantages of Concrete Accelerators

- As per the, 'A. M. Neville', honorary member of the American Concrete Institute, calcium chloride is the most commonly used accelerating admixture because it's cheap, sufficient, and readily available in the market. But **calcium chloride is harmful to reinforced concrete and prestressed concrete,** as excessive amounts of calcium chloride may **cause shrinkage and rapid stiffening** while drying, creating cracks in the cured surface, promote corrosion in steel reinforcements and increase the potential for scaling.
- Hence most of the concrete specifications are restricting the use of calcium chloride or admixtures containing calcium.

Concrete Accelerators

- Most commonly used accelerating admixture was **calcium chloride**, but now a days it is not much used. Instead of calcium chloride, some of the silicates i.e. **fluosilicate**s, soluble carbonates and organic compounds such as **Triethenolamine** are used. From all of them, flu silicates and Triethenolamine are comparatively **expensive**.

FIG.29 CONCRETE FAST ACCELERATOR

RETARDER TYPES AND USES IN CONCRETE

Concrete retarders are the mixture that **slows down the chemical process** of hydration so that the concrete remains plastic and **workable for a long time**.

Retarders are used to overcome the accelerating effect of high temperatures on establishing the properties of concrete in hot climates.

INTRODUCTION TO CONCRETE RETARDERS

In ready mixed concrete practices, concrete is manufactured in a **central batching plant** and transported over a **long distance** to the job sites which may take considerable time.

In these cases the setting of concrete will have to be retarded, so that concrete when finally placed and compacted in the perfect plastic state.

Why retarders are preferred

- It **increases the setting** time of concrete.
- It **improves the workability** of concrete.
- The **appearance** of the concrete is greatly **improved**.
- Drying shrinkage and **creep** rate is also **increased**.

TYPES OF RETARDERS IN CONCRETE

Retarders are divided into **2** categories depending on the nature of the retarders.

ORGANIC RETARDERS:

- Lignosulphonates.
- Hydroxycarboxylic acids and their salts.
- Phosphonates.
- Sugars.

INORGANIC OR CHEMICAL RETARDERS:

- Phosphonates.
- Borates.
- Salts of Pb, Zn, Cu, As, Sb.

EFFECT OF ADMIXTURES ON CONCRETE

1. STRENGTH:
Initial compressive strength of concrete is less than uniform concrete's compressive strength.

2. PRACTICALITY AND RATIONAL VALUE:

Retarders have a small effect on the practicality of concrete; they cause **initial deceleration** to increase by 60–100 mm.

3. SLUMP LOSS
To **reduce the slump loss** and increase initial functionality, retarding admixtures has been shown to be very effective. Concrete retarders are very efficient in decreasing slump loss and raising the preliminary workability.

4. AIR ENTRAINMENT
Inhibitors don't usually enter the air however there are some types of retarders. In particular, depending on hydroxycarboxylic acids, these can actually **reduce air content.**

5. FREEZE-THAW CYCLE
Mixtures that enter the air are typically used to increase the freeze-melting resistance of concrete.

6. BLEEDING
Since the setting process is delayed, the retarder components are always prone to bleeding

7. HEAT OF HYDRATION

Penetration does not reduce the heat production of concrete, although the **peak temperature increases,** causing the concrete to turn into concrete.

8. VOLUME DISTORTION:

Creep and drying shrinkage should not be affected by the addition of retarders, however plastic shrinkage may increase slightly.

9. DURABILITY:

If the concrete is properly cured, the dim concrete should be as durable as flat concrete.

ADVANTAGES OF CONCRETE RETARDERS

1. Retarders **extend the setting time** of the concrete and maintain functionality & consistency for extended periods of time.
2. In large construction projects, concrete retarder **prevents the formation of cold joints i**n gradual lifts and make the concrete workable.
3. Using retarders, you can compensate for the accelerated impact of high temperatures towards the initial setting time and **reduce the risks** of long-distance delivery **in hot weather**.
4. The use of retarder **improves the permeability** of concrete by improving the delayed setting period and the workability of the concrete.
5. Concrete retarder **reduces the isolation and bleeding** in concrete, in which poor sand grading is unavoidable.

DISADVANTAGES OF CONCRETE RETARDERS

1. Concrete retarders may be used with water to avoid cracks and bleeding.
2. Depending on its water-cement ratio, cement content and the amount of C3a in the cement, the dose of retarder admixture should be within the limit.
3. Concrete retarder can **undergo variable action** on different types of cement when used in varying quantities.

USES OF CONCRETE RETARDERS

- Most commonly **used in** concrete in the **summer season**.
- The retarders sprayed on the surface of the formwork, prevent hardening of the matrix at the interface of the concrete and formwork, while hardens the rest of the concrete.
- Retarders are used for large or **large scale construction** work & gritting oil wells.

- It is often used in concrete have to be placed in difficult conditions, **delay in transporting and placing.**
- Also used for pouring consolidation castings without the formation of cold joints, also used in grouting oil wells.
- For all these works cement grout is required to be in mobile condition for about **3 to 4 hours**, even at that high temperature without setting.

WATER REDUCING AGENTS IN CONCRETE

There have **two roles** on concrete quality when mixed the right amount of water reducing agent with concrete:

1 Mixed with the right amount of water reducing agent without changing the case of a concrete mix ratio and water/cement ratio, which can **enhance the fluidity of concrete** without reduce the concrete strength.

2 Water/cement ratio can be reduced while maintaining the fluidity and cement use amount unchanged. Due to the reduction of water consumption makes **concrete density increase**, thereby **increase the strength** and **durability** of concrete.

According to the composition of materials, **water reducing agent** can be divided into **water sulfonate**, **polynuclear a**romatic salts and water-soluble resin sulfonate. Sort by setting time it can be divided into standard type, early strength and retarding type. In accordance with the participation of composition, it can be divided into ordinary water reducers, **super plasticizers, early strength** water reducer and air-entraining water reducing agent.

The economic effect of adding water reducing agent to concrete is as follows:

1 **keep the mix ratio of concrete unchanged**, this can significantly increase the fluidity of concrete;

2 **maintain the fluidity** of concrete and cement usage does not change, it can reduce the amount of water and increase strength;

3 maintain the fluidity and strength intact to **reduce the amount of cement**;

4 keep the concrete liquidity requirements unchanged can reduce the amount of water and increase the **frost resistance** and **im permeability** of concrete;

5 **delay the hydration of cement** and reduce the thermal stress of mass concrete, as well as reduce the possibility of cracking.

Studies show that after joining the reducing agent, the hydrophobic group of reducing agent oriented adsorption on the surface of cement particles, hydrophilic point to the aqueous and form a single molecule or molecules adsorbed film. Due to the adsorption dispersion, moist and lubricated, just use a small amount of water can easily mix concrete evenly, so as to improve the workability of the fresh concrete.

Because of the dispersion of water reducing agent, this keeps the cement particles more isolation and makes early hydration increases the reaction area of cement particles. **Hydration is** reaction of cement of this stage in the process of **dissolution - hydration - crystallization**. While filming of water reducing agent would hinder the reaction, but its impact is small, but its overall effect is to increase the speed of initial hydration. If you have interest in water reducing agent and other construction chemicals, please follow us here or visit www.okchem.com to get more!

How to Make Concrete – Batching, Mixing, Transporting & Placing

Process of Manufacture of Concrete:

Concrete making is not a very complex process. For making good quality concrete, we just have to follow some standard process of mixing its ingredients. It just does not up to making concrete, but making good quality concrete is important. Production of good quality and bad quality of concrete includes the same material, but the proportion and mixing method can be a differentiating factor. It requires proper care and knowledge for making good quality concrete.

FIG.30 CONCRETE POURING

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

(a) Batching:

Measuring proper and sufficient quantity of material for making concrete is known as batching of concrete.

(i) **Volume** batching (ii) **Weigh** batching

(i) **Volume batching**:

Volume batching of concrete is a **too accurate** method for making concrete because of the difficulty it offers to measure granular material in terms of volume. It is a fact that moist sand volume in a loose condition weighs much less than the same volume of dry compacted sand. The solid material quantity in a cubic meter is an indefinite quantity. **For more accurate and good quality concrete weigh batching is more preferable**. However, it is not possible for in site mix concrete to weight this large amount of volume of material. For such situation volume batching can be used. Cement used is always measured by weight not by volume.

FIG.31 VOLUME BATCHING IN CONCRETE

Normally, for each batch of concrete, one bag of cement is used. The volume of a single bag of cement is thirty-five (35) liters. For taking a quantity of fine and coarse aggregates gauge box or volume box is used which has fix size. The standard size gauge box is shown in Figure 31.

The box is made of volume which is equal to the weight of one bag of cement and which has the volume of 35 liters.

The gauge boxes are made with the top narrow surface rather than shallow with the wider surface to facilitate easy estimation of top-level. Gauge boxes or volume boxes are generally called farmas. They can be made of **timber or steel** plates. In Indian condition volume batching is also used for large concreting operations. For important major sites the following gauge boxes at the site to cater for the change in Mix Design or bulking of sand. The volume of each gauge box is clearly marked with paint on the external surface.

TABLE 9 VOLUMES OF VARIOUS GAUGE BOXES

Item	*Width cm*	*Height cm*	*Depth cm*	*Volume litres*	*Quantity number*
A	33.3	30	20	20	1
B	33.3	30	25	25	2
C	33.3	30	30	30	2
D	33.3	30	35	35	2
E	33.3	30	40	40	2
F	33.3	30	45	45	2
G	33.3	30	50	50	1

TABLE 10 BATCH VOLUMES OF MATERIALS FOR VARIOUS MIXES

	Cement kg.	*Sand, litres*	*Coarse aggregate, litres*
1 : 1 : 2 (M 200)	50	35	70
1 : 1 1/2 : 3 (M 200)	50	52.5	105
1 : 2 : 3	50	70	105
1 : 2 : 4 (M 150)	50	70	140
1 : 2 1/2 : 5	50	87.5	175
1 : 3 : 6 (M 100)	50	105	210

Water can be measured in kg or liters. It is due to the fact that the density of water of 1 kg per liter. The amount of water required is a product of water/cement ratio and the weight of cement.

For example, if the water/cement ratio of 0.5 is specified, the quantity of mixing water required per bag of cement is 0.5 x 50.00 = 25 kg. or 25 liters. The quantity is, of coarse, inclusive of any surface moisture present in the aggregate.

Approximate moisture content carried by aggregate is given in the below table:

TABLE 11 APPROXIMATE SURFACE MOISTURE IN AGGREGATE (I.S. 456/2000)

Aggregates	Approximate Quantity of surface water	
	Percent by Mass	Litre per m^3
(1)	(2)	(3)
Very wet sand	7.5	120
Moderately wet sand	5.0	80
Moist sand	2.5	40
Moist gravel or crushed rock	1.25 – 2.5	20 – 40

(ii) **Weigh Batching**:

Weigh batching is an **accurate method of making concrete**. It recommended in many countries **IS code** to use the weight batching process for making concrete for important ant government work

Weight batching facilitates **accuracy, flexibility, and simplicity**. Different types of weighing batches are available, the particular type to be used, depends upon the nature of the job. Large weigh batching plants have automatic weighing equipment. The use of this automatic equipment for batching is one of sophistication and requires qualified and experienced engineers.

FIG.32 WEIGH BATCHING IN CONCRETE PLANT

On large worksites, weigh bucket type equipment is used. This supplies the material from large **storage hopper** and it **discharges by gravity**, straight into the mixer. The material weighting is done through a lever-arm system and two interlinked beams and jockey weights. The required quantity of say, coarse aggregate is weighed, having only the lower beam in operation. After balancing, by turning the smaller lever, to the left of the beam, the two beams are interlinked and the fine aggregate is added until they both balance.

The final balance is indicated by the pointer on the scale to the right of the beams. It is **discharged by a swivel gate** at the bottom. These types of automatic plant are available in small and large capacity. In this, the operator has only to press one or two buttons to put into motion the weighing of all the different materials, the flow of each being cut off when the correct weight is reached. In their most **advanced forms, automatic plants** are electrically operated on a punched card system. These types of plants majorly suitable for making **ready mix concrete** in which very frequent changes in mix proportions have to be made to meet the varying requirements of different customers.

Measurement of Water:

While we choose to weigh batching method, the measurement of water must be done accurately. The addition of water bucket having graduation **in liters** will not be accurate enough for the reason of spillage of water etc. Generally, it measured in a horizontal tank or vertical tank fitted to the mixer. These tanks are empty during batch and again filled for the next batch. The tank filling has such an accuracy to admit any desired quantity of water. For this work sometimes **water meters are fixed** in the main water supply to the mixer from which the exact quantity of water can be let into the mixer.

c) Mixing:

Proper and sufficient mixing of the materials is essential for the production of uniform concrete. The mixing process ensures that concrete becomes homogeneous, uniform in colour and consistency. There are **two methods** used for mixing concrete.

(i) Hand mixing (ii)Machine mixing

1) **Hand Mixing**:

This method is practiced for small scale unimportant concrete works. In this method, as material mixing is not sufficient compared to machine mix it is desirable to **add 10 percent more cement** to cater to the inferior concrete produced by this method.

FIG.33 HAND MIXING OF CONCRETE

If hand mixing is adopted for making concrete,

1) It should be done **over an impervious concrete** platform or brick floor of sufficiently large size to take one bag of cement.

2) First, **spread out the coarse aggregate and fine aggregate in alternate layers** insufficient or measure quantity. **Drop cement on top** this, and mixes them dry by shovel, **turning the mixture** over and over again until uniformity of colour is achieved. With the help of a suitable tool, properly mix these materials. **Water is added** after materials are well mixed. After adding water, the mixing operation is continued until such time a good **uniform, homogeneous** mix is obtained. **Do not add extra water** in concretes and try to use maximum water that is added in the mix. After the concrete is well mixed it is ready to be used.

2) **Machine Mixing**:

For large size construction, the mixing of concrete is done by machine only, for reinforced concrete work and for medium or **large scale** mass concrete work. This method of mixing is not only efficient but also **economical** when the quantity of concrete to be produced is large. These types of mixers produce concrete **batch by batch**, whereas continuous mixers produce concrete continuously without stoppage till such time the plant is working. The process is continuous material for the next batch and is **filled by screw feeders** and the materials are continuously mixed and continuously discharged.

The batch mixer may have **two types pan or drum**. The **drum type** of mixer may further be classified as **tilting, non-tilting**, reversing or forced action type. There is not any analysis of mixing efficiency of the various types of mixers, but some evidence is there to suggest that pan mixers with a revolving star of blades are more efficient. This type of mixer is mainly suitable for stiff and lean mixes, which present difficulties with most other types of mixers, mainly due to the sticking of mortar in the drum

FIG.34 MACHINE MIXING OF CONCRETE

The efficiency of the mixer is mainly affected by the shape of the drum, the angle, and the size of the blades, the angle at which the drum is held. It is found that tilting drum to some extent is more efficient than non-tilting drum and the discharging in not lilting drum; a chute is introduced into the drum by operating a lever. In these concrete mixed in the drum, falls into the inclined chute and gets discharged out.

Generally, it is recommended that to make the batch of concrete having **50 kg of cemen**t. If you are going for the purchase of mixer you should ask for such a capacity mixer that should hold all the materials for one bag of cement

For example, for **1: 2: 4** mixes, the ideal mixer is of **200 liters** capacity,

In the case of a mix ratio of **1: 3: 6**, the requirement will be of **280 liters** capacity to facilitate one bag mix. The mixer of 200-liter capacity may inefficient for 1 : 3: 6 mix and also mixer of 280 liters is too big, hence uneconomical for 1: 2: 4 concrete.

For getting a good quality concrete mix to follow the below steps:

- Firstly, place a half quantity in drum and over which about half the quantity of fine aggregate is poured.

- On this place full quantity of cement, one bag is poured over which the remaining portion of coarse aggregate and fine aggregate is deposited in sequence.
- This sequence of adding material can save spilling of cement while discharging into the skip and also this prevents the blowing away of cement in windy weather.
- Add 25 percent of the total quantity of water required for mixing before loaded skip discharge material into the drum to wet the drum and to prevent any cement sticking to the blades or at the bottom of the drum.
- Immediately after discharging the dry material into the drum, the remaining 75 percent of water is added to the drum.

Mixing Time:

The mixer is generally designed to run at a speed of 15 to 20 revolutions per minute. For well mix concrete, it is seen that about **25 to 30 revolutions** are required in a well-designed mixer. On the construction site, the normal tendency is to speed up the outturn of concrete by reducing the mixing time. This results in the poor quality of concrete. If the mixer runs for a long time, it is uneconomical from the point of view of the rate of production of concrete and fuel consumption. Therefore mixing time of concrete in mixer has an important factor, which will accrue **optimum benefit**.

It is research data result that the quality of concrete in terms of compressive strength will increase with the increase in the time of mixing. In case mixing time more than **2 minutes** the improvement of compressive strength is not significant. Fig. shows the Comparison of mixing time of concrete and its compressive strength.

Generally mixing time of mixer related to the capacity of a mixer. The time of mixing in drum varies between1½ to 2½ minutes. Larger the size or capacity drum the more is the mixing time. However, for producing ready-mix concrete, the mixer can well mix in about 15 to 30 secs. Concrete mixer having one cubic meter capacity high-speed Pan Mixer takes only about 2 minutes for batching and mixing. The **RMC batching plant takes about 12 minutes** to load a transit mixer of **6 m^3** capacities.

e) Transporting Concrete

Its transportation is done by various methods and equipment on site. Only care should be taken is that the **homogeneity of concrete** obtained at the time of mixing should be maintained until it reached its final destination. Following are the methods adopted for transportation are

FIG.35 RMC TRUCK

(a)Mortar Pan (b) Wheel Barrow, Hand Cart (c) Ropeway, Crane, Bucket and (d) Truck Mixer and Dumpers (e) Belt Conveyors (f) Chute (g) Skip and Hoist (h) Transit Mixer (i) Pump and Pipe Line (j) Helicopter.

CONCRETE PLACING

Concrete: Placing, Compaction and Curing

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

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

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

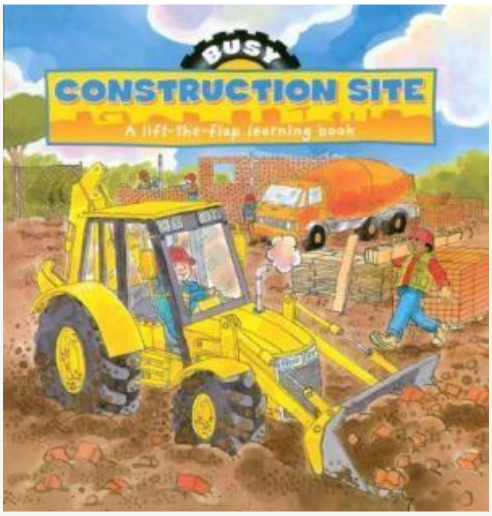

FIG.36 PREPARING SURFACE TO PLACE CONCRETE

Planning Concrete Pour:

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

FIG.37 DEWATER THE SURFACE TO PLACE CONCRETE

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

FIG.38 PLACEING OF CONCRETE

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

Transportation & Placing

- All concrete should be transported with the help of **transit mixers** to the place of lying as rapidly as possible.
- When a truck mixer or agitator is used for transporting concrete, the concrete should be delivered to the site of work and discharge should be complete **within 2 hrs** from plant exit.

FIG.39 PLACEING OF COLUMN CONCRETE

- Acceptable temperature of concrete, air temperature & shade temperature etc. should be as per specifications and verified by supplier before delivery.
- Placing of concrete should generally be done **using pumps** to achieve necessary heights wherever required.
- In case of deep trenches/footings, it may be done with the **help of chutes** or directly from transit mixers from the reasonable height.
- In columns it can be placed **manually with the help of staging**. Concrete from wheel barrows should be dumped into the face of concrete already in place.
- **Suitable platform** should be provided for working wherever required.
- The concrete should be deposited as nearly as practicable in its final position to avoid re-handling.
- The concrete should be placed and **compacted before initial setting** of concrete commences and should not be subsequently disturbed.

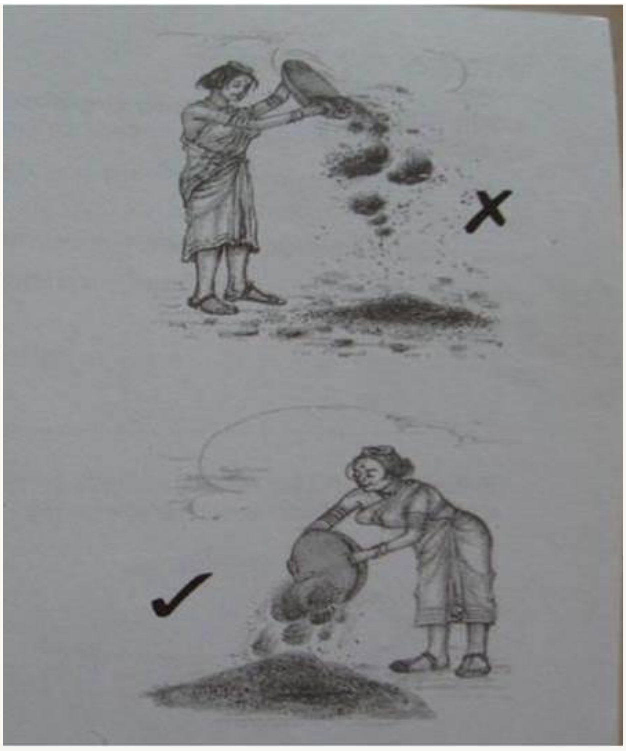

FIG.40 PLACEING OF VERTICAL CONCRETE

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

Compaction of Concrete

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

FIG.41 COMPACTION OF CONCRETE

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

FIG.42 POOR COMPACTION OF CONCRETE

Precautions While Placing and Compacting Concrete

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

Points To Remember - Placing and Compacting Concrete

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

After Pouring Precautions!

Finishing of Concrete

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

FIG.43 FLOOR FINISHING OF CONCRETE

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

FIG.44 CURING OF COLUMN CONCRETE

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

FIG.45 JUTE CURING OF CONCRETE

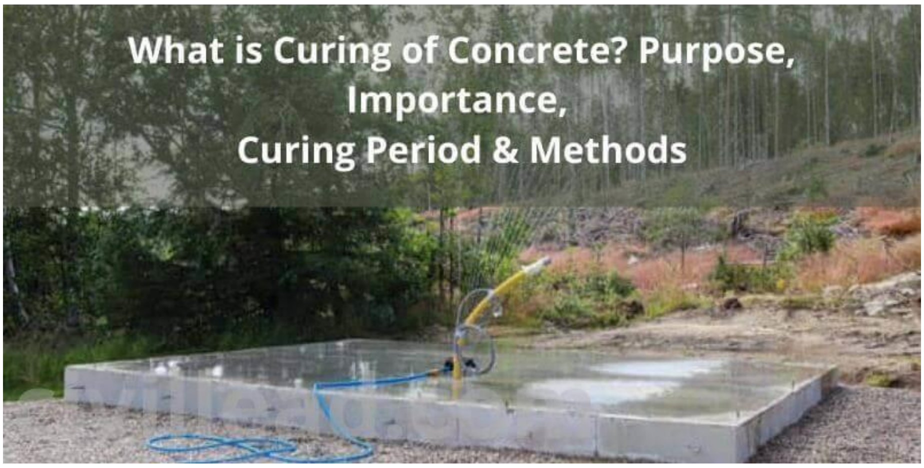

FIG.46 CURING OF CONCRETE SLAB

Curing is the process of maintaining the moisture of freshly placed concrete to complete the hydration process and to ensure proper hardening, attaining desirable strength and durability.

Curing keeps the concrete surface moist and **reduces the shrinkage**. Curing should be **started at the earliest**. It has to be started when the surface is hard enough for a person to walk over it without damage to concrete. Till such time the surface moisture may be maintained by splashing or **spraying water** without force. In fact, concrete derives strength by the hydration of cement.
If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of loss. If curing is not done well after placing of concrete, it will not give the **desirable bond and strength characteristics**.

Purpose of Curing

The following are the purposes of the curing of concrete summarizes bellow

- The **resistance** of concrete **to abrasion** is considerably raised by proper curing.
- The curing **protect**s the concrete surfaces **from sun and wind**.
- The presence of water is essential to cause the chemical action that accompanies the **setting of concrete**.
- Concrete strength moderately increases with age, if curing is efficient.
- The durability and **impermeability** of concrete are increased and shrinkage is decreased.

Importance of Curing

The curing protects the concrete surface from sun and wind. Curing imparts better strength to the concrete. The durability and impermeability of concrete are increased by proper curing.

For the ordinary Portland cement, the curing period is about **7 to 14 days**. If curing of concrete is not done properly it will **reduce the compressive and flexural strengths.**

The frost and weathering resistances are decreased due to improper curing. The cracks are developed due to plastic shrinkage, drying shrinkage and thermal effects if curing is not done properly.

Curing Period

To develop design strength the concrete has to be cured for up to **28 days**. As the rate of hydration and hence the rate of development of strength reduced with time. It is not worthwhile to cure for the full period of 28 days.

IS 456:2000 stipulate a minimum of **7 days moist-curing**, while IS:7861(Part-1)-1975 stipulates a minimum of **10 days** under hot weather conditions. High-early-strength cement can be cured for half the period suggested for OPC. For Pozzolana or blast-furnace-slag cement, the curing period should be increased.

There are many opinions on the length of the curing period. Periods varying from **13 to 30 days** are specified for highway pavements. There cannot be a definite mandate on this matter as there are too many variables involved, such as the type of cement, ambient temperature, nature of the product, method of curing adopted, etc.

Generally increased curing periods are desirable for high-quality concrete products, concrete floors, roads and airfield pavements. The variation of compressive strength with the curing period is given in the figure.

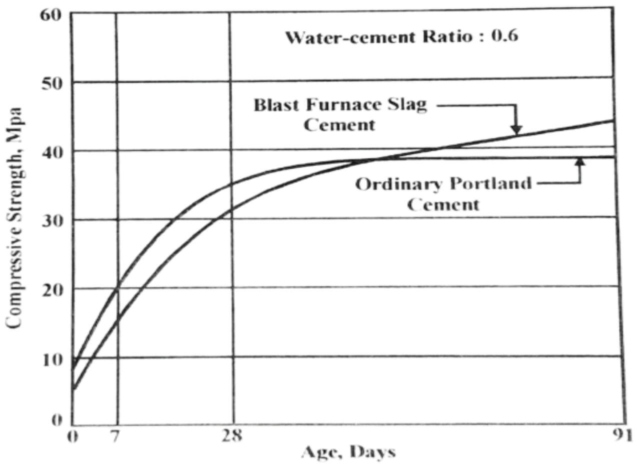

FIG.47 COMPRESSIVE STRENGTH WITH THE CURING PERIOD

Method of Curing

The most common method of curing is as follows

1. Water Curing
2. Membrane Curing
3. Application of heat/steam Curing
4. Application of Curing Compound

Water Curing

It is the best method of curing. In this method, water is applied on the concrete **surface** for certain duration. There are the following ways of water curing.

- Ponding
- Spraying
- Wet Covering

Wet covering slabs, roofs etc. are covered underwater by developing water pond on the concrete surfaces.

FIG.48 PONDING ON CONCRETE SLAB

Vertical walls, columns, plastered surfaces are cured by the sprinkling of water on it. **Vertical surfaces** are also cured by using some wet covering such as **gunny bags, cloth, jute matting, straw** etc.

Horizontal surfaces are kept wet by covering concrete with **wet sand, sawdust** etc.

Membrane Curing

In some places where there is an acute shortage of water, membrane curing is adopted. Generally, water mixed for making concrete is more than sufficient to hydrate the cement.

Membranes are **applied all around the concrete** which will effectively seal off the concrete. The membranes seal over the concrete by means of a firm impervious film to prevent moisture in concrete from escaping by evaporation.

This **prevention of moisture in the concrete** will work as curing of concrete.

Application of heat/Steam Curing

When concrete is subjected to a higher temperature, with an excess of moisture it accelerates the hydration process and results in the higher development of strength.

The **Concrete can't be subjected to dry heat** because of moisture which is also an essential requirement. Thus for achieving this goal concrete is required to subject the steam Curing.

The steam curing will not provide only economical advantages but also technical advantages to the concrete. In general, it is employed on the prefabricated concrete component.

Application of Curing Compound

There are certain curing compounds that **keep the concrete wet**. **Calcium chloride** is the one curing compound. It can be used as a surface coating.

FIG.49 SPRAY CURING ON CONCRETE SLAB

Calcium chloride is a salt; it shows an affinity for moisture. The salt not only absorbs the moisture from the atmosphere but also retain it at the surface. **Salt keeps the concrete wet for a long time** to promote hydration.

The **Curing compounds are** available on various bases like **chlorinated rubbers, sodium silicates, wax, linseed oils, bitumen, acrylate** and other items

PROPERTIES OF CONCRETE

Properties of Fresh Concrete and Factors Affecting Properties

FIG.50 FRESH CONCRETE

Properties of concrete are dividing into two major groups

- Properties of **Fresh Concrete**
- Properties of **Hardened Concrete**

Fresh Concrete

Fresh concrete is that stage of concrete in which concrete can be molded and it is in **plastic state**. This is also called "**Green Concrete**". Another term used to describe the state of fresh concrete is **consistence**, which is the ease with which concrete will flow.

Operations on Fresh Concrete

Batching, mixing, transporting, placing, compacting, surface finishing.

Main properties of fresh concrete during mixing, transporting, placing and compacting

Fluidity or consistency:

Capability of being handled and of **flowing into formwork** and around any reinforcement, with assistance of compacting equipment

Compactability:

Air entrapped during mixing and handling should be easily removed by compaction equipment, such as **poker vibrators**

Stability or cohesiveness:

Fresh concrete should remain **homogenous and uniform**. No segregation of cement paste from aggregates (especially coarse ones)

Fluidity & compact ability known as workability

Higher workability concretes are easier to place and handle but obtaining higher workability by increasing water content decreases strength and durability

Properties of Concrete

Following are the important properties of fresh concrete

1. Setting
2. Workability
3. Bleeding and Segregation
4. Hydration
5. Air Entrainment

1. Setting of Concrete

The **hardening of concrete** before its hydration is known as setting of concrete.

The hardening of concrete before it gains strength.

The transition process of changing of concrete from **plastic state to hardened state**. Setting of concrete is based or related to the setting of cement paste. Thus cement properties greatly affect the setting time.

Factors affecting setting

Following are the factors that affect the setting of concrete.

1. Water Cement ratio
2. Suitable Temperature
3. Cement content
4. Type of Cement
5. Fineness of Cement
6. Relative Humidity
7. Admixtures
8. Type and amount of Aggregate

2. Workability of Concrete

Workability is often referred to as the ease with which a concrete can be transported, placed and consolidated **without excessive bleeding or segregation**.

The internal work done required to overcome the frictional forces between concrete ingredients for full compaction. It is obvious that no single test can evaluate all these factors. In fact, most of these cannot be easily assessed even though some standard tests have been established to evaluate them under specific conditions. In the case of concrete, consistence is sometimes taken to mean the degree of wetness; within limits, **wet concrete are more workable** than dry concrete, but concrete of same consistence may vary in workability.

Because the strength of concrete is adversely and significantly affected by the presence of voids in the compacted mass, it is vital to achieve a maximum possible density. This requires sufficient workability for virtually full compaction to be possible using a reasonable amount of work under the given conditions. **Presence of voids in concrete reduces the density** and greatly **reduces the strength: 5%** of voids can lower the strength by as much as 30%. **Slump Test** can be used to find out the **workability** of concrete.

Factors affecting concrete workability:

i. Water-Cement ratio
ii. Amount and type of Aggregate
iii. Amount and type of Cement
iv. Weather conditions
   1. Temperature
   2. Wind
v. Chemical Admixtures
vi. Sand to Aggregate ratio

3(a). Concrete Bleeding

Bleeding in concrete is sometimes referred as water gain. It is a particular **form of segregation,** in which some of the **water from the concrete comes out to the surface** of the concrete, being of the lowest specific gravity among all the ingredients of concrete. Bleeding is predominantly observed in a **highly wet mix**, badly proportioned and insufficiently mixed concrete. In thin members like **roof slab or road slabs** and when concrete is **placed in sunny weather show** excessive **bleeding**. Due to bleeding, water comes up and accumulates at the surface. Sometimes, along with this water, **certain quantity of cement also comes to the surface.** When the surface is worked up with the trowel, the aggregate goes down and the cement and water come up to the top surface. This formation of cement paste at the surface is known as "**Laitance**". In such a case, the top surface of slabs and pavements will not have good wearing quality. This laitance formed **on roads produces dust in summer and mud in rainy season**.

Water while traversing from bottom to top, makes continuous channels. If the water cement ratio used is more than 0.7, the bleeding channels will remain continuous and un segmented. These **continuous bleeding channels are often responsible for causing permeability** of the concrete structures. While the mixing water is in the process of coming up, it may be intercepted by aggregates. The bleeding water is likely to accumulate below the aggregate. **This accumulation of water creates water voids and reduces the bond between the aggregates and the paste.** The above aspect is more pronounced in the case of flaky aggregate. Similarly, the water that accumulates below the reinforcing bars reduces the bond between the reinforcement and the concrete. The poor bond between the aggregate and the paste or the reinforcement and the paste due to **bleeding can be remedied by re vibration of concrete**. The formation of laitance and the consequent bad effect can be reduced by delayed finishing operations. Bleeding rate increases with time up to about one hour or so and thereafter the rate decreases but continues more or less till the final setting time of cement.

Prevention of Bleeding in concrete

- Bleeding can be reduced by **proper proportioning** and uniform and complete mixing.
- Use of **finely divided pozzolanic** materials reduces bleeding by creating a longer path for the water to traverse.
- **Air-entraining agent** is very effective in reducing the bleeding.
- Bleeding can be reduced by the use of finer cement or **cement with low alkali** content. **Rich mixes** are less susceptible to bleeding than lean mixes.

The bleeding is not completely harmful if the rate of evaporation of water from the surface is equal to the rate of bleeding. Removal of water, after it had played its role in providing workability, from the body of concrete by way of bleeding will do good to the concrete. **Early bleeding when the concrete mass is fully plastic,** may not cause much harm, because concrete being in a fully plastic condition at that stage, will get subsided and compacted. It is the delayed bleeding, when the concrete has lost its plasticity, which causes undue harm to the concrete. Controlled re vibration may be adopted to overcome the bad effect of bleeding.

3(b). Segregation in concrete

Segregation can be defined as the **separation of the constituent materials** of concrete. A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture. There are considerable differences in the sizes and specific gravities of the constituent ingredients of concrete. Therefore, it is natural that the materials show a **tendency to fall apart**.

Segregation may be of three types

1. **Coarse aggregate** separating out or settling down from the rest of the matrix.
2. **Paste** separating away from coarse aggregate.
3. **Water** separating out from the rest of the material being a material of lowest specific gravity.

A well made concrete, taking into consideration various parameters such as **grading, size, shape and surface texture of aggregate** with **optimum quantity of water**s makes a cohesive mix. Such concrete will not exhibit any tendency for segregation. The cohesive and fatty characteristics of matrix do not allow the aggregate to fall apart, at the same time; the matrix itself is sufficiently contained by the aggregate. Similarly, water also does not find it easy to move out freely from the rest of the ingredients.

The conditions favourable for segregation are:

1. **Badly proportioned** mix where sufficient matrix is not there to bind and contain the aggregates
2. **Insufficiently mixed** concrete with excess water content
3. **Dropping of concrete from height**s as in the case of placing concrete in column concreting
4. When concrete is discharged from a badly designed mixer, or from a mixer with worn out blades
5. Conveyance of concrete by conveyor belts, wheel barrow, **long distance** haul by dumper, long lift by skip and hoist are the other situations promoting segregation of concrete

Vibration of concrete is one of the important methods of compaction. It should be remembered that only comparatively **dry mix should be vibrated**. It too wet a mix is **excessively vibrated**; it is likely that the concrete **gets segregated**. It should also be remembered that vibration is continued just for required time for optimum results. If the **vibration is continued for a long time**, particularly, in too wet a mix, it is likely to result in segregation of concrete due to settlement of coarse aggregate in matrix.

4. Hydration in concrete

Concrete derives its **strength by the hydration** of cement particles. The hydration of cement is not a momentary action but a process **continuing for long time**. Of course, the rate of hydration is fast to start with, but continues over a very long time at a decreasing rate In the field and in actual work, even a higher water/cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates and the water available in the concrete will not be sufficient for effective hydration to take place particularly in the top layer.

If the hydration is to continue, **extra water must be added to refill the loss of water** on account of absorption and evaporation. Therefore, the curing can be considered as creation of a favorable environment during the early period for uninterrupted hydration. The desirable conditions are a suitable temperature and ample moisture. Concrete, while hydrating, releases high heat of hydration. This heat is harmful from the point of view of volume stability. Jeat of hydration of concrete may also shrinkage in concrete, thus producing cracks. If the heat generated is removed by some means, the adverse effect due to the generation of **heat can be reduced**. This can be done by a **thorough water curing**.

5. Air Entrainment

Air entrainment reduces the density of concrete and consequently reduces the strength. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

1. Resistance to freeze–thaw action in the hardened concrete.
2. Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.
3. Compaction of low workability mixes including semi-dry concrete.
4. Stability of extruded concrete.
5. Cohesion and handling properties in bedding mortars

REF: Properties of Concrete - Workability, Setting, Bleeding, Segregation, Hydration, Air entrainment (aboutcivil.org)

FACTORS AFFECTING WORKABILITY & STRENGTH

Factors affecting the workability of concrete are materials such as **water content, cement concrete, sand and aggregate properties such as size, shape, grading, mix design ratio and use of admixture**s. Each and every process and materials involved in concrete mixing affects the workability of concrete.

Workability of concrete is measured in terms of ease with which it can be **mixed, transported to construction site, placed in forms and compacted**. It is easy to work with a highly workable concrete as it can be easily mixed, transported, placed and compacted.

Workability and strength of concrete are inversely proportional. **Strength of concrete decreases with increase in workability** of normal concrete affecting the durability of concrete.

FIG.50 SLUMP CONE TEST ON FRESH CONCRETE

Factors Affecting Workability of Concrete

- Cement content of concrete
- Water content of concrete
- Mix proportions of concrete
- Size of aggregates
- Shape of aggregates
- Grading of aggregates
- Surface texture of aggregates
- Use of admixtures in concrete
- Use of supplementary cementations materials

The **primary materials of concrete** are cement, fine aggregates (**sand**), coarse **aggregates** and **wate**r. Many times **admixture**s are used in concrete to enhance its properties. Therefore, properties of these materials and their content affect the workability of concrete.

1. Cement Content of Concrete

Cement content **affects the workability** of concrete in good measure. **More** the quantity of **cement**, the more will be the paste available to coat the surface of aggregates and fill the voids between them. This will help to reduce the friction between aggregates and smooth movement of aggregates during mixing, transporting, placing and compacting of concrete.

Also, for a given water-cement ratio, the increase in the cement content will also increase the water content per unit volume of concrete increasing the workability of concrete. Thus increase in cement content of concrete also increases the workability of concrete.

2. Type and Composition of Cement

There is also effect of type of cement or characteristics of cement on the workability of concrete. The **cement with increase in fineness** will require more water for same workability than the comparatively less fine cement. The water demand increased for cement with high Al_2O_3 or C_2S contents.

3. Water/Cement Ratio of Concrete

Water/cement ratio is one of the most important factors which influence the concrete workability. Generally, a water cement ratio of **0.45 to 0.6** is used for good workable concrete without the use of any admixture. Higher the water/cement ratio, higher will be the water content per volume of concrete and concrete will be more workable.

Higher water/cement ratio is generally used for manual concrete mixing to make the mixing process easier. For machine mixing, the water/cement ratio can be reduced. This generalised method of using water content per volume of concrete is used only for nominal mixes.

For designed mix concrete, the strength and durability of concrete is of utmost importance and hence water cement ratio is mentioned with the design. Generally designed concrete uses low water/cement ratio so that desired strength and durability of concrete can be achieved.

4. Mix Proportions of Concrete

Mix proportion of concrete tells us the ratio of fine aggregates and coarse aggregates w.r.t. cement quantity. This can also be called as the aggregate cement ratio of concrete. The **more cement** is used, concrete becomes richer and aggregates will have proper lubrications for easy mobility or flow of aggregates. The low quantity of cement w.r.t. aggregates will make the less paste available for aggregates and mobility of aggregates is restrained.

5. Size of Aggregates

Surface area of aggregates depends on the size of aggregates. For a unit volume of aggregates with large size, the surface area is less compared to same volume of aggregates with small sizes.

When the surface area increases, the requirement of cement quantity also increase to cover up the entire surface of aggregates with paste. This will make more use of water to lubricate each aggregate.

Hence, **lower sizes of aggregates with same water content are less workable than the large size aggregates**.

6. Shape of Aggregates

The shape of aggregates affects the workability of concrete. It is easy to understand that rounded aggregates will be easy to mix than elongated, angular and flaky aggregates due to less frictional resistance.

Other than that, the **round aggregates** also have less surface area compared to elongated or irregular shaped aggregates. This will make less requirement of water for same workability of concrete. This is why river sands are commonly preferred for concrete as they are rounded in shape.

7. Grading of Aggregates

Grading of aggregates has the maximum effect on the workability of concrete. A **well graded aggregates** have all sizes in required percentages. This helps in reducing the voids in a given volume of aggregates.

The less volume of voids makes the cement paste available for aggregate surfaces to provide better lubrication to the aggregates.

With less volume of voids, the aggregate particles slide past each other and less compacting effort is required for proper consolidation of aggregates. Thus low water cement ratio is sufficient for properly graded aggregates.

8. Surface Texture of Aggregates

Surface texture such as rough surface and smooth surface of aggregates affects the workability of concrete in the same way as the shape of aggregates.

With rough texture of aggregates, the surface area is more than the aggregates of same volume with smooth texture. Thus concrete with **smooth surfaces** are more workable than with rough textured aggregates.

9. Use of Admixtures in Concrete

There are many types of admixtures used in concrete for enhancing its properties. There are some workability enhancer admixtures such as plasticizers and **super plasticizers** which increase the workability of concrete even with low water/cement ratio.

They are also called as water reducing concrete admixtures. They reduce the quantity of water required for same value of slump.

Air entraining concrete admixtures is used in concrete to increase its workability. This admixture reduces the friction between aggregates by the use of small air bubbles which acts as the ball bearings between the aggregate particles.

10. Use of Supplementary Cementitious Materials

Supplementary cementitious materials are those which are used with cement to modify the properties of fresh concrete. Fly ash, fibers, silica fume, slag cements are used as supplementary cementitious materials.

The **use of fly ash** in improves the workability of concrete by reducing the water content required for same degree of workability or slump value.
The **use of steel or synthetic fibers in concrete reduces the workability** of concrete as it makes the movement of aggregates harder by reducing the lubricating effect of cement paste.
The workability of concrete is **reduced** and increased based on the quantity of **silica fume**. The use of silica fume in concrete can improves workability when used at low replacement rates, but can reduce workability when added at higher replacement rates. Silica fume are used as pumping aid for concrete when used as 2 to 3% by mass of cement.
The **use of slag cement** also **improves** workability but its effect depends on the characteristics of the concrete mixture in which it is used

TESTS FOR STRENGTH OF CONCRETE

REF: IS : 516 - 1959 (Reaffirmed 2004) Indian Standard METHODS OF 'rESTS ~'OR Sl~RENGTII OF CONCRErI~E Eighteenth Reprint JlJNE 2006 (Incorporating Amendment No 1 and Including Amendment No 2)

CONCRETE QUALITY CONTROL

The standard platform for information & expertise exchange in the concrete industry. Concrete Quality is a **revolutionary solution for the concrete industry**. With a state of the art technology and a breaking business model, Concrete Quality offers Concrete **QA/QC** & **Mix Design Calculation software** solutions, and something that nobody else does: A universal standard platform for information and expertise exchange what makes Concrete Quality the standard for information and expertise exchange? It's intuitive and easy to learn, useful for novices and experts alike Many options to share your data in-house or with third parties Get online assistance from experts in concrete technology, production, mix design and QA/QC No configuration or special equipment required Supports any unit system with automatic unit conversion Standard independent, can be used with **old an current standards**, for any country Work online or offline, your data is always available Affordable and flexible; anybody can use it: small, medium and big international companies State of the art technology, customizable on demand Unlimited potential We have an ever-growing partners network that provide sales & technical support for customers, as well as **concrete technical consulting services** backed by years of local experience.

Definition of quality of concrete

To add more strength and make the building **structure long-lasting**, the quality concrete is important.

To attain a quality and a stable building structure, retaining the quality and **standard of concrete** is vital.

Quality control perseverance in concrete construction

- **Mechanical properties of the reinforcement to be utilized.**
- **Dimension of the reinforcement.**
- **Positioning of the reinforcement** in construction prior to pouring of concrete.
- **Positioning of pre-stressing ducts**.
- Properties of the concrete **mix designed** to be applied in the structure.
- **Control of the coarse aggregates and fine aggregates** getting into the concrete.
- **Mixing** of the concrete.

- **Transmission of the concrete** to the construction site.
- **Slump** of the concrete.
- **Pouring o**f the concrete.
- Control of adding **water**.
- **Vib**r**ation**/Compaction of the concrete.
- Arrangement of areas where various concrete pours are provided.
- Control of compression test samples.
- Control of **formwork** expulsion.

Starting point of quality control

It starts in the production of material that is applied in concrete (sampling and testing):-

- Portland Cement
- Pozzolana
- Coarse and fine aggregate

Consistency of concrete production depends on the consistency of materials used in the concrete.

How does quality control proceed?

- Handling & stockpiling
- Batching & mixing
- Sampling & testing fresh concrete

    Slump
    Air Content
    Unit Weight
    Temperature

- Transporting and positioning the freshly mixed concrete.

Tests on fresh concrete

- The **slump** test
- The **compact**ing factor test

Tests on hardened concrete

- **Compression** test
- **Tensile** strength test (split cylinder test)

- **Flexural** strength test

Tests on fresh concrete

The slump test

The mound for the slump test contains the shape of frustum of a cone, 300 mm high. The diameter of the base is 200 mm and at the top is 100 mm.

When the slump is :-

- 25-50 = Low workability
- 50-100 = Medium workability
- 100-150 = High workability

The compacting factor test

- Compacting factor is under 0.75 = low workability concrete.
- Compacting factor is under 0.92 = high workability concrete.

Tests on hardened concrete

Compression test

To find out the characteristic strength of the concrete. The size of the concrete cylinder is 150mm dia 300mm long.

Tensile strength test (split cylinder test)

When the cylinder split the tensile strength of concrete is obtained.

Flexural strength test

Test is conducted to find out the tensile strength of the concrete in flexural and the test is substituted by the indirect tensile strength test it is still indicated sometime on pavement & other equivalent projects where the strength of concrete in flexure, or bending, is of great concern

CONCRETE QUALITY CONTROL – STATISTICAL ANALYSIS OF RESULTS – STANDARD DEVIATION – ACCEPTANCE CRITERIA

REF: Lectures-statistical-quality-control-of-concre.pdf (iugaza.edu.ps)

IS 456 provides guidance on concrete Acceptance Criteria

Characteristic compressive strength compliance requirements

The concrete acceptance criteria mentioned in IS 456 as per latest amendment is as follows (reproduced)

ACCEPTANCE CRITERIA

Compressive strength

The concrete shall be deemed to comply with the **strength requirements** when both the following condition are met.

a) The means strength determined from any group of four consecutive test results compiles with the appropriate limits in col 2 of Table 12 in IS456.

b) Any individual test result complies with the appropriate limits in standard column

Flexural Strength

When both the following conditions are met" the concrete complies with the **specified flexural strength**.

a) The mean strength determined from any of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2

b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2.

TABLE 12 COMPRESSIVE STERNGTH REQUIREMENTS

Table 2: Characteristic compressive strength compliance requirement IS 456-2000: (Fourth Revision)- Amendment No. 4 May 2013		
Specified Grade	Mean of Group of 4 Non-Overlapping Consecutive test results in N/mm^2 Minimum	Individual Test Results in N/mm^2 Minimum
1	2	3
M15 and above	f_{ck} + 0.825 x Established Standard Deviation (round off to nearest 0.5) N/mm^2 **or** f_{ck} + 3 N/mm^2 whichever is greater	f_{ck} – 3 N/mm^2
NOTE 1: In the absence of established value of standard deviation, the values given in Table 8 (IS: 456-2000) may be assumed, and attempt should be made to obtained results of 30 samples as early as possible to establish the value of standard deviation. NOTE 2: For concrete quantity up to 30 m^3 (where the number of samples to be taken is less than four) as per frequency of sampling given in 15.2.2, the mean of test results of all such samples shall be f_{ck} + 4 N/mm^2, minimum and the requirement of minimum individual test results shall be f_{ck} – 2 N/mm^2, minimum. However, when the number of samples is only one as per 15.2.2, the requirement shall be f_{ck} + 4 N/mm^2, minimum		

The different terms related to Acceptance criteria and of Acceptance criteria are as follows to understand. (Some views are also highlighted at the end of the topic)**:**

1. **Grade of concrete**

IS 456 has suggested grades of concrete as below:

TABLE 13 COMPRESSIVE STRENGTH OF VARIOUS GRADE OF CONCRETE

Table 2 Grades of Concrete - IS 456: 2000 PLAIN AND REINFORCED CONCRETE - CODE OF PRACTICE -Amendment No. 4, May 2013 (Clauses 6.1, 9.2.2,15.1.1 and 36).

GROUP	GRADE OF CONCRETE	Specified Characteristic Compressive Strength (**f_{ck}**) of 150 mm cube at 28 days **(N/mm^2)**	
Ordinary Concrete	M 10	10	**M 10** M= Mix 10= Specified Compressive Strength of 150 mm cube at 28 days **(N/mm^2)**
	M 15	15	
	M 20	20	
Standard Concrete or Normal strength Concrete	M 25	25	
	M 30	30	
	M 35	35	
	M 40	40	
	M 45	45	
	M 50	50	
	M 55	55	
	M 60	60	
High Strength Concrete	M 65	65	
	M 70	70	
	M 75	75	
	M 80	80	
	M 85	85	
	M 90	90	
	M 95	195	
	M 100	100	
Flexural strength, (f_{cr})=0.7$\sqrt{f_{ck}}$ N/mm2 Where **f_{ck}** is the characteristic cube compressive strength of concrete in N/mm2•			

1. In the designation of concrete mix M refers to the mix and the number to the specified characteristic compressive strength of 150 mm size cube at 28 days, expressed, in N/mm^2

2. For concrete of grades above M 60, design parameters given in the standard may not be applicable and the values may be obtained from specialized experimental results.

The acceptance criteria are valid for specified grade M 15 and above. The note number 2 must be utilized judiciously for concrete grade above M 60.

2. Specimen

The cube or cylinder is casted in a mould. One such cast is called one specimen. As per code provision, two or three moulds (specimen) are casted for a sample. IS456 suggest three specimens for a sample. All the specimen of a sample, when tested should show consistent results without much variations. IS 456 and other code suggest that the strength of each specimen should not exceed the average strength by **15 % (+ or -).**

The clause 15.4 of IS 456:2000 should be satisfied. It states that:

"The test results of the sample shall be the average of the strength of **three** specimens. The individual variation should not be more than **±15 percent** of the average. If more, the test results of the sample are invalid."

If this variability exists beyond specified limits, then the specimen of the **samples is not showing consistent result** and hence **are not valid**. Similarly, the outliers are not considered as consistent and should not be considered as valid specimen of the sample and the sample is not taken for analysis of results. (An outlier is an observation that lies an abnormal distance from other values in a random sample – If the strength of **M 30** Concrete are 30, 32, 42 **then 42 is outlier**; For M30 concrete if the specimen strength are **10, 32,31 then 10 is outlier**). The work specification may have the provision to accept the other two results. (The strength of specimens is **20, 30 40 for M 30 grade**: Average is 30 but because of variability test criteria, such result is not acceptable, and the sample **is invalid**.

3. Sample

Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, **cured, and tested at 28** days in accordance with IS 516. A sample concrete shall be put in three mould (**3 specimen**) of size (150x150x150) mm. (Same procedure is followed if the specimen are casted as cylinders)

Getting the strength of specimen from heterogeneous concrete is also an event and it is random as this and other specimens of the same sample provide different results. The outcome is not predictive; therefore the average strength of three specimens is used as the strength of a sample for consideration.

If several samples of the same batch are taken, they give different results. These results are different from one another but the variations in their strength and average strength show near similarity. If more samples are taken and assessed, they provide more numbers for assessment and the confidence level to accept those increases.

Statistics provide necessary help for coming out to a criterion which may be fruitful for use and develop **acceptance criteria** of concrete test results.

The terms like **average, mean, standard deviation, variance, normal distributions of statistics** are used to explore these random variables for an outcome

The outcome test **samples (say 30 or more**) are tabulated for the strength and its frequency, and this data becomes the data for normal distribution curve – x axis as strength and y axis as frequency.

A criterion for number of samples to be taken is suggested in IS 456 is reproduced as below:

TABLE 14 NUMBER OF SAMPLE CUBES AS PER IS456

Table1: Frequency (IS:456-2000clause15.2.2) The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:	
Quantity of concrete in the work, m^3	**Number of samples**
1 – 5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 and above	4 plus one additional sample for each additional 50 m^3 or part thereof
NOTE: At least one sample shall be taken from each shift where concrete is produced at continuous production unit, such as ready-mixed concrete plant, frequency of sampling may be agreed upon mutually by suppliers and purchasers.	

In large a project that runs for months and years, the same grade of concrete is done in large quantity daily such as $80m^3$ per hour, but because of good quality control the variation causing factors are controlled. The test sample frequency is further decided by the team of stakeholders and the same is followed for the contract or departmental works.

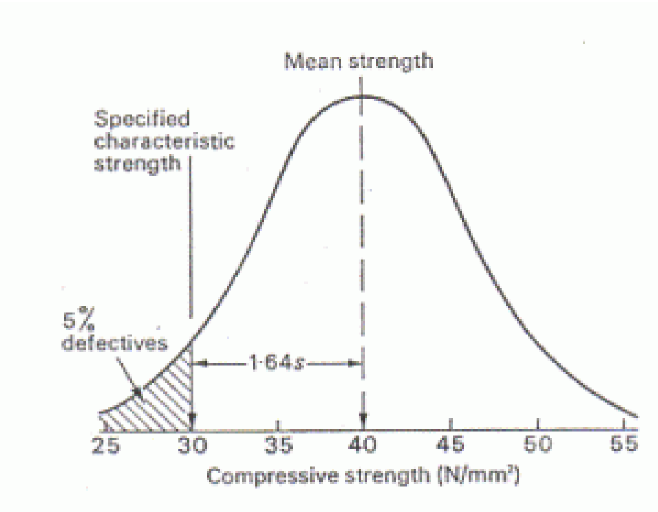

FIG.51 MEAN STRENGTH OF CONCRETE AS NORMAL DISTRIBUTION

4. **Standard deviation**

Standard deviation is a number used to tell **how measurements for a group are spread out from** the average (**mean**) or expected value. A low standard deviation means that most of the numbers are close to the average. A high standard deviation means that the numbers are more spread out.

We know from statistical studies, in a **normal distribution curve** (the curve shown above), if the mean value of a **number of samples is say 100** and **standard deviation is calculated as, say, 4**, then

- 68.26% of all the results fall between 96 and 104.
- 90% of the test results fall between 93.42 & 106.58
- Similarly, 95.45% of samples fall between 92 and 108 and so on.
- It is very important to maintain the desired quality of concrete as concrete production does not involve homogeneity. A good quality control from material management to placement of concrete to sampling and testing is required and so is the assessment of the parameters of hardened concrete. **Concrete production process is, full of heterogeneity** and therefore care-full testing, assessment, and analysis of all its constituents is required as all its constituents are of heterogeneous nature. The testing process of concrete material and the concrete can only be done based on sampling and the sample output is considered valid for the population

5. **Individual test** – Acceptance criteria of concrete suggest acceptability of concrete based on the individual test of a single sample, consisting of

number of specimens as defined in code of practice. **There is provision in the code to accept the compressive strength both for individual sample and the group sample.**

6- Individual test acceptance limit– IS 456 provides **two** limits for individual tests.

If the quantity of concrete **sample is lesser than four** the **limit of compressive strength is f_{ck} – 2 N/mm^2**.. If the quantity of concrete sample is **more than four the limit of compressive strength is f_{ck} – 3 N/mm^2**.

It means that for small quantity the compressive strength of concrete can fall below f_{ck} by 2N/mm^2 (strict quality control) and for more quantity it may fall by 3N/mm^2. But it must be noted that the fall out percentages should not exceed 5%, as is clear from the definition of Characteristic Strength. This is valid for all grade of concrete.

7- Group test – The code says about group of four samples (non-overlapping). If there are sample numbers as

1, 2, 3, 4, 5, 6, 7, 8, 9. 10, 11, 12 then the non-overlapping group shall be Group 1,2,3,4, Group 5,6,7,8, G 9,10,11,12.

8- Group Test limits

The group test limits are defined as:

- f_{ck}+ 0.825 x Established Standard Deviation (round off to nearest 0.5) N/mm^2

or

- f_{ck}+ 3 N/mm^2

which ever is greater. **And the same should be followed**

It means when both are equal then

0.825 x Established Standard Deviation = 3

Or Established Standard Deviation= 3/.825

= 3.64 (Say it is for M25)

Now if established deviation is 2(<3.64), which means the **controls are excellent,** one has to select from A or B for value of SD = 2

A= 25+.825*2 =26.8

B= 25+3=28

And if **established deviation is 5**(>3.64), which means the **controls are not so good**, one has to select from A or B for value of SD= 5

A= 25+.825*5 =29.12

B= 25+3=28

So it means that ‘A’ criteria is valid for SD> 3.64. and for values of SD< 3.64 criteria is constant for all values of SD < 3.64

The summery of criteria comes out as follows:

- For one sample to three sample, fck+4 governs the Acceptance criteria (AC)
- For every non overlapping group of four samples and SD >3.64, fck+0.825 SD governs AC (AC has variability with respect to SD value)
- For every non overlapping group of four samples and SD <3.64, fck+3 governs AC (AC has no variability with respect to SD value, it is a constant value)

The latest revised criteria of acceptance of concrete as given by IS 456 (as given above) has reference for the following points:

It is valid for concrete grade **M20** and above.

It suggests acceptance guidance about individual tests and group tests.

It suggests acceptance value of one sample, less than four samples and group of four samples.

It has relaxed the acceptance criteria as the number of samples increases.

Also, it has not suggested criteria for large quantity of concrete where the sample number may be in hundreds.

The American Concrete Institute (ACI) acceptance is based on the following:

- **Characteristic strength –** A certain percentage of compressive strength of concrete samples may fall below the characteristic strength. ACI 214 R 11 Table 4.2— provides Expected percentages of individual tests lower than f_c (ranging from 0.13% to 46%).

Generally accepted fall value for characteristic strength is 5%. It means that out of **100 sample test results, only 5 samples can fall below the characteristic strength**. ACI further maintains that the samples are taken randomly and the spread of low strength of low strength is not localised and in controlled concrete the chances of 5% of sample to have abnormal strength are not there. The lower limit of less than f_{ck} is not defined.

BIS in its acceptance criteria for lower values of these 5% results has provided a further restriction that the compressive strength of such samples should not go down below f_{ck} – 3. (**It means that for M30 concrete the compressive strength values can go down from 30 N/mm^2, in case of 5% results but not less than 27 N/mm^2)**

- **ACI recommends** that the mean strength of the tested samples must be greater than the Characteristic strength.
- **ACI suggest that the SD should govern the acceptance of concrete in addition to the suggestions mentioned at point 1 and 2 above.**

It has been noticed that on controlled projects the above-mentioned values are maintained.

FIG.52 VARIATION IN STANDARD DEVIATION

Each one point of SD conforms to 30 valid samples (90 specimen) for M25 concrete, and it shows how the variations are controlled by managing quality (done at the large projects)

The **civil engineering codes are the accumulation of tested good practices, which are subject to review from time to time**. The good practices of all other codes should be taken for granted for large national and international projects.

Considering the above, **for large projects**, which have international specifications, the **acceptance criteria should be clearly defined** and followed by the executing agencies. The contents must be conspicuous to avoid any confusion in the mind of stakeholders and Quality Manager

MIX PROPORTIONING (B.I.S METHOD)

British Method of Mix Proportioning

Current method of mix design of concrete is that revised by Dept. of environment (UK) in 1988. British Method recognizes the durability requirements of mix selection. The design is applicable to normal weight concrete made with Portland cement only or Blast furnace slag/fly ash.

FIG.53 PROPORTIONED MIX

British Method of Mix Proportioning

Step 1 – Determination of free w/c ratio in relation to compressive strength
Step 2 – Determination of water content
Step 3 – Determination of Cement content
Step 4– Determination of Total Aggregate content
Step 5 – Fine and Coarse Aggregate Content
Limitations of British Method
This method is based on the characteristics of the materials available in UK.

Hence it may not be applicable to other parts of the world.

Concrete Mix Proportioning

Concrete Mix Proportioning: Determine of the proportions of cement, aggregates and water to attain the desired strength and properties such as workability, durability etc., is called as concrete mix proportioning.

The design of concrete mix is classified into following two types by IS 456:2000 (Clause 9):

(1) Nominal mix concrete

(2) Design mix concrete.

Nominal Mix Concrete

A concrete mix in which the proportions of cement, aggregate and water are adopted is called as nominal mix. It is not necessary that such a mix will give the desired strength and properties. For example, nominal mix proportions of M15 is 1:2:4. Nominal mix is not used for grades higher than M20. It is used for ordinary concrete works only.

As per IS 456:2000 (Clause 9.3.1). The proportional of materials for nominal mix concrete shall be in accordance with the following Table 15.

TABLE 15 PROPORTIONS FOR NOMINAL MIX CONCRETE

Grade	**Total quantity of dry aggregate by mass per 50 kg of cement**	**Proportion of fine aggregate to coarse aggregate (by mass)**	**Maximum quantity of water per 50 kg of cement**
M5	800	Generally 1:2 but may very from 1:1 12 to 1:2	60
M7.5	625		45
M10	480		34
M15	330		32
M20	250	12	30

Design Mix Concrete

The concrete obtained by properly determining the proportions of the ingredients of concrete to get the concrete of desired strength and properties is called as Design Mix Concrete. It is seen that 'mix design' not only produce concrete of desired strength but also an economical one. A design mix concrete is preferred over a nominal mix concrete.

IS 10262:2009 is the code for 'concrete mix design' which gives recommendations for design of concrete mixes. Following information data is required for the design of a concrete mix.

(i) Grade of concrete

(ii) Standard deviation

(iii) Type of cement

(iv) Maximum water cement ratio by weight

(v) Type of aggregate

(vi) Size of aggregate

(vii) Minimum cement content (kg/m^3)

(viii) Degree of workability and expose condition

(ix) Type of admixture to be used.

The step wise procedure for design of concrete mix is as follows :

(i) Calculate the mean target strength (fcm) from the desired characteristic strength (fck) $fcm=fck+1.65\sigma$

where s is the standard deviation which depends upon the quality control. In the absence of any specific data, Table 8 of code IS 456:2000 or Table 16 may be used for values of sigma

.

TABLE 16 ASSUMED STANDARD DEVIATION

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

(ii) Determine the water cement ratio using appropriate charts from IS 20262:2009.

This ratio should not exceed the values given in the Table 5 of IS 456.

(iii) Determine the water content (V_w) based on workability requirements and nominal maximum size of aggregate from (Table 2 of IS 10262) and select the ratio of fine aggregate to coarse aggregate (by mass), based on the type and grading of aggregate from Table 3 of IS 10262.

NOMINAL MIX PROPORTIONING

Proportioning of Nominal Mix Concrete

“Each material has its specific characteristics which we must understand if we want to use it.

The concrete mix design is tested for its strength in laboratory. The test specimens used for are cylinders in USA and cubes in India and UK for example and these are used in various countries as per decision taken in these countries. (The cube size is kept as 150 mm x 150 mm x 150 mm).

Strength of Concrete

Concrete strength units

Previously, concrete was defined as M 200 or M300. M200 means the 200 kg/centimeter ^{2}.

Now it is defined as M20 or M30. M30 means 20 Newton/mm^2.

N = 1/10 Kf (Kilogram force)

As such M 200 Kg/cm^2 is same as M 20 N/mm^2
Also, 1N/mm2 = I MPa (Mega Pascale)

The concrete strength unit is in MPa (Megapascal) and N/mm^2

For example, as 30 MPa (Megapascal) or 30 N/ mm^2

Constituents of concrete

The concrete is composed of following ingredients (in specific limits as per codes and guidelines).
Sand-Natural or Crushed or mix of natural and crushed

Aggregates- Natural or Crushed or mix of natural and crushed

Cementing Materials (Different type of cementing materials are – various types of cements, epoxy resins etcetera required for achieving the desired strength).

Admixtures and Water

The above ingredients are manufacture or collected to the required specifications for concrete production, to maintain the designed concrete strength and workability (Workability means the ease with which concrete can be moved and placed in forms without segregation)

The strength of concrete, produced from these ingredients further depends on production and placement of concrete, along with variations in the properties of constituents of concrete.

Types of Concretes

Regular concrete (ordinary concrete up to M 60)
High-strength concrete- Above M 60
High-performance concrete (have following desirable features)
Ease of placement
Compaction without segregation
Early age strength

Long-term mechanical properties
Permeability
Density
Heat of hydration
Toughness
Volume stability
Long life in severe environments
Ultra-high-performance concrete
Self-consolidating concretes
Vacuum Concrete
Shotcrete
Limecrete
Pervious concrete
Nailing Concrete

Tests on concrete materials

The various tests suggested for constituents of concrete are as follows: (These may be modified as per work speci**fic**ations)

FIG.54 LAYING OF RMC

TABLE 15 TESTS ON CONCRETE INGREDIENTS

S.No	TESTS ON CONCRETE CONSTITUENTS
A)	**Cement**
a)	Compressive Strength
b)	Initial and Final Setting Time test
c)	Fineness test
d)	Soundness test
e)	% Drying Shrinkage
f)	Sampling/Testing at Manufacturer's Plant
g)	Chemical Composition
B)	**Aggregate**
1	**Particle Shape & Size**
	Test Method for Sieve Analysis of Fine and Coarse Aggregates
	Test Method for Material Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
	Determination of Flakiness Index
	Determination of Elongation Index
	Determination of Angularity Number
2	**ESTIMATION OF DELETERIOUS MATERIALS AND ORGANIC IMPURITIES**
	Organic Impurities in Fine Aggregates for Concrete
	Organic Impurities in Fine Aggregate on Strength of Mortar
	Test Method for Lightweight Particles in Aggregate
	Test Method for Clay Lumps and Friable Particles in Aggregates
3	**ESTIMATION OF SPECIFIC GRAVITY, DENSITY, VOIDS, ABSORPTION AND BULKING**
a)	Test Method for Bulk Density ("Unit Weight") and voids in aggregates
b)	Determination of Specific Gravity & Water Absorption
c)	Determination of necessary adjustment for bulking of fine aggregate (field Method)
d)	Determination of surface moisture in fine aggregate (field method).
4	**ESTIMATION OF MECHANICAL PROPERTIES OF AGGREGATES**
a)	Determination of Aggregate Crushing value,
b)	Determination og Aggregate Impact Value

c)	Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
d)	Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine3
e)	Determination of 10% fines value
f)	Determination of Crushing Strength
5	**Soundness**
	Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
6	**Measuring Mortar making prooerties of Fine Aggregate**
	Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
	Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
	Petrographic Examination of Aggregates for Concrete
	Potential Volume Change of Cement-Aggregate Combinations3

The test results have defined limits of acceptance, adopted on good practices (standards, codes, etcetera) Variations in quantities of concrete as required are done.

In order to design a mix of desired strength the concrete, the concrete constituents are specifically proportioned on the basis of good experience; practices are available in the form standard and codes.

The results obtained based on mix proportioning are put to further trials and finally the desired mix proportion is used to produce concrete. It is a good practice to carry on mix proportioning at intervals to accommodate any variations in the qualities of constituents of concrete.

Finally, **workability durability and strength are the factors that govern mix proportioning**.

Nominal Mix Concrete

IS 456 – Plain and Reinforced concrete code of practice, suggest to use Nominal Mix concrete up to M20 and Design Mix concrete above M20 Nominal mix concrete is not designed and it may use excess quantity of cement and must be use for small quantities of works as per direction and approval of Engineer in Charge.
However, if the quality of M20 grade concrete is in mass, it is advisable to use the design mix concrete.

Proportioning of Nominal Mix Concrete

(for small and scattered job and as per approval of engineer in Charge)

TABLE 16 PROPORTIONING OF MATERIALS IN CONCRETE

Grade of Concrete N/mm^2	**Weight of FA and CA / 50 kg of cement** (Kg)	**Weight of water / 50 kg cement** (Kg)			
M 5	800	60	CA= Coarse Aggregates		
M 7.5	625	45	FA= Fine Aggregates		
M 10	480	34			
M15	330	32			
M 20	250	20			
		The proportion of FA and CA may be from 1:1.5 to 1:2.5 depending on the size of the aggregate (lower size to higher size). IS *456 suggest following guideline:*			
Coarse aggregate size	Proportion of FA: CA	For M20, per 50 Kg weight of cement, the proportions may be as follows (Kg)			
		FA	CA	Cement	
10 mm	1:1.5	100	150	50	250 Kg of Aggregate (FA+CA)/50 Kg of Cement
20 mm	1:2	83	167	50	
40 mm	1:2.5	72	178	50	
For M **20, A10** concrete, the proportion is Cement: FA: CA:1:2:3. *The concrete may be produced by weigh batching in the required proportion or converted into volume batching.* M30, A40 means - concrete of Nominal maximum size aggregate 40 mm and strength 30 N/mm^2					

PROCESS OF CONCRETE MAKING

Manufacturing Process of Concrete Mixture - Bing video

CONCRETE QUALITY CONTROL

Mod-01 Lec-12 Principles of quality control in concrete construction - Bing video

mix proportioning (B.I.S method)

the most effective method to do concrete design mix according to is codes and cbc - Bing video

TEXT / REFERENCE BOOKS

1. Arora and Bindra, Building construction, Dhanpath Rai and Sons.
2. Punmia B.C., Building construction. Laxmi Publications.
3. Rangwala S.C., Engineering Materials, Charotar Publishers.
4. Shetty M.S., Concrete Technology, S. Chand & Company.
5. Sahu G.C. & Joygopal Jena., Building Materials and Construction, McGraw Hill Education.
6. Gambhir M.L., Concrete Technology, Tata McGraw Hill.
7. Krishna Raju N, Design of Concrete Mixes, CBS Publishers.
8. National Building Code.
9. Neville A.M. and Brooks.J.J, Concrete Technology, Pearson Education.

QUESTION BANK

PART A

1. List the Mechanical & Physical properties of aggregates.
2. What are the Grading requirements of aggregate?
3. List the types and uses of plasticizers.
4. What are the types of concrete mixers?
5. Narrate the Water quality in concrete.

PART B

1. Explain the Concrete mix proportioning as per I.S method.
2. Compile the statistical analysis of quality control in concrete.
3. Narrate the factors affecting workability & strength of concrete.
4. Explain the Properties of fresh concrete concretes.
5. Narrate the types and uses of accelerators and retarders.

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UNIT – III– CONCRETE AND CONSTRUCTION TECHNOLOGY - SCIA1201

UNIT 3

PROPORTIONING OF CONCRETE MIX 8 Hrs.

Principles of Mix Proportioning – Properties of concrete related to Mix Design – Physical properties of materials required for Mix Design – Design Mix and Nominal Mix – BIS Method of Mix Design – Mix Design Examples

PRINCIPLES OF MIX PROPORTIONING (NPTEL – DELHI) 55 min

(Mix proportioning of concrete and general principles)

REF: https://youtu.be/bOskzXrOqOo

https://youtu.be/bOskzXrOqOo

REF: PRINCIPLES OF CONCRETE MIX DESIGN (PPT FILE)

REF: PROPORTIONING OF CONCRETE MIX (PPT FILE)

REF: DESIGNING AND PROPORTIONING (WORD FILE)

PROPERTIES OF CONCRETE RELATED TO MIX DESIGN

BASIC PROPERTIES OF CONCRETE (NPTEL – KANPUR) 30 min

REF: https://youtu.be/FKIYkvTnSIU

REF: MIX DESIGN MATERIAL PROPERTIES (WORD FILE)

Concrete Properties and Mix Design | Mix Proportioning
Performance-Based Concrete Pavement Mix Design System Mix Design?
It is the process of determining required and specifiable characteristics of a concrete mixture. Prescriptive approach (limits on materials). Performance approach (desirable characteristics). Mix design requirements are based on intended use, environment, etc. Mix design is the process of determining the quantities of concrete ingredients that meet the mix design criteria.

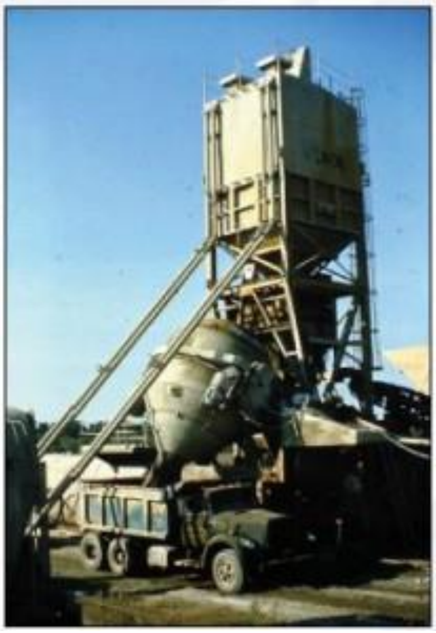

FIG.1 MIXING OF CONCRETE IN RMC

The primary considerations in mix proportioning include:

- The ability to continually meet or exceed specifications (**durability and strength).**
- **Economy**.
- Readily available supply of **raw materials**.

A typical laboratory testing plan includes the following **mix characteristics**:

- Workability.
- Strength.
- Plastic air content.
- Unit weight.
- Permeability.
- Coefficient of thermal expansion.
- Others depending on the mix design requirements.

The relative size and importance of a project determines which of the above tests are performed.

Methods for Proportioning Concrete Mixes

- Water-cement ratio method.
- Weight method. (Design Mix)
- Absolute volume method (ACI 211.1) (Nominal Mix).

- Field experience (statistical data).
- New methodologies currently under development

6 PROPERTIES OF CONCRETE USED BY DESIGNERS

PROPERTIES OF HARDENED CONCRETE

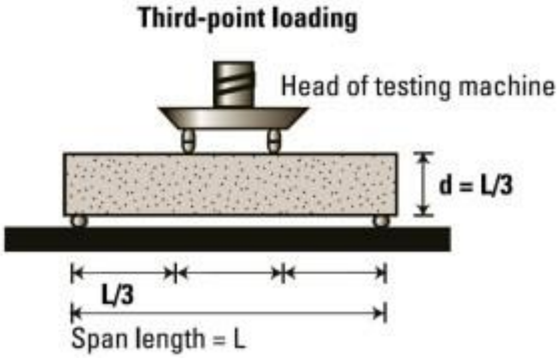

FIG.2 FLEXURAL STRENGTH TEST ARRANGEMENT

The following are the properties of concrete in its hardened state, used by the designer during design process of reinforced concrete structure.

1. COMPRESSIVE STRENGTH

The characteristics strength is defined as the strength of concrete below which not more than 5% of the test results are expected to fall. As per IS: 456 concrete mix always designed for the **target strength computed** as,

Target strength: **Characteristics strength + (1.65 x standard deviation)**

M_{20} is the minimum grade of concrete for use in RCC work.

2. TENSILE STRENGTH

Flexural strength is one measure of the Tensile strength of concrete. In concrete structure one set of visible cracks occur under flexure to compute load factor against cracking .According to IS: 456 the tensile strength of concrete can be computed from the compressive strength using empirical relation given by:

Flexural strength: $\mathbf{f_{cr}=0.7\sqrt{fck}}$ N/mm^2

3. MODULUS ELASTICITY

Modulus of elasticity of concrete is significantly influenced by the following factors.

- Type of the aggregates used
- Type of cement
- Mix proportions

This property is required for the computations of **deflection**s of structural concrete members which forms an important limit state in the design of concrete members. In the absence of test data, the modulus of elasticity of concrete is normally related to the **compressive strength** and is computed by the empirical relation recommended by IS: 456-2000 code and is expressed as,

$$\mathbf{E_c=5000\sqrt{fck}}$$

Where E_c is the short term **static modulus of elasticity** of concrete expressed in N/mm^2

f_{ck} is the **characteristic compressive strength** of concrete expressed in N/mm^2.

4. SHRINKAGE OF CONCRETE

The ingredients of concrete and environmental conditions like **temperature** and humidity influence the total shrinkage of concrete. **Water content in concrete significantly affects the shrinkage**. IS 456-2000 recommends the shrinkage strain as **0.0003** in the absence of test data. Drying shrinkage in plain concrete may result in surface cracks. Shrinkage of concrete also influences the deflections of reinforced concrete members.

5. CREEP OF CONCRETE

The inelastic time dependent strain developed in a concrete member under sustained loading is referred to as creep of concrete. Creep of concrete is influenced by following **factor**s.

- Cement content,
- W/C ratio,
- Temperature and humidity,
- Size of structural element,
- Type of loading and period of loading.

In the absence of reliable experimental data, the **creep coefficient** is expressed as the **ratio of ultimate creep strain/elastic strain** at various ages of loading as recommended by IS: 456-2000 is given below.

TABLE 1 AGE AND CREEP OF CONCRETE

Age at Loading	**Creep Coefficient**
7 days	2.2
28 days	1.6
1 year	1.1

Creep of concrete significantly **affect**s the **deflection**s of reinforced concrete flexural members. **Higher creep** coefficient results in **large deflections**. The value of creep coefficient is useful in the computation of time dependent deflections in reinforced concrete members.

6. COEFFICIENT OF THERMAL EXPANSION

The coefficient of **thermal expansion** of concrete, **influenced** mainly by the **type** of **aggregate** used in concrete is required for the design of structures like chimneys, water tanks, silos etc. the values recommended in IS:456-2000 are compiled below.

TABLE 2 AGGREGATE TYPES WITH THERMAL EXPANSION IN CONCRETE

Type of Aggregate	**Coefficient of Thermal Expansion for Concrete**
Quartzite	1.2 to 1.3 x 10^{-5}
Sandstone	0.9 to 1.2 x 10^{-5}
Granite	0.7 to 0.95 x 10^{-5}
Basalt	0.8 to 0.95 x 10^{-5}
Lime stone	0.6 to 0.9 x 10^{-5}

PHYSICAL PROPERTIES OF MATERIALS REQUIRED FOR MIX DESIGN

REF: MIX DESIGN MATERIAL PROPERTIES word file

DESIGN MIX AND NOMINAL MIX

REF: Difference Between Nominal Mix & Design Mix - Bing video (6.5 min)

https://youtu.be/t3R3vjH3P54

What is the Difference between Nominal Mix and Design Mix Concrete?
Mix design is a process of selecting suitable ingredients and determining their relative **proportion**s with the objective of producing concrete of having certain minimum workability, strength and durability as economically as possible.

FIG.3 PLACING OF CONCRETE

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

1. Nominal Mix
2. Design

NOMINAL MIX

It is used for relatively unimportant and simpler concrete works. In this type of mix, all the ingredients are prescribed and their proportions are specified. Therefore there is no scope for any deviation by the designer. Nominal mix concrete may be used for concrete of M-20 or lower. The various ingredients are taken as given in the table below

TABLE 3 QUANTITIES OF INGREDIENTS IN NOMINAL MIX

Grade	Max. quantity of dry Aggregates per 50 kg of cement	Fine Aggregate to Coarse Aggregate Ratio, by mass	Max. Qu of water
M-5	800	Generally 1:2 but may varies from 1:1.5 to 1:2.5	60
M-7.5	625		45
M-10	480		34
M-15	330		32
M-20	250		30

DESIGN MIX

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

BIS METHOD OF MIX DESIGN

REF: Mix design of Concrete: General and IS Method - Bing video (NPTEL DELHI 1.0.27min)

https://youtu.be/HshCd-3XChQ

Methods of Concrete Mix Design: 5 Methods

The following points highlight the five methods of concrete mix design. The methods are:

1. American Method of Mix Design
2. Graphic Method of Mix Design
3. Mix Design by Indian Standard Method
4. American Concrete Institute Method of Mix Design
5. Rapid Method of Mix Design

Mix Design by Indian Standard Method:

The bureau of Indian standards has recommended a procedure for mix design of concrete based on the experimental work carried out in the national laboratories. The **mix design procedure is given in IS-10262- 1982**.(REF: PDF FILE). After that no revision has been done in this procedure, whereas IS 456-1968 has been revised in 2000. Hence IS 10262-1982 needs revision as the strength of cement available in the country has improved significantly.

Thus following changes need to be effected

1. The **28 day strength** of A, B, C, D, E & F category of cements needs **to be revised.**
2. The **relation between** the different **strengths of cement and w/c ratio** should be re-established.
3. The **relation between** 28 days **compressive strength and w/c ratio** should be extended upto a compressive strength of 80 MPa (800 kg/cm^2), if the graph is to be used for high strength concrete.
4. As per the revised IS 456-2000 the degree of **workability is expressed in terms of slump** in place of compacting factor. This change needs new values of sand and water content to be used for normal concrete upto 35 MPa and higher strength Concrete above 35 MPa.

However in the absence of any revision in IS 10262-1982, the existing procedure of IS 10262 is described below step wise.

The IS recommendations for mix design include the design for nominal concrete mixes (non-air entrained) for both medium and high strength concrete.

The method of mix design consists of determining the followings

(a) **Water content**

(b)**Percentage of fine** aggregate corresponding to the maximum nominal size of aggregate for the reference value of workability

(c) **Water-cement** ratio, and

(d) **Grading** of fine aggregate.

The water content and percentage of fine aggregate is then adjusted for any difference in workability. Finally the **mass of ingredients** per unit volume of concrete is **calculated by** absolute **volume method**. This method is applicable to both ordinary port-land and port-land Pozzolanic cements. The final mix proportions selected after trial mixes, may need minor adjustment. In case of fly ash cement concrete, water content may be reduced by about 3 to 5% and proportion of fine aggregate may be reduced by 2 to 4%

MIX DESIGN EXAMPLES

REF: Mix design of Concrete: General and IS Method - Bing video NPTEL DELHI 1.00.27 MIN

https://youtu.be/bOskzXrOqOo

TEXT / REFERENCE BOOKS

1. Arora and Bindra, Building construction, Dhanpath Rai and Sons.
2. Punmia B.C., Building construction. Laxmi Publications.
3. Rangwala S.C., Engineering Materials, Charotar Publishers.
4. Shetty M.S., Concrete Technology, S. Chand & Company.
5. Sahu G.C. & Joygopal Jena., Building Materials and Construction, McGraw Hill Education.
6. Gambhir M.L., Concrete Technology, Tata McGraw Hill.
7. Krishna Raju N, Design of Concrete Mixes, CBS Publishers.
8. National Building Code.
9. Neville A.M. and Brooks.J.J, Concrete Technology, Pearson Education.

QUESTION BANK

PART A

1. List the Principles of Mix Proportioning.
2. What are the Properties of concrete?
3. List the Physical properties of materials in concrete.
4. What are the defences between Design Mix and Nominal Mix
5. Narrate the Principles of Mix Design

PART B

1. Explain the Principles of Mix Proportioning as per I.S method.
2. Compile the process of concrete Mix Design
3. Narrate by numerically the concrete Mix Design Examples.
4. Narrate the Physical properties of materials required for concrete Mix Design.

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DEPARTMENT OF CIVIL ENGINEERING

UNIT – IV– CONCRETE AND CONSTRUCTION TECHNOLOGY - SCIA1201

UNIT 4

FRESH AND HARDENED PROPERTIES OF CONCRETE 9 Hrs.

Workability – Tests for workability of concrete – Segregation and Bleeding – Determination of strength Properties of Hardened concrete – Compressive strength – split tensile strength – Flexural strength – Stress-strain curve for concrete – Modulus of elasticity – durability of concrete – water absorption – permeability – corrosion test – acid resistance- destructive and non destructive test.

PROPERTIES OF FRESH CONCRETE

Fresh Concrete can be easily moulded into any designed shape in construction. It can be prepared on the spot and may give a wide range of properties from easily available raw materials.

The different properties of Fresh concrete.

- Workability.
- Setting.
- Segregation.
- Plastic Shrinkage.
- Thermal Shrinkage.
- Thermal Expansion.
- Water Cement Ratio.

FIG.1 LAYING OF FRESH CONCRETE

Workability

Workability, is the ease with which freshly prepared concrete can be transported and placed for the job and compacted to a dense mass.

The fresh concrete which may be expected to give the best results must possess the property of workability. This is the **most important property** of fresh concrete.

Fresh concrete should be capable of spreading uniformly **without** inducing any **segregation** of the aggregates.
A workable concrete should have a right balance between the **plasticity** and **mobility** for a particular job in particular place.

To develop such a balance, you must **select** the **right type of aggregates**, proper **proportioning** of cement, sand, coarse aggregates, and water, and thorough mixing of the constituents.
Besides plasticity or consistency and mobility, the third most important aspect considered to define workability is the ease with which the freshly placed concrete can be compacted without developing any defects.

Workability Tests:
Since workability depends on a number of factors, no single test is thought to be sufficient to express this property of fresh concrete.

For quality construction, the following three tests are required to be carried out.

- Slump test.
- Compacting factor test.
- V-B Consistometer test.

Slump Test:
Slump Test gives us an idea of about the consistency of the mix.

Compaction Factor Test:
This test is developed in the UK by Glanville. In this test samples of **concrete are weighed** first when **concrete is partially compacted, and then after the full compaction.**

Then, the samples are compacted using specified techniques and apparatus.

The **ratio between partially compacted weights to the fully compacted weight gives a measure of compaction factor. It is always less than 1.**

The reliability of this test has been questioned by many peoples. But still, for very stiff and dry concrete, this test is often considered to be a good indicator of workability.

V-B Consistometer Test:

This test is developed by Bahrner in Sweden. In this test samples of **fresh concrete is** taken in a metallic cone and **compacted by a specified vibrator** to an ultimate shape of a flat cylindrical mass.

Total **time taken** for this process, **in seconds, is recorded**. This is called **V-B time** and gives a measure of compatibility of the concrete.

This test is useful in determining the workability of concrete mixes with aggregates size up to 20 mm.

It is expensive as compared to Slump Test and Compaction Factor Test and is used mostly in precast concrete works.

Setting:

When **concrete** changes its state from **fresh to harden** then this process is **called setting**. And the time required to complete this process is known as Setting Time of Cement.

Setting time depends on the type of cement, aggregates, etc., used in concrete-mix. For increasing or decreasing the setting time Admixtures is used.

The setting time for Portland cement is about **30 – 45 minutes**.

Segregation:

The **separation of** concrete **ingredients** from each other is **known as segregation**. This can be caused **due to excessive vibration** in concrete mixer machine or **falling concrete from** more than **1-meter height**.

Plastic Shrinkage:

This is the shrinkage that the **fresh concrete undergoes until it sets completely**. It may also be called initial shrinkage.

This can be **due to excessive loss of water** from the concrete **due to evaporation, bleedin**g, and soaking by formwork.

Excessive shrinkage at initial stages may **develop cracks**. Therefore, all precautions should be taken to avoid excessive loss of water.

Thermal Shrinkage:

This may be **due to falling in temperature** of concrete-mix from the time it laid to the time it sets completely.

Due to change in temperature, some shrinkage may be expected. Sometimes, it may be negligible on its own account.

Thermal Expansion:

In massive concrete works, **when the upper layers are laid before the lower layers have completely set**, there may arise a phenomenon of thermal expansions – in the lower layers.

This is because the heat of hydration gets accumulated in those layers and may attain magnitudes beyond acceptable limits.

Water Cement Ratio:

The **compressive strength decreases**, in general, **with increasing water cement ratio** and vice versa.

Hence, when minimum water is used just to ensure complete hydration of the cement, the resulting concrete will give maximum compressive strength on proper compaction.

What is bleeding in concrete?

Bleeding is responsible for **causing permeability** in concrete. In the process of bleeding (i.e. while **water** is in the process of **coming towards top**) sometimes gets accumulated below the aggregate. This accumulation of water **creates a water voids and reduces bond between the aggregate and cement past**.

Bleeding of Concrete

Concrete is most common construction material, is composed of individual constituents like cement, fine and coarse aggregates mixed in certain proportions. A number of problems happen with concrete **due to improper proportioning, mixing and placement of concrete and bleeding** of concrete is one of these **problems**.

For example, if you mix some concrete in water and allow it to settle down in a glass to see what happens. You will notice that heavier particle settle down first, followed by lighter particles and finally clean water will accumulate on the top. Similar phenomenon happens in concrete containing higher water contents, in which heavier particles tend to settle down followed by lighter particles depending upon the specific gravities of each pushing the water to upward in a squeezing manner, being of the lowest specific gravities of all of ingredients of concrete.

This **upward movement of water creates channels and gives rise to increased permeability**, also bleed water sometime accumulates under particles of aggregates and results into voids under these aggregates. But if water to cement ratio of concrete is low, very less free water is available to bleed.

Bleeding is helpful at some situations where loss of moisture from surface of fresh concrete leads to surface cracking and bleed water tends to restore this surface moisture. Bleeding also lowers the water to cement ratio in some ways.

What is Bleeding of Concrete

Bleeding is the appearance of a layer of **water at the top** or the **surface of freshly placed concrete** after it has been consolidated and struck off, but before it has set (Mindess and Young 1981). Bleeding may also be referred to as water gain, weeping, or sweating.

Concrete Bleeding is a phenomenon in which the relative quantity of water in freshly mixed concrete rises to surface and sometime transport fine particles with it, these fine particles of cement get accumulated at the top surface in the form of laitance.

Significance of Bleeding

Bleeding is caused by the settlement of solid particles (cement and aggregate) in the mixture and the simultaneous upward migration of water (Kosmatka, Kerkhoff, and Panarese 2002). A small amount of bleeding is normal and expected in freshly placed concrete.

In fact, some bleeding is actually helpful in **controlli**ng the development of **plastic shrinkage cracking**. If the rate of moisture evaporation at the surface exceeds the bleeding rate (Kosmatka 1994; Poole 2005), the surface will dry and crack. A lack of bleed water can also lead to a dry surface that can be very difficult to finish (Kosmatka 1994).

However, **excessive bleeding reduces concrete strength and durability** near the surface. The rising water can carry with it a considerable amount of fine cement particles, forming a layer of weak and nondurable material, called laitance, at the surface (Neville 1996).

Excessive **bleeding also** may **delay the finishing process**, which in general should not proceed until the bleed water has evaporated from the surface (Kosmatka 1994). If the surface is finished with bleed water present, a thin and weak layer is created on the surface that is susceptible to scaling and delamination. In some cases, if the fresh concrete surface is prematurely sealed by troweling while the underlying concrete is still releasing bleed water, blisters (small hollow bumps beneath the concrete surface) can form.

Bleed water can also accumulate within the concrete mix itself, under large aggregate particles or reinforcing bars (Mindess and Young 1981). The former **results in reduced concrete strength** (due to decreased aggregate-paste bond). The latter may reduce the paste-steel bond, possibly **promoting the corrosion of steel** because the steel is not in contact with the corrosion-resistive paste (Kosmatka 1994).

Causes of Bleeding

There are several causes of bleeding in concrete, but main causes of bleeding of concrete are as follow

1. **Segregation** in concrete is one of main causes in which heavier aggregate particles settle down and squeezes the water to rise upward.
2. **High water to cement ratios** provides suspension system in which heavier particle settle down easily result into excessive bleeding as more free water is available.
3. **Higher values of Fineness modulus** results into increase in tendency of concrete to bleed with fewer fines available.
4. **Low cement content** has the same effect as higher values of fineness modulus as lesser quantity of fine particles is available.
5. **Depth of placed concrete** also effects the bleeding as deep sections of concrete bleed more than thinner sections due to increase of pressure with increase in depth.

Effects of concrete bleeding

Although, bleed has some useful affects like reduction in water cement ratio as well as restoration of surface moisture for control of surface shrinkage cracks.

But mostly, bleed in concrete has adverse effects on properties and performance of concrete. Below are some listed effects of bleeding.

1. Some water is trapped under aggregates and reinforcing steel and **reduces the bonding** among individual constituents as well as with steel reinforcements.
2. **Permeability of concrete increases** as bleed water rises to the top by making small channels, later these channel allow the inflow of water and dissolved salts. This whole process leads to decrease in durability also.
3. **Delays in surface finishing** due to accumulation of bleed water on surface of pavements or floors and unsightly sand streaks due to rise of bleed water to form surface cause poor aesthetics and surface defects in formed and finished surfaces.
4. Accumulation of laitance at the surface of concrete due to bleeding **reduces the bonding** in horizontal joints in concrete placed in several lifts.
5. **Choking of concrete pumps lines** can happen due to excessive bleeding of concrete mixes.

How to control concrete bleeding

Bleeding of concrete can be reduced considerably by employing following control measures.

1. **Reducing water cement ratio** and slump of concrete, increasing cement content, use of fine cement.
2. **Increasing the percentage of fine aggregates** in mix, using finer sand (FM 2.5 or less).
3. **Proper proportioning** of concrete mix to achieve homogeneity and cohesiveness.
4. **Entrainment of air into the mix** to increase workability and decrease in water demand.

Factors Affecting Bleeding of Concrete

The initial bleeding process generally begins after agitation of the concrete mix ends, and bleeding continues until the cement paste has stiffened sufficiently to resist the settlement of the solid particles (Neville 1996). The duration of bleeding depends on the thickness of the concrete section as well as the setting properties of the cementitious materials, with thinner sections or faster setting concretes exhibiting less bleeding (Kosmatka 1994).

A number of different concrete mix constituents can affect the development of bleeding.

1. **Water Content and Water-Cementitious Materials (W/CM) Ratio**

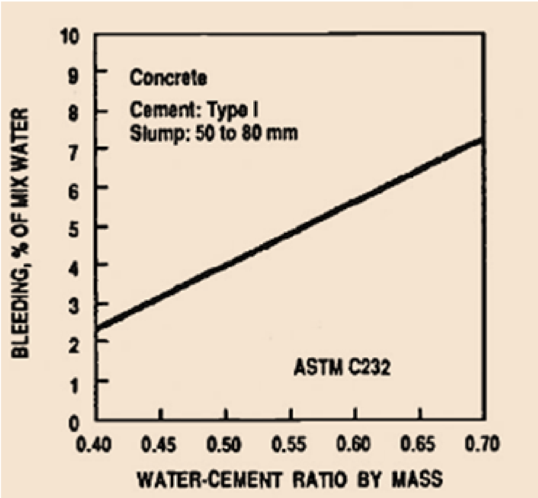


FIG.2 BLEEDING WITH WATER CONTENT IN FRESH CONCRETE

Any increase in the amount of water or in the w/cm ratio results in more water available for bleeding (Kosmatka 1994).

2. **Cement**

As the **fineness of cement increases**, the amount of **bleeding decreases**, possibly because finer particles hydrate earlier and also because their rate of sedimentation (settlement) is lower (Neville 1996). **Increasing cement content** also **reduces bleeding** (Kosmatka 1994). **Cement with a high alkali** content or a high calcium aluminate (C3A) content will exhibit **less bleeding** (Neville 1996).

3. **Supplementary Cementitious Materials**

Concrete containing **fly ash** generally exhibits a **lower bleeding rate**, but due to retarded setting the total bleed volume may be similar or greater than portland cement-only concrete. Ground, granulated blast-furnace slags have little effect on bleeding rates (Wainwright and Rey 2000). **Silica fume** can greatly **reduce**, or often stop, **bleeding**, largely because of the extreme fineness of the particles (Neville 1996).

4. **Aggregate**s

Ordinary variations in aggregate grading have little effect on the bleeding of concrete mixtures, provided that there is no appreciable variation in material smaller than 75 µm. However, concrete mixtures containing aggregates with a high amount of **silt,** clay, or other material **passing the 75-µm** (#200) sieve can significantly **reduce bleeding** (Kosmatka 1994), although there may be other adverse **effects** on the concrete, like **increased water requirement and shrinkage**.

5. **Chemical Admixtures**

Air-entraining agents have been shown to significantly **reduce bleeding** in concrete, largely because the air bubbles appear to keep the solid particles in suspension (Neville 1996). **Water reducers** also r**educe** the amount of **bleeding** because they release trapped water in a mixture.

Summary

1. Bleeding is the **appearance of water at** the **surface** of newly placed, plastic concrete due to settlement of the heavier particles.
2. Some **bleeding helps avoid plastic cracking** in the surface, which can occur when water evaporating from the surface causes the surface to dry quickly.
3. Excessive **bleeding can result in voids** under large aggregate particles and the formation of channels through the concrete.
4. Excessive bleeding will also increase the effective water-cementitious materials ratio at the surface and weaken the surface.
5. Ideally, finishing and curing should occur when bleeding has finished and bleed water has evaporated.
6. **Bleeding is reduced with increasing fines content** and with air-entraining and/or water-reducing admixtures

PROPERTIES OF HARDENED CONCRETE

FIG.3 PROPERTIES OF HARDEDED CONCRETE

Workability and related properties of fresh concrete are essential for transport and laying. The properties which determine the quality of the hardened concrete broadly fall into the following **three** groups

1. **Strength.**
2. **Durability.**
3. **Dimensional stability**.

Characteristic strength, drying shrinkage, creep, modulus of elasticity, permeability and resistance to chemical attack are hardened and time-dependent properties of concrete that may influence structural performance.

1. STRENGTH

In simple language, the strength of concrete means the **maximum amount of load which it can handle.**

In common practice, it is the **power of the concrete** which is considered its most valuable property.

In fact, high-strength concrete is synonymous with good quality concrete.

The **Strength** of Concrete can be determined by the **compressive strength and tensile strength.**

COMPRESSIVE STRENGTH

It may be defined as the **maximum compressive load that can be taken by concrete** per unit area.

It has been shown that with special care and control, concrete can be made to bear as high loads as 800 kg/sq.cm or even more, however, concrete with compressive Strength between 200-500 kg/sq.cm can be easily made on the site for the common type of construction.

The **compressive strength is also called** the **crushing strength**, and it is determined by **loading axially cube-shaped** (or **cylindrical shaped**, in the USA) **specimen**s made out of the concrete.

The tests are carried out in **3 days, 7 days and 28 days after the casting** of the samples.

It has been observed that the compressive (crushing) strength of concrete is influenced by a huge number of factors.

Some of the important factors are:

i. Type of Cement:
The composition, quality and 'age' of the material which is used in the manufacture of cement that have been stored for the considerable time make concrete of lower strength.
Cement with higher proportions of **tri-calcium silicate** produce concrete that **show higher strengths**, at least in earlier stages.

Similarly, **finer the particle size of the cement**, **higher** is the ultimate **compressive strength**.

ii. Nature of Aggregates.
Sand and coarse aggregates form the other two essential components of concrete. A good bond between cement and the aggregates is possible only when the aggregates have **sharp edges, clean surfaces, and rough texture**.
Smooth and rounded aggregates result in comparatively weak bonds. Similarly, the aggregates used in the concrete making should have in themselves good compressive strength.

For example, if chalk (very soft limestone) is used in making of concrete instead of massive limestone, the resulting concrete will be weak in compressive strength because of the reduced strength of the aggregate.

iii. Water-Cement Ratio.

The compressive **strength decreases**, in general, **with increasing water cement ratio.**

Hence, when minimum water has been used just to ensure complete hydration of the cement, the resulting concrete will give maximum compressive strength on proper compaction.

iv. Curing Conditions.

Great importance is attached to proper curing of concrete after it's laying for obtaining maximum compressive strength.

Incomplete curing and intermittent drying of concrete during the curing period may cause a **loss in the compressive strength** to the extent of 40 percent or even more.

v. Weather Conditions.

The same concrete placed in different climates - extremely cold and dry hot, may develop different strength values.

The cause is related to **incomplete hydration** of the cement in the concrete.

vi. Admixtures.

Certain admixtures are added to the concrete at the mixing stage for achieving some specific purposes.

It has been observed that certain admixtures especially **calcium chloride, increase the compressive strength.**

Some other admixtures (e.g., **air entraining agents**) however, affect the compressive **strength** adversely if proper controls are not maintained on the water-cement ratio.

vii. Method of Preparation.

Improper mixing of the concrete and careless transport and placing may result in poor (in strength) quality, despite the best cement and aggregates used in it.

It is the workmanship that determines the quality of the concrete-work in the ultimate analysis. A skilled worker can produce best concrete-mix despite some other deficiencies.

An **incompetent labour**, however, may spoil the entire work despite being given the best-designed concrete-mix.

The voids left in the concrete on compaction and curing have a profound influence on the strength of the concrete.

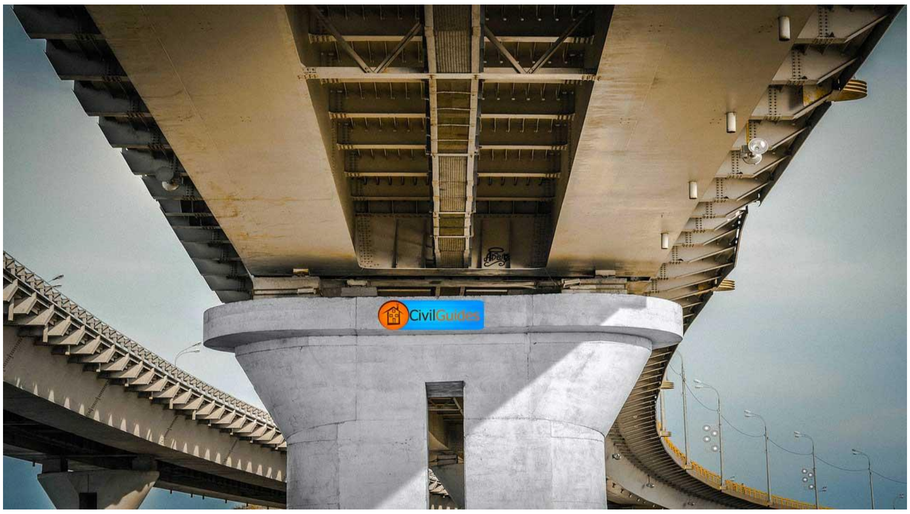


FIG.4 PIER WITH HIGH COMPRESSIVE STRENGTH

Tensile Strength:
Plain concrete (without steel reinforcement) is quite **weak in tensile** strength which may vary from **1/8th to 1/20th of** the ultimate **compressive strength**.

It is primarily for this reason that steel bars (reinforcement) are introduced into the concrete at the laying stage to get a block of reinforced cement concrete which is very Strong in compression as well as in tension.
In plain concrete, tensile strength depends largely on the same factors as of the compressive strength.

The Tensile strength of concrete becomes a valuable property when it is to be used in road making and runways. It is determined by using indirect methods

In one of such methods, it is deduced from the flexural strength test. In this test, a **beam of concrete is cast** in standard dimensions depending upon the nominal size of the aggregate.
Then, the **beam is properly cured and tested after 28 days**.

In the second indirect method, called the **split-cylinder method**, the **cylinder** of specified dimensions is made to **fail under tension by applying compressive load across the diameter.**
This is **termed as Splitting Tensile Strength**.

The testing machine is adjusted to distribute the load along the entire, length of the cylinder; from the load at failure, tensile strength is calculated.

2. Durability:
Durability is the second most important **quality of hardened concrete**. It may be defined as the **capacity** of hardened concrete **to withstand all the forces** of deterioration that are likely to act on it, **after setting**, in a given environment.

Among these **force**s, the following are more likely to act.

1. **Frost action.**
2. **Abrasive forces.**
3. **Chemical action.**
4. **Alkali-aggregate** reaction.

A brief note on each of these is given below.

i. Frost Action.
Frost Action is a major **cause of deterioration** of concrete in Cold Climates. It takes place **due to freezing** or **water within the concrete pores and cavities during extremely cold weather.**

Water on freezing expands and exerts pressure on the walls of the pores. This **cyclic freezing of water in the pores are responsible for** the development of **cracks** of various nature in the concrete.

To minimize frost actions following measures should be taken.

- In cold weather, the **water-cement ratio should be kept as low** as possible. This will not allow any extra water to remain within the concrete pores. Hence frost formation will not take place.
- Use **good drainage and covering methods** for removing any surface water from staying on the concrete during the curing process.

ii. Chemical Attack.
Concrete is **liable to attack** to various degrees **by acids alkalies** and **salt** solutions.

Among the acids, **hydrochloric, Sulphuric, nitric and hydrofluoric acid, acetic acid, lactic acid, and formic acid are very harmful** to concrete.

The sources of these acids can be from within or outside the environment in which concrete has been used. Thus, **hydrochloric acid** and sulphuric acid may be **present in** industrial and **domestic sewage**.

They will destroy gradually the calcium hydroxide components of concrete used for sewage disposal. Other acids may attack the concrete used in the industrial buildings of acids.

The **organic acids** are common though in traces, **in food processing factories and dairy farms**. Concrete used in these buildings will gradually deteriorate from these acids at a fast rate.

iii. Alkali-Aggregate Reaction
Sodium and potassium hydroxides of cement are capable of reaction with silica.

Since amorphous silica is a common component of many coarse aggregates, such an alkali-aggregate reaction may create harmful effects on cement concrete.

This is because the gel-like silicate structures produced by the above reaction are quite weak and unstable and result in greater expansion.

These may be the **cause of frequent cracking** in some concrete. For avoiding this reaction, either the **percentage of alkalies** (K_2O and Na_20) has **to be kept very low** in the Portland Cement.
Or a great care has to be taken for selecting aggregates free of amorphous silica-like opal, chert, cristobalite, etc.

FIG.5 CHEMICAL ATTACK ON CONCRETE

3. DIMENSIONAL STABILITY:

CREEP This defines the behaviour of concrete under loads.

It is now well established that **concrete is not** a truly **elastic material**. Also, it is **not** entirely **plastic material**. When hardened concrete is loaded, it deforms.

1. partly as a result of elastic strain (which is recovered on the removal of the load);
2. Partly as a result of plastic strain (a permanent deformation).

This latter **non-elastic time dependent deformation** is a typical property of concrete and is commonly **referred as CREEP**.

The various causes of creep

1. **Closure of the void-structures** of concrete on the application of load;
2. **Squeezing of water f**rom within the cement gel when the concrete is loaded,
3. The flow of cement-water paste, in a viscous state, causing a permanent shrinkage under load;
4. **Readjustment of aggregates under load**.

It is believed that the proportion of mix and the type of cement used in concrete have a profound influence on the rate of creep.

Concrete mixes with **higher water-cement ratio** will also **show higher creep rates.**

Creep is thought to be beneficial in some cases and harmful in other cases.

In reinforced concrete, it helps in transferring stresses to the reinforcement and, thereby reducing chances of failure by stress-concentration.

4 SHRINKAGE:

Hardened Concrete undergoes in **three types** of shrinkage that are important with respect to its dimensional stability:

1. Plastic shrinkage.
2. Drying shrinkage.
3. Thermal shrinkage.

i. Plastic Shrinkage

This is the shrinkage that the **freshly placed concrete undergoes till it sets completely**. It may also be called initial shrinkage.

Such a **volumetric change** is due to loss of water from the fresh concrete **due to evaporation, bleeding, seepage,** and soaking by formwork.
Excessive shrinkage at initial stages may **develop extensive cracking** in the concrete on the setting. Therefore, all precautions should be taken to avoid excessive loss of water due to evaporation.

ii. Drying Shrinkage

As the concrete has completely set and hardens, some further shrinkage may result **because of contraction of gel-structure** due to further loss of moisture, or drying (against the term evaporation used in the first type of shrinkage).

This kind of shrinkage is practically an essential and **irreversible property** of concrete. It has to be met with by careful design of reinforcement to avoid its ill effects (cracking of hardened concrete).

iii. Thermal Shrinkage.

This may be **due to fall in temperature of concrete** from the time it is laid till it sets completely.

Thus, when concrete is **laid at 30°C cools down to 15°-18°C**, some shrinkage may be expected. It may be negligible on its own account.

But when added to drying shrinkage, it becomes necessary.

5.EXPANSION:

Concrete may expand on hardening due to the following **two reasons**:

Thermal Expansion: In massive concrete works, when the upper layers are laid before the lower layers have completely set, there can arise a phenomenon of thermal expansion in the lower layers.
This is because the heat of hydration gets accumulated in those layers and may attain magnitudes beyond acceptable limits.

Chemical Reactions: Alkali-aggregate reactions are known to cause a definite expansion in the concrete.
The reaction between amorphous silica of aggregates and oxides of potassium and sodium – from the cement used in aggregate yield crystalline structures of bigger volumes.

This change becomes harmful because these gel-structures are not as stable and strong as those formed by reaction between calcium oxide and silica.

They become the cause of cracking and quicker deterioration of hardened concrete

SPLIT TENSILE STRENGTH

What is the Split Tensile Strength of Concrete and Why do we Measure it?

The split tensile strength of concrete is one of the basic and important properties which greatly **affect the extent and size of cracking** in structures. The concrete is not usually expected to resist the direct tension due to its low tensile strength and brittle nature.

However the determination of split tensile strength of concrete is necessary to **determine the load at which the concrete members may crack**. The test split tensile strength of concrete is very simple to perform and the most important fact is that it gives uniform results than the other tension tests like ring tension test and double punch test.

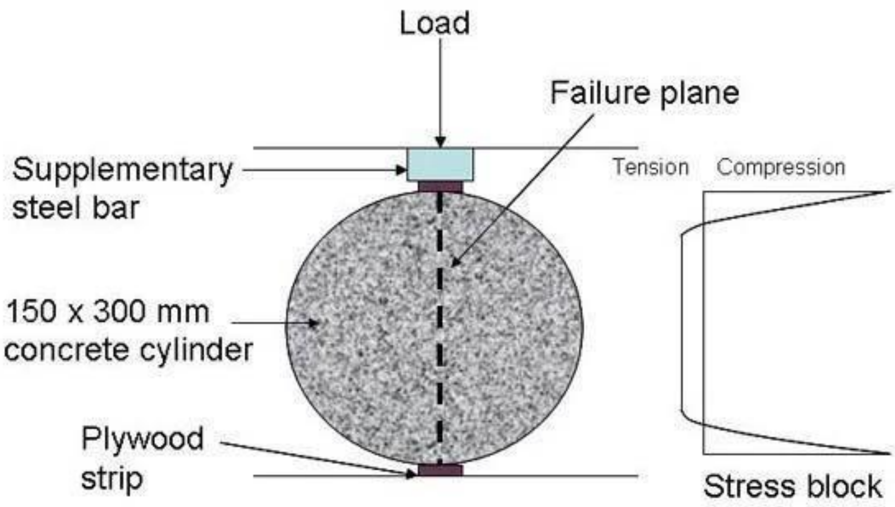


FIG.6 SPLIT TENSILE STRENGTH TEST

DETERMINATION OF SPLIT TENSILE STRENGTH OF CONCRETE AS PER IS: 5816: 1999 AND IS: 456: 2000

Apparatus Required for Split Tensile Strength of Concrete Test:-

- Compression testing machine
- Tamping rod
- Weighing device
- Tools and containers for mixing
- Tamper

IS Code for Split Tensile Strength Test of Concrete Mix:-

- IS: 456: 2000, Code for method of practice for plain and reinforced concrete
- IS: 5816: 1999, Method of test for split tensile strength of concrete

Advantage of Test for Split Tensile Strength of Concrete:-

- Same type and same specimens can also be used for compression test.
- The test split tensile strength of concrete is simple to perform and the most important fact is that it gives uniform results than the other tension tests like ring tension test and double punch test.

FIG.7 SPLIT TENSILE STRENGTH TEST APPARATUS

Procedure for Split Tensile Strength Test of Concrete:-

Preparation of Concrete Cube Specimens

Sampling of Materials – Samples of aggregates and cement for each batch of concrete will be of the desired grading and will be in an air-dried condition. On arrival at the laboratory, the cement samples will be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

Proportioning – The proportions of the materials (aggregates, cement, water, etc.) will be similar in all respects to those to be employed in the work.

Weighing – The quantities of cement, each size of aggregate and the amount of water for each batch will be determined by weight to an accuracy of 0.1 % of the total weight of the batch.

Mixing Concrete – The cement and aggregates are mixed by hand or preferably in a laboratory batch mixer in such a manner as to avoid loss of water or other materials. It is done until the mixture ensures the greatest possible blending and of uniform colour.

Each batch of concrete will be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

Mould – The **cylindrical** mould will be of **150 mm diameter and 300 mm height** conforming to IS: 10086-1982.

Compacting – The test specimens will be made as soon as practicable after mixing.

1. The moulds will be wiped clean and applied oil here.

2. The obtained concrete will be filed in the moulds in layers approximately 5 cm thick.
3. **Each layer will be compacted** with not less than **35 strokes per layer** using a tamping rod (a steel bar of 16 mm diameter and 60 cm long, bullet pointed at lower end).
4. The top surface will be levelled and smoothed with a trowel.

Curing – The test specimens will be stored in a place free from vibration in moist air of at least 90 percent relative humidity and at a temperature of 25 °C to 29 °C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients. After this period the specimens will be marked and removed from the moulds and kept submerged in clear freshwater until taken out prior to the test.

Procedure for Determination of Splitting Tensile Strength of Concrete:-

1. The specimens will be removed from the water after specified curing time and wiped out excess water from the surface. The dimensions of the specimens will be noted to the nearest 0.2m.
2. The bearing surfaces of the compression testing machine will be wiped clean. And any loose sand or other materials will be removed from the surfaces of the specimens which are to be in contact with the rollers.
3. Two bearings strips of nominal (1/8 inch i.e. 3.175 mm) thick plywood free of imperfections approximately (25 mm) wide and of length equal to or slightly longer than that of the specimen should be provided for each specimen.
4. These two bearing strips (plywood strips) are placed between the specimen and both the upper and lower bearing blocks of the strength testing machine. Also they can be placed between the specimen and the supplemental bars or plates.
5. Now draw diametric lines at each end of the specimen using a suitable device that will make sure that they are in the same axial plane.
6. One of the bearing strips (plywood strips) will be cantered along the centre of the lower bearing block.
7. The specimen will be placed on the bearing strip (plywood strip) and aligned carefully so that the lines marked on the ends of the specimen will be vertical and cantered over the plywood strip.

8. The second plywood strip (bearing strip) will be placed lengthwise on the cylinder, cantered on the lines marked on the ends of the cylinder.
9. The **load will be applied** continuously and without shock, at a **constant rate within, the range of 689 to 1380 kPa/min** splitting tensile stress **until failure** of the specimen.

The maximum applied load indicated by the testing machine at failure will be recorded. Also the type of failure and appearance of fracture will be noted.

Observation and Calculation:-

1) Mix proportion =………………………………..

2) Date of casting=………………………………….

3) Date of Testing=………………………………….

4) Age of concrete=………………………………….

TABLE 1: SPLITTING TENSILE STRENGTH OF CONCRETE

Description	Trail No 1	Trail No 2
Wt. of specimen (kg)		
Diameter of specimen (mm)		
Length of Specimen (mm)		
Failure load P (mm)		
Split tensile strength		

Formula for split tensile strength of concrete:-

Calculate the splitting tensile strength of the concrete specimens as follows:-

$$T = \frac{2P}{\Pi DL}$$

Where D is the Diameter (in meter), L is the length (in meter), P is the maximum applied load indicated by testing machine (in kN), T is the splitting tensile strength of concrete and ∏ = 22/7.

Result:-

The average **split tensile strength of concrete** sample in 7 days is found to be ……….

The average **split tensile strength of concrete** sample in 28 days is found to be ……….

FLEXURAL STRENGTH OF CONCRETE

Flexural strength of concrete is the measure of the tensile strength of concrete and to resist failure in the bending it is a measure of non-reinforced concrete beam or slab.

With a span length at least three times the depth, flexural strength of concrete is measured by loading 150 x 150mm concrete beams. As Modulus of Rupture (MR) in MPa, the flexural strength is expressed and by standard test methods ASTM C78 (third-point loading) or ASTM C293 (center-point loading) it is determined.

The specimen size and type of loading does impact the measured flexural strength and comparisons or requirements should be based on the loading configuration and same beam size. It is also observed that with larger beam specimens, a lower flexural strength of concrete will be measured.

Depending on the type, size, and volume of coarse aggregate flexural Modulus of Rupture is about 10 to 20 percent of compressive strength and for given materials and mix design, the best correlation for a specific material is obtained by laboratory tests. The modulus of rupture determined by third point loading is lower than the MR determined by center point loading sometimes as much as 15 percent.

WHY DO WE TEST FLEXURAL STRENGTH OF CONCRETE?

The designers of pavements use a theory that is based on flexural strength so laboratory mix design based on flexure may be required or to yield the needed design MR, **cement content** may be selected from past experience. Some also use MR for acceptance of pavements and field control and few use this test for structural concrete.

TEST FOR FLEXURAL STRENGTH OF CONCRETE:

APPARATUS:

There are the following apparatus used for determining the flexural strength of concrete as given below;

1. Beam Mould
2. Tamping Bar
3. Flexural Testing Machine

PROCEDURE:

There are the following steps in the procedure of flexural strength of concrete as given below;

1. By filling the concrete into the mold in **3 layers** of approximately equal thickness, prepare the test specimen and by using the **tamping** bar, tamp each layer **35 times**. Over the entire cross-section of the beam mold and throughout the depth of each layer, tamping should be distributed uniformly.
2. Then clean the bearing surfaces of the supporting and **loading rollers**, and from the surfaces of the specimen where they are to make contact with the rollers remove any loose sand or other material.
3. For providing support and loading points to the specimens, circular rollers manufactured out of steel having cross-section with a diameter of 38 mm will be used. The length of the rollers shall be at least 10 mm more than the width of the test specimen and a total of four rollers shall be used. The distance between the inner rollers shall be **d** and the distance between the outer rollers (i.e. span) shall be **3d** and the inner rollers shall be equally spaced between the outer rollers.
4. The specimen stored in water shall be tested instantly on removal from water and at right angles to the rollers, the test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen. The mold filling direction shall be normal to the direction of loading for molded specimens.
5. For the 15 cm specimens and at a rate of 180 kg/min for the 10 cm specimens, the load shall be applied at a rate of loading of 400 kg/min.

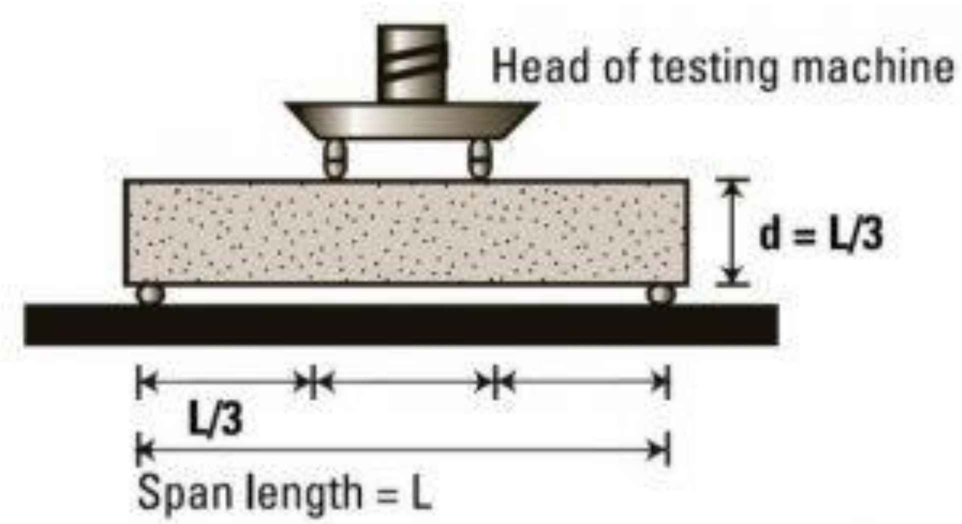


FIG.8 FLEXURAL STRENGTH APPARATUS

CALCULATION:

The flexural strength $\mathbf{f_b}$ is given by;

$\mathbf{F_b = pl/bd^2}$ (when **a** > 13.0cm for 10cm specimen or **a** > 20.0cm for 15.0cm specimen)

Or

$\mathbf{F_b = 3pa/bd^2}$ (when **a** < 13.3 cm but > 11.0cm for 10.0cm specimen or **a** < 20.0cm but > 17.0 for 15.0cm specimen)

Where,

a is the distance between the nearer support and the line of fracture.

b is the width of specimen in cm.

d is the failure point depth in cm.

l is the supported length in cm.

p is the max. Load in kg.

SAFETY & PRECAUTIONS:

1. At the time of the test, use hand gloves.
2. Switch off the machine after the test.
3. Grease all the exposed metal parts.
4. To the base & top plate, keep the guide rods firmly fixed.
5. Before testing & after testing equipment should be cleaned.

PROBLEMS WITH FLEXURAL:

To specimen preparation, handling, and curing procedure flexural tests are extremely sensitive and beam specimens are very heavy and there will be yield lower strengths by allowing a beam to dry. Beams must be tested while wet and must be cured in a standard manner. A sharp drop in flexural strength is produced due to a short period of drying.

For control and acceptance of concrete, the concrete industry and inspection agencies are much more familiar with traditional cylinder compression tests and for design purposes flexural can be used.

FIG.9 FLEXURAL FAILURE OF BEAM

STRESS-STRAIN CURVE FOR CONCRETE

Stress strain curve of concrete is a graphical representation of concrete behavior under load. It is produced by plotting concrete compress strain at various interval of concrete compressive loading (stress). Concrete is mostly used in compression that is why its compressive stress strain curve is of major interest.

The stress and strain of concrete is obtained by testing concrete cylinder specimen at age of 28days, using compressive test machine. The stress strain curve of concrete allows designers and engineers to anticipate the behavior of concrete used in building constructions.

Finally, the **performance of concrete structure is controlled by the stress strain curve** relationship and the type of stress to which the concrete is subjected in the structure.

Stress-strain Curve for Concrete

Fig. 10 and Fig. 11 shows strain stress curve for normal weight and lightweight concrete, respectively. There is a set of curves on each figure which represents the strength of the concrete. So, higher curves show higher concrete strength. Fig. 12 shows how the shape of concrete stress strain curve changes based on the speed of loading.

Despite the fact that, speed of testing and concrete density influences the shape of the stress-strain curve, but it can be noticed that, all curves show nearly the same character. i.e. they undergo the same stages under loading. Various portions of concrete stress stain curve are discussed below:

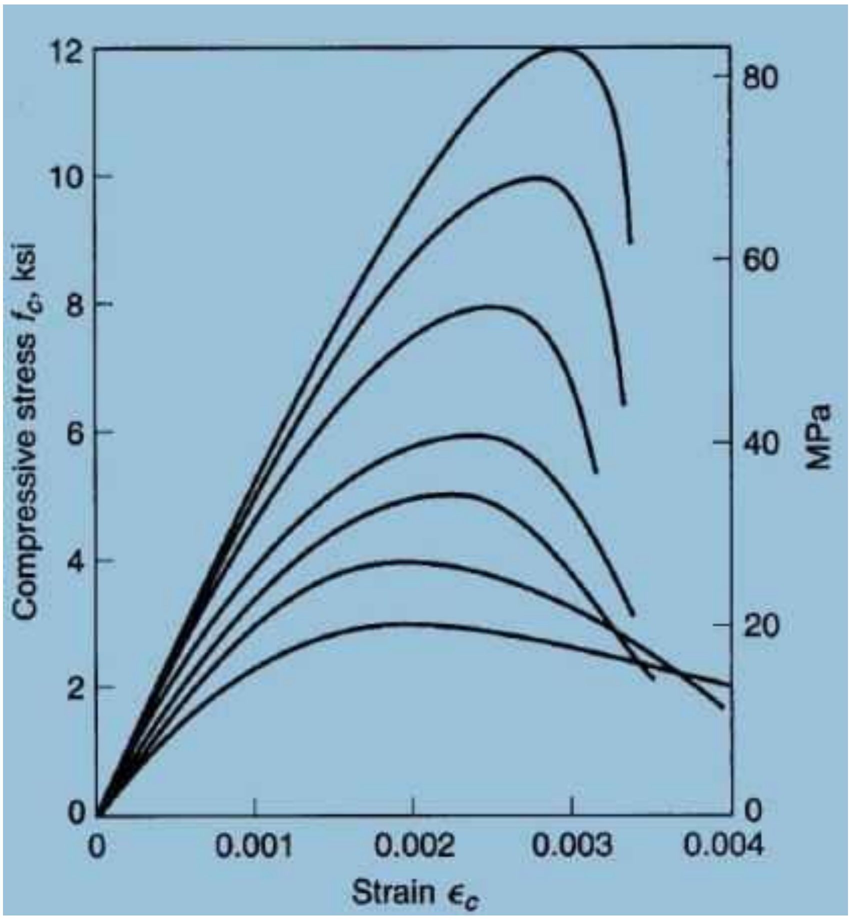


FIG.10 STRESS STRAIN CURVE FOR NORMAL DENSITY CONCRETE

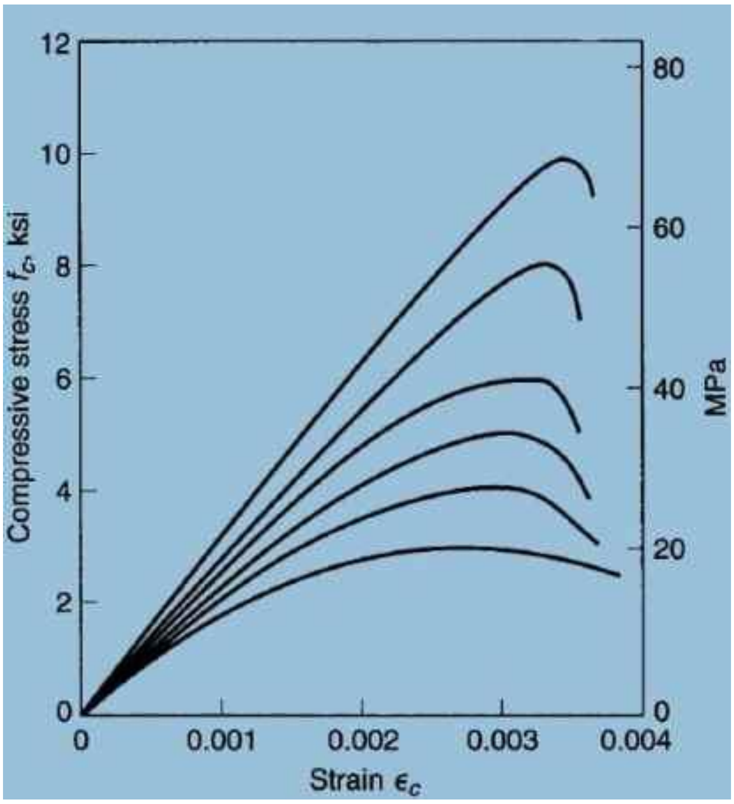


FIG.11 STRESS STRAIN CURVE FOR LIGHT WEIGHT CONCRETE

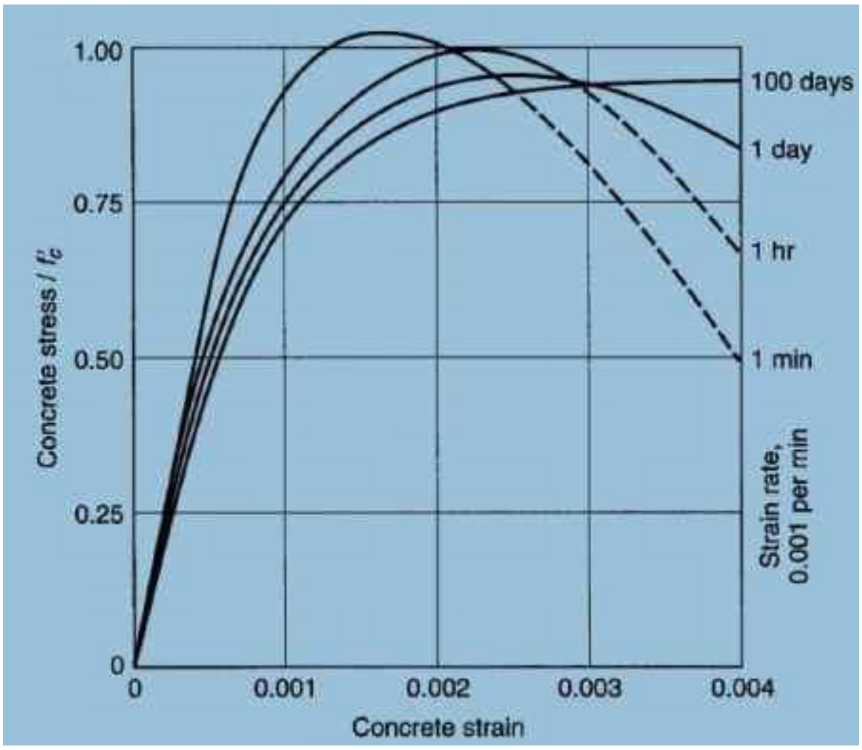


Fig.12 Stress Strain Curve of Concrete Varies Based on Speed of Testing

1. Straight or Elastic Portion

Initially, all stress strain curves (Fig.10 and Fig.11) are fairly straight; stress and strain are proportional. With this stage, the material should be able to retain its original shape if the load is removed. The elastic range of concrete stress strain curve continues up to 0.45fc' (maximum concrete compressive strength).

The slope of elastic part of stress strain curve is concrete modulus of elasticity. The modulus of elasticity of concrete increases as its strength is increased. ACI Code provides equations for computing concrete modulus of elasticity.

2. Peak Point or Maximum Compress Stress Point

The elastic range is exceeded and concrete begin to show plastic behavior (Nonlinear), when a load is further increased. After elastic range, the curve starts to horizontal; reaching maximum compress stress (maximum compressive strength).

For normal weight concrete, the maximum stress is realized at compressive strain ranges from 0.002 to 0.003. however, for lightweight concrete, the maximum stress reached at strain ranges from 0.003 to 0. 0035.The higher results of strain in both curves represent larger strength.

For normal weight concrete, the ACI Code specified that, a strain of 0.003 is maximum strain that concrete can reach and this value used for design of concrete structural element. However, the European Code assumes concrete can reach a strain of 0.0035, and hence this value is used for the design of concrete structural element.

3. Descending Portion

After reaching maximum stress, all the curves show descending trend. The characteristics of the stress strain curve in descending part is based on the method of testing.

Long stable descending part is achieved if special testing procedure is employed to guarantee a constant strain rate while cylinder resistance is decreasing. However, if special testing procedure is not followed, then unloading after peak point would be quick and the descending portion of the curve would not be the same.

MODULUS OF ELASTICITY OF CONCRETE

What is the Modulus of Elasticity?

Modulus of elasticity (also known as **elastic modulus**, the **coefficient of elasticity**) of a material is a number which is defined by the **ratio of the applied stress to the corresponding strain within the elastic limit**. Physically it **indicates a material's resistance to being deformed when a stress is applied** to it. Modulus of elasticity also **indicates the stiffness of a material**. Value of elastic modulus is higher for the stiffer materials.

Modulus of Elasticity, E=fs Modulus of Elasticity, E=fs

Here, f= applied stress on a body
s= strain to correspond to the applied stress

FIG.13 DETERMINING MODULUS OF ELASTICITY OF CONCRETE.

Source: http://civilarc.com

Units of elastic modulus are followings:

- In SI unit MPa or N/mm^2 or KN/m^2.
- In FPS unit psi or ksi or psf or ksf.

Modulus of Elasticity of Concrete

Modulus of Elasticity of Concrete can be **defined as the slope of the line drawn from stress of zero to a compressive stress of** 0.45**f'**$_c$. As concrete is a **heterogeneous material**. The strength of concrete is dependent on the relative proportion and modulus of elasticity of the aggregate.

To know the accurate value of elastic modulus of a concrete batch, laboratory test can be done. Also, there are some empirical formulas provided by different code to obtain the elastic modulus of Concrete. These formulas are **based on**

the relationship between modulus of elasticity and concrete compressive strength. One can easily obtain an approximate value of modulus of elasticity of concrete using 28 days concrete strength (f'_c) with these formulas.

Elastic Modulus of Concrete from ACI Code

Different codes have prescribed some empirical relations to determine the Modulus of Elasticity of Concrete. Few of them are given below.

According to ACI 318-08 section 8.5,

Modulus of elasticity for concrete,

Ec=w1.50c×0.043√$\boxed{f'c}$MPaEc=wc1.50×0.043fc′MPa

This formula is valid for values of w_c between 1440 and 2560 kg/m^3.

For normal-weight concrete,

Ec=4700√$\boxed{f'c}$MPa(inFPSunitEc=57000√$\boxed{f'c}$psi)Ec=4700fc′MPa(inFPSunitEc=57000fc′psi)

Elastic Modulus of Concrete from BNBC

According to BNBC 2006 section 5.13.2.1,

For stone aggregate concrete,

Ec=44 w1.50c√$\boxed{f'c}$N/mm2Ec=44 wc1.50fc′N/mm2

When w_c between 15 and 25 kN/m^3 and $\sqrt{f'_c}$ in N/mm^2.

Ec=4700√$\boxed{f'c}$N/mm2Ec=4700fc′N/mm2

For normal density concrete

For brick aggregate concrete,

Ec=3750√$\boxed{f'c}$N/mm2

DURABILITY OF CONCRETE

FIG.14 NON DURABLE CONCRETE

Definition

The **ability of concrete** to withstand the conditions for which it is designed **without deterioration for a long period** of years is known as durability.

OR

Durability of concrete may be defined as the **ability of concrete to resist weathering action, chemical attack, and abrasion** while maintaining its desired engineering properties.

Durability is defined as the capability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. It normally refers to the duration or **life span of trouble-free performance.** Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than indoor concrete.

Concrete will remain durable if:

- The cement paste structure is **dense and of low permeability**
- Under extreme condition, it has entrained air to **resist freeze-thaw cycle**.
- It is made with graded **aggregate** that are **strong and inert**

- The ingredients in the mix contain minimum impurities such as alkalis, Chlorides, sulphates and silt

Durability of Concrete depends upon the following **factors**

- **Cement content**

Mix must be designed to ensure cohesion and **prevent segregation and bleeding.** If cement is reduced, then at fixed w/c ratio the workability will be reduced leading to inadequate compaction. However, if water is added to improve workability, water/cement ratio increases and resulting in highly permeable material.

- **Compaction**

The concrete as a whole contain voids can be caused by inadequate compaction. Usually it is being governed by the compaction equipments used, type of formworks, and density of the steelwork

- **Curing**

It is very important to permit proper strength development aid moisture retention and to ensure hydration process occur completely.

- **Cover**

Thickness of concrete cover must follow the limits set in codes

- **Permeability**

It is considered the most important factor for durability. It can be noticed that higher permeability is usually caused by higher porosity. Therefore, a proper curing, sufficient cement, proper compaction and suitable concrete cover could provide a low permeability concrete

TYPES OF DURABILITY

Physical durability of concrete
Chemical durability of concrete

Physical Durability

Physical durability is against the following actions

1. **Freezing** and thawing action
2. Percolation / **Permeability** of water
3. Temperature stresses i.e. **high heat** of hydration

Chemical Durability

Chemical durability is against the following actions

1. Alkali Aggregate Reaction
2. Sulphate Attack
3. Chloride Ingress
4. Delay Ettringite Formation
5. Corrosion of reinforcement

1. External Causes:

1. Extreme Weathering Conditions
2. Extreme Temperature
3. Extreme Humidity
4. Abrasion
5. Electrolytic Action
6. Attack by a natural or industrial liquids or gases

2. Internal Causes

a) Physical

- Volume change due to difference in thermal properties of aggregates and cement paste
- Frost Action

b) Chemical

- Alkali Aggregate Reactions

  i. Alkali Silica Reaction

  ii. Alkali Silicate Reaction

  iii. Alkali Carbonate Reaction

- Corrosion of Steel

REF: https://youtu.be/3WKx9NZKkVQ

(NPTEL IIT DELHI 58 SEC)

WATER ABSORPTION OF CONCRETE

What is water absorption?

The water absorption by immersion gives an estimation of the total (reachable) pore volume of the concrete, but gives no indication on the concrete permeability, which is more important with regard to durability.

The water absorption of concrete mixes is the fundamental and important property which depicts the state of the pore size distribution of concrete and **is a measure of its durability.** The density of concrete is mainly dependent on its unit weight hence; both the terms are often mixed and are used in the same meanings

The water absorption test determines the water absorption rate (absorptivity) of both the outer and inner concrete surfaces. The test involves the measurement of the increase of mass of concrete samples resulting from the absorption of water as a function of time when only one face of the specimen is exposed to water.

The concrete specimens are either taken from drilled cores or molded in cylinders. The samples should be saturated and weighted before the test. The absorption can be estimated at different distances from the exposed surface.

Factors Influencing Water Absorption of Concrete

1. Concrete mix proportions.
2. Chemical admixtures and supplementary cementitious materials in the concrete.
3. Composition and physical properties of the cementitious component and the aggregates
4. Entrained air content
5. Type and duration of curing
6. Degree of hydration
7. Presence of microcracks
8. Concrete surface treatments such as sealers or form oil
9. Placement method, including consolidation and finishing.

10. Concrete moisture condition at the time of testing.

Purpose

The water absorption test aims to determine the rate of water absorption by hydraulic cement concrete.

Tools and Materials

1. Pan
2. Support device, rods, pins, or other devices
3. Top-pan balance, accurate to at least ±0.01 g
4. Timing device
5. Paper towel or cloth
6. Environmental chamber
7. Polyethylene storage containers
8. Caliper
9. Sealing materials like duct tape or aluminum tape
10. Plastic bag or sheeting

Concrete Sample Preparation

1. Concrete specimens are either drilled cores or molded cylinders. They should be 100 ±6 mm in diameter and with a length of 50 ±3 mm.
2. The test result is equal to the average test result of a minimum of two samples. The test surfaces should be at the same distance from the original exposed surface of the concrete.
3. Vacuum saturate the drilled core specimens obtained from the field.
4. After that, measure the mass of each test specimen to the nearest 0.01 g.
5. Put test samples in the environmental chamber at a temperature of 50 ± 2 degrees and RH of 80 ±3 % for three days.
6. After that, put each specimen in a sealable container, leave a small space between the sample and container wall to allow free airflow around the specimen.
7. Store the container at 23 ±2 degrees for a minimum of 15 days at the start of the absorption test.

8. Conduct the absorption procedure at 23 ±2 degrees with tap water conditioned to the same temperature.

Vacuum-saturation Procedure

1. Place specimen directly in vacuum desiccator. Both end faces of the sample must be exposed.
2. Seal desiccator and start the vacuum pump and maintain it for three hours.
3. Fill separatory funnel with the de-aerated water.
4. With vacuum pump still running, open water stopcock and drain sufficient water into the container to cover the specimen.
5. Close water stopcock and allow the vacuum pump to run for one additional hour.
6. Close vacuum line stopcock, and then turn off the pump.
7. Turn vacuum line stopcock to allow air to re-enter desiccator.
8. Soak specimen underwater in the beaker for 18 ± 2 hours.

Water Absorption Test Procedure

1. Take out specimens from the storage container and weigh them to the nearest of 0.01 g.
2. Measure a minimum of four diameters of the specimen at the surface to be exposed to water and calculate the specimen's average diameter.
3. Seal the side surface of specimens with suitable seal material, and seal one end that is not exposed to water with a plastic sheet that can be secured using an elastic band or other equivalent systems.
4. Weigh the sealed specimen and record it as the initial mass.
5. Place specimen support at the pan's bottom and pour tap water into the pan until it rises nearly 3 mm above the specimen supports, see Figure 15. This level of water in the pan needs to be maintained during the test.
6. Start the timing device and put the unsealed surface of the specimen on the supports in the pan. Write the time and date of the initial contact of the sample with the water.
7. Record the mass of the specimen after first contact according to the time interval provided in Table 2.

8. For each record of a mass, remove the concrete specimen from the pan. Then, stop the timing device if the contact time is less than 10 minutes, and wipe out any surface water with dampened paper or cloth. Invert the specimen so that the wet surface does not contact the balance pan. Measure the mass within 15 seconds of specimen removal from the pan. Finally, place the specimen on the support in the pan and restart the timing device.

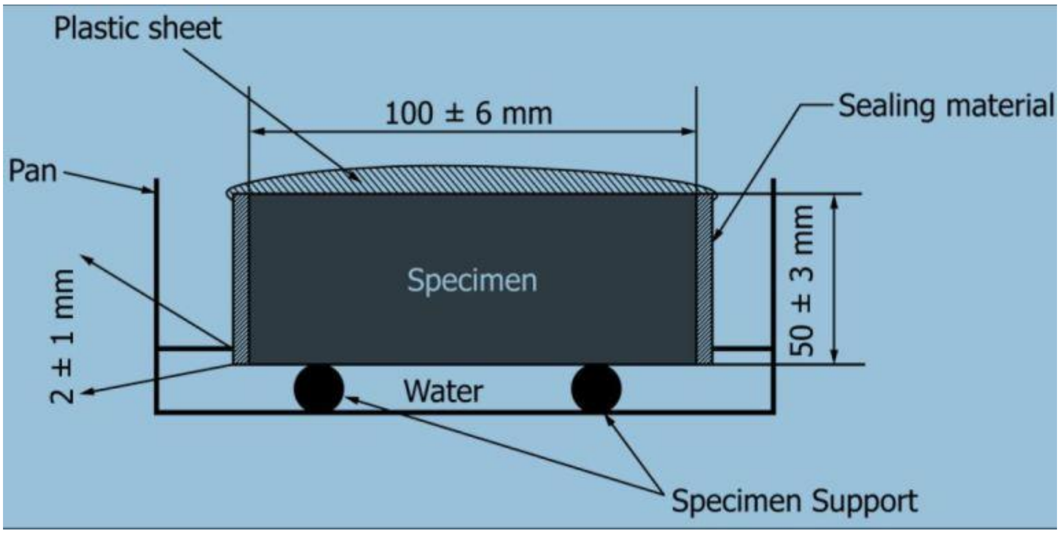


FIG.15 SCHEMATIC REPRESENTATION OF ABSORPTION TEST

TABLE 2 TIME INTERVAL FOR RECORDING THE MASS OF CONCRETE SPECIMEN

Time interval	**Tolerances**
60 second	2 second
5 minutes	10 second
10 minutes	2 minutes
20 minutes	2 minutes
30 minutes	2 minutes
60 minutes	2 minutes
Every hour up to 6 hours	5 minutes
Once a day up to 3 days	2 hours

Day 4 to 7 3 measurements 24 hours apart	2 hours
Day 7 to 9 One measurement	2 hours

Calculations

The following expression can be used to compute the absorption rate of concrete:

Absorption (I)= m_t/ (a*d) Equation 1

Where:

m_t: the change in specimen mass in grams, at the time t,
a: exposed area of the specimen, mm^2
d: density of the water, g/mm^3
As shown in Figure 16, the initial rate of water absorption is the slope of the line that is the best fit to I plotted against the square root of time using all the points from 1 minute to 6 hours.
The secondary rate of water absorption is the slope of the line that is the best fit to I plotted against the square root of time using all the points from 1 day to 7 days.

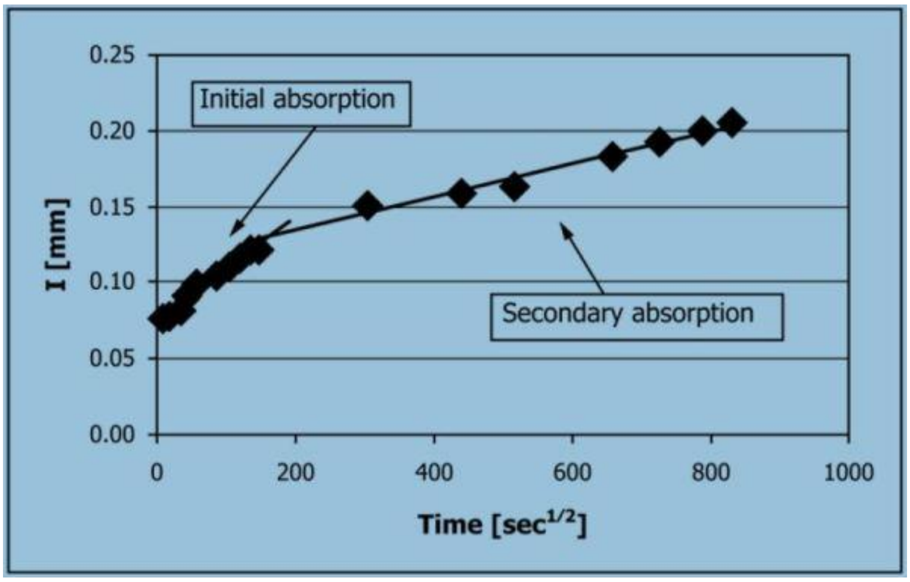


FIG.16 INITIAL ABSORPTION RATE AND SECONDARY ABSORPTION OF CONCRETE

What is water absorption rate test (sorptivity test) of hydraulic-cement concrete?

It is a test method by which the rate of absorption (sorptivity) of water by hydraulic cement concrete is estimated by measuring the increase of mass of the specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water.

How do you calculate the water absorption rate of concrete?

The water absorption rate of concrete is equal to the change in mass of concrete specimen divided by area of the sample exposed to water times the density of water.

What are the factors influencing water absorption of concrete?

1. Concrete mixture proportions
2. Entrained air
3. Moisture condition of the concrete
4. Type and duration of curing
5. Composition and physical properties of cement materials and aggregate
6. Chemical admixtures and supplementary cementitious materials in conrete
7. Concrete surface treatment like sealers
8. Presence of microcracks
9. Concrete placement method, including compaction and finishing
10. Degree of cement hydration

PERMEABILITY OF CONCRETE

The Permeability of Concrete:

Porosity:

Every material either it may be sand, soil, cement, etc. has pores, which contains voids in it. Porosity is an intrinsic property of the material measured concerning the amount of **void space** as a percentage of total volume. It is generally expressed as a percentage between 0% to 100%

Permeability of Concrete:-

Concrete is a composite material comprising of Cement, Sand & coarse aggregate. Every material has pores, which contains voids in it. Aggregates have a more substantial void ranging from 1mm to 10mm which cement paste fills these. Even cement has voids ranging from 1micron to 10micron. Due to this interconnected and continuous link to fill one void by other material concrete is prone to permeate fluid or gases into it.

or

In simple words, **Presence of voids in concrete makes permeable** which in turn allows water or gas to flow into it. The permeability of concrete is the ability of concrete to resist the water flow or any other substance into it when the external force is applied.

Why the Permeability of Concrete is Important?

Durability of concrete is most important and complex property of concrete. If concrete is permeable, Deleterious materials like water, CO_2, SO_2 & Cl which permeates through the pores of the concrete and reacts with the reinforcement forms rust which increases the volume of the reinforcement and damages the structure. Prior understanding of the extent and rate of permeation helps to design structure better.

Take an example of a dam; We know that Dam is made of concrete. In monsoon season, the rate of flow of water is increased. When the water pressure is applied from one side of the dam, it resists the flow of water to the other side due to the impermeable nature of concrete. If the concrete is permeable and allows water into it, the reinforcement present in concrete is prone to corrosion and forms rust (increases volume of reinforcement) which ultimately leads to surface cracking and collapse.

Factors affecting the Concrete Permeability :

1. Water-Cement ratio:

Excessive water is added to the concrete mix to increase the workability of concrete. This additional mixing of water, more than required increases the porosity in concrete and degrades the durability of concrete. To resist the entry of water into the concrete 0.4 water-cement ratio is adopted. Experiments proved that taking a water-cement ratio of 0.4 makes concrete impermeable.

2. Improper compaction of concrete:

Improper compaction in concrete is the major problem for porosity in concrete. Concrete should be adequately compacted using hand compaction method or machine compaction methods. Poorly compacted concrete leads to the formation of honeycomb which ultimately makes steel to corrode and forms surface cracks.

3. Improper Curing:

Concrete should be adequately cured by considering the atmospheric weather. Improper curing in concrete leads to the formation of cracks and in turn, it increases the permeability of concrete.

Two Different purposes to check the Permeability of concrete:-

1. Measuring the Permeability of concrete as a quality control parameter: To assess and study the property of the material that we are using or going to use. Suppose we need a zero permeable concrete for construction. After investigating we found that there is a 2% of porosity, then we dismiss the concrete for construction as it is not as per specifications.

2. Evaluating the permeability of already laid concrete structure: As an engineer, we often check the Permeability property of concrete of older monuments or existing structures. This type of measuring requires a Non-destructive test as cutting concrete from the structure is not possible

Permeability test of concrete:

This test is more important in RCC as we know that reinforcement is prone to corrosion when it reacts with the water, which in turn forms a layer around the reinforcement and causes an increase in the volume of concrete which ultimately leads to surface cracking. To resist the reinforcement to corrode, the concrete is set to permeable and Permeability test of concrete tests the same. Not only the water or moisture there are other atmospheric deleterious materials which ingress with reinforced concrete leads to corrosion of steel.

There are **different methods** to measure the Concrete Permeability out of them below mentioned tests are most commonly used

1. Rapid Chloride Permeability Test
2. Water Permeability by pressure
3. Ponding with a salt solution

1. Rapid Chloride Permeability test [RCP Test]:

For Specifications and the quality control purposes on site, we prefer a test that is simple to conduct and that can be performed in a short time. The rapid chloride permeability test [RCPT] meets these goals.

Rapid Chloride Permeability test is covered by **AASHTO T 277 or ASTM C 1202** it is the test for chloride ions**.** As the name it proves that, this test is performed to check the **Concrete's Ability to Resist Chloride Ion Penetration.**

This test is an Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration. This test enables to predict the service life of concrete structures. It can also be used for durability-based quality control purposes.

In this test, the constant voltage (V) is applied on a concrete specimen for 6 hours and the current (i) passing through the concrete is recorded to find the coulombs.

What is coulomb?

Current is measured in amperes. A coulomb is an ampere – second; which means 1 ampere passed through the concrete specimen in 1 second is a 1 coulomb, and the charge passed in 60 seconds would be 60 coulombs. The more permeable the concrete, the higher the coulombs; the less porous the concrete, the lower the coulombs.

Apparatus:

This test is made possible by an equipment which is known as Rapid Chloride Permeability test equipment, The test equipment consists of two reservoirs. One of them has 3.0% of NaCl solution and another reservoir has 0.3M NaOH Solution, Concrete having thickness 50mm and dia 90-100mm is used as a test specimen.

Look at the below image for more details:

FIG. 17 RAPID CHLORIDE PERMEABILITY TEST APPARATUS

Chloride test procedure:

1. The concrete specimen having dia 100mm and thickness 50mm is cast and saturated.

2. The concrete sample is placed in between the two reservoirs (which is called as a single cell) having NaCl solution in one reservoir and NaOH solution in the other.
3. These reservoirs are connected to DC supply and the voltage of 60V is applied to the concrete specimen at both the ends for 6 hours.
4. Now measure the current passing through the concrete at different time intervals.
5. The current passing through the concrete is determined by an LCD which is connected to the cell.

Formula of RCPT Test

$$Q = 900 [I_0 + 2I_{30} + 2I_{60} + 2I_{90} + 2I_{120} + ... + 2I_{330} + 2I_{360}$$

$Q \longrightarrow$ Current flowing through one cell (coulombs)

$I_0 \longrightarrow$ Initial Current reading in amperes immediately after voltage is applied

$I_t \longrightarrow$ Current reading in amperes at t minutes after the voltage is applied

For determining the accurate concrete permeability 2-3 samples are taken from same batch of concrete mix and measured as mentioned, the average value is taken as a final reading. Permeameter can have 2-3 cells with separate LCD digital meter to determine 2-3 samples at a time.

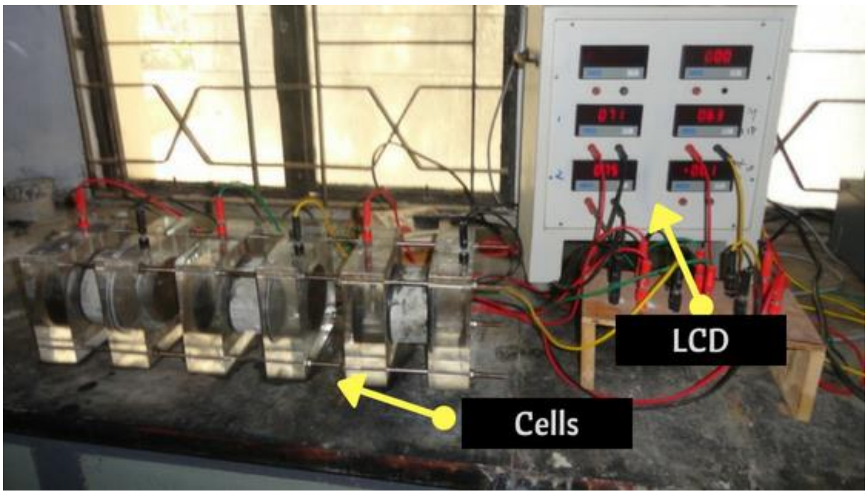


FIG. 18 RAPID CHLORIDE PERMEABILITY TEST SETUP

Table to interpret RCPT test Results:

The total charge passed is determined by the above mentioned formula and used to rate the concrete according to the below criteria.

TABLE 3 INTERPRETATION OF RCPT RESULT

Charge (Coulombs)	Chloride Permeability
>4000	High Permeable Concrete
2000 - 4000	Moderate
1000 - 2000	Low
100 - 1000	Very Low
<100	Negligible

2. Water Permeability test for concrete by Pressure:

This test is suited and applied to the concrete having high permeability. This test is also called as water penetration test of concrete.

As in the above test, we check the concrete permeability based on chloride penetration. This test is not suitable for concrete having low permeability and takes a lot of time for results.

This test is carried out using a disc of concrete and involves water flowing out through the disc at a steady rate.

Apparatus:

The concrete disc having a thickness of more than 20mm is cast and saturated. The apparatus consists of a permeameter and water collection jar. Look at the following image for more details.

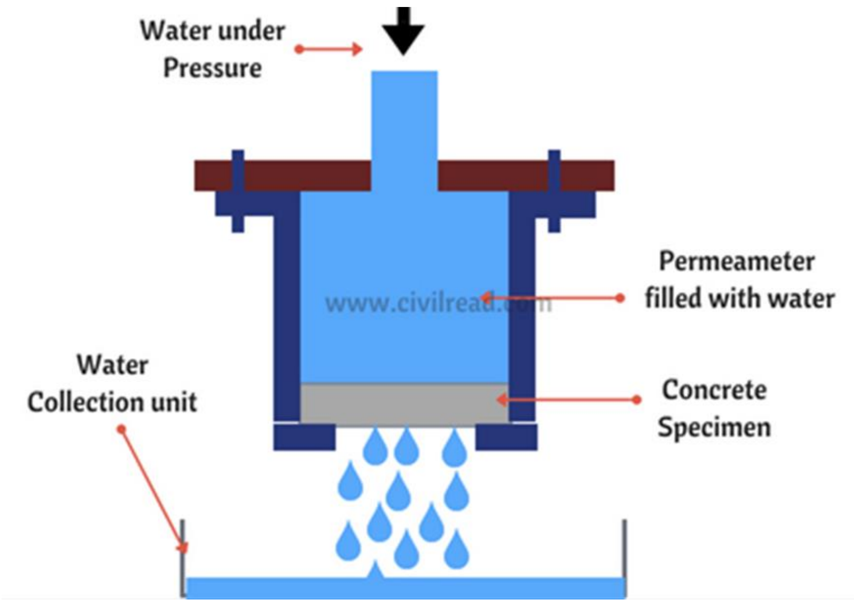


FIG. 19 WATER PERMEABILITY BY PRESSURE TEST APPARATUS

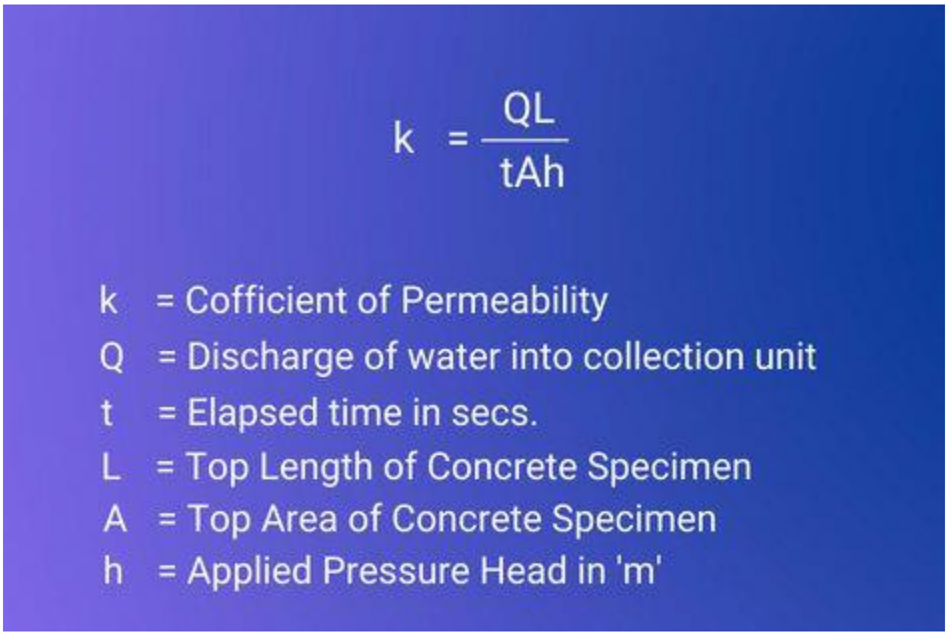
Procedure:

1. The concrete having a thickness more than 20mm is placed on permeameter.
2. And then the permeameter is filled with the water.
3. To find the permeability of concrete the water passing through the disc is collected at the water collection unit.
4. To accelerate the process, the pressure is applied to the water from the top.

Formula for Water Permeability by pressure test:

Coefficient of Permiability "k" is calculated by using the below formula:-

FIG. 20 WATER PERMEABILITY BY PRESSURE TEST SETUP



3. Salt Ponding test:

This test is first covered by **AASHTO T259**. This test measures the resistance of concrete to chloride ion penetration. The penetration of chlorides into concrete is very severe when compared with the other deleterious substances. This bought attention to most of the researchers to find the permeability of concrete based on chlorides compared to other mechanisms. This test is used as a specification writing.

In this test, the concrete sample is sealed on sides and the 3.0% NaCl Solution is ponded above the surface of the concrete.

Apparatus:Concrete sample (300mmx300mmx75mm), NaCl Solution

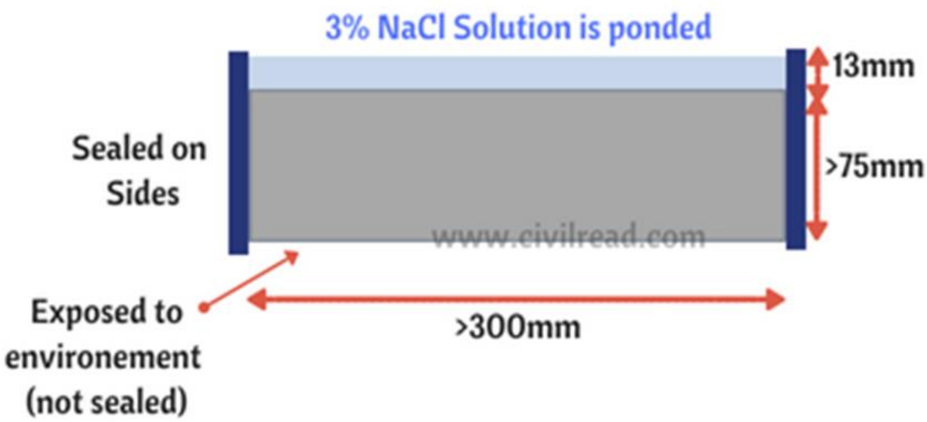


FIG. 21 SALT PONDING TEST APPARATUS

Procedure for Salt Ponding test:

1. This test requires a large sample of concrete when compared with the other tests. 3 concrete slabs of length & breadth 300mm x 300mm and thickness 75mm are cast and cured for 14 days and kept in the drying room for 28 days with a 50% relative humidity environment before conducting the test.
2. Each concrete slab is sealed on both sides and 3% of NaCl Solution is ponded on the top surface for 90days.
3. The bottom face of the concrete slab is left exposed to the drying environment.
4. The specimens are maintained with a constant amount of chloride solution at top surface for 90 days.

After completion of 90 days, the specimen is sliced as a layers having thickness 12mm each which means each specimen is cut into 6 segments.

.

FIG. 21 SALT PONDING TEST SETUP

Results:

If the concrete is impervious the chloride penetration in the layers is zero. If the concrete is more permeable then chlorides may penetrate up to the second or third layer from top.

As mentioned, this test is used as a specification writing where you can choose the strength of concrete based on the chloride penetration. Suppose, if you want an excellent impervious concrete you may write specification as Chloride penetration up to a layer 1

CORROSION TEST ON CONCRETE

Definition - What does Concrete Corrosion mean?

Concrete corrosion is the chemical, colloidal or **physicochemical deterioration** and **disintegration of solid concrete** components and structures, due to attack by reactive liquids and gases.

This type of corrosion **causes** widespread **damage to** critical sewage **pipelines**, **bridges** and other critical assets made of concrete. Coatings and other **preventive measures** are used to combat this type of corrosion. Different types of cements and production techniques are being developed to monitor and minimize damage.

Corrosionpedia explains Concrete Corrosion

While concrete structures are corroded by chemical reaction, the steel **reinforcement** in many of these structures **is corroded by electrochemical** reaction.

Concrete corrosion is mainly **caused by**:

- **Salt water** or acidic ground water
- Microbes in **sewer** pipes
- Sulphates
- Chlorides
- Nitrates
- Fluorides
- Sulphides
- Industrial waste like slag and **corrosive gases**

Preventive measures include:

- **Paint** application such as **varnish, oil** or lacquer-based paint
- Surface treatment
- Appropriate choice of cement mix and **chemicals** during cement production
- Action to **prevent** attack of corrosive **water** or other liquids **and gases**

Biological sulfuric acid attack is a chronic problem in sewage pipes, leading to rapid deterioration of concrete. Because of the role of bacteria in the corrosion reaction, mechanical engineers have focused on the study of corrosion resistance of different concrete mixes in an effort to prevent this type of corrosion.

ACID RESISTANCE ON CONCRETE

Acid Attack on Concrete

FIG. 22 ACID ATTACK ON CONCRETE

Definition:

Ordinary Portland Cement (**OPC**) is highly **alkaline** in nature with **pH** values above **12**. When the cement paste comes into contact with the acids its components break down, this phenomenon is known as acid attack.

If pH decreases to values lower than stability limits of cement hydrates, then the corresponding hydrate loses calcium and decomposes to amorphous hydrogel. The final reaction products of acid attack are the corresponding calcium salts of the acid as well as hydrogels of silicium, aluminum, and ferric oxides.

When acid attacks concrete it dissolves both hydrated and un-hydrated cement compounds as well as calcareous aggregates. In many of the cases the chemical reaction results in water soluble calcium compounds which are leached away. Concrete vulnerability to acid attack increases as the pH of the acid in contact decreases from 6.5. Degree of aggression is **Slight** for pH: **6.5** to **5.5**, **Severe** for pH: **5.5** to **4.5** and **Very Severe** for pH less than **4.5**.

Note that the aggression of the **acid attack is** not only **because of** its **pH value** but also due to the **presence of CO_2** in relation with the hardness of water.

Effect of Sulphuric Acid on Concrete:

Sulphuric acid attack causes extensive formation of gypsum in the regions close to the surfaces, and tends to cause disintegration and mechanical stresses which ultimately lead to spalling and exposure of the fresh interior surface. Normally, the chemical changes of the cement matrix are restricted to the regions close to the surfaces because of less penetration of the Sulfuric acid in concrete.

However, in some cases it is observed that scaling and softening of the concrete occurs due to the early decomposition of calcium hydroxide and the subsequent formation of large amount of gypsum. The chemical reactions involved in sulphuric acid attack on cement based materials can be given as follows:

$$Ca(OH)_2 + H_2SO_4 \Longrightarrow CaSO_4.2H_2O$$

$$3CaO.2SiO_2.3H_2O + H_2SO_4 \Longrightarrow CaSO_4.2H_2O + Si(OH)_4$$

Effect of Nitric Acid on Concrete

Nitric acid usually occurs in chemical plants producing explosives, artificial manure and other similar products. Nitric acid can be formed from the compounds and radicals of nitrates in the presence of water

$$3NO_2 + H_2O \Longrightarrow 2HNO_3 + NO$$

Though HNO_3 is not as strong as H_2SO_4, its effect on concrete at brief exposure is more destructive since it transforms CH into highly soluble calcium nitrate salt and low soluble calcium nitro-aluminate hydrate.

Nitric acid attack is a typical acidic corrosion for shrinkage of the corroded layer due to leaching of highly soluble calcium nitrate. Such volume contractions of the corroded layer, especially for the case of nitric acid, can result in the formation of visually observable cracks across the corroded layer. In the presence of these cracks the transport rate of acid and corrosion products to and from the corrosion front increases and this accelerates the process of deterioration.

Effect of Acetic Acid on Concrete

Concrete in use in agricultural applications may be attacked by the silage effluents containing mainly acetic and lactic acid. Acetic acid reacts with cement hydration products to form calcium acetate

$$2CH_3COOH + Ca(OH)_2 ==> Ca(CH_3COO)_2 + 2H_2O$$

$$2CH_3COOH + C\text{-}S\text{-}H ==> SiO_2 + Ca(CH_3COO)_2 + 2H_2O$$

Attack by Acetic acid resembles the process of corrosion in nitric acid. However the growth of the corroded layer in solutions of acetic acid is relatively slower than that in the same concentrations of nitric acid solution. The chemical composition of the corroded layer is different from that in nitric acid solution of the same concentration due to higher pH values of the acetic acid solution, and due to its buffering effect in corroded layer.

In lower concentrations of both acetic and nitric acid solutions, e.g. 0.025 mol l^{-1}, results in the formation of an additional zone, called as core-layer, which is relatively hard and located behind the corroded layer.

Hydrochloric Acid Attack on Concrete

The chemicals formed as the products of reaction between hydrochloric acid and hydrated cement phases are some soluble salts and some insoluble salts. Soluble salts, mostly with calcium, are subsequently leached out, whereas insoluble salts along with amorphous hydrogels, remain in the corroded layer. Besides dissolution, the interaction between hydrogels may also result in the formation of some Fe-Si, Al-Si, Ca-Al-Si complexes which appear to be stable in pH range above 3.5.

$$Ca(OH)_2 + 2HCl ==> CaCl_2 + 2H_2O$$

The reaction essentially causes leaching of $Ca(OH)_2$ from the set cement.

Hydrochloric acid attack is a typical acidic corrosion which can be characterized by the formation of layer structure. Chandra divided the cross section of damaged prisms into three main zones; undamaged zone, hydroxide mixture zone or brown ring, and attacked zone. By hydroxide mixture zone, he referred to a layer formed by undissolved salts seen as a dark brown ring.

Carbonic acid attack

Carbonic acid attack usually occurs in the case of buried concrete structures exposed to acidic ground water fro a long time. Atmospheric carbon dioxide absorbed by rain enters ground water as carbonic acid. Factors affecting the rate of carbonic acid attack are;

- Quality of concrete
- Concentration of aggressive carbon dioxide
- External exposure conditions

When concrete is exposed to carbonic acid, a reaction producing carbonates take place which is accompanied by shrinkage. Limited carbonation of surface layer of concrete is known to seal the pores by forming calcium carbonate, which reduces the permeability and increases the strength of the carbonated layer. However, continued carbonation may cause a reduction in alkalinity of the cement paste which can be a serious problem not only in de-passivation and corrosion of steel bars but also in dissolution of cement hydrates.

Grube and Rechenberg described that continued carbonation due to carbonic acid attack causes:

The transformation of calcium carbonate into soluble bicarbonate which is removed by leaching into the acidic solution and thus increasing the porosity.

$$H_2CO_3 + Ca(OH)_2 ==> CaCO_3 + 2H_2O$$

$$H_2CO_3 + CaCO_3 ==> Ca(HCO)_3$$

Decomposition of cement hydration products, leading to formation of gel-like layer consisting of hydrogels of silica, alumina and ferric oxide.

Conclusions

- In the case of sulphuric acid attack, although the formation of gypsum has been reported frequently, there is no agreement on its consequences
- Attack by Acetic acid resembles the process of corrosion in nitric acid. However the growth of the corroded layer in solutions of acetic acid is

relatively slower than that in the same concentrations of nitric acid solution

- The chemical composition of the corroded layer is different from that in nitric acid solution of the same concentration due to higher pH values of the acetic acid solution
- Though HNO_3 is not as strong as H_2SO_4, its effect on concrete at brief exposure is more destructive
- Limited carbonation is found to be somewhat beneficial but continued carbonation reduces alkalinity of the cement paste which can be a serious problem not only in de-passivation and corrosion of steel bars but also in dissolution of cement hydrates

DESTRUCTIVE AND NON DESTRUCTIVE TEST ON CONCRETE.

Evaluation of the concrete quality using destructive and non- destructive tests (Jl paper, a case study)

Abstract

This work presents the results of an assessment carried out on the structure of a civil building to check the homogeneity of the concrete implementation. The determination of investigations of the structure was based on a preliminary study of documents and a preliminary visit of the book. Then a detailed visual inspection of the work was performed in which we achieved a record of disorders. These were qualified and quantified to the extent possible using auscultation devices and laboratory analysis. The profometer has been useful for the localization of reinforcements in concrete and the estimation of the thickness of coating. A Schmidt **Rebound Hammer was used to evaluate the quality and compressive strength of the concrete**. The **carbonation depth was determined by the phenolphthalein method.**

Keywords: auscultation, coating thickness, Profometer, schmidt rebound hammer, drilling cores, compressive strength test, carbonation depth

Introduction

Reinforced **concrete can deteriorate under** the influence of causes related to its original quality or to exploitation or **environmental stresses**. Apparent or hidden pathologies can occur. In order to know their nature, their extent and their evolution potential, a necessary diagnosis is made for taking decisions concerning the maintenance of the structure concerned. There are many methods or techniques of expertise that can help diagnose the main causes of deterioration, including non–destructive testing (**NDT**) that do not damage the buildings and allow contractors and building owners have an inventory of structures and pathologies. NDT such as the Schmidt **Rebound Hammer** have been widely applied to the study of mechanical properties and integrity of concrete structures. The results of these investigations are most often presented in the form of graphic plates: sections, maps of anomalies and interpreted measurement profiles. In this context, a great deal of research has been done to prove that the physical properties of concrete can be related to the compressive strength. In our study these auscultation techniques were adopted according to the type of disorders affecting the structure. Indeed, the profometer has been useful for the localization of reinforcements in concrete and the estimation of the thickness of coating. The **evaluation of the quality and strength of the concrete was determined using a Schmidt Rebound Hammer**; it is the most widely used instrument in the field of non–destructive testing of the compressive strength of concrete. This measurement technique is always approximate and is **limited to depths of about 8 cm** for surface measurements. The measurement of the carbonation depth was determined by the phenolphthalein method. The origin of the chemical disorders was determined by analyzes on two soil samples from the bottom of the excavations in order to assess their swelling abilities and their sulphate ion content.

Experimental study

Non–destructive tests

Measurement of the coating thickness of the concrete and location of the reinforcements by the profometer

The profometer is a light and compact metal r**einforcement** detector, uses non–destructive pulsed induction technology to allow the localization of metal reinforcement in concrete (Figure 23). It also makes it possible to estimate the coating thickness of the reinforcements. This test was performed on the specimens according to standards BS 1881, Part 204.[10]

FIG. 23 PROFOMETER ZIRCON MT 6 REBAR LOCATOR

The detection of metal frames and other metal building elements is not possible beyond 8 cm of concrete thickness. In the case of very dense reinforcement networks, reading is sometimes uncertain. The coating thickness is detected with an error of the order of 4mm, and the diameter of the steel with an accuracy of 2mm.

The **procedure** of the profometer Zircon MT 6 Rebar Locator is as follows:

1. Turn on the sound by placing the selector on either AUDIBLE or SILENCE. This is done in the air and away from any metal.
2. Clean the area to be scanned of any sand and pebble. If the surface is rough enough, slide a thin sheet of cardboard between the surface and the unit. The thickness of the cardboard must be deduced from the depth reading to determine the actual distance to the target using this method.
3. Place the profometer on the surface to be scanned and sweep from one side to the other. As you approach, the number of depth bars increases. At the nearest point of the metal, the plus sign toggles at least accompanied by a sound signal (in AUDIBLE mode)
4. Once a target has been located, reposition the sure–looking pro–sphere and scan it perpendicular to your original scan direction to be sure you have determined the target's importance.
5. Read the value of the coating thickness of each bar: this is the maximum value displayed on the depth bar.
6. Mark the location of the frames. The Crosshairs on the top of the device show where awareness is maximum.

Schmidt Rebound Hammer test

The Schmidt rebound hammer is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges (Figure 24). There is little apparent theoretical relationship between the strength of concrete and the rebound number RN of the hammer. This test was performed on the specimens according to standards EN 12504–2 and EN 12309–3. Schmidt rebound hammer test gave values of RN. The compressive strength of the concrete was derived using the chart provided with the device. No action has been located within 40 mm of the flat faces of the specimen. The hammer has to be used against a smooth surface, preferably a formed one. Open textured concrete cannot therefore be tested. If the surface is rough, e.g. a trowelled surface, it should be rubbed smooth with a carborundum stone. RN was equal to the median of 9 measures spread.

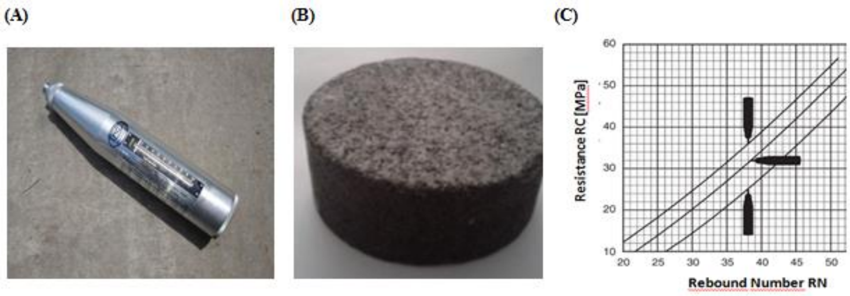


Fig.24 SCHMIDT REBOUND HAMMER TEST

A: Schmidt rebound hammer,

B: Carborundum stone,

C: Chart for determining the resistance as a function of RN.

DESTRUCTIVE TEST

Drilling cores from the hardened concrete

The hardened concrete cores were sampled according to standard NF EN 12504–1 using a core cutting machine (Figure 25). It is usually helpful to collect carrots not only in the most deteriorated areas but also in healthy areas. Comparative analysis of test results often helps to identify the causes of the damage. Core drilling should not affect the stability or structural strength of the structure. The positions of the reinforcements were detected before the coring using the profometer to avoid as much as possible to recover concrete specimens with reinforcements. The cores used to determine the compressive strength shall not contain any reinforcement parallel to their longitudinal axis. The diameter of core specimens for the determination of compressive strength in load bearing structural members shall be at least 3.94 mm. For non–load bearing structural members or when it is impossible to obtain cores with length–diameter ratio (L/D) greater than or equal to 1, core diameters less than 94 mm are not prohibited.

Fig.25 DRILLING OPERATIONS FROM HARDENED CONCRETE.
A: Core cutting machine;
B: Drilling operation;
C: Visual examination of cylindrical core specimen.

Compressive strength test

The compressive strength of core specimens was determined by destructive testing with a compression test machine according to the requirements of NF EN 12390–3. Progressive loading with a rate of 0.5 MPa/s was applied to the crushing of the specimen. The value of the compressive strength was determined by dividing the value of the maximum load by the section of the specimen. The core specimens were cut to reduce their slenderness to twice the diameter (Figure 26). If the slenderness (Ratio of Length to Diameter) of the core specimen is different from 2, the value of the compressive strength must be corrected by multiplying by the appropriate correction factors indicated in the Table 4.

TABLE 4 FACTOR OF CORRECTION OF THE COMPRESSIVE STRENGTH ACCORDING TO THE SLENDERNESS OF THE CORE SPECIMEN

Ratio of length to diameter (L/D)	Strength correction factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

FIG.26 COMPRESSIVE STRENGTH TEST OF CORE SPECIMEN

Measurement of hardened concrete carbonation depth

The measurement of the carbonation depth was determined by the phenolphthalein method according to BS EN 14630 on the cores removed. Phenolphthalein is a colored pH indicator whose turn is around 9. Phenolphthalein turns non–carbonated concrete red, and remains colourless in carbonated concrete.

The principle of the test consists in:

1. Slit the carrots along their longitudinal axis (if possible at mid–diameter of the carrot) (Figure 27A).
2. Spray the surfaces of the carrot with the phenolphthalein indicator solution (Figure 27B) to moisten them by ensuring that the spray does not run off the surface. When the concrete is very dry, a slight mist of water may be applied to the broken surface just before the phenolphthalein solution is applied.
3. Measure the carbonation depth d_k between the outer surface of the concrete and the edge of the colored region in red–purple and deduce the average carbonation depth d_{ka} (Figure 27C). The determination of depth of carbonation should be carried out immediately after collection

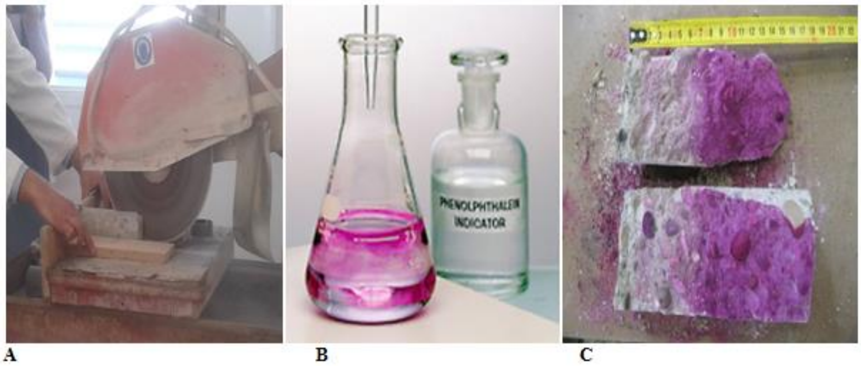


FIG. 27 MEASUREMENT OF HARDENED CONCRETE CARBONATION DEPTH.

Results and discussion

Measurement of the coating thickness of the concrete by the profometer

The tests were carried out on reinforced concrete elements such as columns, beams and stringers. Figure 28 gives the values of the coating thickness corresponding to the analysis points. According to the results, we note that the average value of the coating thickness measured on the different surfaces is equal to 23 mm which is in accordance with the requirements of standard BS EN 1992–1–1.

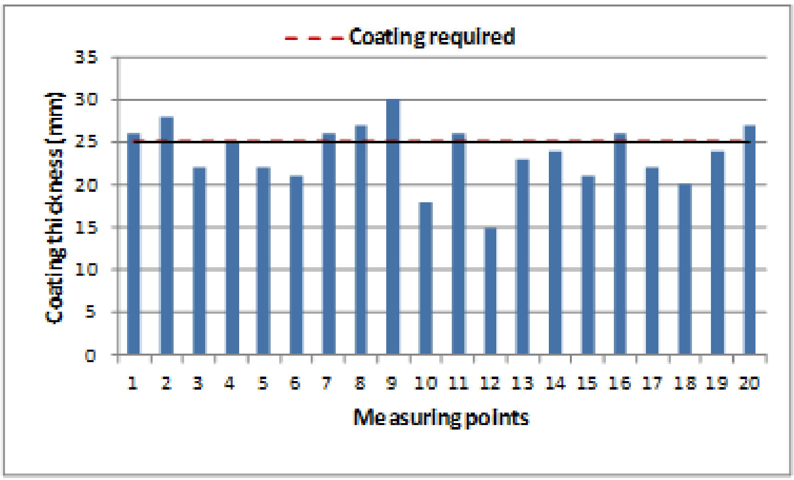


FIG.28 MEASUREMENT OF THE COATING THICKNESS OF THE CONCRETE.

Schmidt Rebound Hammer Test

The Schmidt rebound hammer test was carried out on reinforced concrete elements such as pre–columns, columns, footings, beams and stringers. The Schmidt Rebound Hammer gives indications only on concrete on the surface and not at heart. Measurements made on old concrete can be so distorted if the concrete is carbonated. Indeed, a carbonated concrete on the surface increases the superficial compactness and therefore the compressive strength determined by the Schmidt Rebound Hammer test. Figure 29 gives the values of the compressive strength deduced from the Schmidt Rebound Hammer test carried out on reinforced concrete elements. It is noted that the compressive strength values (between 09 MPa and 25.5 MPa) are lower than the average value required for concrete dosed at 350 Kg/m^3 at an age exceeding 28 days.

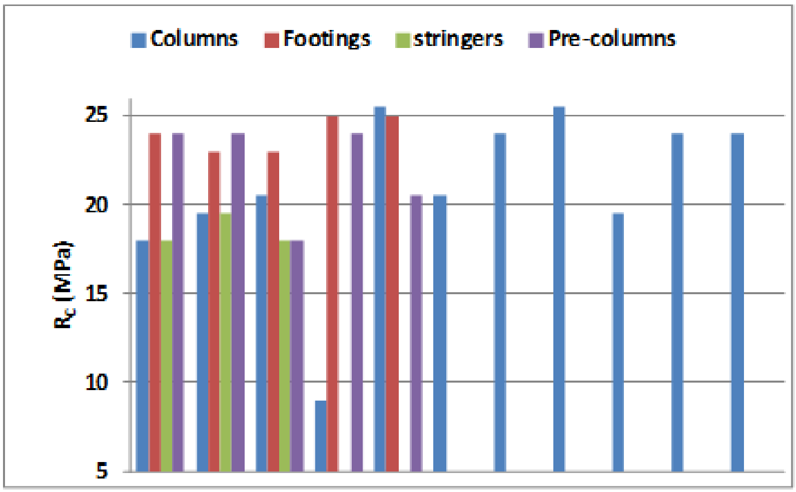


FIG.29 COMPRESSIVE STRENGTH OF REINFORCED CONCRETE ELEMENTS

Compressive strength test

Figure 30 gives the values of the compressive strength of eleven concrete cores taken from the footings, pre–columns and columns. We note that compressive strength values vary between 8.10 MPa and 27.40 MPa. The density of the different cores has been also measured; it is between 2.15 t/m^3 and 2.41 t/m^3. The different cores have an average resistance of 17 MPa lower than the average value required for a concrete dosed at 350 Kg/m^3 at an age exceeding 28 days.

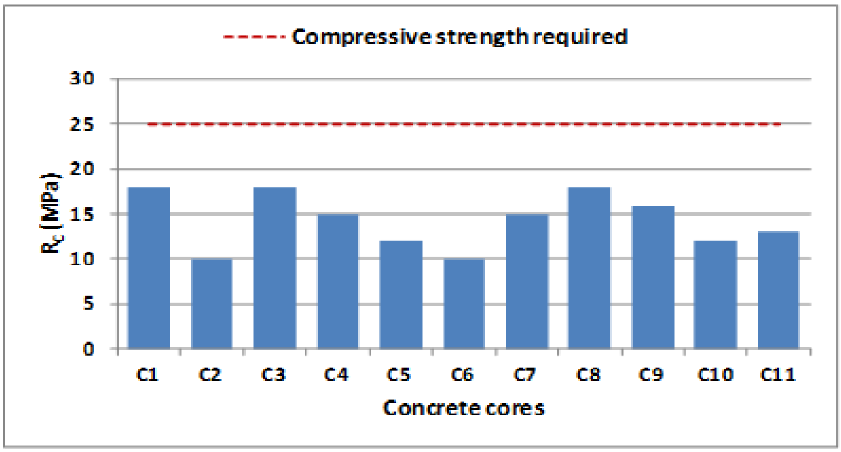


FIG.30 COMPRESSIVE STRENGTH OF REINFORCED CONCRETE CORES

Hardened concrete carbonation depth

Carbonation is a source of degradation of reinforced concrete structures, which affects their durability. This phenomenon leads to the de passivation of the reinforcements and their oxidation. This is why it is necessary to evaluate the stage of aging of a concrete with a view to its repair knowing until, at a given moment, the carbonation has penetrated, that is to say the limit of protection still existing relative to the locations of the frames. Figure 31 gives the values of the carbonation depth measured on the cores taken from the footings, pre–columns and columns. We note that the average carbonation depth is equal to 14.27 mm which is less than the value of the coating (23 mm). These results confirm that the reinforcements are sheltered from the carbonation phenomenon.

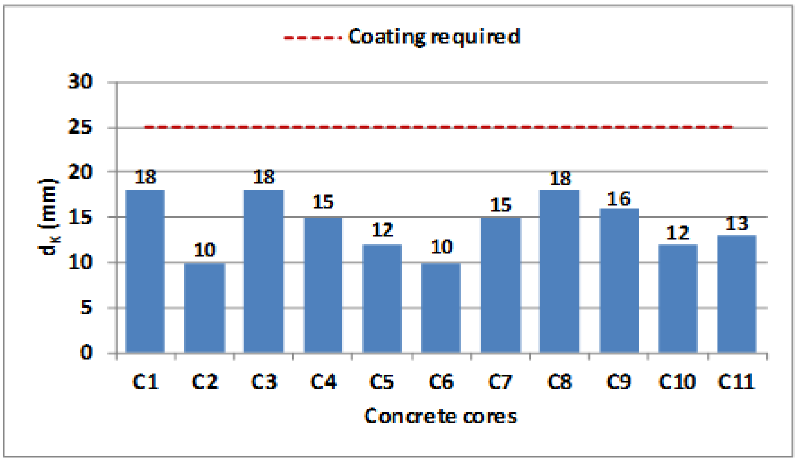


FIG.31 HARDENED CONCRETE CARBONATION DEPTH OF REINFORCED CONCRETE CORES

Inflation test and sulfate ion content SO_4^{2-}

The collection of two soil samples from the bottom of the excavations was carried out in order to assess their swelling abilities and their sulphate ion content. The chosen depth was about three meters. Table 5 illustrates the results for the two samples tested, it is noted that the average content of sulphate ions is equal to 1025 mg/l and the average water content is equal to 8.74%. These results confirm that the soil is non–swelling.

TABLE 5 RESULTS OF INFILTRATION AND SULFATE ION CONTENT SO_4^{2-} TESTS

Samples	Depth (m)	Water content (%)	Sulfate ion content SO42- (mg/l)
1	-2.5	8.53	1030
2	-3	8.96	1020

Conclusion

Through this work, it has been shown that the realization of a diagnosis is essential for the proper maintenance of buildings. Various auscultation techniques were discussed with their limitations and their use according to the disorders observed. The simplicity and speed of the test contrast with several drawbacks which can lead to misleading or useless results. The results of compressive strength deduced from Schmidt Rebound Hammer Test are significantly influenced by several factors.

The following conclusions can be drawn:

I. The profometer allowed the **localization of metal reinforcement** in the concrete and the estimation of the coating thickness. The combination of the results of the coating and carbonation measurements shows that there is no risk of development of a corrosion phenomenon since the thickness of the coating of the steels greatly exceeds the depth of carbonation.

II. **Concrete compressive strength deduced from Schmidt Rebound Hammer** Test on pre–columns, columns, footings and stringers show an average resistance of 18 MPa **lower than the average value required** for a concrete dosed at 350 Kg/m^3 at an age exceeding 28 days. This measurement technique is always approximate and is limited to depths of about 8 cm for surface measurements.

III. The **compressive strength deduced from the axial compression tests** on the concrete cores show an average resistance of 17 MPa **lower than the average value** required for a concrete dosed at 350 Kg/m^3 at an age exceeding 28 days.

IV. The values of the carbonation depth measured on the cores taken from footings, pre–columns and columns confirm that the reinforcements are sheltered from the carbonation phenomenon.

V. The **results of sulphate ion** content $SO4^{2-}$ and infiltration tests on soil samples from excavations confirm that the **soil is non–swelling**.

VI. Following these results, we note that the probable causes of the disorders are the differential settlements of the foundations caused by the infiltration of wastewater as well as the poor quality of the concrete recorded.

TEXT / REFERENCE BOOKS

1. Arora and Bindra, Building construction, Dhanpath Rai and Sons.
2. Punmia B.C., Building construction. Laxmi Publications.
3. Rangwala S.C., Engineering Materials, Charotar Publishers.
4. Shetty M.S., Concrete Technology, S. Chand & Company.
5. Sahu G.C. & Joygopal Jena., Building Materials and Construction, McGraw Hill Education.
6. Gambhir M.L., Concrete Technology, Tata McGraw Hill.
7. Krishna Raju N, Design of Concrete Mixes, CBS Publishers.
8. National Building Code.
9. Neville A.M. and Brooks.J.J, Concrete Technology, Pearson Education.

QUESTION BANK

PART A

1. List the Principles of Workability in concrete.
2. What is Segregation and Bleeding of concrete?
3. Determine the strength Properties of Hardened concrete.
4. What are the factors of durability of concrete?
5. Narrate the Principles of corrosion in steel.

PART B

1. Explain the Tests for workability of concrete.
2. Compile the Properties of Hardened concrete.
3. Narrate the destructive and non destructive test on concrete.
4. Narrate the tests on durability of concrete and water absorption.
5. Narrate the corrosion test and acid resistance test on concrete.

SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – V– CONCRETE AND CONSTRUCTION TECHNOLOGY - SCIA1201

UNIT 5

SPECIAL CONCRETES 8 Hrs.

Light weight concretes – foam concrete- self compacting concrete – vacuum concrete – High strength concrete – Fibre reinforced concrete – Ferrocement – Ready mix concrete – SIFCON – Shotcrete – Polymer concrete – High performance concrete – Geopolymer Concrete- Bio Concrete.

SPECIAL CONCRETES

Special types of concrete are those **with out-of-the-ordinary properties** or those **produced by unusual techniques**. Concrete is by definition a **composite material** consisting essentially of a binding medium and aggregate particles and it can take many forms.

These concretes do have advantages as well as disadvantages.

Types of Special Concrete

High Volume Fly Ash Concrete
Silica Fume Concrete
GGBS, Slag Based Concrete
Ternary Blend Concrete
Light Weight Concrete
Polymer Concrete
Self Compacting Concrete
Colored Concrete
Fiber-Reinforced Concrete
Previous Concrete
Water-Proof Concrete
Temperature Controlled Concrete

High Volume Fly Ash Concrete

- Is used to **replace** a portion of the Portland cement used in the mix.
- According to IS: 456-2000 replacement of **OPC** by Fly-ash up to **35%** as binding material is permitted.
- HVFAC is a concrete where excess of 35% of fly-ash is used as replacement.

Silica Fume Concrete

- Very fine non-crystalline silica produced in electric arc furnaces as a byproduct.
- Highly reactive Pozzolanic used to improve mortar and concrete.
- Silica fume in concrete produces two types of effect viz.

1. Physical Effect
2. Chemical Effect

GGBS, Slag based Concrete

- **By-product** of the **iron manufacturing** industry, replacement of Portland cement with GGBS will lead to significant reduction of carbon dioxide gas emission.
- GGBS powder is almost white in color in the dry state. Fresh GGBS concrete may show mottled green or bluish-green areas on the surface mainly due to the presence of a small amount of sulphate.
- Due to its **longer setting** time, it can be transported to distant places but care should be taken while casting because there are chances that bleeding may take place.

Ternary Blend Concrete

- Ternary concrete mixtures include **three different Cementitious** materials i.e. combinations of OPC, slag cement, and a third Cementitious material. The third component is often **fly ash**, but silica fume is also common.
- Other material in combination with Portland and slag cement, such as rice husk ash are not currently in common usage.

Light Weight Concrete

- Structural lightweight concrete is similar to normal weight concrete except that it has a **lower density**.
- Made with **lightweight aggregates**.
- Air-Dry d**ensity** in the range of **1350** to 1850 kg/m^3.
- **28 days compressive strength** in excess of **17** Mpa.

Polymer Concrete

- Polymer concrete is part of group of concretes that use **polymers** to supplement or **replace cement** as a binder. The tires include polymer-impregnated concrete, polymer concrete, and Polymer-Portland-Cement concrete.
- Polymer concrete may be used for new construction or repairing of old concrete.
- It can also be used as a **replacement for asphalt pavement**, for higher durability and higher strength.
- Polymer concrete is also composed of **aggregates** that include **silica, quartz, granite, limestone**, and other high quality material.

Self Compacting Concrete

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

Colored Concrete

- Colored concrete can be produced by using colored aggregates or by **adding color pigments** or both.
- It surfaces are to be washed with acid, a delay of approximately two weeks after costing is necessary.
- **Synthetic pigments** generally give more uniform results.
- The amount of color pigments added to a concrete mixture should not be more than **10%** of the mass of the cement.

Fiber Reinforced Concrete

- The role of randomly distributes **discontinuous fibers** is to bridge across the cracks that develop provides some post-cracking “**ductility**”.
- The real contribution of the fibers is to **increase** the **toughness** of the concrete under any type of loading.

- Fiber reinforced concrete may be defined as a **composite materials** made with Portland cement, aggregate, and incorporating discrete discontinuous fibers.

Previous Concrete

- **Low water-cement ratio**, low-slump concrete resembling popcorn held together by cement paste.
- Produces a concrete with a high volume of **voids** and a high permeability that allows water to flow through it easily.
- Previous concretes have also been used in tennis courts and greenhouses.

Previous Concrete

- **Low water-cement ratio**, low-slump concrete resembling popcorn held together by cement paste.
- Produces a concrete with a high volume of voids and a high permeability that allows water to flow through it easily.
- Previous concrete is used in hydraulic structures as drainage media, and in **parking lots, pavements**, and airport local groundwater supply by allowing water to penetrate the concrete to the ground below.

Water-Proof Concrete

- Top proof waterproof concrete contains two specially formulated admixtures. The first **reduces the water/cement ratio, increasing the density** of the mix and **minimizin**g the size of the **pores**. The second fills the remaining pores ensuring a completely watertight finish. This means there is no need for external membranes, reducing cost and labour.

Mass Concrete

- Mass concrete includes not only **low-cement** –content concrete used in dams and other massive structures but also moderate to high cement content concrete in structural members of bridge and buildings.
- As the interior concrete increases in temperature and expands, the surface concrete may be cooling and contracting.
- The width and depth of cracks depends upon the temperature differential, physical properties of the concrete, and the reinforcing steel.

LIGHT WEIGHT CONCRETES
REF: LIGHT WEIGHT CONCRETE MP4

What is Lightweight Concrete?
Lightweight concrete mixture is made with a **lightweight coarse aggregate** and sometimes a portion or entire fine aggregates may be lightweight instead of normal aggregates. Structural lightweight concrete has an in-place density (unit weight) on the order of **440 to 1840** kg/m³.

Normal weight concrete a **density** in the range of **2240** to 2400 kg/m³. For structural applications the concrete strength should be greater than 2500 psi (17.0 MPa).

Lightweight aggregates used in structural lightweight concrete are typically expanded **shale, clay or slate materials** that have been fired in a rotary kiln to develop a **porous structure**. Other products such as air-cooled blast furnace slag are also used.

There are other classes of non-structural LWC with lower density made with other aggregate materials and higher air voids in the cement paste matrix, such as in cellular concrete.

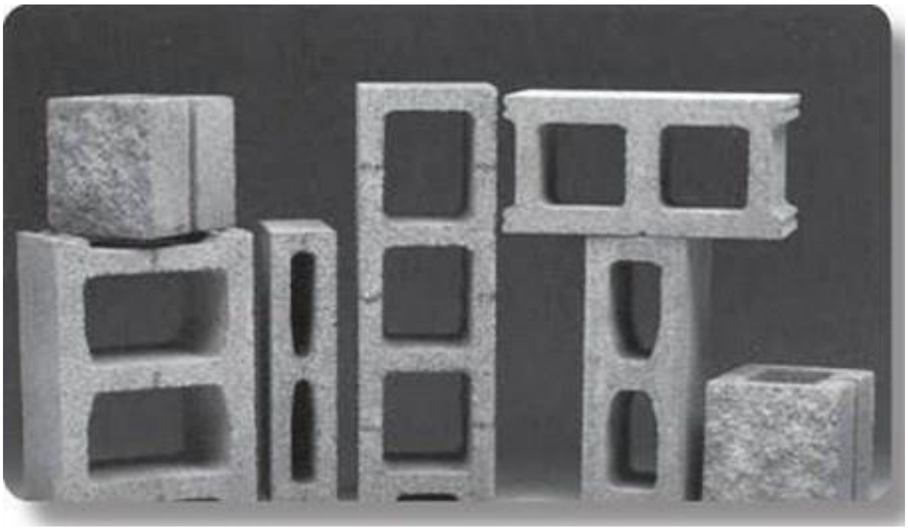


FIG.1 LIGHT WEIGHT CONCRETE BLOCKS

Classification of Lightweight Concrete
It is convenient to classify the various types of lightweight concrete by their method of production. These are:

1. By using porous lightweight aggregate of low apparent specific gravity, i.e. lower than 2.6. This type of concrete is known as **lightweight aggregate concrete.**

2. By introducing large voids within the concrete or mortar mass; these voids should be clearly distinguished from the extremely fine voids produced by air entrainment. This types of concrete is variously knows **as aerated, cellular, foamed or gas concrete.**
3. By omitting the fine aggregate from the mix so that a large number of interstitial voids is present; normal weight coarse aggregate is generally used. This concrete as **no-fines** concrete.

LWC can also be classified according to the purpose for which it is to be used: it can distinguish between structural lightweight concrete (ASTM C 330-82a), concrete used in masonry units (ASTM C 331-81), and insulating concrete (ASTM C 332-83).

This classification of structural lightweight concrete is based on a minimum strength: according to ASTM C 330-82a, the **28-day** cylinder **compressive** strength should not be less than **17 MPa**

The density (unit weight) of such concrete (determined in the dry state) should not exceed 1840 kg/m³, and is usually between 1400 and 1800 kg/m³. On the other hand, masonry concrete generally has a density between 500 and 800 kg/m³ and a strength between 7 and 14 MPa.

Types of Lightweight Concrete

1. Lightweight Aggregate Concrete

In the early 1950s, the use of lightweight concrete blocks was accepted in the UK for load bearing inner leaf of cavity walls. Soon thereafter the development and production of new types of artificial LWA (Lightweight aggregate) made it possible to introduce LWC of high strength, suitable for structural work.

These advances encouraged the structural use of LWA concrete, particularly where the need to reduce weight in a structure was in a structure was an important consideration for design or for economy.

Listed below are several types of lightweight aggregates suitable for structural reinforced concrete:-

1. **Pumice** – is used for reinforced concrete roof slab, mainly for industrial roofs in Germany.
2. **Foamed Slag** – was the first **lightweight aggregate** suitable for reinforced concrete that was produced in large quantity in the UK.
3. **Expanded Clays and Shales** – capable of achieving sufficiently high strength for prestressed concrete. Well established under the trade names of Aglite and Leca (UK), Haydite, Rocklite, Gravelite and Aglite (USA).

4. **Sintered Pulverised** – fuel ash aggregate – is being used in the UK for a variety of structural purposes and is being marketed under the trade name Lytag

2. Aerated Concrete

Aerated concrete has the **lowest density**, thermal conductivity and strength. Like timber it can be sawn, screwed and nailed, but there are non-combustible. For works in-situ the usual methods of aeration are by mixing in stabilized foam or by whipping air in with the aid of an air entraining agent.

The precast products are usually made by the addition of about **0.2 percent aluminums powder** to the mix which reacts with alkaline substances in the binder forming hydrogen bubbles.

Air-cured aerated concrete is used where little strength is required e.g. roof screeds and pipe lagging. Full strength development depends upon the reaction of lime with the siliceous aggregates, and for the equal densities the strength of high pressure steam cured concrete is about twice that of air-cured concrete, and shrinkage is only one third or less.

Aerated concrete is a lightweight, cellular material consisting of cement and/or **lime and sand** or other **silicious material**. It is made by either a physical or a chemical process during which either air or gas is introduced into a slurry, which generally contains no coarse material.

Aerated concrete used as a structural material is usually high-pressure steam-cured. It is thus **factory-made** and available to the user in precast units only, for **floors, walls and roofs**. Blocks for laying in mortar or glue are manufactured without any reinforcement.

Larger units are reinforced with steel bars to resist damage through transport, handling and superimposed loads. Autoclaved aerated concrete, which was originally developed in Sweden in 1929, is now manufactured all over the world.

3. No Fines Concrete

The term no-fines concrete generally means **concrete composed of cement and a coarse (9-19mm) aggregate only** (at least 95 percent should pass the 20mm BS sieve, not more than 10 percent should pass the 10mm BS sieve and nothing should pass the 5mm BS sieve), and the product so formed has many uniformly distributed voids throughout its mass.

No-fines concrete is mainly **used for load bearing**, cast in situ external and internal wall, non load bearing wall and under floor filling for solid ground floors (CP III: 1970, BSI). No-fines concrete was introduced into the UK in 1923, when 50 houses were built in Edinburgh, followed a few years later by 800 in Liverpool, Manchester and London.

This description is applied to concrete which contain only a single size 10mm to 20mm coarse aggregate (either a dense aggregate or a light weight aggregate such as sintered PFA). The density is about two-third or **three quarters** that of **dense** concrete made with the same aggregates.

No-fines concrete is almost always cast in situ mainly as load bearing and non load bearing walls including in filling walls, in framed structures, but sometimes as filling below solids ground floors and for roof screeds.

No-fines concrete is thus an agglomeration of coarse aggregate particles, each surrounded by a coating of cement paste up to about 1·3 mm (0·05 in.) thick. There exist, therefore, large pores within the body of the concrete which are responsible for its low strength, but their large size means that no capillary movement of water can take place.

Although the **strength of no-fines** concrete **is** considerably **lower** than that of normal-weight concrete, this strength, coupled with the lower dead load of the structure, is sufficient in buildings up to about 20 storeys high and in many other applications.

Types of Lightweight Concrete Based on Density and Strength
LWC can be classified as :-

1. Low density concrete
2. Moderate strength concrete
3. Structural concrete

1. Low Density Concrete
These are employing chiefly for insulation purposes. With low unit weight, seldom exceeding **800 kg/m^3,** heat insulation value are high. Compressive strength are low, regarding from about 0.69 to **6.89 N/mm2**.

2. Moderate Density Concrete
The use of these concrete requires a fair degree of compressive strength, and thus they fall about midway between the structural and low density concrete. These are sometimes designed as ‘fill’ concrete. **Compressive strength** are approximately 6.89 to **17.24 N/mm^2** and insulation values are intermediate.

3. Structural Concrete
Concrete with full structural efficiency contain aggregates which fall on the other end of the scale and which are generally made with expanded shale, clay, slates, slag, and fly-ash. Minimum compressive strength is 17.24 N/mm^2.

Most structural LWC are capable of producing concrete with compressive strength in excess of **34.47 N/mm^2.**

Since the unit weight of structural LWC are considerably greater than those of low density concrete, insulation efficiency is lower. However, thermal insulation values for structural LWC are substantially better than NWC.

Uses of Lightweight Concrete

1. Screeds and thickening for general purposes especially when such screeds or thickening and weight to **floors** roofs and other structural members.
2. Screeds and **walls** where timber has to be attached by nailing.
3. Casting structural steel to protect its **against fire** and corrosion or as a covering for architectural purposes.
4. **Heat insulation** on roofs.
5. Insulating **water pipes**.
6. Construction of **partition walls** and panel walls in frame structures.
7. Fixing bricks to receive nails from joinery, principally in domestic or domestic type construction.
8. General insulation of walls.
9. Surface rendered for external walls of **small houses**.
10. It is also being used for reinforced concrete.

Advantages of Lightweight Concrete

1. **Reduced dead load** of wet concrete allows longer span to be poured un-propped. This save both labor and circle time for each floor.
2. Reduction of dead load, faster building rates and lower haulage and handling costs. The eight of the building in term of the loads transmitted by the foundations is an important factor in design, particular for the case of tall buildings.
3. The use of LWC has sometimes made its possible to proceed with the design which otherwise would have been abandoned because of excessive weight. In frame structures, considerable savings in cost can be brought about by using LWC for the construction floors, partition and external cladding.
4. Most building materials such as clay bricks the haulage load is limited not by volume but by weight. With suitable design containers much larger volumes of LWC can haul economically.
5. A less obvious but nonetheless important characteristics of LWC is its relatively **low thermal conductivity**, a property which improves with decreasing density in recent years, with the increasing cost and scarcity of energy sources, more attention has been given the formerly to the need for reducing fuel consumption while maintaining, and indeed improving,

comfort conditions buildings. The point is illustrated by fact that a 125 mm thick solid wall of aerated concrete will give thermal insulation about four times greater than that of a 230 mm clay brick wall.

Durability of Lightweight Concrete

Durability is defined as the **ability of a material to withstand** the effect of its **environment**. In a building material as chemical attack, physical stress, and mechanical assault:-

Chemical attack is as aggregate ground-water particularly sulfate, polluted air, and spillage of reactive liquids LWC has no special resistant to these agencies: indeed, it is generally move porous than the ordinary Portland cement. It is not recommended for use below damp-course. A chemical aspects of durability is the stability of the material itself, particularly at the presence of moisture.

Physical stresses to which LWC is exposed are principally frost action and shrinkage and temperature stresses. Stressing may be due to the drying shrinkage of the concrete or to differential thermal movements between dissimilar materials or to other phenomena of a similar nature. Drying shrinkage commonly causes cracking of LWC if suitable precautions are not taken.

Mechanical damage can result from abrasion or impact excessive loading of flexural members. The lightest grades of LWC are relatively soft so that they subject to some abrasion were they not for other reasons protected by rendering

FOAM CONCRETE

REF: **Foam Concrete (WORD DOCUMENT)**

REF: **Foam concrete** mp4

Foam concrete**,** also known as **Lightweight Cellular Concrete** (LCC), **Low Density Cellular Concrete** (LDCC), and other terms is defined as a cement-based slurry, with a minimum of **20%** (per volume) **foam** entrained into the plastic mortar. As mostly no coarse aggregate is used for production of foam concrete the correct term would be called mortar instead of concrete; it may be called "foamed cement" as well. The **density** of foam concrete usually varies from **400 kg/m^3** to 1600 kg/m^3. The density is normally controlled by substituting fully or part of the fine aggregate with foam**.**

Terminology

It is also called aircrete, foamed concrete, foamcrete, cellular lightweight concrete or reduced density concrete.

History

FIG.2 USEAGE OF FOAMED CONCRETE AS INFILLING

The 1930s-era Smithy bridge used foamed concrete for infilling.

The history of foam concrete dates back to the early **1920**s and the production of autoclaved aerated concrete, which was used mainly as insulation. A detailed study concerning the composition, physical properties and production of foamed concrete was first carried out in the 1950s and 60s. Following this research, new admixtures were developed in the late 1970s and early 80s, which led to the commercial use of foamed concrete in construction projects. Initially, it was used in the Netherlands for filling voids and for ground stabilisation. Further research carried out in the Netherlands helped bring about the more widespread use of foam concrete as a building material. More recently, foam concrete is being made with a continuous foam generator. The foam is produced by agitating a foaming agent with compressed air to make "aircrete" or "foamcrete". This material is fireproof, insect proof, and waterproof. It offers significant thermal and acoustic insulation and can be cut, carved, drilled and shaped with wood-working tools. This construction material can be **used to** make foundations, subfloors, **building blocks, walls, domes**, or even arches that can be reinforced with a construction fabric.

MANUFACTURING OF FOAM CONCRETE

Foamed concrete typically **consists of** slurry of cement or **fly ash and sand** and **water**, although some suppliers recommend pure cement and water with the **foaming agent** for very lightweight mixes. This slurry is further mixed with a synthetic aerated foam in a concrete mixing plant. The foam is created using a foaming agent, mixed with water and air from a generator. The foaming agent used must be able to **produce air bubbles** with a high level of stability, resistant to the physical and chemical processes of mixing, placing and hardening.

Foamed concrete mixture may be poured or pumped into moulds, or directly into structural elements. The foam enables the slurry to flow freely due to the thixotropic behaviour of the foam bubbles, allowing it to be easily poured into the chosen form or mould. The viscous material requires up to 24 hours to solidify (or as little as two hours if steam cured with temperatures up to 70 °C to accelerate the process.), depending on variables including ambient temperature and humidity. Once solidified, the formed produce may be released from its mold. New application in foam concrete manufacturing is to cut the big size concrete cakes into blocks of different sizes by a cutting machine using special steel wires. The cutting action takes place when concrete is still soft.

PROPERTIES OF FOAM CONCRETE

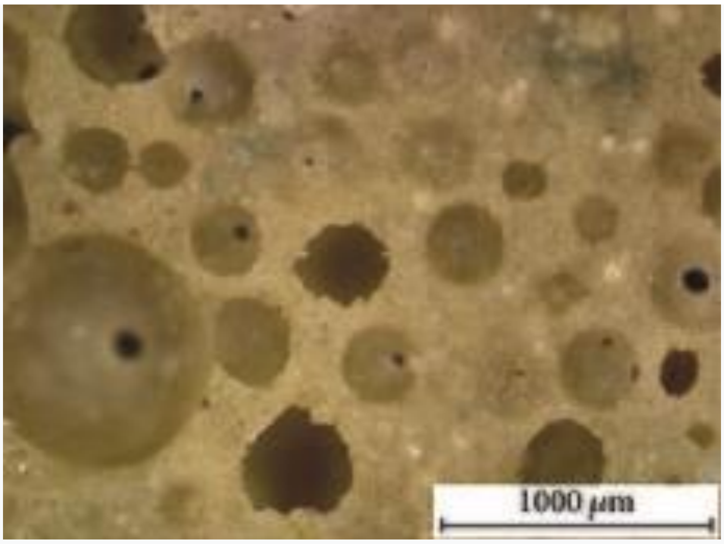


FIG.3 FOAMED CONCRETE SAMPLE

A sample of foamed concrete used for measurement.

Foam concrete is a versatile building material with a simple production method that is relatively inexpensive compared to autoclave aerated concrete. Foam concrete compounds utilising fly ash in the slurry mix is cheaper still, and has less environmental impact. Foam concrete is produced in a variety of **densities from 200 kg/m^3** to 1,600 kg/m^3 depending on the application. Lighter density products may be cut into different sizes. While the product is considered a form of concrete (with **air bubbles replacing aggregate**), its high thermal and acoustical insulating qualities make it a very different application than conventional concrete.

APPLICATIONS OF FOAM CONCRETE

Foamed concrete can be produced with dry densities of 400 to 1600 kg/m^3, with **7-day strengths** of approximately **1 to 10 N/mm^2** respectively. Foam concrete is **fire resistant**, and its thermal and **acoustical** insulation properties make it ideal for a wide range of purposes, from **insulating floors and roofs**, to void filling. It is also particularly useful for trench reinstatement.

A few of the **applications** of foam concrete are:

- bridge approaches / embankments
- **pipeline** abandonment / annular fill
- **trench** backfill
- precast **blocks**
- precast wall elements / panels
- cast-in-situ / cast-in-place walls
- insulating compensation laying
- insulation **floor** screeds
- insulation **roof** screeds
- **sunken** portion filling
- trench reinstatement
- sub-base in highways
- filling of hollow blocks
- prefabricated insulation boards

TRENDS AND DEVELOPMENT OF FOAM CONCRETE

Until the mid-1990s, foam concrete was regarded as weak and non-durable with high shrinkage characteristics. This is due to the unstable foam bubbles resulted in foam concrete having properties unsuitable for producing very low density (Less than 300 kg/m^3 dry density) as well as load bearing structural applications. It is therefore important to ensure that the air entrained into the foamed concrete is contained in stable, very tiny, uniform bubbles that remain intact and isolated, and do not thus increase the permeability of the cement paste between the voids.

The development of synthetic-enzyme based foaming agents, foam stability enhancing admixtures and specialised foam generating, mixing and pumping equipment has improved the stability of the foam and hence foam concrete, making it possible to manufacture as light as 75 kg/m^3 density, a density that is just 7.5% of water. The enzyme consists of highly active proteins of biotechnological origin not based on protein hydrolysis. In recent years foamed concrete has been used extensively in highways, commercial buildings, disaster rehabilitation buildings, schools, apartments and housing developments in countries such as Germany, USA, Brazil, Singapore, India, Malaysia, Kuwait, Nigeria, Bangladesh, Botswana, Mexico, Indonesia, Libya, Saudi Arabia, Algeria, Iraq, Egypt and Vietnam.

SHOCK-ABSORPTION OF FOAM CONCRETE

Foamed concrete has been investigated for use as a bullet trap in high intensity US military firearm training ranges.[14] This work resulted in the product SACON being fielded by the U.S. Army Corps of Engineers, which when worn out, can be shipped directly to metal recycling facilities without requiring the separation of the trapped bullets, as the calcium carbonate in the concrete acts as a flux.

The energy absorption capacity of foamed concrete was approximated from drop testing and found to vary from 4 to 15 MJ/m^3 depending on its density. With optimum absorption estimated from a 1000 kg/m^3 moderate density mix at water to cement (w/c) ratios from 0·6 to 0·7.

SELF COMPACTING CONCRETE
REF: https://youtu.be/S2NC6KUqexI (NPTEL 56.53 MIN)

In the 1980s, the construction industry in Japan experienced a decline in the availability of skilled labour. This situation aroused a need for concrete that could overcome the problems of defective workmanship.

This led to the development of self-compacting concrete (SCC). It was primarily started through the work of Prof. Dr. Hajime Okamura (Father of **SCC** Technology). A committee was formed to study the properties of self-compacting concrete, including a fundamental investigation on the workability of concrete. This was carried out by Ozawa et al. at the University of Tokyo. The usable version of self-compacting concrete was completed in 1988. It was **named "High-Performance Concrete**". Later it was proposed as "Self Compacting High-Performance Concrete".

High-performance concrete is used basically for two reasons.

1. **Higher Compressive Strength**.
2. Workability and Compactibility.

In large and complex construction projects, congestion of bars is a very common phenomenon. It becomes very tough to compact concrete with vibrators. Also, segregation takes place during placing the concrete in the formwork. This situation can be tackled with highly workable concrete. Highly workable concrete has a slump of over 650 mm-800 mm. Their testing (Slump flow test instead of normal slump test) and quality assurance procedure is different from normal concrete.

Self-Competing Concrete is also **known as self-consolidating concrete**. In this article, we will discuss the definition of self-compacting concrete along with the practical application field of it.

What is Self-Consolidating or Self-Competing Concrete?

Self Consolidating or **Self Compacting Concrete (SCC)** is a highly **flowable**, deformable, **non-segregating** concrete that spreads and fills in the formwork under its own weight. Flowability is maintained by using a high range of water-reducing admixtures.

Stability (avoiding segregation) is **increased** by using admixtures or increasing the number of fine aggregates in the plastic concrete. This also changes the viscosity of the mixture.

SCC has a more improved interface between aggregate and cement paste. It increases the strength of concrete.

Self Compactibility = High Deformability + High Segregation-resistance

Self-compacting concrete can also be defined as a mix **balancing the fluidity and resistance to segregation** where those two properties are conflicting with each other. A balanced equilibrium should be maintained between them.

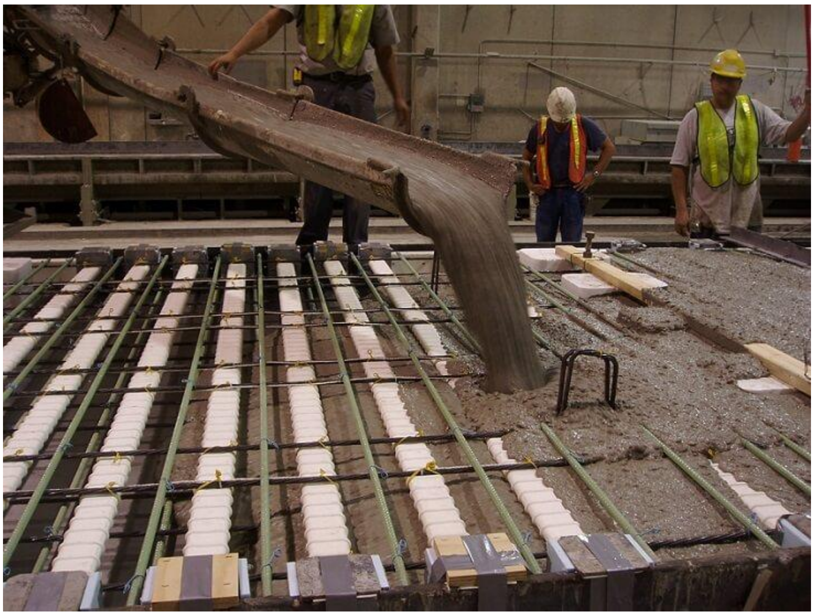


FIG.4 SELF COMPACTING CONCRETE

Application of Self-Competing or Self-Consolidating Concrete

The followings are the applications of self-consolidating/compacting concrete.

- Areas of **congested reinforcements**.
- **Bridges** and precast sections.
- Drilled shaft **columns**, earth retaining structures.
- High concentration rebars where normal tempering or vibrating is difficult.
- Manufacturers of **concrete pipes**.
- Flow in closed spaces-pipes (during pumping).

VACUUM CONCRETE

What is Vacuum Concrete?

All the water used in mixing concrete is not required for hydration. Therefore, **removal of excess water before hardening** take place **improves concrete strength**.

Vacuum concrete is the type of concrete in which the excess water is removed for improving concrete strength. The **water is removed by use of vacuum mats** connected to a vacuum pump.

FIG.5 LYING OF VACUUM CONCRETE

Procedure

In the usual manner, a concrete mix with good workability is pace in the form-works. As fresh concrete contains continues the system of water-filled channels, the application of a vacuum to the surface concrete results in a large amount of a vacuum to the surface of the concrete. This results in a **large amount of water being extracted** from a certain depth of the concrete. The vacuum is applied through porous mats connected to a vacuum pump. The **final water cement ratio before setting is thus reduced** and as this ration largely controls the strength, vacuum concrete has a **higher strength** and also **density** a **lower permeability** and a greater **durability**.

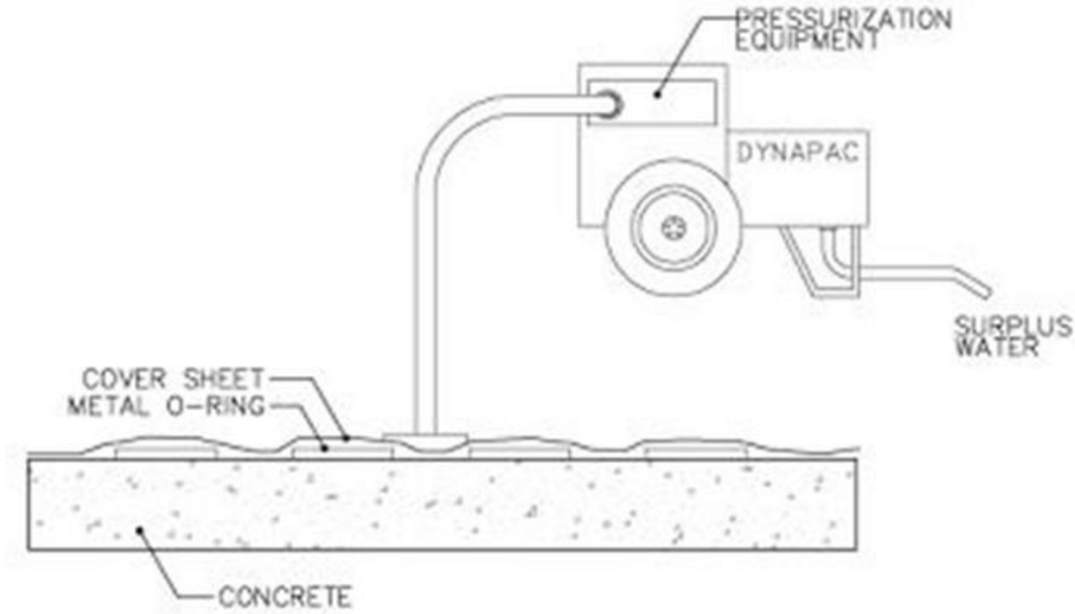


FIG.6 VACUUM PUMP

Advantages of Vacuum Concrete

Vacuum Concrete has several advantages over normal concrete. Some of the advantages are given below.

- The **final strength of concrete is increased by about 25%.**
- Sufficient **decrease in The permeability** of concrete is sufficiently decreased.
- Vacuum concrete **stiffens very rapidly** so that the form-works can be removed within 30 minutes of casting even on columns of 20 ft. high.
- This is of considerable economic value, particularly in a precast factory as the forms can be reused at frequent intervals.
- The **bond strength** of vacuum concrete is about **20% higher**.
- The **density** of vacuum concrete is **higher**.
- The surface of vacuum concrete is entirely free from pitting and the uppermost 1/16 inch is highly resistant to abrasion. These characteristics are of special importance in the construction of concrete structures which are to be in contact with flowing water at a high velocity.
- It **bonds well to old concrete** and can, therefore, be used for resurfacing road slabs and other repair works.

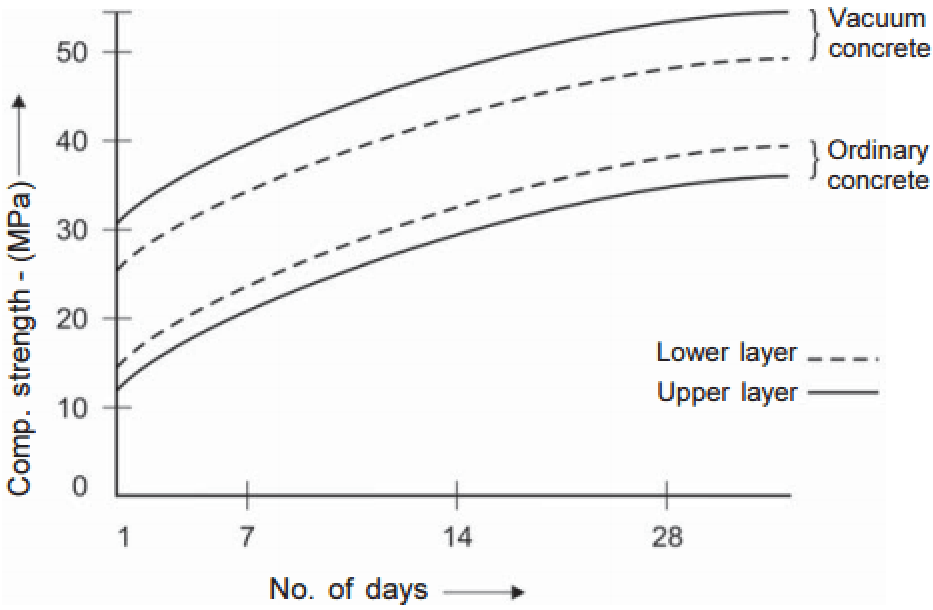


FIG.7 COMPRESSIVE STRENGTH OF VACUUM CONCRETE

HIGH STRENGTH CONCRETE

REF: https://youtu.be/qBq8EgLzhfo (NPTEL 52.18)

REF: HIGH STRENGTH CONCRETE – CONCRETE OF TOMORROW (IN PPT)

In the early 1970s, experts predicted that the practical limit of ready-mixed concrete would be unlikely to exceed a compressive strength greater than 11,000 pounds square inch (psi). Over the past two decades, the development of high-strength concrete has enabled builders to easily meet and surpass this estimate. Two buildings in Seattle, Washington, contain concrete with a compressive strength of 19,000 psi.

The primary difference between high-strength concrete and normal-strength concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to applied pressure. Although there is no precise point of separation between high-strength concrete and normal-strength concrete, the American Concrete Institute defines high-strength concrete as concrete with a compressive strength greater than 6,000 psi.

Likewise, there is not a precise point of separation between high-strength concrete and ultra-high performance concrete, which has greater compressive strength than high-strength concrete and other superior properties. See ultra high-performance concrete.

Manufacture of high-strength concrete involves making optimal use of the basic ingredients that constitute normal-strength concrete. Producers of high-strength concrete know **what factors affect compressive strength** and know **how to manipulate those factors to achieve the required strength**. In addition to selecting a high-quality portland cement, producers optimize aggregates, then optimize the combination of materials by varying the proportions of cement, water, aggregates, and admixtures.

When selecting aggregates for high-strength concrete, producers consider the strength of the aggregate, the optimum size of the aggregate, the bond between the cement paste and the aggregate, and the surface characteristics of the aggregate. Any of these properties could limit the ultimate strength of high-strength concrete.

Admixtures

Pozzolans, such as **fly ash and silica fume**, are the most commonly used mineral admixtures in high-strength concrete. These materials impart additional strength to the concrete by reacting with Portland cement hydration products to create additional C-S-H gel, the part of the paste responsible for concrete strength.

It would be difficult to produce high-strength concrete mixtures without using **chemical admixtures**. A common practice is to use a **superplasticizer** in combination with a water-reducing retarder. The superplasticizer **gives** the concrete **adequate workability at low water-cement ratios**, leading to concrete with **greater strength**. The water-reducing retarder slows the hydration of the cement and allows workers more time to place the concrete.

FIG.7 HIGH RISE STRUCTURE WITH HIGH STRENGTH CONCRETE

High-strength concrete is specified where reduced weight is important or where architectural considerations call for small support elements. By carrying loads more efficiently than normal-strength concrete, high-strength concrete also **reduces** the total amount of **material placed** and **lowers the overall cost** of the structure.

The most common use of high-strength concrete is for construction of high-rise buildings. At 969 feet, Chicago's 311 South Wacker Drive uses concrete with compressive strengths up to 12,000 psi and is one of the tallest concrete buildings in the United States.

FIBRE REINFORCED CONCRETE

REF: https://youtu.be/PPlQPTlKdrQ (NPTEL IIT KANPUR 54.46 MIN)
REF: Application of Fiber Reinforced Concrete (FRC) (IN PPT)

Fiber Reinforced Concrete can be defined as a **composite material** consisting of mixtures of cement, mortar or **concrete** and discontinuous, discrete,

uniformly dispersed **suitable fibres**. Fibre reinforced concrete is of different types and properties with many advantages. Continuous **meshes**, **woven fabrics** and **long wires or rods** are **not considered to be discrete fibres**.
Fiber is a **small piece of reinforcing material** possessing certain characteristics properties. They can be **circular or flat**. The fiber is often described by a convenient parameter called “aspect ratio”. The aspect ratio of the fiber is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

Fiber reinforced concrete (FRC) is concrete containing fibrous material which **increases** its **structural integrity**. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include **steel fibers, glass fibers, synthetic fibers and natural fibers**. Within these different fibers that character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities.

Fibre-reinforcement is mainly **used in shotcrete**, but can also be used in normal concrete. Fibre-reinforced normal concrete are mostly **used for** on-ground floors and **pavements**, but can be considered for a wide range of construction parts (**beams, pliers, foundations** etc) either alone or with hand-tied rebars

Concrete reinforced with fibres (which are usually **steel, glass or “plastic**” fibres) is **less expensive** than hand-tied rebar, while still increasing the tensile strength many times. Shape, dimension and length of fibre is important. A thin and short fibre, for example short hair-shaped glass fibre, will only be effective the first hours after pouring the concrete (**reduces cracking** while the concrete is stiffening) but will not increase the concrete tensile strength

Effect of Fibers in Concrete
Fibres are usually used in concrete to **control plastic shrinkage** cracking and drying shrinkage cracking. They also **lower the permeability** of concrete and thus **reduce bleeding** of water. Some types of fibres produce greater impact, **abrasion** and shatter **resistance** in concrete. Generally fibres do not increase the flexural strength of concrete, so it can not replace moment resisting or structural steel reinforcement. Some fibres reduce the strength of concrete.

The **amount of fibres** added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed volume fraction

(V_f). V_f typically **ranges from 0.1 to 3%.** Aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio.
If the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. However, fibres which are too long tend to “ball” in the mix and create workability problems.

Some recent research indicated that **using fibres in concrete has limited effect on the impact resistance** of concrete materials.This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibres. The results also pointed out that the micro fibres is better in impact resistance compared with the longer fibres.

Necessity of Fiber Reinforced Concrete

1. It **increases the tensile strength** of the concrete.
2. It **reduce the air voids** and water voids the inherent porosity of gel.
3. It **increase**s the **durability** of the concrete.
4. Fibres such as graphite and glass have excellent **resistance to creep**, while the same is not true for most resins. Therefore, the orientation and volume of fibres have a significant influence on the creep performance of rebars/tendons**.**
5. Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fibre and the concrete as the matrix. It is therefore imperative that the behavior under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized.
6. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties.

Factors Affecting Properties of Fiber Reinforced Concrete

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depends upon the efficient transfer of stress between matrix and the fibers. The factors are briefly discussed below:

1. Relative Fiber Matrix Stiffness

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but the help in the absorption of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite.

Interfacial bond between the matrix and the fiber also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite.

2. Volume of Fibers

The strength of the composite largely depends on the quantity of fibers used in it. Fig 8 and 9 show the effect of volume on the toughness and strength. It can see from Fig 8 that the increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

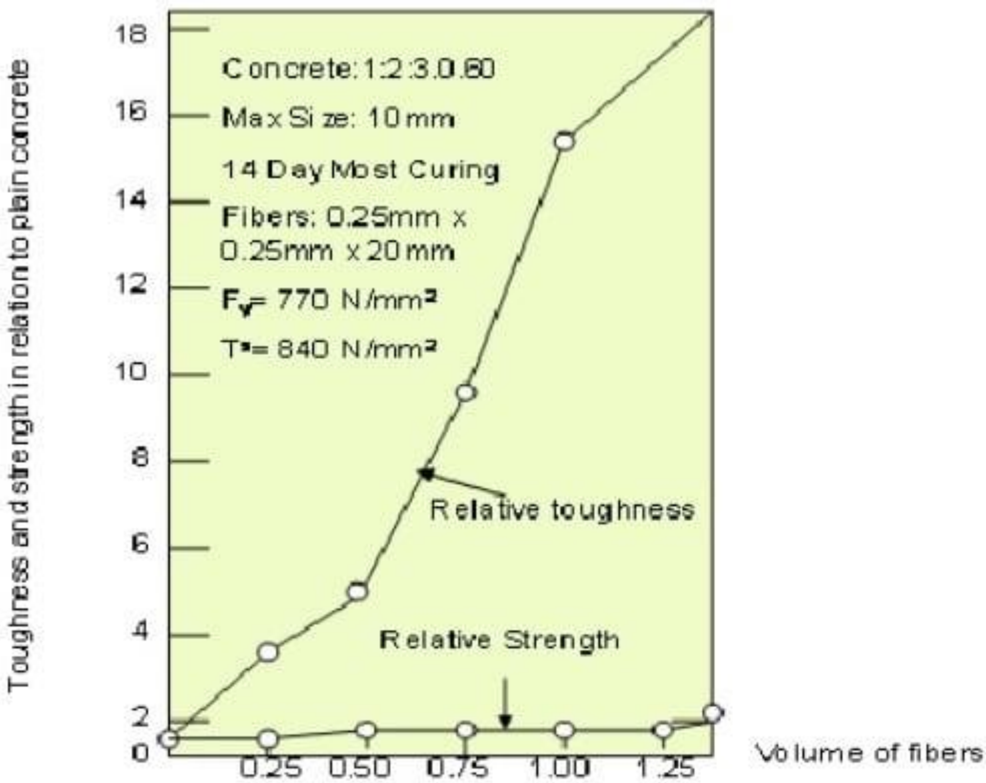


FIG.8 EFFECT OF VOLUME OF FIBERS IN FLEXURE

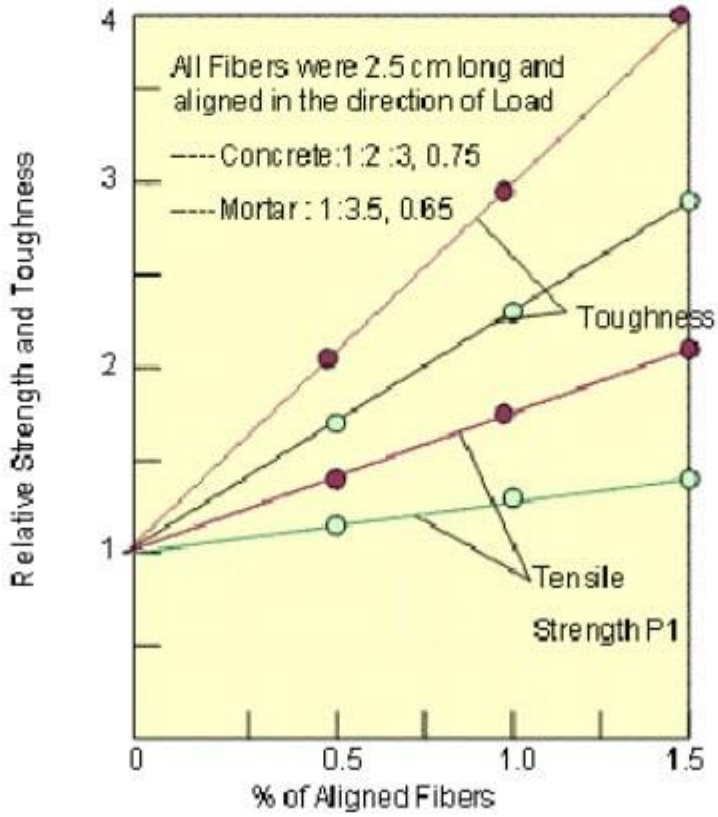


FIG.9 EFFECT OF VOLUME OF FIBERS IN TENSION

3. Aspect Ratio of the Fiber

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced. Table-1 shows the effect of aspect ratio on strength and toughness.

TABLE-1: ASPECT RATIO OF THE FIBER

Type of concrete	Aspect ratio	Relative strength	Relative toughness
Plain concrete	0	1	1
With	25	1.5	2.0
Randomly	50	1.6	8.0
Dispersed fibres	75	1.7	10.5
	100	1.5	8.5

4. Orientation of Fibers

One of the differences between conventional reinforcement and fiber reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibers are randomly oriented. To see the effect of randomness, mortar specimens reinforced with 0.5% volume of fibers were tested. In one set specimens, fibers were aligned in the direction of the load, in another in the direction perpendicular to that of the load, and in the third randomly distributed. It was observed that the fibers aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

5. Workability and Compaction of Concrete

Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fiber volume at which this situation is reached depends on the length and diameter of the fiber.

Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures.

6. Size of Coarse Aggregate

Maximum size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite. Fibers also in effect, act as aggregate. Although they have a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite. Friction reducing admixtures and admixtures that improve the cohesiveness of the mix can significantly improve the mix.

7. Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fiber content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix.

It is important that the fibers are dispersed uniformly throughout the mix; this can be done by the addition of the fibers before the water is added. When mixing in a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers. For field use, other suitable methods must be adopted.

Different Types of Fiber Reinforced Concrete
Following are the different type of fibers generally used in the construction industries.

1. **Steel Fiber** Reinforced Concrete
2. Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
3. GFRC **Glass Fiber** Reinforced Concrete
4. **Asbestos** Fibers
5. **Carbon** Fibers
6. **Organic** Fibers

1. Steel Fiber Reinforced Concrete
A no of steel fiber types are available as reinforcement. Round steel fiber the commonly used type are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick.

Fiber made from mild steel drawn wire. Conforming to IS:280-1976 with the diameter of wire varying from 0.3 to 0.5mm have been practically used in India. Round steel fibers are produced by cutting or chopping the wire, flat sheet fibers having a typical c/s ranging from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm in width are produced by silting flat sheets.
Deformed fiber, which are loosely bounded with water-soluble glue in the form of a bundle are also available. Since individual fibers tend to cluster together, their uniform distribution in the matrix is often difficult. This may be avoided by adding fibers bundles, which separate during the mixing process.

2. Polypropylene Fiber Reinforced (PFR) cement mortar and concrete

Polypropylene is one of the cheapest & abundantly available polymers polypropylene fibers are resistant to most chemical & it would be cementitious matrix which would deteriorate first under aggressive chemical attack. Its melting point is high (about 165 degrees centigrade). So that a working temp. As (100 degree centigrade) may be sustained for short periods without detriment to fiber properties.

Polypropylene fibers being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly distressed in the mix.

Polypropylene short fibers in small volume fractions between 0.5 to 15 commercially used in concrete.

FIG.10 POLYPROPYLENE FIBER REINFORCED CEMENT-MORTAR AND CONCRETE

3. GFRC – Glass Fiber Reinforced Concrete

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm.

The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used verities of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR-glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

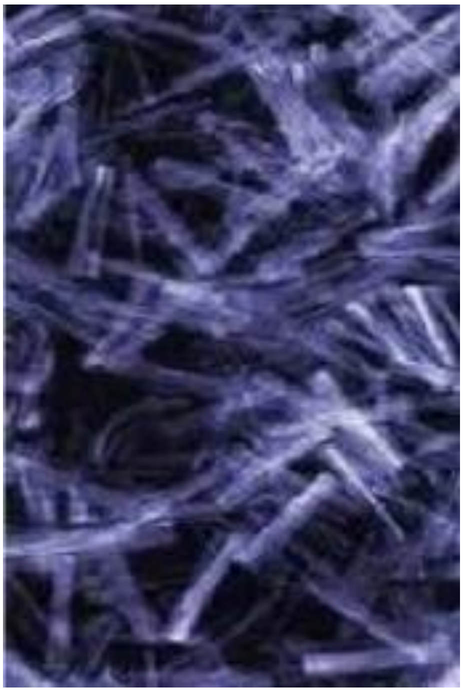


FIG.11 GLASS-FIBER REINFORCED CONCRETE

4. Asbestos Fibers

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement. Asbestos fibers here thermal mechanical & chemical resistance making them suitable for sheet product pipes, tiles and corrugated roofing elements. Asbestos cement board is approximately two or four times that of unreinforced matrix. However, due to relatively short length (10mm) the fiber have low impact strength.

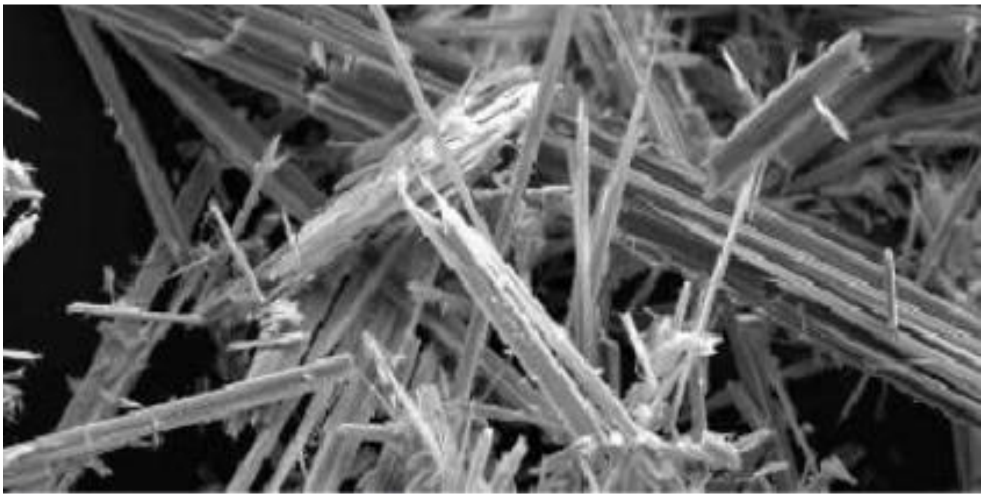


FIG.12 ASBESTOS FIBER

5. Carbon Fibers

Carbon fibers from the most recent & probability the most spectacular addition to the range of fiber available for commercial use. Carbon fiber comes under the very high modulus of elasticity and flexural strength. These are expansive. Their strength & stiffness characteristics have been found to be superior even to those of steel. But they are more vulnerable to damage than even glass fiber, and hence are generally treated with resign coating.

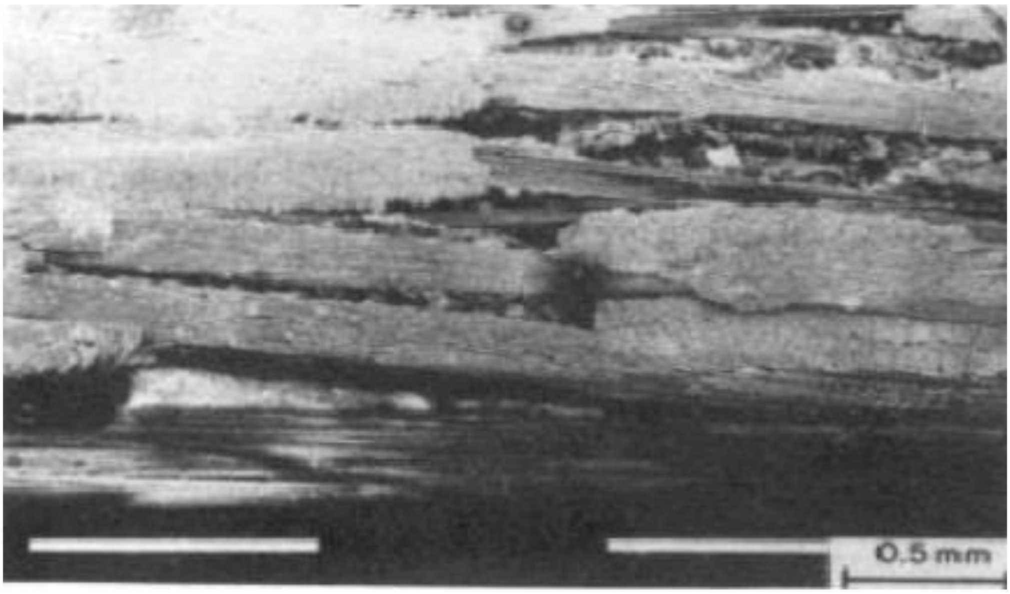


FIG.13 CARBON FIBERS

6. Organic Fibers

Organic fiber such as polypropylene or natural fiber may be chemically more inert than either steel or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable fiber may be used to obtain a multiple cracking composite. The problem of mixing and uniform dispersion may be solved by adding a superplasticizer

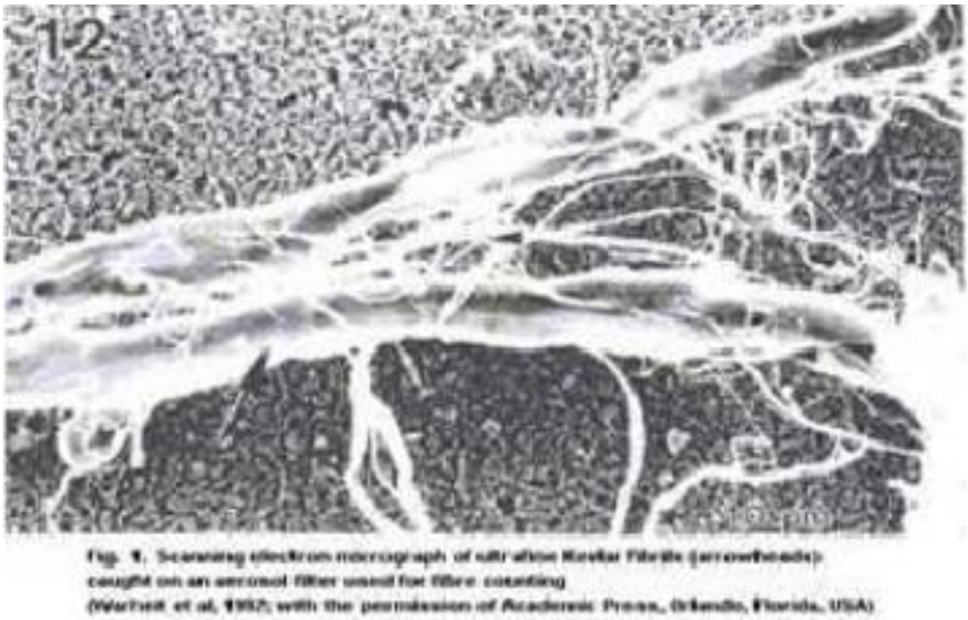


FIG.14 ORGANIC FIBERS

FERROCEMENT

REF: FERROCEMENT (IN PPT)

Ferrocement is a type of **thin-walled reinforced concrete** constructed of hydraulic cement mortar, reinforced with steady and comparatively small size **wire mesh**; the mesh could also be fabricated from metal or other appropriate materials.

Mortar offers a mass and wire mesh offers a tensile strength and flexibility.

Here we will learn about ferro cement, its properties & difference between ferro cement and ferro concrete!

INTRODUCTION TO FERROCEMENT:

Ferro cement is much thinner than reinforced concrete and the mesh can be formed to any shape without a conventional form, then plastered or mortared by hand.

Ferrocement is a brilliant reinforced concrete, it differs from conventional concrete and has a higher ratio of cement mortar to steel.

By altering the cement / steel ratio to make ferro cement, we really produce a material that reveals properties which might be superior than steel or cement.

PROPERTIES OF FERROCEMENT:

- Ferro cement has **high tensile strength** and s**tiffness**.
- It improves the influence and **punching shear resistance**.

- Undergo **massive deformation** earlier than rupture or high deflection.
- Also it is **Light weight**.
- A low w/c ratio produces the **impermeable** structures.
- It is a very **durable**, i**nexpensive** and versatile material.

MATERIAL USED IN FERROCEMENT:

CEMENT MORTAR:

In this, ordinary Portland cement and fine aggregate are used.

The particle size of sand should not more than 2.36mm and less than 1.18mm.

More than 2.36mm particle can make the mortar porous and particles less than 1.18mm requires more water to the impermeable structure.

Sand occupies 60- 75% mortar volume.

REINFORCEMENT:

It is used in Ferro cement & they are further classified as follows:

A. SKELETON STEEL:

The skeleton steel frame is made conforming exactly to shape of the structure and the geometry.

The steel rods are spaced at 70 to 100 mm apart and diameter may vary from 3 to 8 mm.

This is used for holding the wire mesh in the shape of the structure.

In the case where higher stresses may occur, the mild steel bars are used.

B. WIRE MESH:

The wire mesh consists of galvanized wire spaced at 6 to 20 mm centre to centre and 0.5 to 1.5 mm in diameter.

The wire mesh may be of the shape as welded wire mesh or square is woven wire mesh, hexagonal wire or mesh expanded metal etc.

The yield strength of plain wires used in fabric should not be more than 415 MPa and 500 MPa for deformed wires.

The metal content might vary between 300 kg to 500 kg per cubic meter of mortar.

FERROCEMENT MANUFACTURING PROCESS:

1. HAND PLASTERING:

In this method, control thickness is hard and the minimum thickness is a stream that is 2cms.

The strength achieved by this technique shall be lower than different methods.

Units can be inserted by this process and used if various higher methods are not present.
These items can be utilized for pipes, storm buildings, and gas holder units.

2. **SEMI MECHANIZED PROCESS**:
This system also is known as semi-mechanized because the mould can be rolled to facilitate the dynamic to the mortars.
The consistency of this system may be greater than the earlier system.
Better compaction can be obtained using a straight edge pressed against the inner mould in this method.
Local, un-skilled people can handle this process.

3. GUNITING:
The **gun-running process** can be adapted to apply the mortar to the wire mesh system.
This is the most suitable process for the large-scale construction of ferrocement prefabricated units.
If this process is utilized with a skilled gunner, can provide a compact and uniform surface.

4. BY CENTRIFUGING:
Centrifuging courses are often adopted for the development of solid cylindrical units.
Ferro cement pipes are cast by centrifuging and it is used as tension pipes.

DIFFERENCE BETWEEN FERROCEMENT AND FERROCONCRETE:

Ferrocement is a composite material made of mortar reinforced with mild steel mesh, which is used to make thin sections.	Ferrocement is a composite material made of mortar reinforced with mild steel mesh, which is used to make thin sections.

ADVANTAGES OF FERROCEMENT:
1. Ferro cement can be fabricated in any **desired shape**, hence it is more suitable to a special structure like shells, roofs, water tank etc.
2. It is a highly suitable material for **precast** merchandise.
3. It has high **ductility** and **resistance to crack**.
4. Also, has favourable to **tensile** properties.
5. It has **low maintenance**.

6. They are environmentally friendly.

DISADVANTAGES OF FERROCEMENT:
1. Ferro cement is sensitivity to **stress failure**.
2. They have **Low shear** strength.
3. It can be **perforated by hitting sharp objects**.
4. **Corrosion** in the reinforcing materials as a result of incomplete protection of metallic by mortar.

USES OF FERROCEMENT:
Marine Applications:
Boats, fishing vessels, barge, cargo tugs, and flotation buoys are the main criteria for marine applications.
Water Supply and Sanitation:
Water tanks, sedimentation tanks, swimming pool linings, well coverings, septic tanks, etc.
Agriculture:
Grain storage bins, silos, canal lining, pipes, shells for fish and poultry farms.
Residential Building:
Houses, community centres, precast housing elements, corrugated roofing sheets, wall panels, etc.
Rural energy biogas digesters, biogas holders, incinerators, panels for solar energy collectors, etc.
Miscellaneous Uses:
Mobile homes, kiosks, wind tunnels, silos and cans.

Conclusion:
Ferro cement is often used in the constructions for resistant to earthquakes.

READY MIX CONCRETE
REF: https://youtu.be/qyjLWOwpTqc (3.06 MIN)

Ready-Mix Concrete is concrete that is manufactured in a **batch plant**, according to a set engineered mix design. Ready-mix concrete is normally delivered in two ways.
First is the barrel truck or in–transit mixers. This type of truck delivers concrete in a plastic state to the site.

Second is the volumetric concrete mixer. This delivers the ready mix in a dry state and then mixes the concrete on site.

Batch plants combine a precise amount of gravel, sand, water and cement by weight (as per mix design formulation for grade of concrete recommended by the Structural consultant), allowing specialty concrete mixtures to be developed and implemented on construction sites. The **first ready-mix** factory was built in the **1930s**. The industry did not expand significantly until the 1960s, and has continued to grow since then.

Ready-mix concrete is often used instead of other materials due to the cost and wide range of uses in building, particularly in large projects like high rise buildings and bridges. It has a long life span when compared to other products of a similar use, like road ways. It has an average life span of 30 years under high traffic areas compared to the 10 to 12 year life of asphalt concrete with the same traffic.

Ready-mix concrete, or RMC as it is also known, refers to concrete that is specifically manufactured for customers' construction projects, and supplied to the customer on site as a single product. It is a mixture of Portland or other cements, water and aggregates: sand, gravel, or crushed stone. All aggregates should be of a washed type material with limited amounts of fines or dirt and clay. An admixture is also added to improve work-ability of the concrete and/or increase setting time of concrete (using retarders) to factor in the time required for the transit mixer to reach the site.

Ready-mixed concrete is used in construction projects where the construction site is not willing, or unable, to mix concrete on site. Using ready-mixed concrete means product is delivered finished, on demand, in the specific quantity required, in the specific mix design required. For a small to medium project, the cost and time of hiring mixing equipment, labour, plus purchase and storage for the ingredients of concrete, added to environmental concerns (cement dust is an airborne health hazard) may simply be not worthwhile when compared to the cost of ready-mixed concrete, where the customer pays for what they use, and allows others do the work up to that point. For a large project, outsourcing concrete production to ready-mixed concrete suppliers means delegating the quality control and testing, material logistics and supply chain issues and mix design, to specialists who are already established for those tasks, trading off against introducing another contracted external supplier who needs to make a profit, and losing the control and immediacy of on-site mixing.

Ready-mix concrete is bought and sold by volume – usually expressed in cubic meters (cubic yards in the US). Batching and mixing is done under controlled conditions. In the UK, ready-mixed concrete is specified either informally, by constituent weight or volume (1-2-4 or 1-3-6 being common mixes) or using the formal specification standards of the European standard EN 206+ A1, which is supplemented in the UK by BS 8500. This allows the customer to specify what the concrete has to be able to withstand in terms of ground conditions, exposure, and strength, and allows the concrete manufacturer to design a mix that meets that requirement using the materials locally available to a batching plant. This is verified by laboratory testing, such as performing cube tests to verify compressive strength and supplemented by field testing, such as slump tests done on site to verify plasticity of the mix.

The performance of a concrete mix can be altered by use of admixtures. Admixtures can be used to reduce water requirements, entrain air into a mixture, to improve surface durability, or even superplasticise concrete to make it self-levelling, as self-consolidating concrete, the use of admixtures requires precision in dosing and mix design, which is more difficult without the dosing/measuring equipment and laboratory backing of a batching plant, which means they are not easily used outside of ready-mixed concrete.

Concrete has a limited lifespan between batching / mixing and curing. This means that ready-mixed concrete should be placed within 30 to 45 minutes of batching process to hold slump and mix design specifications in the USA, though in the UK, environmental and material factors, plus in-transit mixing, allow for up two hours to elapse. Modern admixtures and water reducers can modify that time span to some degree.

Ready-mixed concrete can be transported and placed at site using a number of methods. The most common and simplest is the chute fitted to the back of transit mixer trucks (as in picture), which is suitable for placing concrete near locations where a truck can back in. Dumper trucks, crane hoppers, truck-mounted conveyors, and, *in extremis*, wheelbarrows, can be used to place concrete from trucks where access is not direct. Some concrete mixes are suitable for pumping with a concrete pump.

In 2011, there were 2,223 companies employing 72,925 workers that produced RMC in the United States.

Advantages and disadvantages of ready-mix concrete

- Materials are combined in a batch plant, and the hydration process begins at the moment water meets the cement, so the travel time from the plant to the site, and the time before the concrete is placed on site, is critical over longer distances. Some sites are just too distant. The use of admixtures, retarders and cements like pulverized fly ash or ground granulated blast furnace slag (GGBS) can be used to **slow the hydration process**, allowing for **longer transit** and **waiting time**.
- Concrete is formable and pourable, but a steady supply is needed for large forms. If there is a **supply interruption**, and the concrete cannot be poured all at once, a cold joint may appear in the finished form.
- The biggest advantage is that concrete is **produced under controlled conditions**. Therefore, **Quality concrete is obtained**, as a ready-mix concrete mix plant makes use of sophisticated equipment and consistent methods. There is strict control over the testing of materials, process parameters and continuous monitoring of key practices during the manufacturing process. Poor control on the input materials, batching and mixing methods in the case of site mix concrete is solved in a ready-mix concrete production method.
- **Speed in the construction practices** followed in ready mix concrete plant is followed continuously by having mechanized operations. The output obtained from a site mix concrete plant using a 8/12 mixer is 4 to 5 metric cubes per hour which is **30-60 metric cubes per hour** in a ready mix concrete plant.
- Better handling and proper mixing practice will help **reduce** the **consumption of cement by 10 – 12%.** Use of admixtures and other cementitious materials will help to reduce the amount of cement as is required to make the desired grade of concrete.
- Less consumption of cement indirectly results in less environmental pollution.

- Ready mix concrete manufacture has **less dependency on human** labours hence the chances of human error is reduced. This will also reduce the dependency on intensive labour.
- Cracking and shrinkage. Concrete shrinks as it cures. It can shrink $\frac{1}{16}$ inch (1.59mm) over a 10 foot long area (3.05 meters). This causes stress internally on the concrete and must be accounted for by the engineers and finishers placing the concrete, and may require use of steel reinforcement or pre-stressed concrete elements where this is critical.
- Access roads and site access have to be able to carry the weight of the **ready-mix truck plus load** which can be up to **32 tonnes** for an eight-wheel **9 m^3 truck**. (Green concrete is approximately 3,924 pounds per cubic yard, or 2,400 Kg/m^3). This problem can be overcome by utilizing so-called "mini mix" trucks which use smaller 4 m^3 capacity mixers able to reach more weight restricted sites. Even smaller mixers are used to allow a 7.5 tonne truck to hold approximately 1.25 m^3, to reach restricted inner city areas with bans on larger trucks.

FIG.15 RMC TRUCK

FIG.15 RMC PLANT

SLURRY INFILTRATED FIBER CONCRETE (SIFCON)

REF: Slurry Infiltrated Fiber Concrete as Sustainable Solution for Defected Buildings (PDF FILE)

What is SIFCON? Meaning of SIFCON SIFCON Stands? When SIFCON Used SIFCON Tutorial

SIFCON means slurry infiltrated fiber concrete.

SIFCON is a **special type of fiber reinforced composite** containing **steel fiber from 5% to 20%** (by volume).

In this formwork molds are filled to capacity with randomly-oriented steel fiber, usually in loose condition and resulting fiber network is infiltrated by a cement-based slurry.

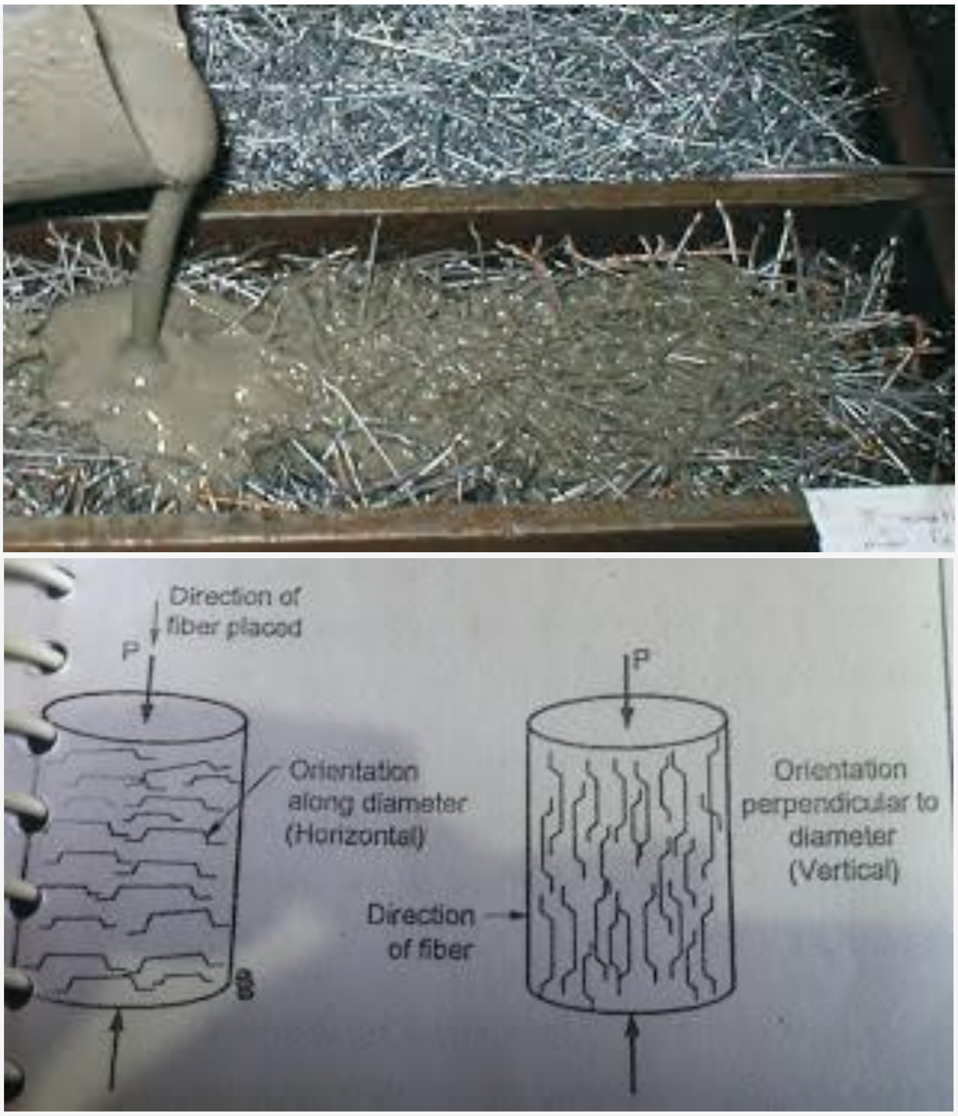


FIG.16 SIFCON

The amount fibers required for composite is depends on aspect ratio, fiber geometry and placement technique.

If the fiber are aligned along the diameter of cylinder, a much higher strength can be expected to the cylinder in which fibers are aligned along the axis of the cylinder.

APPLICATIONS

•Bridge deck rehabilitation.

•Pavement rehabilitation.

•Repairing of structural components such as damaged pre-stressed concrete beams

SHOTCRETE

REF: https://youtu.be/Qwpq78eighE (8.48 min)

REF;

https://youtu.be/WpqOdpK17_A

Shotcrete, or **sprayed concrete** is concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface, as a construction technique, first used in 1914. It is typically **reinforced by conventional steel rods, steel mesh, or fibers**.

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

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

Shotcrete is commonly used to line **tunnel walls, in mines, subways**, and automobile tunnels. **Fire-resistant** shotcrete developed in Norway is used on the Marmaray tunnel in Istanbul.

Shotcrete is used to reinforce both temporary and permanent excavations. It may be employed, in concert with lagging and other forms of earth anchor, to stabilize an excavation for an underground parking structure or hi-rise during construction. This provides a large **waterproof** enclosure in which a structure can be erected. Once the structure is completed the area between its foundation and the shotcrete is backfilled and compacted.

Shotcrete is also a viable means and method for placing structural concrete. Shotcrete is very useful in hard **rock mining**. Development of decline pathway to go underground is critical for movement of heavy machinery, miners, and material. Shotcrete helps make these paths safe from any ground fall.[6]

In-ground **swimming pool**s can use either the wet or dry application method. Shotcrete-wet is ideal for covering large areas quickly, whereas shotcrete-dry (Gunite) is more useful for frequent start-and-stop operations. Neither is superior for this application, and the technique should be selected based on individual project needs.

Costs vary depending on project needs. Shotcrete swimming pools are typically more durable and longer lasting than poured concrete. Poured concrete can have a compressive strength of 2,500-3,000 psi, whereas shotcrete exceeds 4,000 psi. Additionally, the use of Shotcrete allows for customization in shape, depth, and styles that are not typically available in traditional pool kits.

POLYMER CONCRETE

Polymer concrete is a type of concrete that **uses polymer to replace** lime-type **cement**s as a binder. In some cases the polymer is used in addition to portland cement to form **Polymer Cement Concrete (PCC)** or **Polymer Modified Concrete (PMC)**. Polymers in concrete have been overseen by Committee 548 of the American Concrete Institute since 1971.

Composition

In polymer concrete, thermoplastic polymers are used, but more typically thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a wide variety of chemicals. Polymer concrete is also composed of aggregates that include **silica, quartz, granite, limestone**, and other high quality material. The aggregate must be of good quality, free of dust and other debris, and dry. Failure to fulfill these criteria can reduce the bond strength between the polymer binder and the aggregate.

Uses

Polymer concrete may be used for **new construction or repairing of old** concrete. The adhesive properties of polymer concrete allow repair of both polymer and conventional cement-based concretes. The corrosion resistance and low permeability of polymer concrete allows it to be used in swimming pools, sewer structure applications, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids or corrosive chemicals. It is especially suited to the construction and rehabilitation of manholes due to their ability to withstand toxic and corrosive sewer gases and bacteria commonly found in sewer systems. Unlike traditional concrete structures, polymer concrete requires no coating or welding of PVC-protected seams. It can also be used as a bonded wearing course for asphalt pavement, for higher durability and higher strength upon a concrete substrate, and in skate parks, as it is a very smooth surface.

Polymer concrete has historically not been widely adopted due to the high costs and difficulty associated with traditional manufacturing techniques. However, recent progress has led to significant reductions in cost, meaning that the use of polymer concrete is gradually becoming more widespread.

Properties

The exact properties depend on the mixture, polymer, aggregate used etc. etc. but generally speaking with mixtures used:

- The **binder is more expensive than cement**

- Significantly greater **tensile strength** than unreinforced Portland concrete (since plastic is 'stickier' than cement and has reasonable tensile strength)
- Similar or **greater compressive strength** to Portland concrete
- Much **faster curing**
- Good **adhesion** to most surfaces, including to reinforcements
- Good long-term **durability** with respect to freeze and thaw cycles
- **Low permeability** to water and aggressive solutions
- Good **chemical resistance**
- Good resistance **against corrosion**
- **Lighter weight** (slightly less dense than traditional concrete, depending on the resin content of the mix)
- May be vibrated to fill voids in forms
- Allows use of regular form-release agents (in some applications)
- Dielectric
- Product hard to manipulate with conventional tools such as drills and presses due to its density. Recommend getting pre-modified product from the manufacturer
- Small boxes are more costly when compared to its precast counterpart however pre cast concretes induction of stacking or steel covers quickly bridge the gap.

TABLE 2 SPECIFICATIONS OF POLYMER CONCRETE

SpecificationsMaterial	Density kg/m^3	Compressive strength
Urea formaldehyde polymer concrete	2260	37 MPa (5,400 psi)
Polyester concrete	N/A	95 MPa (13,800 psi)

HIGH PERFORMANCE CONCRETE
REF: HIGH PERFORMANCE CONCRETE (PDF DOCUMENT)

High performance concrete is a concrete mixture that has higher **durability and high strength t**han conventional concrete.
This concrete consists of **one or more** cementitious materials **such as fly ash, silica fume or ground granular blast furnace slag** and usually a **superplasticizer**.
The use of certain mineral and chemical admixtures such as silica fume and superplasticizer greatly enhances strength, durability and practicality properties.

Here we will learn about high performance concrete, types of high performance concrete, advantages & disadvantages of HPC.

Introduction to High Performance Concrete:

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

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

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

Characteristics of High Performance Concrete:

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

Types of High Performance Concrete:

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

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

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

Properties of High Performance Concrete:

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

-The tensile strength is improved by 11.64%.

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

ADVANTAGES OF HIGH PERFORMANCE CONCRETE:

1. This HPC are **easy for placement** and consolidation without affecting strength.
2. It **reduce the size of structural member**s and increasing the usable space.

3. Structural members are reduced in size because smaller sections are sufficient to hold higher loads.
4. **Reduction in thickness of flooring** slabs and supporting beam is a significant component of the buildings.
5. The **reduction of** structural members such as **beams, columns and slabs** leads to a reduction in self-weight and dead load leading to a substantial reduction in prices.
6. It had higher **seismic resistance** as compare to standard concrete.
7. Also, had high **abrasion resistance**.
8. The formwork area and its value are reduced.
9. Shoring and stripping time is reduced due to the high initial strength.
10. The construction of high-rise buildings in congested areas is **cost savings**.
11. Long spans and short beams for the same magnitude of loading, used in **bridge construction**.
12. The ability of HPC for long distances reduces the number of supports and foundations.
13. It **extends the life of construction** in extreme environments.
14. They are high **efficiency under** static, dynamic and **fatigue loads**.
15. It had **less creep** and shrinking.
16. They are greater **stiffness** resulting from a higher modulus.
17. It had high **resistance to chemical attack**, long-term durability, and significantly improve crack propagation.
18. These cement reduces the maintenance and repair.

DISADVANTAGES OF HIGH PERFORMANCE CONCRETE:

1. Extended Quality Control.
2. High Cost.
3. Special Constituents.
4. They are manufacture and Placed carefully.

APPLICATION OF HIGH PERFORMANCE CONCRETE:

PAVEMENTS:

HPC is used for highway efficiency due to potential economic benefits
Fast track concrete paving (FTCP) technology can be utilized for full pavement reconstruction.

BRIDGE:

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

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

SKYSCRAPERS:

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

MISCELLANEOUS APPLICATIONS:

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

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

GEOPOLYMER CONCRETE

REF: GEOPOLYMER CONCRETE (PPT FILE)

Geopolymer concrete is an innovative and **eco-friendly** construction material and an alternative to Portland cement concrete. Use of geopolymer **reduces the demand of Portland cement** which is responsible for high CO_2 emission.

Geopolymer cement concrete is made from **utilization of waste materials** such as **fly ash** and ground granulated **blast furnace slag** (GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant.

Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

The main constituent of geopolymers source of silicon and aluminium which are provided by thermally activated natural materials (e.g. kaolinite) or industrial byproducts (e.g. fly ash or slab) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement.

Composition of Geopolymer Concrete

Following materials are required to produce this concrete:

- **Fly ash** – A byproduct of thermal power plant
- GGBS – A byproduct of steel plant
- Fine aggregates and coarse aggregates as required for normal concrete.
- Alkaline activator solution for GPCC as explained above. Catalytic liquid system is used as alkaline activator solution. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of alkaline activator solution is to activate the geopolymeric source materials containing Si and Al such as fly ash and GGBS.

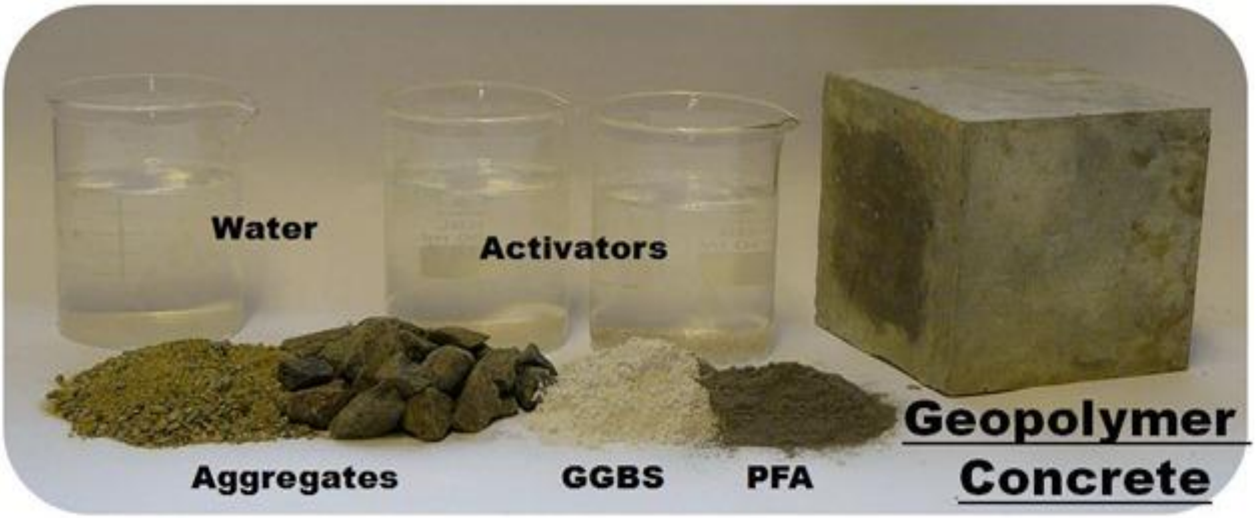


FIG.17 COMPOSITION OF GEOPOLYMER CONCRETE

Mechanical Properties of Geopolymer Concrete

Compressive strength of geopolymer concrete have been found up to 70 MPa (N/mm^2). The concrete gains its compressive strength rapidly and faster than ordinary Portland cement concrete.

The **concrete strength** after **24 hours** has been found to be more than **25 MPa**. Compressive strength **after 28 days** has been found to be 60 to **70 MPa**.

Other Properties of Geopolymer Concrete:

- The **drying shrinkage** of is much **less** compared to cement concrete. This makes it well suited for thick and heavily restrained concrete structural members.
- It has **low heat of hydration** in comparison with cement concrete.

- The **fire resistance** is considerably better than OPC based concrete.
- This concrete as chloride permeability rating of ‘low’ to ‘very low’ as per ASTM 1202C. It offers better protection to reinforcement steel from corrosion as compared to traditional cement concrete.
- This concrete is found to possess very high acid resistance when tested under exposure to 2% and 10% sulphuric acids.

Applications of Geopolymer Concrete

The applications is same as cement concrete. However, this material has **not yet** been popularly used for various applications.

This concrete has been used for construction of pavements, retaining walls, water tanks, precast bridge decks.

FIG.17 HIGH RISE STRUCTURE WITH GEOPOLYMER CONCRETE

Recently world’s first building Structural Building, The University of Queensland’s Global Change Institute (GCI) has been constructed with the use of geopolymer concrete. It is a four storey high building for public use.

BIO CONCRETE
REF: BIO CONCRETE (PDF FILE)

As the most commonly used material in construction, concrete has been relied on for decades to provide **durability, strength, and flexibility**. Significant advancements have been made in the world of concrete manufacturing and usage over the years. Builders can now access concrete in multiple grades, compositions, and performance levels.

But In 2017, a Dutch researcher (Hendrick Jonkers) developed one of the most innovative features that concrete could have. By slightly tweaking the composition of regular concrete, he infused a biological ingredient that made concrete have self-healing properties.

Bio-concrete is proving to become a game-changer in the world of construction. By having the material essentially "**heal itself**" from cracks and breakage, builders will have an easier time completing projects and handling costly repairs. Bio-concrete will also play a critical role in **structural integrity** and **durability** by reducing the risk of a building collapsing.

What is bio-concrete?
Bio-concrete is an innovative building material that can heal itself when cracks occur. How does it work? This concrete mixture contains bacteria that can produce limestone under specific conditions. If a crack occurs along the concrete surface, the **bacteria will be "activated**" to produce limestone that essentially "heals" the crack. This makes concrete more durable and environmentally friendly. Furthermore, less mining will have to occur to obtain concrete, and fewer resources will be spent on building maintenance.

The extra ingredient that's present in bio-concrete is clay pellets. These pellets contain bacillus bacteria spores mixed with calcium lactate. When a crack occurs on concrete, external elements (such as air and water) will react with the bacteria to form limestone. This limestone is what eventually covers up the cracks and allows your concrete to "heal".

Bio-concrete is applicable in real-world situations because the bacteria can last for many years without losing their active properties. They essentially lie dormant within the clay pellets and are activated by external elements when a crack occurs.

How Bio-concrete can help construction companies

Research surrounding self-healing concrete surfaced in 2015, sparking interest in builders, estimators, engineers, and other stakeholders as to how bio-concrete could be utilised to streamline daily construction activities.

Does bio-concrete have the potential to become the future of construction? The numerous benefits of this material make it a front-runner for widespread adoption in years to come.

Bio-concrete is useful and applicable to construction companies in the following ways.

Sealing small cracks that could eventually become larger

Perhaps one of the most powerful applications of bio-concrete is that it can be used to seal up small cracks within larger slabs of concrete. It is these small cracks that eventually expand to cause significant damage in buildings, bridges, and other infrastructure.

Bio-concrete **can seal cracks of up to 0.8mm** in width, catching the problem in advance and preventing significant structural damage.

Applicable to different types of infrastructure

Bio-concrete is also usable in many different contexts. The flexibility of bacillus bacteria makes it functional for bridges, buildings, tunnels, and other types of infrastructure.

The wider use functions of this material can open up many new possibilities in engineering, microbiology, and construction. Not only can you save on costs during your future projects, but you can also explore new designs, enjoy more durable structures, and cut costs down the road.

An environmentally friendly solution

The benefits of bio-concrete extend beyond economic applications. This material also reduces carbon emissions, making it possible for commercial and residential builders to lower their carbon footprints. By using less concrete to carry out maintenance and repairs, there will be fewer carbon emissions into the environment over time.

Sustainable construction is the future of our industry and bio-concrete is at the forefront of promoting this revolution.

Active for long periods

Endurance tests were recently carried out on bio-concrete to assess its durability and strength. Results show that the material is expected to last for over **200 years** within its proper composition. This also means that clay pellets in the biochemical mixture are durable even under multiple weather and physical conditions.

The durability of bio-concrete is a game-changer that makes this material applicable in many different contexts. Hendrick Jonkers, the Dutch researcher who produced bio-concrete, is also working on a new technique for encapsulating bacillus bacteria into concrete mixtures.

TEXT / REFERENCE BOOKS

1. Arora and Bindra, Building construction, Dhanpath Rai and Sons.
2. Punmia B.C., Building construction. Laxmi Publications.
3. Rangwala S.C., Engineering Materials, Charotar Publishers.
4. Shetty M.S., Concrete Technology, S. Chand & Company.
5. Sahu G.C. & Joygopal Jena., Building Materials and Construction, McGraw Hill Education.
6. Gambhir M.L., Concrete Technology, Tata McGraw Hill.
7. Krishna Raju N, Design of Concrete Mixes, CBS Publishers.
8. National Building Code.
9. Neville A.M. and Brooks.J.J, Concrete Technology, Pearson Education.

QUESTION BANK

PART A

1. List the types of Light weight concretes.
2. What are SIFCON and Shotcrete?
3. Determine the performance of Geopolymer concrete.
4. What are the factors of Bio Concrete?
5. Narrate the Principles of Ferrocement.

PART B

1. Explain the properties of High strength concrete.
2. Compile the Properties of vacuum concrete.
3. Narrate the tests on Fibre reinforced concrete.
4. Narrate the tests on durability of Ready mix concrete.
5. Narrate the uses of foam concrete.